# PALYNOLOGY OF THE
# LOWER COLORADO GROUP, CENTRAL ALBERTA

# PALYNOLOGY OF THE LOWER COLORADO GROUP (LATE LOWER CRETACEOUS) AND ITS LITHOLOGICAL EQUIVALENTS IN CENTRAL AND WEST-CENTRAL ALBERTA, CANADA

by

WAYNE WILFRED BRIDEAUX, M.Sc.

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfillment of the Requirements

for the degree

Doctor of Philosophy

McMaster University

October 1968

DOCTOR OF PHILOSOPHY (1968)
(Biology)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Palynology of the Lower Colorado Group (Later Lower Cretaceous) and its Lithological Equivalents in Central and West-Central Alberta, Canada.

AUTHOR: Wayne Wilfred Brideaux, B.Sc. (Carleton University)
M.Sc. (McMaster University)

SUPERVISOR: Professor N. W. Radforth

NUMBER OF PAGES: xvii,533

SCOPE AND CONTENTS:

161 miospore species and 122 microplankton species are described from 106 samples in six sections of the Lower Colorado Group and its equivalents in central and west-central Alberta. Two miospore species, and two genera and twenty-five species of microplankton, are newly described.

The miospore and microplankton assemblages are used as a basis for division of the Lower Colorado Group into several time-stratigraphic units. The age of the Group is determined as Upper Albian (latest Lower Cretaceous).

A method for defining recurrent microplankton species groups is developed and applied to assemblages from two of the sections. The distribution of the recurrent groups formulated is shown to be correlated in part with palynological, lithological and other data.

Application and extension of the results and conclusions of this investigation should prove useful in understanding many aspects of western Canadian Cretaceous stratigraphy and in the investigation of microplankton occurrence patterns from other deposits.

# PREFACE

Palynology, a word coined by Hyde and Williams (1945), is the term applied to all facets of investigation of modern and fossilized pollen grains, and spores of both vascular and non-vascular plants. It has also come to include the study of fossil and modern phytoplankton (mainly dinoflagellates), their cyst forms, related entities known as discoasters (Bursa, 1964), microfossils of unknown affinity collectively termed Acritarcha (Evitt, 1963a), and fossil coccoliths and chitinozoans. With the exception of the palaeoecological information provided by their presence in the sample, palynology is not concerned with fossil and modern microfaunal groups such as the foraminifera, conodonts and ostrocodes.

This thesis is restricted to an investigation of the fossil spores, pollens, dinoflagellate cysts and related microfossils referred to the acritarchs, present in a Lower Cretaceous sequence in central Alberta, Canada. For convenience, the term "miospore" is introduced to include any type of spore, pollen grain, or related plant microfossil less than 200μ in diameter (Guennel, 1958). The collective term "microplankton" is used to mean any combination of undoubted dinoflagellate cysts or thecae, dinoflagellate affiliates, and marine microfossils belonging to the Acritarcha.

The division of this thesis into two parts diverges from common practice. It is thought that this will allow a more efficient and coherent treatment of the material. The two sections should be regarded as correlative with, but distinct, from each other.

The first section deals with the objectives of the investigation, problems of a stratigraphic nature, the qualitative and quantitative palynology of the sequence, and a discussion involving the interpretation and discussion of these results. The second section includes an exposition and discussion of nomenclatural procedures used in the taxonomy of fossil miospores and microplankton. A major constituent of this section is the systematic palynology of the fossil miospore and microplankton assemblages encountered in the investigation. Discussion of dinoflagellate taxonomy and morphology has been included in this section because of its special relation to systematics, rather than placing it in the general discussion.

In many instances entities have been referred to by a code number in order to reduce the tedious spelling out entailed in binomial expression. A complete list of code numbers is to be found in Appendix II at the end of the thesis.

Finally, the author draws attention to the use of the expression, "time-stratigraphic unit" used extensively in a later portion of the thesis. This expression does not refer to an ideal, worldwide geochronological time subdivision but rather to the local biostratigraphic subdivision based solely on the local and regional ranges of the miospore and microplankton species described in this work. Extension of these units beyond the immediate locale of investigation would depend on lateral extension of similar biostratigraphic investigations. Hence these "time-stratigraphic units" may be most closely comparable to the "zonule" (Code of Stratigraphic Nomenclature, Art. 20, (f), p. 655, 1961).

# ACKNOWLEDGEMENTS

The author expresses his deepest appreciation for the assistance, encouragement and stimulating discussion provided by Dr. N. W. Radforth throughout the course of this investigation.

Dr. S. A. J. Pocock, and others on the staff of Imperial Oil Limited, Calgary, kindly provided the samples used for this investigation as well as much useful data on well logs and other matters. For this the author is most grateful.

A special thanks is entended also to W. John Richardson, graduate in Biology (now at Cornell University), for the development of the computer program used in this study.

Dr. D. C. McGregor (Ottawa) and Mr. R. L. Cox (Calgary), Officers of the Geological Survey of Canada, Dr. J. M. Stewart and Dr. G. E. G. Westermann, members of the committee, Dr. C. Singh of the Research Council of Alberta, Dr. G. Norris of the University of Toronto and Dr. R. G. Walker, Department of Geology, McMaster University, provided an opportunity either in person or by mail to conduct much fruitful discussion. Thanks are extended also to members of the Department of Biology, especially Dr. E. L. McCandless Dr. D. M. Davies, Dr. S. T. Bayley and Mr. B. A. L. Ewens for general assistance throughout the course of this work.

Miss Joan Fink carried out the labourious task of typing the manuscript. Mrs. Hanna Lindemann helped to lighten some of the load and Miss E. Athawes contributed preliminary typescripts. Mrs. Lynn Howlett, Miss Mary Lou Hamilton and Miss Marjorie E. Bennett helped with the Bibliography and collation of the several copies of the final thesis.

Financial assistance was provided by the receipt of a National Research Council of Canada Studentship throughout the project. This assistance is gratefully acknowledged.

# TABLE OF CONTENTS

PART ONE GENERAL PALYNOLOGY OF THE LOWER COLORADO GROUP AND EQUIVALENTS

PART TWO SYSTEMATIC PALYNOLOGY OF THE MIOSPORE AND MICROPLANKTON ASSEMBLAGES OF THE LOWER COLORADO GROUP

# LIST OF TABLES

TABLE

## LIST OF TEXT-FIGURES

TEXT-FIGURE

TEXT-FIGURE

TEXT-FIGURE

# PART ONE

# GENERAL PALYNOLOGY
# OF THE LOWER COLORADO GROUP
# AND EQUIVALENTS

# I

# INTRODUCTION

## THE COURSE OF CRETACEOUS PALYNOLOGY

Although the history of Cretaceous palynology extends back for over 130 years, Cretaceous deposits were not extensively investigated for their miospore and microplankton content until the mid-1950's. In the decade preceding this time, the potential value of these microfossils had become apparent (Wilson, 1946; Just, 1951). Their usefulness in the time correlation of sedimentary rocks and coals, in the search for oil, and as palaeoecological and palaeobotanical indicators became generally recognized. The successful application of these concepts in the decade following the mid-1950's has given rise to a voluminous literature and a corresponding wealth of information.

The present investigation offers a further contribution to Cretaceous palynology, and is motivated by and forms part of, the continuing rapid expansion and development of the field. It is appropriate therefore, before beginning the account of this present work, to place it in historical perspective and to evaluate the major achievements of previous endeavours in Cretaceous palynology. In this manner one may better assess the proposed contribution of this research to Cretaceous palynology and to palynology as a whole.

Cretaceous palynology was initiated in the late 1830's by the microscopist, C. G. Ehrenberg, who described and illustrated the first examples of Cretaceous microplankton (Ehrenberg, 1838; 1843).

His interest in these fossil organisms stemmed from a general curiosity about microscopic organisms. Neither Ehrenberg nor other microscopists who, stimulated by his influence, published similar papers (Reade, 1839; Bowerbank, 1841a; and others), realized the potential biostratigraphic and taxonomic significance of their discoveries. In several decades, interest waned, and with the exception of Merrill's (1895) paper on "sponge spicules" from the Lower Cretaceous of Texas, there ensued a hiatus lasting over sixty-five years.

It was not until the mid-1920's that further interest was shown in Cretaceous microplankton. At this time, W. Wetzel and O. Wetzel began investigations of Upper Cretaceous flints and described some of the microplankton contained therein (W. Wetzel, 1922; O. Wetzel, 1926a; 1926b; 1932; and 1933). Then Deflandre (1934a, and later) initiated his extensive series of investigations of Cretaceous and other Mesozoic microplankton, describing and illustrating the forms as well as commenting on their taxonomic position. Several other workers, notably Lejeune-Carpentier (1937 and later) began to publish similar papers. Unlike investigators a century earlier, these workers were interested in extending their understanding of fossil microplankton and were not content merely to demonstrate their existence in Cretaceous rocks. Their publications indicate an awareness of the palaeontological and stratigraphical significance of these fossil microplankton. They have provided a foundation on which rests a large part of the more recent studies of fossil microplankton.

In contrast to the interest of 19th century microscopists in Cretaceous microplankton, no investigations of Cretaceous miospore or megaspore assemblages were published until the early 1930's. The history of Cretaceous palynology up to this time is the history of microplankton studies. The pioneer publications on Cretaceous miospores and megaspores appear to be Kircheimer's (1932) description of South African Upper Cretaceous miospores and Miner's (1932) paper on Greenland Cretaceous coals. Miner (1935) described spores from the Cretaceous Kootenai Formation of Montana; Deflandre (1934b) noted the presence of bisaccate pollen grains similar to those of the conifer group, the Abietineae. This constituted the literature on Cretaceous miospores and megaspores until the late 1940's.

In the late 1940's and early 1950's, a number of papers appeared which reflected a revived interest in Cretaceous miospores. These include the publications of Hofman (1948; 1950), Malyavkina (1949), Ross (1949), Schemel (1950), Thiergart (1949) and Weyland (1951). Undoubtedly much unpublished data also existed, as is indicated by the papers of Armstrong (1953) and Kuyl, _et_ _al_. (1955). These papers were concerned with illustrating and describing isolated assemblages of Cretaceous miospores or megaspores. Their contribution was the establishment of the presence of these microfossils in Cretaceous rocks of varying ages and lithologies.

The advent of the 1950's saw the initiation of more systematic and comprehensive investigations than had hitherto been made. Many of the classic references on the taxonomy of Cretaceous miospores and their stratigraphical distribution were published at this time, including descriptions of assemblages from New Zealand (Couper, 1953), Russia (Bolkhovitina, 1950; 1951; and 1953), Canada (Radforth and Rouse, 1954; Rouse, 1957), and Germany (Weyland and Greifeld, 1953; Weyland and Kreiger, 1953). A little later, Balme (1957) published the first formal descriptions of Australian Cretaceous miospores.

During the war period, investigations of Cretaceous miospore assemblages lapsed, but Deflandre and Lejeune-Carpentier in France, W. Wetzel in Germany, and other workers contributed some papers on microplankton. In the mid-1950's, the volume of work on microplankton began to increase rapidly. New centres of activity became established in England, the United States, Germany, Australia, and to a lesser extent in Russia. As a result of this renewed interest, assemblages of Cretaceous microplankton have now been described from many parts of the world, including England (Neale and Sarjeant, 1962), North America (Singh, 1964; Pocock, 1962), Germany (Gocht, 1957; Alberti, 1961; and many others), Australia (Cookson and Eisenack, 1958 and later; and many others), and Russia (Zaklinskaya, 1963; and others), to cite but a few of the investigations. This intense interest has created a need for extensive bibliographies and compilations of genera, not only for Cretaceous assemblages but for those of other periods. Bibliographies have appeared by Downie and Sarjeant (1964), generic and specific compilations by Eisenack (1964; and 1967) of the dinoflagellates, and compilations of all microplankton genera by Norris and Sarjeant (1965). A similar work has been published in Russia by Vozzhennikova (1965).

## CRETACEOUS PALYNOLOGY IN NORTH AMERICA

The Cretaceous interval to be examined palynologically in this thesis is located in Alberta, Canada. Consequently the published information on North American Cretaceous assemblages will play a part in shaping the objectives of the investigation. It is useful in this context to comment briefly on the available literature.

When the literature is examined, it becomes evident that the rapid increase of published material on a world-wide scale is clearly reflected in North American work. Of approximately 63 papers published, only 10 had been published up to and including 1959. Since then over 53 papers have appeared, at least 30 of them since 1964. The interest in North American Cretaceous palynology is thus comparatively recent. Secondly, the major part of the research has been concerned with the biostratigraphy and taxonomy of Cenomanian-Maestrichtian assemblages. (See Table 1 for stages.) A recent review by Srivastava (1967b) mentions nearly 50 papers which include or treat exclusively Upper Cretaceous assemblages from North America. There has also been some interest in the palynology of the Aptian-Albian stages of North America, principally because of the apparently "sudden" appearance of angiosperm pollen grains in the mid to late Albian stage (Brenner, 1963; Norris, 1967). A secondary motivation has been to delineate the changes in the miospore and microplankton assemblages at the Lower-Upper Cretaceous boundary. This situation obtains in the section chosen for study.

Relatively few papers have been concerned with Berriasian-Barremian assemblages. Pocock (1962) has published taxonomical and biostratigraphical data on the palynology at the Jurassic-Cretaceous boundary. Singh (1964) provides similar information on some material

| SYSTEM | SERIES | STAGE | ABSOLUTE AGE (MILL. YRS.) |
|---|---|---|---|
| TERTIARY | | | 63 |
| CRETACEOUS | UPPER CRETACEOUS | (Danian)? | |
| | | Maestrichtian | 72 |
| | | Campanian | |
| | | Santonian | 84 |
| | | Coniacian | 90 |
| | | Turonian | |
| | | Cenomanian | 110 |
| | LOWER CRETACEOUS | Albian | 120 |
| | | Aptian | |
| | | Barremian | |
| | | Hauterivian | |
| | | Valanginian | |
| | | Berriasian | 135 |
| JURASSIC | UPPER JURASSIC | Purbeckian | |
| | | Portlandian | |
| | | Kimmeridgian | |
| | | Corallian | |
| | | Oxfordian | |
| | | Callovian | |
| | MIDDLE JURASSIC | Bathonian | 166 |
| | | Bajocian | |
| | LOWER JURASSIC | Toarcian | |
| | | Pleinsbachian | |
| | | Sinemurian | |
| | | Hettangian | 181 |
| TRIASSIC | UPPER TRIASSIC | | 200 |
| | MIDDLE TRIASSIC | | |
| | LOWER TRIASSIC | | 230 |
| PERMIAN (UPPER PALAEOZOIC) | | | |

TABLE 1. Geologic systems and time relationships in the Mesozoic Era. Absolute ages date from the base of the interval. Data from Kulp, *et al.* (1961).

from the late Barremian of east-central Alberta. Few others have been concerned with this part of the sequence in North America.

Further examination reveals that very little has been published on North American Cretaceous microplankton assemblages. Only 8 papers deal exclusively with microplankton found in whole or part from North American Cretaceous deposits. A few of these papers contain comprehensive taxonomic sections on the microplankton (Pocock, 1962; Singh, 1964; Stanley, 1965; and Drugg, 1967). The presence and potential value to biostratigraphy of microplankton assemblages in North America has been established. However, the extent and distribution of these assemblages and their relation to assemblages from other parts of the world is still little understood. There is thus an important contribution to be made in that record.

## THE MAJOR ACHIEVEMENTS OF CRETACEOUS PALYNOLOGY

The volume of published work on Cretaceous palynology has made available a large amount of data. These data, for convenience, may be classified as taxonomical, stratigraphical, distributional (palaeoegeographical) and palaeoecological. However, these classes are closely interrelated and information in one has bearing on all the other areas. Although it is not proposed here to review the whole body of literature, some assessment of the accomplishments of Cretaceous palynology will be set forth.

A considerable portion of the literature is devoted to the description of miospores and microplankton from Cretaceous deposits. Hundreds of generic concepts and thousands of species have been proposed for both types of microfossils; the number continues to increase at a rapid rate. Many of these earlier generic concepts have been documented and annotated by R. Potonié (1956, and later) for miospores, and by Norris, Sarjeant, Eisenack and Vozzhennikova for microplankton. The large volume of taxonomic data in publications by these and other workers presents problems because of its bulk and because of the varied taxonomic approaches suggested. Some workers (Pierce, 1961) propose and set out a fully artificial system of nomenclature. Others (Bolkhovitina, 1953; and Rouse, 1956) favour a system indicating natural affinities of the dispersed miospores to a greater or lesser degree respectively. Pierce (1961) presents a more detailed discussion of this aspect of palynology. The same problem is found in microplankton studies, where Eisenack (1964; and 1967) places fossil forms into as many modern families as possible. Sarjeant and Downie (1966) in contrast, propose a number of cyst-families which are in whole or part, artificial, and based on presumed fossil cyst forms. These, and other more minor questions of nomenclature, have somewhat diminished the usefulness of the published data. Nevertheless, form species remain the fundamental data and enable the comparison of assemblages on a local and long distance basis in a variety of ways.

Knowledge of Cretaceous assemblages has allowed the construction of a number of reference sections for stratigraphic time determinations based on the palynology of the deposits. These sections have significance in time correlations beyond their immediate geographical location. Some important contributions have been made in this area by Couper (1958) and Hughes (1955; and 1958) in England, Bolkhovitina (1953) and others in Russia, Dettman (1963), and others in Australia, as well as many workers in North America and other regions. Couper (1964) has recently compiled data on the stratigraphic distribution of miospores in Cretaceous deposits on a world-wide basis. While Couper's analysis is generalized for major miospore groupings, it also indicates the great measure of success in using these forms to define time-stratigraphic breaks on a world-wide scale. Sarjeant (1967) shows the distribution in time for microplankton species of all ages, including the occurrence of individual species in each of the European Cretaceous stages. Sarjeant also points out that many of the anomalies in distribution of the microplankton are fortuitious because of the inadequate stratigraphic control for many of the earlier assemblages described and the discrete ranges of time intervals from which assemblages have been reported. In both cases this leads to an incomplete knowledge of the actual ranges of many species.

The accumulation of taxonomical and stratigraphical data has allowed a certain success in assessment of the palaeogeographic distribution of Cretaceous miospores and microplankton. Studies of the distribution of fossil spores attributed to the fern family, Gleicheniaceae, by Bolkhovitina (1960; and 1962), in part for the Cretaceous, and the delineation of Upper Cretaceous angiosperm pollen provinces in Russia by Zaklinskaya (1962), suggest methods of utilizing this type of data. Many of the miospore form species are known to be world-wide in distribution while others have been found only in restricted geographical regions. A striking example of the latter case is the unique series of miospore assemblages described from equatorial Africa by Belsky and Boltenhagen (1963), Belsky, et al. (1965), Stover (1963), and others. This may be contrasted with the distribution of the fossil miospore genus, Gleicheniidites, which achieved world-wide distribution in the Jurassic and Cretaceous. Most of these data, however, have remained scattered in various papers and have never been correlated. Factors relating to definition of species concepts and delineation of species ranges operate here as in the fields of taxonomy and stratigraphy.

Very little work has been published on the palaeoecological evaluation of Cretaceous assemblages. Much of the available data are included as comment arising from the botanical affinities of the miospores. This comment is based on the principle that in general, miospore assemblages reflect the parent floras living in the vicinity of the depositional basin. Some workers (Pierce, 1961; Stanley, 1965) have attempted to reconstruct the ecological conditions existing at the time of deposition of the miospore assemblage, using information gained from analogous situations in living floras. Hughes and Moody-Stuart (1967) have attempted another approach, that of examination of a small portion of a succession in terms of distribution of various microfossil entities. Their objective was to define palynological facies by the types and abundance of microfossils present. This method emphasizes the environment of the depositional basin rather than attempting speculation about the environment of the provenance region, although the latter is not ignored in their discussion. Sarmiento (1957) proposed the use of the ratio of total microplankton/total miospores in the determination of the shoreline position with reference to the sample. This study was made in the

Upper Cretaceous Mancos shale located in the northwestern United States. The information from this ratio enabled the recognition of a number of minor transgressions and regressions in the region, thus facilitating understanding of the stratigraphy in terms of both time and lithology. Other than this, palaeoecological studies have not been published for Cretaceous assemblages. General discussions arising from studies of modern situations have been published (Muller, 1959; Williams and Sarjeant, 1966; and others); these will be discussed in a later chapter. G. Norris (pers. comm.) is at present engaged in determining recurrent species groups in the miospore assemblage from one sequence in the Lower Colorado Group (subsurface) near Edmonton, Alberta. This appears to be the first attempt to investigate Cretaceous miospore assemblages in this manner. The method has been used in modern ecological studies (Cole, 1949; Fager, 1957) to group species which recur together most frequently. Such relations have been shown (Fager, 1957) to have ecological significance in modern faunal associations. Valentine and Mallory (1965) have applied this to Pleistocene mollusc assemblages and Norris and Harris (Norris, pers. comm.) have done this for Holocene miospore data. There have been no attempts to apply this to microplankton assemblages, fossil or recent.

## THE FUTURE DEVELOPMENT OF CRETACEOUS PALYNOLOGY

The fundamental source of data in palynology remains the disclosure and description, formally or numerically, of miospore and microplankton entities. In some regions where sections have been more completely investigated, refinement of existing concepts and investigations of a more detailed nature become the dominant pursuit. There are many regions however, as in Africa and North America, where description of assemblages, has just commenced. This is perhaps more applicable to microplankton than to miospores.

For reasons discussed earlier, the stabilization of existing nomenclature is equally as important as the description of new taxa. While names in themselves mean little, they should be attached to clearly defined form-generic and form-specific concepts. It is only through such procedure that stratigraphical, distributional and palaeoecological investigations may be confidently carried out. One solution to the problem involves extensive monographing of single generic and even specific concepts. Sarjeant's (1967b) paper on *Palaeoperidinium* Deflandre ex Sarjeant and Skarby's (1964) paper on *Gleicheniidites senonicus* (Ross) Skarby are examples of this approach.

In stratigraphic palynology, the establishment of reference sections and palynological zones is a fundamental pursuit. Many geographical regions remain relatively unexplored in this regard, as do many parts of the stratigraphic column. Revision of much early work, using more rigorous stratigraphical control is also essential. In North America, for example, relatively little work has been published on Berriasian-Barremian sequences and only a little more on Aptian-Albian-Cenomanian deposits. Most of the North American marine Cretaceous sequences, as well as those in South America, Africa and parts of Asia, have not been investigated for their microplankton content. Knowledge of Cretaceous microplankton assemblages is essentially based on European, British and Australian data with some contribution from North America and Russia.

One of the least explored areas of research in Cretaceous palynology, and in the whole of palynology, is the investigation of the palaeogeographic distribution of miospore and microplankton species. Analysis of microplankton assemblages in relation to their palaeogeographic distribution in time, using well-dated material, would no doubt lead to much information on the history of Cretaceous microplankton.

Finally, it is evident that the most neglected aspect of research in Cretaceous palynology is the environmental significance of miospore and microplankton assemblages, for both the provenance region and the depositional basin. Much discussion occurs scattered throughout the literature, but little quantitative research has been undertaken on Cretaceous assemblages. If Mesozoic (Cretaceous) palynology was almost a virgin field in 1951 (Just, 1951), so today this aspect of palaeoecology occupies that position. This statement applies not only to Cretaceous assemblages but also to those of pre-Pleistocene deposits in general, the more so as the age of the deposit increases.

Investigation of Cretaceous deposits in this context may be classed into three divisions: the relationships of the microfossils to each other, to the depositional environment, and to conditions existing in the provenance region. There are many parameters collected in the course of descriptive and stratigraphical work which may have palaeoecological significance. These include presence or absence of species, species groupings and distributional patterns, among others, and will be discussed later in this account. It is sufficient at present to point out that these are often ignored in work on Cretaceous and other assemblages.

## RESEARCH OBJECTIVES IN THE INVESTIGATION OF THE PALYNOLOGY OF THE LOWER COLORADO GROUP

Preceding sections of this account have reviewed the history, previous work and accomplishments of Cretaceous palynology in general terms. Using the observations from this review as guidelines, it is now possible to consider the material available and to outline specific research objectives which will provide some contribution to previously unemphasized or poorly understood areas of Cretaceous palynology.

The Lower Colorado Group and its equivalents in Central and Western Alberta (see TABLE 2) were chosen to be investigated for several reasons. Firstly, these sequences contain abundant assemblages of miospores and microplankton (Norris, 1967; Pocock, pers. comm.) and are comprised of varied lithologies and depositional environments (Badgley, 1952; and others). Secondly, although some previous work has been done (Norris, 1967; Pocock, 1962; Singh, in progr.), there has been no comprehensive study published on the Lower Colorado Group on either a geographical or taxonomical basis. Except for the work of Norris on miospores, mentioned earlier, the assemblages in these sequences have not been evaluated on a palaeoecologial or distributional basis. The abundance of microfossils and possible assemblages and the variety of conditions of deposition within the Lower Colorado Group offer the possibilities of profitable research in those fields of palynology. Thirdly, the Lower Colorado Group contains several producer horizons (Viking Formation; Cadotte Member, Peace River Formation) and is thus of economic importance. Fourthly, there has been some controversy concerning the age relationships of the lithological units comprising the Group and its equivalents (Badgley, 1952; Glaister, 1959; Stelck, 1958, and others).

Finally, the age of the Lower Colorado Group is middle Albian to late Albian and perhaps basal Cenomanian in Alberta (Norris, 1967, p. 82). This position near the boundary of the Lower and Upper Cretaceous series is interesting from both a stratigraphical and palaeobotanical point of view. Stratigraphically, the section offers an opportunity to examine in detail miospore and microplankton assemblages at the top of the Lower Cretaceous series in western Canada. Knowledge of these assemblages should provide a basis for future studies of the biostratigraphic significance of basal Upper Cretaceous assemblages in western Canada. It also constitutes the first step in determining changes in the characters of the assemblages across this boundary. Palaeobotanically, the boundary is marked by an increasing differentiation of angiosperm pollen types (Brenner, 1967; Pierce, 1961; and others), indicative of extensive evolutionary change in parent angiosperm floras. Detailed examination of the microfossil assemblages may help to date the top of the sequence more exactly. As well, the Lower Colorado Group contains the first appearances of undoubted angiosperm grains in the western Canada region (Norris, 1967) and may include elements of the oldest Cenomanian assemblages.

Some previous publications have dealt with aspects of the palynology of the Lower Colorado Group. Norris (1967) described eighty-nine species of miospores from a subsurface section near Edmonton, Alberta. Singh (pers. comm.) is at present investigating assemblages in outcrops of the type section of the Upper Fort St. John Group along the Peace River in west-central Alberta. Pocock has described a small number of microplankton species from basal Lower Colorado Group equivalents in southern Saskatchewan.

The opportunity exists to extend and complement these studies both geographically and taxonomically. Because the lithologies and depositional environments are varied, even intensive study of one section cannot give a complete picture of the range and distribution of the assemblages. In this study, the northernmost subsurface section is approximately four hundred miles distant from the southernmost section. The type section of the Upper Fort St. John Group mentioned earlier is nearly one hundred miles further north. A basic objective therefore, is to give a comprehensive report on the taxonomy of the miospore and microplankton assemblages of the Lower Colorado Group over much of its geographical extent.

These data will allow the completion of a standard palynological column for the Lower Cretaceous series in the western Canada region. Previous work has provided data on the lower portion (Berriasian to middle Albian) and some preliminary understanding has been contributed to the post-middle Albian section by Norris (1967). The work set forth in this thesis will complete the task.

Regionally, there is still an incomplete understanding of time relationships among the various lithological units comprising the Lower Colorado Group in east-central Alberta with those in west-central Alberta. Micro- and macrofaunal assemblages have been used to date the deposits in terms of the standard European Cretaceous stages (Stelck, 1958; Wickenden, 1951, and others). They have not provided more than a sketchy internal zonation of these units, nor have they satisfactorily outlined the relationships of the units to each other, in the opinion of the writer. It is hoped that the abundance of palynological entities and the variety of depositional environments in the Lower Colorado Group will provide the data necessary to understand fully the time relationships within the lithological units. The solution of this stratigraphical problem would be a further contribution to western Canadian stratigraphy, especially as the sequence concerned includes several producing horizons.

The data provided from the taxonomic study and the stratigraphical correlations will allow comparison of the Lower Colorado assemblages with those of other regions of North America as well as in others parts of the world. This is especially significant when it is recalled that little such information is now available for Cretaceous microplankton from North American sequences. These data hopefully may also provide new evidence in the evaluation of fossil microplankton structure and morphology.

The variety of depositional environments in the Lower Colorado Group also provides an opportunity to investigate the distributional patterns of the microplankton assemblages on a vertical and lateral basis in relation to these environments. Special emphasis will be placed on the analysis of recurrent species groups in the microplankton assemblages of two of the available sections. It is hoped to demonstrate that definite relationships exist between recurrent species groups and depositional environment, nearness to shoreline, and other factors. Such treatment may reveal patterns of distribution in the microplankton assemblages which have significance beyond the immediate location of this investigation.

On a more general basis, the miospore assemblages may yield information on the general distribution of parent floral groups in the provenance regions. The geographical extent of this investigation will certainly allow some speculation on the distribution of the major plant groups in central and west-central Alberta during the late Albian stage of the western Canada sequence.

As the first step in the account of this palynological investigation, it is appropriate to begin with an appreciation of the geological and stratigraphical setting of the research region, and more important, the collection and treatment of the research samples.

# II

# STRATIGRAPHY AND PROBLEMS OF CORRELATION IN THE LOWER COLORADO GROUP

## THE COLORADO GROUP

The term "Colorado" was originally applied to outcrop located at the base of the Rocky Mountain Front Range in the state of Colorado, U.S.A. The name was given informally to that sequence by King (1876, 1878), and later applied to sedimentary rocks outside the immediate area. In Alberta, clear lithological correlatives could not be distinguished. Hence the name was given formational status and defined to include strata overlying the Blairmore Formation and underlying the Lea Park Formation in Alberta. Hume (1930) introduced the term Alberta shale, which included the younger Lea Park Formation; Nauss (1945) proposed the name Lloydminister Shale, but these terms have either not been adopted or have been discarded. Finally, Badgley (1952) suggested that the sequence be considered a Group and introduced the name Lower Colorado Group, outlining the main formational divisions over much of its extent. This term has become the established name for the strata in Alberta overlain by the Lea Park Formation and underlain by the Mannville Group (see TABLE 2).

In Alberta, the Colorado Group is present throughout central and southern regions, having a minimum thickness of about 600' and a maximum thickness in its western reaches of 3000'. The major lithology of the Group consists of dark grey, marine shales. Prominent sandstone intervals and thinner bands of limestone and basal conglomerate also occur. It extends into southern Saskatchewan and lithological equivalents have been traced into Southern Manitoba (Ashville, Favel, and Vermillion Formations).

The intervals to be examined palynologically in this thesis include only the lower part of this Group, called the Lower Colorado Group, its lithological equivalents in west-central Alberta, and immediately underlying strata of the Mannville Group (uppermost Grand Rapids Formation). In central and southern Alberta, the Lower Colorado Group comprises in ascending order, the Joli Fou and Viking Formations and an unnamed but relatively thick sequence of shales termed the "Upper Shale Unit" (Norris, 1967). The top of the Lower Colorado Group is placed for convenience at the base of the Fish Scales Sandstone marker bed. This sandstone body is interpreted by many workers (Gleddie, 1954; Alta. Soc. Petrol. Geol., 1960) as indicative of a widespread break in deposition throughout Alberta. It is recognized in the absence of a well-defined lithological unit by a distinct positive "kick" in electric logs through most of Alberta. Further discussion of the significance of this "zone" as a time marker will be presented later.

In west-central Alberta (Peace River district), the underlying Mannville Group is absent and is replaced by a marine regressive sequence comprising near shore, shallow water beds and ending in deltaic deposits. This sequence is given the name Peace River Formation and the intervals are termed in ascending order, the Harmon, Cadotte and Paddy Members. The basal Harmon Member is

TABLE 2. Table of Formations in Central and Southern Alberta, Southern Saskatchewan and Northern Montana. Time equivalence not indicated exactly. Data after various sources.

| TIME UNIT | | WEST-CENTRAL ALBERTA | NORTHEAST & E. CENTRAL ALBERTA | SOUTH-CENTRAL ALBERTA | SOUTHERN SASKATCHEWAN | NORTHERN MONTANA - USA |
|---|---|---|---|---|---|---|
| UPPER CRETACEOUS | CENOMANIAN | Upper Shaftesbury Formation | Labiche Formation | Upper Colorado Group | Upper Colorado Group | Mowry Shale |
| LOWER CRETACEOUS | ALBIAN | — — — FISH SCALE HORIZON — — | — — — FISH SCALE HORIZON — — | FISH SCALE HORIZON — — | FISH SCALE HORIZON — — | FISH SCALE HORIZON — — |
| | | Lower Shaftesbury Fm. | "Upper Shale" Unit | Upper Shale U. | Upper Shale U. | |
| | | Paddy Mem.<br>Cadotte Member | Pelican Fm. | Viking Fm. | Viking Fm. | Skull Creek Fm. |
| | | | Joli Fou Fm. | Joli Fou Fm. | Joli Fou Fm. | Newcastle Fm. |
| | | Harmon Mem. | ▨ | ▨ | ▨ | Fall River Formation |
| | NEOCOMIAN - APTIAN | Spirit River Formation | Grand Rapids Formation | Upper Mannville Group | Upper Mannville Group | Fuson Formation |
| | | Bluesky Formation | Clearwater Formation<br>Wabiskaw M. | | | |
| | | Gething Formation | McMurray Formation | Lower Mannville Group | Lower Mannville Group | Lahota Formation |
| | | Cadomin Fm.<br>▨ | ▨ | ▨ | ▨ | ▨ |
| | | JURRASIC | DEVONIAN | DEVONIAN | JURASSIC | JURASSIC |

underlain by the Notikewin Member of the Spirit River Formation; the Paddy Member is succeeded by the Shaftesbury Formation, in part a lithological correlative of the Upper Shale Unit in the east and south. The Fish Scale interval is recognizable in the Shaftesbury Formation, and in this thesis, strata below this marker horizon will be referred to as the Lower Shaftesbury Formation.

A brief description of the lithological units investigated in this thesis is presented in the next section. Text-Fig. 1, referred to below, shows locations of type sections and other data mentioned in the text. More detailed and more geographically extensive discussions of lithologies and interrelations are given by Rudkin (1964, pp. 161-167). Precise location of type sections and further data is given in the publication of the Lexicon Committee of the Alberta Society of Petroleum Geologists (1960). All formations are Middle Albian in age or younger.

## Lithological Units: Central and South-Central Alberta

Grand Rapids Formation - This formation is underlain by the marine Clearwater Formation and overlain unconformably by the Joli Fou Formation. It belongs to the upper part of the Upper Mannville Group and is mainly continental in origin with some shallow marine intervals. Badgley (1952, pp. 4-5) states that this formation is:

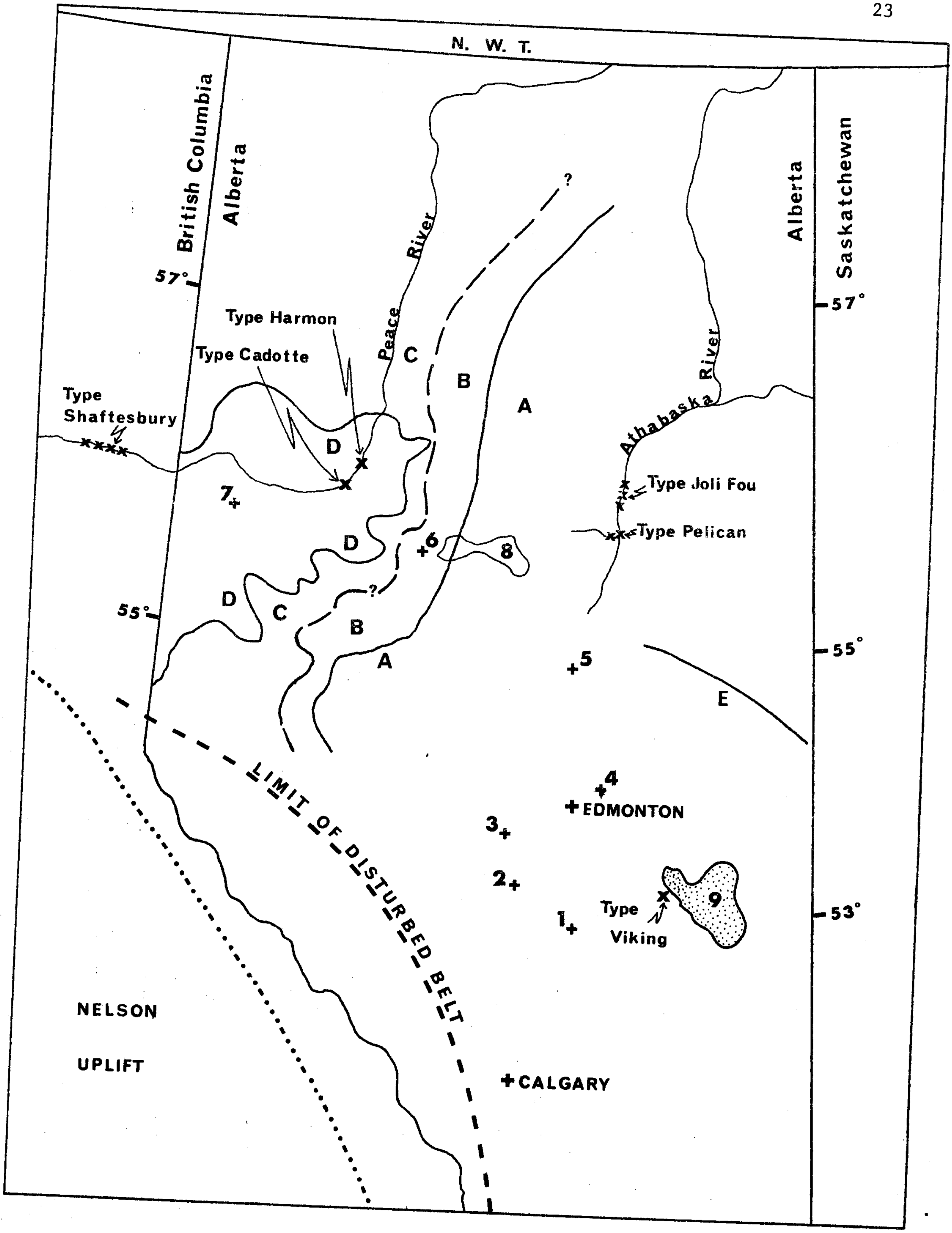
> "... a complex succession of interbedded graywackes, siltstones and shales with several thin coal beds. Locally it contains a few thin winnowed graywackes, and several persistent quartzose sandstone units... towards the east and southeast. With the exception of these...units, the other...components usually exhibit extreme lateral lenticularity. The formation is dominantly non-marine, and, for the most part, is believed to have been deposited in a deltaic environment...."

Text-figure 1. Sketch map of Central Alberta showing locations of well sites, type sections of formations and other data referred to in the text.

<u>Explanation of Symbols</u>:

1. Kissinger Imperial Chigwell No. 1.
2. Imperial Battle Lake No. 1.
3. Anglo-Canadian Wabamun No. 1.
4. Anglo-Canadian East Fort Augustus No. 1.
5. Imperial Grosmont No. 1.
6. Imperial Grouard No. 1.
7. Imperial Spirit River No. 1.
8. Great Slave Lake.
9. Viking-Kinsella Field.

A. Joli Fou, Viking (Pelican) Upper Shale present.
B. Joli Fou-Pelican overlie Harmon-Cadotte ("Transition region").
C. Harmon, Cadotte, Lower Shaftesbury present.
D. Paddy Member present in sequence.
E. Limit of Viking Formation. North of this line Viking "shales out".


N. W. T.
British Columbia
Alberta
Alberta
Saskatchewan
Peace River
Athabaska River
57°
57°
55°
55°
53°
Type Harmon
Type Cadotte
Type Shaftesbury
Type Joli Fou
Type Pelican
Type Viking
A
B
C
D
E
?
1
2
3
4
5
6
7
8
9
EDMONTON
CALGARY
LIMIT OF DISTURBED BELT
NELSON
UPLIFT

Locally, the unconformable contact is marked by a thin chert-pebble conglomerate grading into overlying dark shales.

No direct lithological correlatives can be traced in the Peace River district and the formation ceases to be recognized in this area. The type section is located near Grand Rapids, along the Athabaska River (McConnell, 1893).

Joli Fou Formation - This formation is underlain unconformably by the Grand Rapids Formation and overlain by the Pelican Formation in the north and the Viking Formation in the south; the contact is often gradational. The formation is generally considered marine in origin and consists of dark gray, noncalcareous, fissile shale with minor siltstone or sandstone lenses. Westward, where the Grand Rapids Formation thins, the Joli Fou rests on sandstones of the Cadotte Member, Peace River Formation. The thickness of the Joli Fou varies from 35' to 110' at the type section, located along the Athabaska River near Pelican Rapids (Wickenden, 1949).

Viking Formation - This formation is underlain by the Joli Fou Formation and overlain by the Upper Shale Unit. The contact with the former is gradational and with the latter is sharply defined. Badgley (1952) suggests an offshore bar environment as the depositional environment for this formation. The lithologies of the formation are variable, ranging from fine to coarse-grained winnowed sandstones, siltstones and occasional shale bands. Eastwards and northeastwards from south-central Alberta, the Viking becomes less sandy and gradually grades into siltstones and shales. The Viking Formation is a lithological correlative of the northern Pelican Formation. Westwards, the

Viking thins to a zero edge and is lost in the shales of the Lower Shaftesbury Formation and underlying sandstones of the Peace River district. The thickness of this formation in central and southern Alberta varies between 60 and 200 feet. The type section is not defined but appears to be a subsurface sequence in the Viking-Kinsella gasfield (Dowling, et al., 1919). In this thesis, the unit is considered to be a formation and distinct from the Pelican Formation in central Alberta.

Pelican Formation - The formation is underlain by the Joli Fou Formation and overlain by the Upper Shale Unit. Remains of ammonites and plants have been found indicating a near-shore or shallow water environment of deposition. Wickenden (1949) gives the lithology as light gray to whitish sandstone with variable lenses of gray shale. This formation occurs in north-central Alberta and reaches up to 40 feet in thickness, thinning westward as the Peace River section is approached. The type section is located at the mouth of the Pelican River in the Athabaska River region. It was described first by McConnell (1893) and later restricted by Wickenden (1949) to include only the upper sandstones, the lower shales being placed in the Joli Fou Formation.

Upper Shale Unit - This name is an informal one applied to the succession of dark gray, marine shales and occasional silty lenses which overlie the Viking Formation in the south and the Pelican Formation in the north. The top of this unit is considered to occur at the base of the Fish Scale Beds. The advent of this marker bed is heralded by an increasing frequency of silty lenses. This unit is likely late Albian in age and the Fish Scale marker is conventionally chosen as the top of the Lower Cretaceous in much of the Alberta plains region (Stelck, Wall and Wetter, 1958). The age relationships of this marker and other units will be discussed later.

The shale unit can be traced throughout central and eastern Alberta, and westwards becomes indistinguishable from the Lower Shaftesbury Formation. The thickness varies from 100 feet up to 250 feet in some areas. The section present in Imperial Battle Lake No. 1 well, Twp. 46, Rge. 3, W4M, may be considered as the informal sub-surface type section for purposes of this work.

## Lithological Units: West-Central Alberta

### Peace River Formation

**Harmon Member** - This is the basal member of this formation and conformably overlies the Notikewin Member of the Spirit River Formation, and underlies the Cadotte Member of the Peace River Formation. It consists of dark gray shale with occasional thin interbeds of sandstone or siltstone and a few gray bentonitic shale beds. The thickness of this member varies from 30 feet to 110 feet; the unit thins eastwards and disappears under the Lower Colorado succession (Text-Fig. 1). There is no direct lithological correlative in the Lower Colorado section with this unit (Stelck, 1958). Several wells in the transition regions between regimes show the Joli Fou-Viking sequence resting on Cadotte sandstones with Harmon shales stratigraphically below this. The type section of the Harmon is located near Peace River, Alberta; the unit was named by the Alberta Study Group (1954).

Cadotte Member - The Cadotte Member is underlain conformably by the Harmon Member. The lithology consists of grayish, fine to very fine-grained, occasionally course-grained, friable or firm, often glauconitic, "salt and pepper" sandstones (the subgraywackes of Pettijohn, 1949). Interbeds of siltstone or gray shale occur, especially outside of the type region. The thickness of the unit varies from 30 to 170 feet. South of Twp. 88, the Cadotte Member is overlain, probably disconformably, by the Paddy Member (Wickenden, 1951). North of Twp. 88, the member is overlain disconformably by the Lower Shaftesbury Formation and to the east disconformably by the Joli Fou Formation. The type section was not designated but the section described by Wickenden (1951) on a tributary of the Peace River in Twp. 85, Rge. 21, W5M has been proposed. The original name was suggested by McLearn (1944).

Paddy Member - This member is underlain, probably disconformably by the Cadotte Member and is overlain disconformably by the Lower Shaftesbury Formation. The lithology comprises white, buff to light gray sandstones, poorly sorted, with varied grain size and often includes silty and carbonaceous beds. A few coal beds also occur. The lithology supports an interpretation of a continental and deltaic environment of deposition for this member. The thickness of the unit varies considerably from 0 to 130 feet and its shape and lateral extent appear similar to a bird-foot delta (Rudkin, 1964). The type section of the Paddy Member is located north of Peace River, Alberta (Wickenden, 1951).

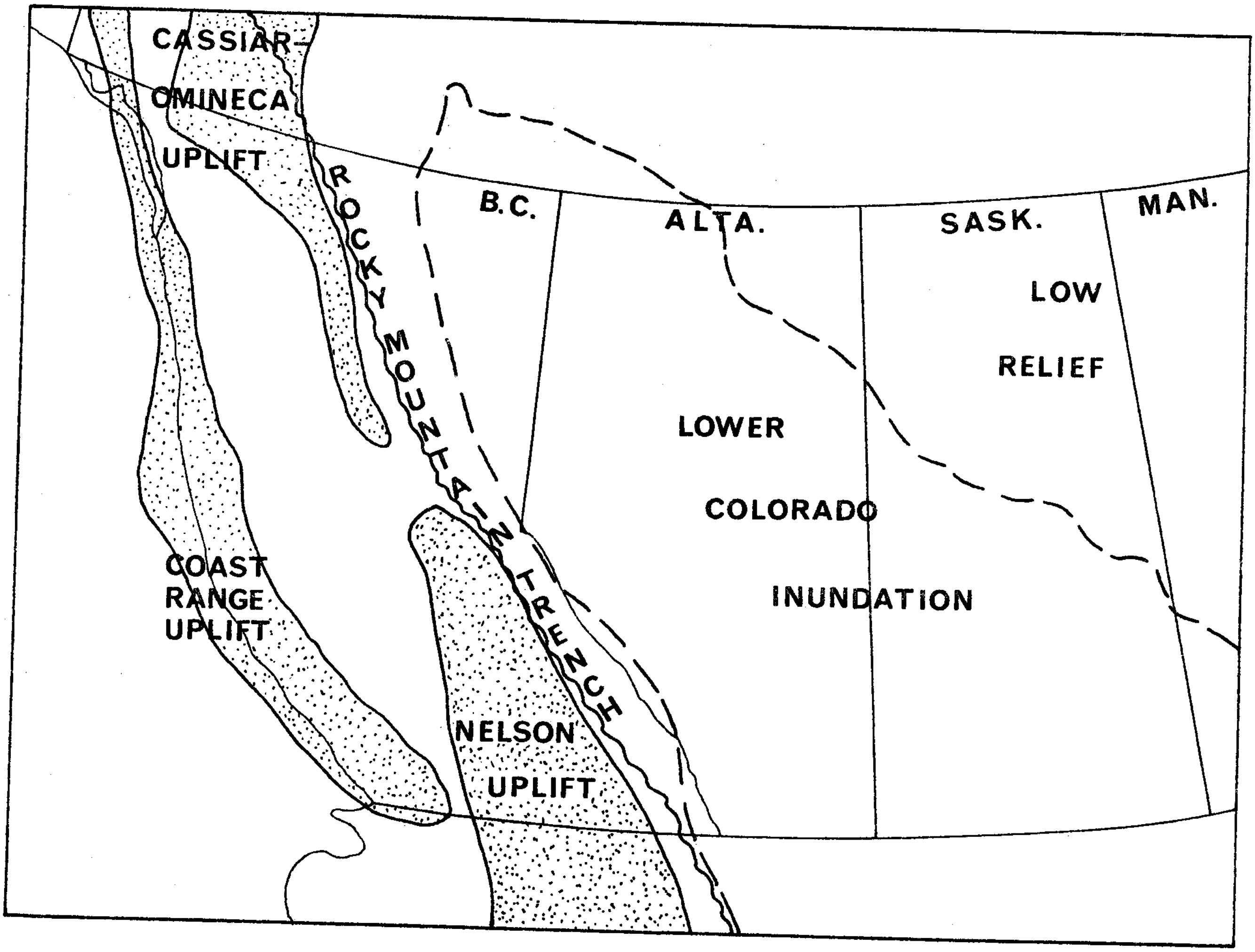
Lower Shaftesbury Formation - In Alberta, this formation is underlain disconformably by the Cadotte Member of the Peace River Formation, or the Paddy Member if present. It includes, and in the upper part extends above, the Fish Scale marker bed in west-central Alberta. To the east, the Lower Shaftesbury passes into the Upper Shale Unit and associated formations. The lithology of this formation is predominantly dark gray or bluish gray shale, of marine origin, and having occasional ironstone concretions. The type section of the Shaftesbury Formation occurs on the lower Peace River in British Columbia. The thickness at the type section is 70 feet but this increases eastwards to over 600 feet. Approximately 400 feet are present in the Peace River region.

## REGIONAL GEOLOGY

As a final step in the understanding of the geological background, a brief outline of the regional geology of the area of investigation, from a historical and structural standpoint, will be useful.

### Geological History of the late Lower Cretaceous in Central Alberta

The Upper Mannville Group (Grand Rapids Formation) represents the eastward extension of sedimentary deposits equivalent to the Blairmore Group in the western part of the basin. In eastern and central Alberta, during late Mannville deposition, there occurred a period of emergence and erosion, followed by cratonic subsidence and northward transgression of the gulfian epicontinental sea. Meanwhile in the Peace River district, a marine transgression of the boreal continental sea from the Arctic regions had reached its peak. Thick deposits of marine and shallow marine beds with occasional nearshore



Text-figure 2. The tectonic framework of the Western Canada Sedimentary Basin in Lower Cretaceous time. Modified after Webb (1964).

sequences had formed. Then, while the gulfian sea transgressed in the south and the Joli Fou-Viking sequence was being deposited, a marine regressive succession began to develop in the Peace River area (Wickenden 1951, p. 31). This cycle progresses at any given location through shallow marine, nearshore, and then deltaic facies if the Paddy Member is present. Again, it may be noted that the Harmon Member is thus part of a different sedimentation cycle than the Joli Fou Formation (Stelck, 1958) and thus is not an equivalent as some authors have suggested (Workman, 1959).

The marine transgressive cycle continued in central and eastern Alberta and the gulfian sea finally inundated even the Peace River area, submerging the deltaic deposits of the Paddy Member. It was during this phase that the Lower Shaftesbury and Upper Shale Unit were deposited. The marine inundation persisted into the Upper Cretaceous series in the western Canada basin. In its greatest extent, the epicontinental sea covered most of what is now Alberta, southern Saskatchewan and southwestern Manitoba (Text-Fig. 2).

## Tectonic Framework and Sediment Sources

Examination of the tectonic framework in Lower Cretaceous time (Webb, 1964) shows highland regions existing to the west of the depositional basins of Alberta. These uplifted regions, which were formed in the late Jurassic, are named the Nelson Uplift in southeastern British Columbia and the Cassiar-Omineca Uplift in northern British Columbia (Text-Fig. 2). A structural saddle also existed between these two uplifted areas. Just east of the uplifts, the Rocky Mountain Trench can be traced, trending northwesterly. West of this region, in the vicinity of present-day interior British

Columbia and the Pacific Coast, there was a eugeosynclinal basin and a highland region, the Coast Range Uplift. On the eastern margin of the Alberta-Saskatchewan basin, the boundary of the Canadian Shield trended northwest at this time. These highlands probably contributed some clastic material to these eastern areas of the basin.

The western highlands provided much of the clastic material deposited as the Blairmore Group, and farther away in the central and east-central region of the basin, the Grand Rapids Formation of the Upper Mannville Group. It is likely that they also functioned as the provenance area for much of the sediments of the regressive marine sequence of the Peace River Formation. Later reworking of these beds, fresh material from the highland sources, and recycled material from older exposed strata of Carboniferous and Permo-Triassic age, provided the material for the deposits of the marine transgression which finally succeeded the relatively emergent phase.

Norris (1967) reports recycled Carboniferous and Permo-Triassic spores in the Viking Formation near Edmonton. These recycled spores give some indication of sediment sources of the Lower Colorado succession.

It is apparent from this summary that the sections through the Lower Colorado Group in central and south-central Alberta will be representative of deposition relatively far offshore, the nearest shorelines being more than a hundred miles away. Local topographic highs may be present. In contrast, sections nearer the Peace River district will reflect a gradual encroachment of nearshore and probable deltaic depositional environments; this regime will end only with the major marine transgression of the latest Lower Cretaceous.

## LITHOLOGICAL CORRELATIONS IN THE LOWER COLORADO GROUP

Lithological correlation is not to be confused with time correlation based on faunal and floral assemblages. Where lithological correlations are made between sections only a few miles apart, formation boundaries may approximate time lines. However at greater distances, these boundaries cease to be time lines and must logically exhibit diachronism to a greater or lesser degree. In the past, much confusion has been engendered by the use, interchangeably, of time units and lithological units to mean time boundaries. A formation is defined classically as a lithological unit which may be mapped over a wide geographical area; it can and generally must transgress time lines. The following correlations are thus purely lithological and bear no time values.

While most of the units, except for the Viking Formation are defined in surface outcrop, most of the sections examined in detailed studies are subsurface. This is because there is a relatively narrow outcrop region at the surface for most of these units. Within the Lower Colorado Group, most of the subsurface contacts are relatively sharply defined on lithological grounds alone. The Joli Fou-Viking contact, however, may be gradational and in many subsurface sections is defined on the basis of a characteristically positive "kick" on the electric log scales as well as lithological change.

These lithological units are recognizable throughout central Alberta and in the transition region (see Text-Fig. 1) in west-central Alberta, where typical Lower Colorado strata come to overlie the Cadotte-Paddy sequence of the Peace River Formation. In this transition region, Joli Fou shales rest unconformably on sandstones of the Cadotte Member and the Pelican Formation thins to a zero edge. A little further west the Joli Fou and Upper Shale Units lose their identity and merge into the Lower Shaftesbury Formation shales.

Within the Peace River Formation, the various members may be separated on a lithological basis throughout their extent. The Cadotte-Paddy boundary is sometimes difficult to draw and some arbitrary point must often be chosen. The Paddy Member exhibits extreme lateral variation in thickness within relatively short distances and may disappear entirely, leaving the Cadotte Member lying unconformably below the Lower Shaftesbury. The relationship between the Harmon Member and the Joli Fou Formation is well-shown in subsurface well sections from the transition regions (Bear Villa No. 1; Imperial Grouard No. 1; Text-Fig. 1) where the Joli Fou lies unconformably on the Cadotte sandstones and stratigraphically above the Harmon beds.

## DIACHRONOUS BOUNDARIES AND FACIES CHANGES IN THE LOWER COLORADO-PEACE RIVER SUCCESSION

Disconformable contacts usually indicate periods of non-deposition or erosion of varying lengths of time. Mellon and Wall (1963) and Norris (1967) present evidence which supports a possible disconformable contact between the Upper Grand Rapids Formation and the Joli Fou Formation in central Alberta. In the Peace River district, the contacts of the Cadotte Member with overlying strata appear in most cases to be disconformable, especially in the transition region where this member is overlain directly by marine deposits of the Joli Fou Formation transgressing from the southeast. In all likelihood some of these contacts may prove to be diachronous, especially if they extend over wide regions. The various movements of the gulfian and boreal epicontinental seas introduce, also, an element of diachronism within the formations themselves.

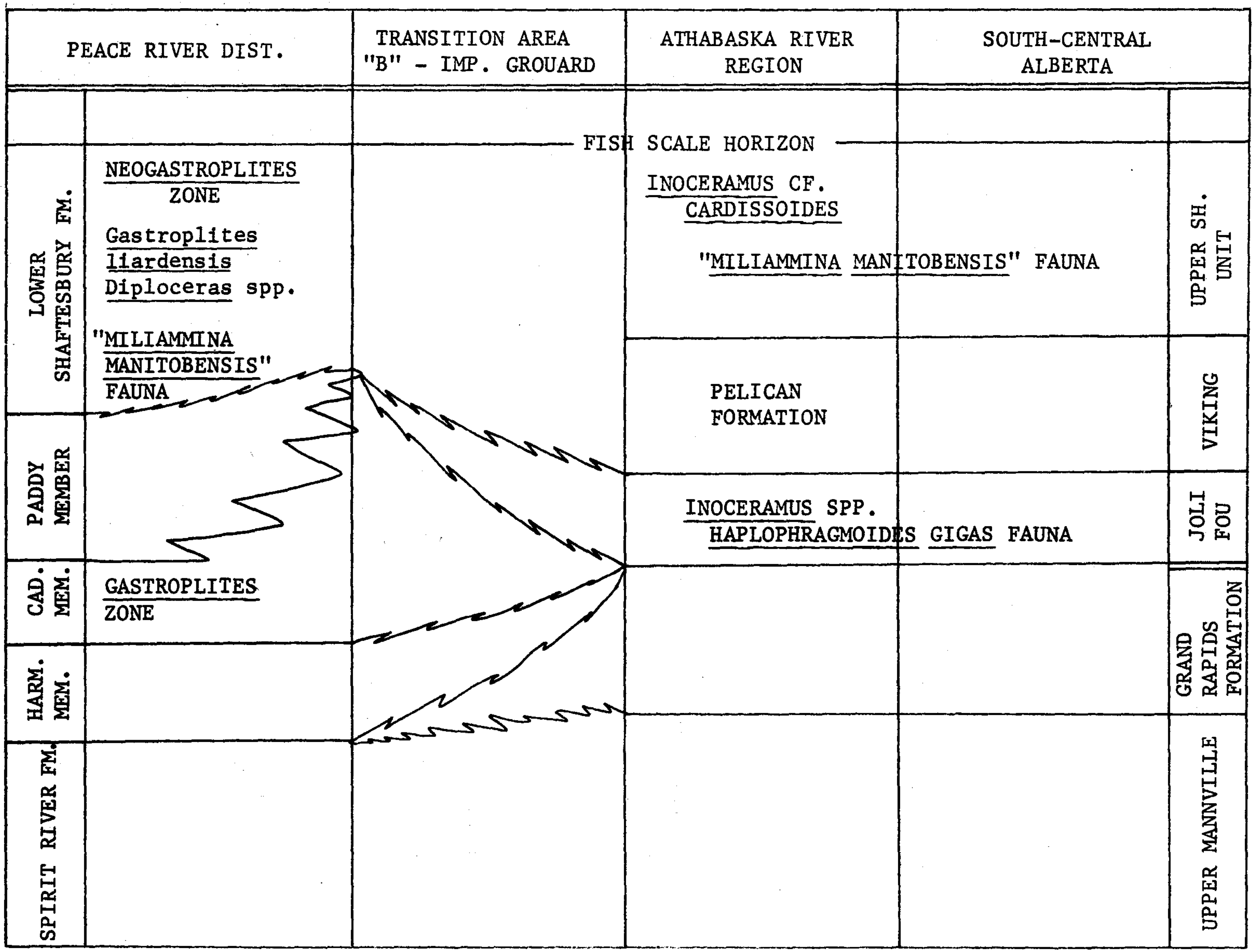
The preceding summary of the lithological units and the regional geology of the area of investigation has indicated that a variety of facies is present. Facies, as used here, means a deposit which is associated with a generalized type of depositional environment, essentially an environmental facies. The deposits in this region come from marine, shallow marine, nearshore or deltaic, and perhaps even some non-marine environments. In the transition region, marine shales of the Joli Fou Formation onlap sandstones of the Cadotte Member. Further west, deltaic or nearshore facies interfinger with more marine units. These factors make the understanding of time relations within and between the formational units more difficult. Some attempt has been made to understand these time relationships using faunal assemblages. These efforts will now be discussed.

## FAUNAL ASSEMBLAGES AND TIME RELATIONSHIPS IN THE LOWER COLORADO PEACE RIVER SUCCESSION

Jeletzky (1956), Newell (1962), and others, have forcefully argued that fossil assemblages are the only practical guide to time relationships between rock units. It follows that fossil assemblages are also the only practical means of assessing the extent of diachronism between lithological boundaries over extensive geographical regions.

The question of time relationships within the formations of this sequence and across the major boundaries has been approached in earlier studies using faunal assemblages (Wickenden, 1951; Stelck, 1958; Stelck, et al., 1958; Mellon and Wall, 1963; and others). Because of the scarcity of faunal assemblages and the paucity of data made available by their study, this work has been only moderately useful in understanding the time relations. As will be outlined later, these drawbacks do not occur when miospore and microplankton assemblages can be used.

A foraminiferal assemblage, the Haplophragmoides gigas Cushman assemblage, occurs throughout central and eastern Alberta and in southern Saskatchewan in the lower portion of the Joli Fou Formation (Wickenden, 1949, p. 20; Stelck, 1958). The Upper Shale Unit and part of the Lower Shaftesbury Formation carry the "Miliammina manitobensis" fauna throughout much of Alberta (Stelck, 1958). Stelck, et al. (1958) also describe a microfauna, along with an associated macrofauna in the Peace River district and adjacent British Columbia which is indicative of latest Albian age. This is termed the "Neogastroplites zone" because of the presence of this characteristic ammonite in the assemblage. Scattered ammonite locations in the Cadotte Member place this unit at the top of the Middle Albian (Stelck, 1958). As the Joli Fou-Pelican (Viking) sequence comes to overlie the Cadotte Member disconformably in the transition region, Stelck also concludes that the Viking (and Pelican) are basal upper Albian in age. The "Neogastroplites zone" can be traced into west-central Alberta where it approximates the position of the Fish Scale marker horizon.



Text-figure 3. Major faunal zones in the Lower Colorado Group and equivalents in Central Alberta. Vertical scale highly distorted; thickness of strata highly conjectural. Data from many sources.

These and other faunal associations are shown in Text-Fig. 3. Only the Foraminifera and Ammonoidea have been useful in this regard.

Stelck (1958, p. 5), citing Badgley (1952), states that the pelycepod, Inoceramus altifluminis McLearn, found in the Paddy Member, is also found at the top of the Joli Fou Formation in the Athabaska region. The writer cannot find any such reference in Badgley (1952). Further, Wickenden (1949) refers only to one specimen, uncollectable and incomplete, but photographed. McLearn (quoted in Wickenden, 1949, p. 18) comments "The large specimen in the photograph shows at least a superficial resemblance to the late Lower Cretaceous species Inoceramus altifluminis". The writer feels that this determination is insufficient to support the statement of Stelck.

When the evidence is reviewed, it becomes apparent that the faunal assemblages in these formations can provide only general age determinations and cannot be used to understand time relationships within units or the extent of diachronism across lithological boundaries. The evidence is limited by the relatively sparse foraminiferal assemblages and the even more scattered ammonite remains. The density and frequency of faunal remains also makes it impossible to determine the time values of these assemblages. Faunal assemblages are also controlled in many cases by their palaeoecology; it is always possible that these faunal "zones" may in fact transgress time lines. Only dense distribution and wide geographical distribution can provide the information necessary to evaluate palaeoecological control (Ager, 1963: and many others).

Abundant assemblages of miospores and microplankton are known to occur in several subsurface sections of the Lower Colorado Group (Norris, 1967; Pocock, pers. comm.). It is likely therefore, that these microfossil types would be ideal for the purpose of examining time relations in the Lower Colorado and its equivalents. The final section of this chapter outlines some of the reasons for this belief.

## PALYNOLOGY AND TIME-STRATIGRAPHIC DETERMINATIONS IN THE LOWER COLORADO GROUP AND ITS EQUIVALENTS

Miospores and microplankton occur in varying concentrations in rocks of the Palaeozoic to the Holocene, as well as in organic and non-organic deposits of recent origin. They are found most abundantly in fine-grained clastic sediments and less abundantly in limestones, evaporites, and least commonly in coarse-grained clastic sediments. Such is their concentration that even samples low in abundance may yield several hundred grains per slide. These microfossils are widespread geographically and, as a group, are not restricted to any particular environment or facies.

Miospores represent the gametophytic generation of lower and vascular plants. They are released from the reproductive structures, the sporangia, and then dispersed by water, wind or other natural agents. Eventually, some of these are carried into depositional basins and fossilized. Miospores are found in greatest absolute abundance (number per gram of sediment) in continental or nearshore deposits (Muller, 1959; Stanley, 1965; and others) and near the mouths of river systems, generally decreasing in absolute abundance away from shore (Hoffmeister, 1954) and from the river mouth (Muller, 1959; Traverse and Ginsberg, 1966). Long shore drift currents may also redistribute the miospores as well as the action of other currents, turbidity currents or even wave action. The microfossils are not limited to any particular environment or lithofacies. Natural oxidation and reduction or diagenetic processes of compaction and lithification may preferentially destroy grains. Because miospores are essentially sedimentary particles (Williams and Sarjeant, 1966; and others), they may be sorted and winnowed. Despite these forces, miospores, because of their variety and abundance and the other factors discussed, provide an excellent means of time correlation.

Fossil microplankton are found in marine or shallow marine-nearshore deposits, occurring rarely in non-marine rocks (Churchill and Sarjeant, 1963). They thus have environmental significance. These fossils comprise dinoflagellate cysts, or related entities, algal cysts, and may include members of other groups. Unlike the miospores they are subject to the influences of the life and depositional environments. They may or may not be facies-specific, and they are controlled in their vertical and lateral stratigraphic distribution by sea movements and migration with facies changes. The absolute abundance of microplankton is low near shore but increases rapidly seaward before dropping off slowly (Sarmiento, 1957; Muller, 1959). They are subject, like miospores, to sedimentary and diagenetic processes.

Where mispores and microplankton occur together in abundance, they provide an excellent opportunity to conduct detailed time-stratigraphic correlations. Both land-introduced and marine microfossils are present, affording a chance to integrate miospore and microplankton biochronology. Such conditions are present in the deposits chosen for investigation. Because the assemblages are composed of both marine and non-marine entities, because they are abundant, and because they both transgress and occur in restricted facies, use of miospores and microplankton in the Lower Colorado Group and equivalents appears to be the best technique in the solution of time relationships in those sequences.

Sampling techniques, extraction methods and choice of material all affect the final results of such work. These areas will be discussed in the next section.

# III

# THE SELECTION OF MATERIAL AND THE PREPARATION OF SAMPLES

## TYPE OF MATERIAL

The samples used in this work are derived from cores of subsurface sections located in west-central, central, and south-central Alberta. These cores are stored in the Oil and Gas Conservation Board sheds in Edmonton, Alberta, Canada. Each five foot interval of recovered core is stored in two-and-a-half foot sections in a separate labelled box. Samples from these cores are collected either as channel samples of the complete interval and bagged as chips, or as small segments of core, 1-2" in length, chipped from throughout the sampled interval. For this thesis, the span of the sampled interval varies from one, five, up to ten feet, the latter being the most commonly used. Sections have been sampled both continuously, except for gaps due to non-recovery of core, and discretely, where the stratigraphic thickness to be examined was very great.

## LIMITATIONS OF CORE MATERIAL

There are disadvantages in working with core material as opposed to the collection of samples from surface outcrop. Non-recovery of part of the cored interval may occasionally occur. There is always the possibility of contamination from admixture of drill mud, cave-ins from the wall rock, and airborne debris with the actual core. The very abundance of material in cored sections makes it necessary to be selective both as to intervals and sampling within the intervals. The procedure is necessarily subjective and may affect the final results to a greater or lesser degree. The arbitrary choice of a sample interval may cause confusion of two biostratigraphic zones, leading to anomalous results. The choice of intervals, even one-foot intervals, means that the assemblages in that interval are essentially being averaged. The significance of the assemblages is thus generalized. Gross elements of the changes in miospore and microplankton assemblages may be discerned, but more subtle changes are of necessity obscured in this average picture. Finally, the core is only a few inches in diameter and thus samples a very small lateral extent of the beds penetrated by the drill bit.

## PRACTICAL ADVANTAGES OF CORE MATERIAL

The primary advantage of the use of subsurface sections is the greatly increased geographical coverage made available to the investigator. Surface sections allow the study of one section only; this section is spread over a considerable distance and may overlap at several outcrops, presenting a mosaic pattern to the worker. Subsurface sections may be drilled wherever it is practical, and they provide a more or less complete section at that location. In the Lower Colorado interval, for example, the sections are available from geographical locations otherwise unlikely to be studied. The number of sections from which selection could be made is over one hundred, with many of these providing a continuously cored interval.

The opportunity exists to exercise stratigraphic control to whatever degree, within limits of the number of sections drilled, that the investigator wishes. This is not possible with the use of surface sections at outcrop localities.

While core material covers only a small lateral area in itself, it provides a means for investigating far more lateral geographical variation in fossil assemblages, as well as selected intervals in the section. Although the choice of sample interval is somewhat arbitrary, it is also in a sense random, because the sample interval limits usually begin at some base point and then proceed upwards in the section. These base points are most often determined by lithological (formational) boundaries or electric-log tracings; the deliberate avoidance of coarse-grained intervals in the sequence may also have some influence on sample intervals. Finally, the well data provide much more preliminary information on the regional geology and stratigraphy of the area than could be determined using surface outcrops alone.

Thus the writer feels that the advantages far outweigh the disadvantages which are incurred in using core material. This type of material in fact appears most suited to the development of the objectives proposed earlier in this account.

## SOURCE OF MATERIALS

Samples have been taken from selected portions of six subsurface sections of the Lower Colorado Group and its equivalents from west-central to south-central Alberta. Descriptions of the lithologies of the samples, intervals and other information is given in Appendix II. The locations of these well sites are shown in

Text-Fig. 1, and further information is set out in TABLE 3 below. Locations of wells for which samples were obtained from other workers are given following the primary wells used in this investigation. The numbers in the location column refer to lot sub-division, section, township, range and meridian reference respectively.

TABLE 3. Location of well sites and other sections used in the investigation of the Lower Colorado Group and its equivalents in Alberta

| NAME OF WELL | LOCATION | INTERVAL | FOOTAGE | NO. SAMP. |
|---|---|---|---|---|
| Imperial Battle Lake No. 1 ("Battle Lake") | 16-12-46-3-W5M | 5216-5530 | 324 | 38 |
| Kissinger Imperial Chigwell No. 1 ("Chigwell") | 11-8-41-25-W5M | 4803-4943 | 140 | 15 |
| Anglo-Canadian Wabamun No. 1 ("Wabamun") | 5-10-51-4-W5M | 4478-4639 | 171 | 9 |
| Imperial Grosmont No. 1 ("Grosmont") | 13-17-67-23-W4M | 1402-1574 | 172 | 13 |
| Imperial Grouard No. 1 ("Grouard") | 12-16-175-15-W5M | 1379-1402 | 24 | 5 |
| Imperial Spirit River No. 1 ("Spirit River") | 12-20-78-6-W6M | 2045-2680 | 635 | 26 |
|  |  |  | TOTAL | 106 |
| Anglo-Home - C and E Fort Augustus No. 1 | 7-29-55-21-W4M | (Singh, 1964; Norris, 1967) |  | 3 |
| Imperial Willingdon No. 1 | 14-14-55-15-W4M | (Singh, 1964) |  | 1 |
|  |  |  |  | 110 |

In addition to these well sites, information where available, has been integrated with results of this study from palynological investigations of surface type sections of the Peace River Formation (Singh, in progr.) and information communicated orally (Norris, pers. comm.; Pocock, pers. comm.). The information from surface sections extends the geographical coverage of this interval nearly one hundred miles north from the Imperial Spirit River No. 1 well site of this study.

These particular well sites were chosen, where possible, to conform to a pattern of sampling which provided maximum lateral and vertical coverage of the Lower Colorado intervals. The southern well sites pass through the typical Joli Fou-Viking-Upper Shale Unit section and include the Fish Scale marker. The "Grosmont" well site includes the Joli Fou-Pelican sequence in the Athabaska region. The "Grouard" well site provides an example of the Cadotte Member-Joli Fou Formation boundary and the "Spirit River" section provides a complete section from the base of the Harmon Member to beyond the Fish Scale horizon in the Shaftesbury Formation. The additional sources of information include the intervals re-examined for microplankton content from Imperial Willingdon No. 1 and East-Fort Augustus No. 1 well sites in east-central Alberta (Singh, 1964; Norris, 1967) and information about the palynology of the type sections of the Peace River Formation (Singh, in progr.).

In order to provide continuity with earlier investigations, uppermost portions of the Grand Rapids Formation (Upper Mannville Group) were also investigated at the "Grosmont" and "Battle Lake" well sites. Together with similar work by Norris (1967), this should provide a fairly complete understanding of miospore assemblage changes across this boundary. It is to be regretted that the part of the section which includes the upper portion of the Joli Fou Formation, the Pelican Formation and the succeeding shale sequence, as cored in Imperial Grouard No. 1 well, was not available from the Alberta Oil and Gas Conservation Board. Similarly, the Upper Pelican Formation and Upper Shale Unit in Imperial Grosmont Well No. 1 were also unavailable for sampling. However, it was thought that the available core would be adequate for the purposes outlined earlier in this thesis.

## THE PREPARATION OF SAMPLES

Prior to sampling the material derived from the core interval, large chips and core segments are washed briefly, or if well indurated, scrubbed with a wire brush under hot water in order to remove any surface contamination. All of these pieces are then dried and small chips taken from each of them are placed in an iron mortar. In this manner, it is believed that the best sampling of the available material is achieved and the amount of unsampled material is kept to a minimum. This process yields approximately 30-50 grams of rock chips which are then crushed to about 1 mm. in size and placed in a copper beaker (300 ml. capacity). After each sample has been crushed, the work area is thoroughly cleaned and all implements are washed under hot running water and scrubbed with a wire brush. The next sample is unpacked and the procedure begins again.

The chemical processing of the crushed sample is a simple variation of standard techniques described in many papers (Brown, 1960; Brideaux, 1965) and will be briefly outlined here:

1. The crushed material is treated with cold concentrated HCl from 15-20 minutes to remove carbonates. The residue is washed.

2. Cold reagent grade Hydrofluoric Acid (52%) is added carefully to the residue. The sample is then left in cold HF for 48-72 hours, with fresh acid added after 48 hours; the sample may also be treated in hot acid for 2-4 hours with fresh acid after 2 hours, in order to speed the process. The mixture is then allowed to settle, excess acid is poured off and further washes remove the remaining acid.

3. Two to ten washes with warm concentrated HCl follow, each lasting 10-15 minutes. This is continued until the residue becomes "loose" in texture. The process removes silicate gels (Norem, 1953; Forsman and Hunt, 1959). During these and all following steps, a few drops of 1% solution of Kodak Photo-Flo are added to facilitate dispersion of residue in the reagents.

4. One wash with Darvan #4 (a weak inorganic salt) follows, and then the residue is treated with concentrated or diluted Nitric Acid, depending on the degree of oxidation necessary. This process oxidizes humic material and excess organic debris, rendering it soluble in a base. Excess acid is washed out.

5. If necessary, treatment with a mild base, preferably with a 5% solution of sodium carbonate, but occasionally with 5% potassium carbonate, follows. The excess alkali is then washed out and the supernatant liquid containing the soluble humic material is decanted.

6. If necessary, a further two washes with concentrated HCl follow. This helps disperse any remaining gelatinous material. The pH of the residue is adjusted to basic by addition of 5% sodium carbonate solution; excess base is then washed out.

7. Staining, where needed, is carried out by the addition of a 1% solution of safranin-O in alcohol, and a few drops of a saturated solution of basic fuscin in water, to the residue. The excess stain is washed out and the residue is now stored until further need in a solution of glycerine, water and 1% phenol mixture in a suction-top plastic vial.

It is important to note that the whole process is done so as to minimize contamination and loss of microfossils during the procedure. The oxidation process is the most critical part of the procedure and the residue is examined periodically to ensure that no microfossil types are being destroyed. Oxidation is often stopped while some microfossils are incompletely oxidized in order that no microfossils may be destroyed. Ordinary tap water is used in place of distilled water as no contamination has been noted from this source in over 200 preparations.

Preliminary tests on residues from many different geological periods and varying lithologies, have shown that no microfossils, or only a few of the most common types present in the residue, are lost in decanting supernatant material from 50 ml. test tubes following short-centrifuging (Funkhouser and Evitt, 1959; and others).

Slides are prepared in the following manner. Two drops of warm glycerine jelly, with phenol crystals (Courteville, 1937) and one drop of residue are mixed carefully on a warmed slide, then spread out evenly in a line nearly the length of the 22 x 40 mm. No. 1 coverslip. The coverslip is allowed to touch the mixture and then is lowered carefully into place. Care is taken to prevent loss of the mixture from under the coverslip. The slides are then placed upside down on a glass rack and allowed to cure for 24 hours. They are allowed to cool in this position before being righted. The edges of the coverslip are then scored with a razor blade and the slides are sealed with clear nailpolish (Cutex brand).

Labels bearing the well name, the maceration number and slide number (e.g.: BW 148/2) and other information if necessary, are placed at one end of the slide and coated also with nailpolish to keep them from being damaged. The slides are then stored flat in a cool place until used. Two to four slides are prepared in this manner for each sample investigated in this thesis.

## THE INVESTIGATION OF THE SAMPLES

Scanning - Each slide used in this investigation is provided with a reference X scratched on the slide with a diamond pencil. The co-ordinates of the centre of this X are recorded and form a reference reading for all grains on the slide. The slide is placed on the stage with the label always to the right. Scanning is begun at the upper right-hand corner of the slide using the X125 power, and continued at 2 mm. intervals thereafter. A second slide is examined in the same manner but at 4 mm. traverse intervals. Where necessary, specimens are examined at 500X, 1200X and occasionally 1500X. This method of traversing covers 75% of the area of the first slide and 40% of the area of the second slide. Other slides prepared from the residue are examined in a random manner but not systematically traversed. The writer thinks that this method ensures adequate coverage of the assemblages present in the samples. This is particularly important where assemblages are being examined for presence of species, especially rare species of importance to time-stratigraphic studies.

Retrieval of Information - The co-ordinates recorded for type specimens, other specimens, and other data of interest, are those on the stage of Leitz Microscope 669334, currently in the Palaeobotany Laboratory, Hamilton Hall, McMaster University, Hamilton, Ontario, Canada. Any specimen may be recovered, if recorded, by finding the co-ordinates of the reference X on the stage on the other microscope and then converting co-ordinates to locate the desired specimen. Co-ordinates of all type material and photographed specimens are stated in this thesis either in the section on taxonomy or in plate legends near the end of the account.

Photographs of type specimens and other selected specimens were taken with a Leica II camera mounted on a standard monocular tube, equipped with a viewer, timer, and trip mechanism operating the shutter system. Kodak Improved Panatomic-X film (ASA 32) was used throughout the work and developed in Kodak Microdol-X stock solution, diluted 1:3 with water, for 11 minutes at 24°C. This procedure secured the maximum definition of image with adequate contrast. Orange, shades of green, and blue filters were used where required to secure enhanced detail or contrast. Many photographs were taken at X1200 power under oil immersion, but most were taken at a standard 500X. Photographic prints are enlarged to standard values of 500X, 1000X and occasionally 1800X for the small angiosperm tricolpate grains.

Counting Procedures - Brookes and Thomas (1967) have shown conclusively that standard counting procedures used in pollen analysis, and employed also in pre-Pleistocene studies, are biased. This results from a non-random distribution of pollen grains on the slide, influenced perhaps by size, shape and ornamentation of the grain. Brookes and Thomas (1967) point out that in this case, a random sample could be obtained only by counting all the grains on the slide. The counting of a complete slide in the case of assemblages from the Lower Colorado Group would involve more than 10,000 grains for many samples and would be impractical for more than a few samples. In view of this, the author thinks that some other method must be devised to minimize the bias inherent in the non-random distribution of grains on the slide.

It is important in any counting procedure to sample the whole of the slide and not just one portion. Hence counting a specified number of grains (Barkley, 1934) will not likely give a result without serious bias. Brookes and Thomas (1967) state that work is in progress on the evaluation of various counting methods. Brookes (pers. comm.) stresses the need to count more grains, to standardize the counting procedure and to sample the whole slide.

The author has adopted the following method and thinks that it overcomes some of the difficulties discussed earlier. One slide is traversed parallel to the long edge of the coverslip at 2, 7, 12, 17, and 21 mm. from the edge of the coverslip. At X250, this procedure covers approximately 15% of the total slide area, and at X125, it covers 34%. A second slide is then traversed at 4, 11 and 18 mm. from one long edge, covering about 9% of the area at X250 and 18% at X125. The magnification used is determined by the density of grains on the slide. The two counts are then totalled to give a final value for the sample.

Any differences between the two slides will arise from non-random distribution of the grains, non-random sampling of the residue and operator error (Smith and Butterworth, 1967).

Brookes (pers. comm.) appears to favour crosswise traverses rather than lengthwise traverses. However, in the absence of conclusive data, the author thinks that spaced lengthwise traverse should yield results similar to crosswise traverses. Preliminary investigations on several samples are inconclusive on this point. These results and interpretations will be further discussed later.

The reasons for counting the various ratios outlined below will be discussed later after presentation of the results. It may be stated at this time, however, that the author believes these ratios have biological and distributional significance. Five separate components will be counted and three ratios calculated for each sample. The components are:

a) trilete, monolete and hilate spores,

b) bisaccate, inaperturate, sulcate and tricolpate grains,

c) acanthomorph and polygonomorph acritarchs,

d) all other acritarchs,

e) dinoflagellates.

It may sometimes be useful to separate the totals for hilate spores, for tricolpate grains, and for acanthomorph and polygonomorph acritarchs. These entities have some significance apart from the major categories (Dettmann, 1963; Wall, 1965).

The following ratios will be calculated:

1) Total spores and pollen / Total microplankton
2) Total spores / Total pollen
3) Total acritarchs / Total dinoflagellates

Ratio (1) is that used by Upshaw (1964) and is derived from the inverse of the ratio proposed by Sarmiento (1957). The writer prefers to use a decreasing ratio rather than increasing ratio to indicate increase in the total microplankton fraction. The other ratios are based on considerations of the writer to be discussed in a later chapter of this account. Traverse and Ginsberg (1966) point out the difficulty of distinguishing inaperturate pollen with smooth walls from members of the leiosphaerid sphaeromorphs (acritarchs). In presenting the results of the counts, the criteria used to refer such types to one grouping or the other will also be presented.

Finally, a study of recurrent species patterns in the microplankton assemblages will also be attempted. The description of the method and discussion of the implications of this procedure are deferred to a later chapter in this thesis. A print-out of the computer program used to calculate the numerical values and a sample page of data print-out are included as Appendix IV.

# IV

# QUALITATIVE AND QUANTITATIVE PALYNOLOGY OF THE LOWER COLORADO GROUP

In this section are presented all of the qualitative and quantitative data derived from the scanning and counting procedures outlined in the previous chapter. While much of these data are presented in the form of tabulations, charts and graphs, some comment is also included in the text for each major unit. Discussion and interpretation of these results as well as exposition of certain newly proposed methods is deferred to the following chapter.

## GENERAL CHARACTER OF LOWER COLORADO ASSEMBLAGES

A total of 106 samples selected from the six well sites listed in TABLE 3 were processed and the residues were examined for their microfossil content. Only 3 samples proved to be barren of plant microfossils. Approximately 25% of the samples yielded poor assemblages, both in preservation and abundance of entities. The remaining 75% of the samples yielded assemblages showing fair to excellent preservation and adequate to extremely abundant numbers of entities. The number of microfossils present in a drop of residue ranged from less than 10 in nearly barren samples to values probably exceeding 10,000 in abundantly microfossiliferous samples. Samples of the Upper Mannville Group in the "Battle Lake" section as well as the base of the Fish Scale Beds in the same well and the upper Cadotte-lower Paddy Members of the "Spirit River" section comprised the bulk of the sparsely microfossiliferous material.

Preservation of the assemblages varied considerably. Regionally, consistently more poorly preserved material was obtained from the Upper Mannville-Joli Fou-Viking units from wells in south-central Alberta, although preservation tended to improve in the Upper Viking Formation and continued this trend in the Upper Shale Unit assemblages. Assemblages obtained from samples of the "Wabamun" section in south-central Alberta were perhaps slightly better preserved than those from the other wells in this region. It should be pointed out that exceptions to this general regional grade of preservation did occur in samples from all sections examined. In samples from well sites in west-central and central Alberta, preservation improved markedly and was consistently good to sometimes excellent. The best preserved assemblages were encountered in the samples from the "Grouard" well site, and the Upper Mannville Group in the "Grosmont" section. The exceptions in this region were the sparse, badly preserved assemblages obtained from the upper Cadotte-lower Paddy Member units in the "Spirit River" section.

Within individual samples, the various microfossil entities showed considerable variation in preservation. Bisaccate pollen grains were perhaps the most susceptible to corrosion and damage from impingement of mineral grains. Trilete spores were probably the least affected, especially spores assigned to the genera *Gleicheniidites*, *Cicatricosisporites* and *Deltoidospora*. Specimens of *Gleicheniidites* were often the only major constituent of poorly preserved assemblages which could be consistently recognized. It is difficult to assess the differential preservation and resistance to corrosion of the microplankton forms. Their appearance before and after oxidation treatment did not appear to differ to any recognizable extent. Most of the forms, pale in color before such treatment, remained so afterwards. Although prolonged oxidation had destructive effects on these, as well as other microfossil forms, the usual procedures adopted in this thesis in the processing of samples did not seem to have much effect. Careful checks made during the oxidation and alkali treatment indicated that no loss of material was taking place. It may be noted that cysts of the Pseudoceratiaceae seemed the most affected by natural and artificial oxidation while the thick-walled cysts referred to <u>Gonyaulacysta</u> Deflandre 1964 seemed the least affected. Most of the spores and pollen grains retained sufficient natural color after processing so that staining was not needed. Many of the thinner-walled angiosperm grains and the majority of microplankton were pale in color. Angiosperm pollen grains were easily stained but most of the microplankton forms were difficult to stain. Usually, however, the combination of the 1% solution of Safranin-O in alcohol and the saturated solution of basic fuscin gave a faint pinkish tinge to microplankton forms, sufficient for the purposes of this study. In a few samples from the basal Lower Shaftesbury Formation in the "Spirit River" section, all the microfossils stained heavily; this occurrence was an exception.

The writer notes that the acetolysis method, as outlined in Erdtman (1952; 1960) might have been used without harm to the microplankton (R. L. Cox, pers. comm.), but with loss of natural color of the miospores. Because both types were present in the samples to be processed and because it would be time-consuming to prepare separate residues for each sample, conditions and processing were adjusted to obtain the best results for the combined assemblages.

In addition to the late Albian miospores and microplankton assemblages present in the residues, many samples contained recycled Carboniferous and Permo-Triassic miospores. Other forms of microfossils and fragments of larger plant forms also occurred in many of the samples. These latter types included:

1) Chitinous or calcium fluoride-replaced inner linings of the proloculum and one or more chambers of planispiral "microforaminifera" (Wilson and Hoffmeister, 1952; Tappan and Loeblich, 1965).

2) Rare occurrences of microfossil forms probably referable to the Discoasteraceae (especially in sample BW 187 - at the 4495-4502' level of Imp. Wabamun No. 1 well).

3) Tracheid fragments, cuticle fragments, occasional megaspore fragments and much degraded plant material of undetermined origin.

4) A few rare occurrences of fish scale fragments.

These microfossils and fragments of other origin are not formally described, although some representatives are figured in the Plates in Appendix I.

Further relevant data of a general nature, including the lithologies and other data observed in hand samples of the intervals processed for microfossils are noted in Appendix II. Occurrences of microfossils other than miospores and microplankton is presented in the occurrence chart (Text-figure 4e).

## OCCURRENCE OF MIOSPORES AND MICROPLANKTON

The occurrence charts presented as Text-figures 4a to 4e represent the basic data for the development of a biostratigraphic zonation and for the investigation of the possibility of recurrent species groups in the microplankton assemblages of the Lower Colorado Group. The information in these charts shows the presence or absence in the samples investigated of all the species described and illustrated in the Systematics (Part II - Chapter III). Examination of this presence-absence data reveals several general patterns of occurrence exhibited by the species. These are noted below and have reference to miospore and microplankton species.

Many species occur in all or nearly all of the sections. They have wide regional distribution and are well represented in vertical sequence. These forms comprise the basic assemblages found in nearly all of the samples from the Lower Colorado Group, including those yielding poorly preserved or sparse material. These forms are listed below.

Miospores:

*Stereisporites antiquasporites*
*Cyathidites minor*
*Deltoidospora hallei*
*Biretisporites potoniae*
*Lycopodiumsporites austroclavatidites*
*Cicatricosisporites minutaestriatus*
*Gleicheniidites senonicus*
*Cedripites cretaceus*
*Vitreisporites pallidus*
*Alisporites bisaccus*
*Inaperturopollenites dubius*
*I. hiatus*

Text-figures 4a-4e. Charts showing occurrence of miospore and microplankton species (x) in all samples investigated from Central and West-Central Alberta. Occurrence of other microfossil forms given in Text-figure 4e. Species code numbers given in Appendix III.

Explanation of Symbols:

| | |
|---|---|
| x | Species occurrence. |
| CRS | Carboniferous recycled miospores. |
| P-T RS | Permo-Triassic recycled miospores. |
| FORAM | Chitinous foraminiferal linings. |
| F.S. | Fish Scale fragments. |
| DISCO | Discoasteraceae. |
| MEGASP | Megaspore fragments. |
| ALG | Algal fragments. |

| | IMPERIAL BATTLE LAKE NO. 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5520-30 | 5507-17 | 5502-07 | 5499-5503 | 5486-93 | 5479-86 | 5477-79 | 5475-76 | 5472-75 | 5465-70 | 5452-62 | 5447-52 | 5440-47 | 5430-40 | 5420-25 | 5415-20 | 5411-16 | 5409-11 | 5389-99 | 5385-90 | 5375-85 | 5365-70 | 5342-45 | 5327-37 | 5319-27 | 5309-19 | 5304-09 | 5294-5304 | 5284-94 | 5274-84 | 5265-74 | 5259-65 | 5249-59 | 5239-49 | 5234-36 | 5226-34 | 5216-26 |
| 00001 | - | - | - | - | - | - | - | x | x | - | x | x | - | x | - | x | - | - | - | - | - | x | - | - | x | - | x | - | x | x | x | x | x | x | - | x | - |
| 00002 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00003 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00004 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - |
| 00005 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | - | x | - | - | - | - | - | - |
| 00006 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00007 | - | - | x | x | - | - | x | - | x | x | x | - | - | x | - | x | - | - | - | - | - | x | - | - | - | - | x | x | x | x | x | - | - | x | x | - | - |
| 00008 | - | x | x | - | - | - | - | - | - | - | x | - | - | x | x | - | - | x | - | - | - | x | - | - | - | - | x | x | x | x | x | - | - | - | - | x | - |
| 00009 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | - | - | - | x | x | - | - | - |
| 00010 | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | x | - | x | - | - | - | - |
| 00011 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00012 | - | - | - | - | - | - | x | - | - | - | x | - | - | - | - | x | x | - | - | - | - | x | - | - | x | - | x | - | x | x | x | x | x | x | - | x | - |
| 00013 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00015 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00101 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00121 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00104 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00114 | - | - | x | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00115 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | - | - | - | - |
| 00122 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00113 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - |
| 00118 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00117 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00116 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00120 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00119 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00106 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00112 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00109 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00111 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00110 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00201 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - |
| 00234 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00223 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00202 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00203 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00204 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | x | x | x | x | x | - | - |
| 00230 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00207 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | x | x | - | x | - |
| 00205 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00208 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00209 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00210 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00211 | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | x | - | - | - | - | - | x | - | x | x | - | - | - | - | - | - |
| 00212 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - |
| 00213 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00206 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | - | - | - | - | - | - | - | - | x | - |
| 00215 | - | - | - | - | - | - | - | x | x | - | - | - | - | - | - | x | - | - | - | x | - | x | - | - | - | - | x | x | - | x | x | x | x | x | - | x | - |
| 00216 | - | - | x | x | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - |
| 00217 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - |
| 00218 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | - | - | - |
| 00219 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | x | - | - | - |
| 00222 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - |
| 00231 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00232 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00233 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00401 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00403 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00402 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00404 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | KISSINGER IMPERIAL CHIGWELL | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4943.1 | 4933.3 | 4923.3 | 4913.2 | 4903.3 | 4893.1 | 4883.7 | 4874.7 | 4862.9 | 4853.6 | 4846.2 | 4842.7 | 4823.5 | 4813.3 | 4803.0 |
| 00001 | x | x | x | x | - | x | x | - | x | - | - | x | x | x | x |
| 00002 | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - |
| 00003 | | | | | | | | | | | | | | | |
| 00004 | | | | | | | | | | | | | | | |
| 00005 | x | x | - | - | x | - | - | - | x | x | - | x | - | - | x |
| 00006 | x | - | - | x | - | x | - | - | - | x | x | - | - | x | x |
| 00007 | x | x | x | x | - | x | - | - | x | x | - | x | x | - | x |
| 00008 | - | x | x | - | x | x | - | - | - | x | - | x | x | x | x |
| 00009 | - | x | x | - | x | x | - | - | - | x | x | x | - | - | x |
| 00010 | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - |
| 00011 | x | - | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00012 | x | x | x | x | - | x | - | - | x | x | x | x | x | x | x |
| 00013 | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00015 | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - |
| 00101 | | | | | | | | | | | | | | | |
| 00121 | | | | | | | | | | | | | | | |
| 00104 | - | x | x | - | - | x | - | - | - | x | x | x | x | - | x |
| 00114 | - | - | x | - | - | - | - | - | - | - | - | - | x | - | - |
| 00115 | - | x | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00122 | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00113 | - | x | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00118 | - | x | x | - | x | - | x | - | x | - | - | x | x | - | - |
| 00117 | | | | | | | | | | | | | | | |
| 00116 | | | | | | | | | | | | | | | |
| 00120 | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - |
| 00119 | | | | | | | | | | | | | | | |
| 00106 | - | - | x | - | - | - | - | - | - | - | x | - | - | - | - |
| 00112 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | x |
| 00109 | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00111 | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - |
| 00110 | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - |
| 00201 | | | | | | | | | | | | | | | |
| 00234 | | | | | | | | | | | | | | | |
| 00223 | | | | | | | | | | | | | | | |
| 00202 | | | | | | | | | | | | | | | |
| 00203 | | | | | | | | | | | | | | | |
| 00204 | - | x | - | - | - | - | - | - | - | - | - | - | - | x | x |
| 00230 | | | | | | | | | | | | | | | |
| 00207 | | | | | | | | | | | | | | | |
| 00205 | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - |
| 00208 | | | | | | | | | | | | | | | |
| 00209 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00210 | - | - | - | - | - | - | - | - | - | x | - | x | - | - | - |
| 00211 | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x |
| 00212 | | | | | | | | | | | | | | | |
| 00213 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00206 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00215 | x | x | x | x | x | x | x | - | x | x | x | x | x | x | x |
| 00216 | - | - | - | - | x | - | - | - | - | x | x | - | x | - | - |
| 00217 | | | | | | | | | | | | | | | |
| 00218 | | | | | | | | | | | | | | | |
| 00219 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00222 | | | | | | | | | | | | | | | |
| 00231 | - | x | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00232 | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00233 | | | | | | | | | | | | | | | |
| 00401 | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - |
| 00403 | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - |
| 00402 | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - |
| 00404 | - | - | x | - | - | - | - | - | - | x | - | - | - | - | - |

| | ANGLO-CAN WABAMUN | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4622-32 | 4573-83 | 4558-68 | 4538-48 | 4494-4502 | 4469-79 | 4439-49 | 4399-4409 | 4369-79 |
| 00001 | x | x | x | x | x | x | x | x | x |
| 00002 | | | | | | | | | |
| 00003 | - | - | - | - | x | x | x | - | - |
| 00004 | | | | | | | | | |
| 00005 | - | - | - | x | - | x | - | - | - |
| 00006 | | | | | | | | | |
| 00007 | - | - | x | x | x | - | - | x | x |
| 00008 | - | x | x | x | x | x | x | x | x |
| 00009 | | | | | | | | | |
| 00010 | - | x | - | - | - | x | - | x | - |
| 00011 | | | | | | | | | |
| 00012 | x | - | x | x | - | - | x | - | x |
| 00013 | | | | | | | | | |
| 00015 | | | | | | | | | |
| 00101 | | | | | | | | | |
| 00121 | - | - | - | - | - | x | - | - | - |
| 00104 | | | | | | | | | |
| 00114 | | | | | | | | | |
| 00115 | | | | | | | | | |
| 00122 | | | | | | | | | |
| 00113 | | | | | | | | | |
| 00118 | x | - | x | - | x | x | - | x | - |
| 00117 | x | - | - | - | - | - | x | - | - |
| 00116 | | | | | | | | | |
| 00120 | | | | | | | | | |
| 00119 | | | | | | | | | |
| 00106 | - | - | - | x | - | - | - | - | - |
| 00112 | | | | | | | | | |
| 00109 | | | | | | | | | |
| 00111 | - | - | - | - | - | - | x | - | - |
| 00110 | | | | | | | | | |
| 00201 | | | | | | | | | |
| 00234 | - | - | x | - | - | - | - | - | - |
| 00223 | | | | | | | | | |
| 00202 | | | | | | | | | |
| 00203 | - | - | - | - | - | x | - | - | - |
| 00204 | - | x | - | - | - | x | x | x | x |
| 00230 | | | | | | | | | |
| 00207 | x | x | - | - | - | - | x | - | - |
| 00205 | | | | | | | | | |
| 00208 | | | | | | | | | |
| 00209 | - | - | - | - | - | - | - | - | x |
| 00210 | | | | | | | | | |
| 00211 | - | x | x | x | x | x | x | x | x |
| 00212 | | | | | | | | | |
| 00213 | | | | | | | | | |
| 00206 | | | | | | | | | |
| 00215 | x | x | x | x | x | x | x | x | x |
| 00216 | | | | | | | | | |
| 00217 | - | - | - | - | x | - | - | - | - |
| 00218 | - | - | - | - | x | - | - | - | - |
| 00219 | | | | | | | | | |
| 00222 | | | | | | | | | |
| 00231 | - | x | - | - | - | - | - | - | - |
| 00232 | | | | | | | | | |
| 00233 | | | | | | | | | |
| 00401 | | | | | | | | | |
| 00403 | - | - | - | - | x | - | - | - | x |
| 00402 | | | | | | | | | |
| 00404 | | | | | | | | | |

| | IMPERIAL GROSMONT | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1573-74 | 1536-37 | 1521-28 | 1516-17 | 1510-15 | 1500-05 | 1486-90 | 1475-85 | 1469-74 | 1455-60 | 1429-38 | 1409-21 | 1402-08 |
| 00001 | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 00002 | | | | | | | | | | | | | |
| 00003 | - | - | - | - | - | - | - | x | - | - | - | - | - |
| 00004 | - | - | - | - | - | - | - | - | - | - | - | - | x |
| 00005 | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00006 | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00007 | x | x | x | - | - | - | x | x | x | x | x | - | - |
| 00008 | x | x | - | x | - | - | x | x | - | x | x | x | - |
| 00009 | x | - | - | - | - | - | - | x | - | x | - | x | x |
| 00010 | | | | | | | | | | | | | |
| 00011 | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00012 | x | x | x | - | - | - | - | x | x | x | - | x | x |
| 00013 | | | | | | | | | | | | | |
| 00015 | | | | | | | | | | | | | |
| 00101 | x | - | x | - | - | - | - | - | - | - | - | - | - |
| 00121 | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00104 | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00114 | | | | | | | | | | | | | |
| 00115 | | | | | | | | | | | | | |
| 00122 | | | | | | | | | | | | | |
| 00113 | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00118 | - | - | x | x | - | - | x | x | x | - | - | x | - |
| 00117 | - | - | - | - | - | - | - | - | - | - | x | - | x |
| 00116 | | | | | | | | | | | | | |
| 00120 | x | - | x | - | - | - | - | x | - | - | - | x | - |
| 00119 | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00106 | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00112 | | | | | | | | | | | | | |
| 00109 | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00111 | | | | | | | | | | | | | |
| 00110 | | | | | | | | | | | | | |
| 00201 | - | - | - | - | - | - | - | x | x | - | - | - | - |
| 00234 | | | | | | | | | | | | | |
| 00223 | - | - | - | - | - | - | - | - | - | x | - | - | - |
| 00202 | - | - | - | x | - | - | - | - | - | - | x | - | - |
| 00203 | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00204 | - | - | x | x | x | - | - | x | x | x | x | x | x |
| 00230 | | | | | | | | | | | | | |
| 00207 | - | - | - | - | - | - | - | - | - | x | x | x | - |
| 00205 | x | x | - | - | - | - | x | - | - | x | - | - | - |
| 00208 | x | x | - | - | - | - | - | - | - | - | - | - | - |
| 00209 | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00210 | x | - | - | x | - | - | - | - | - | - | - | - | x |
| 00211 | x | x | - | x | - | - | - | x | x | x | - | x | x |
| 00212 | - | - | - | - | - | - | - | - | x | - | - | - | - |
| 00213 | x | - | - | - | - | - | - | - | - | - | - | - | - |
| 00206 | - | - | - | - | - | - | - | x | - | - | - | - | - |
| 00215 | - | - | - | x | - | x | x | x | x | x | x | x | x |
| 00216 | x | x | x | x | - | - | - | - | - | - | - | - | x |
| 00217 | x | - | x | - | - | - | - | - | x | - | - | - | - |
| 00218 | x | - | x | - | - | - | - | - | - | - | - | - | - |
| 00219 | - | - | - | - | - | - | - | - | x | - | - | - | - |
| 00222 | | | | | | | | | | | | | |
| 00231 | - | - | - | - | - | - | - | x | - | - | x | - | - |
| 00232 | | | | | | | | | | | | | |
| 00233 | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00401 | - | x | x | x | - | - | - | - | - | - | - | - | x |
| 00403 | - | - | x | - | - | - | - | - | x | - | - | - | - |
| 00402 | | | | | | | | | | | | | |
| 00404 | | | | | | | | | | | | | |

| | IMP GROUARD | | | | |
|---|---|---|---|---|---|
| | 1397-1402 | 1394-97 | 1389-94 | 1384-89 | 1379-84 |
| 00001 | x | x | x | x | - |
| 00002 | | | | | |
| 00003 | | | | | |
| 00004 | | | | | |
| 00005 | x | - | - | - | x |
| 00006 | x | - | - | x | x |
| 00007 | - | x | x | x | x |
| 00008 | x | - | x | x | x |
| 00009 | x | - | - | x | - |
| 00010 | x | - | - | x | - |
| 00011 | | | | | |
| 00012 | - | x | x | - | x |
| 00013 | | | | | |
| 00015 | | | | | |
| 00101 | | | | | |
| 00121 | | | | | |
| 00104 | | | | | |
| 00114 | | | | | |
| 00115 | | | | | |
| 00122 | | | | | |
| 00113 | - | - | x | - | - |
| 00118 | | | | | |
| 00117 | | | | | |
| 00116 | | | | | |
| 00120 | | | | | |
| 00119 | | | | | |
| 00106 | | | | | |
| 00112 | | | | | |
| 00109 | | | | | |
| 00111 | | | | | |
| 00110 | | | | | |
| 00201 | | | | | |
| 00234 | | | | | |
| 00223 | | | | | |
| 00202 | | | | | |
| 00203 | x | - | - | - | - |
| 00204 | | | | | |
| 00230 | | | | | |
| 00207 | - | x | - | - | x |
| 00205 | | | | | |
| 00208 | | | | | |
| 00209 | | | | | |
| 00210 | | | | | |
| 00211 | - | x | - | x | - |
| 00212 | | | | | |
| 00213 | - | - | - | - | x |
| 00206 | | | | | |
| 00215 | x | x | x | x | x |
| 00216 | - | - | - | - | x |
| 00217 | | | | | |
| 00218 | | | | | |
| 00219 | | | | | |
| 00222 | | | | | |
| 00231 | | | | | |
| 00232 | | | | | |
| 00233 | | | | | |
| 00401 | | | | | |
| 00403 | | | | | |
| 00402 | | | | | |
| 00404 | | | | | |

| | IMPERIAL SPIRIT RIVER NO. 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2670-80 | 2650-60 | 2625-35 | 2600-10 | 2590-2600 | 2570-75 | 2555-60 | 2540-45 | 2535-38 | 2515-20 | 2490-2500 | 2470-80 | 2450-60 | 2420-30 | 2380-90 | 2350-60 | 2330-40 | 2284-94 | 2249-59 | 2221-31 | 2191-2202 | 2161-71 | 2132-42 | 2103-13 | 2074-82 | 2045-55 |
| 00001 | x | x | - | x | x | - | - | - | - | x | x | x | - | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 00002 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00003 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - |
| 00004 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00005 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | x | - | x | - | x | - | - |
| 00006 | x | x | x | x | x | - | - | - | - | - | - | - | x | - | x | x | - | - | - | x | - | - | - | x | - | x |
| 00007 | - | x | - | - | x | - | - | - | - | - | x | x | x | - | x | x | x | - | - | x | x | - | x | x | x | x |
| 00008 | x | - | - | x | x | x | - | x | - | x | - | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 00009 | x | - | x | x | x | - | - | - | - | - | - | - | x | - | x | - | - | - | - | - | - | x | - | - | - | - |
| 00010 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | x | x |
| 00011 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00012 | x | x | x | x | x | - | - | - | - | - | - | x | - | - | x | x | - | x | - | - | - | x | x | x | x | x |
| 00013 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00015 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00101 | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00121 | x | - | x | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00104 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00114 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00115 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00122 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00113 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - |
| 00118 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | x | - | - | - |
| 00117 | - | - | - | x | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00116 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00120 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00119 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00106 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00112 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00109 | - | - | x | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00111 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00110 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00201 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | x | - | - |
| 00234 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00223 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00202 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00203 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - |
| 00204 | - | - | - | x | - | - | - | - | - | - | - | - | - | - | x | x | x | - | x | x | x | - | x | x | x | - |
| 00230 | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00207 | - | - | - | - | - | - | - | - | - | x | - | - | - | - | x | x | x | - | x | x | x | - | x | x | x | - |
| 00205 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | x | - | - |
| 00208 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00209 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| 00210 | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00211 | - | - | x | - | x | - | - | - | - | x | x | - | - | - | - | x | x | - | x | - | - | x | x | - | x | x |
| 00212 | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | - | - | x | - | x | - | - | x | - | x | - |
| 00213 | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | x | - | - | x | - | - | - |
| 00206 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - |
| 00215 | x | x | - | - | x | - | - | - | - | x | x | x | x | - | x | x | - | x | - | x | - | x | x | - | x | x |
| 00216 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00217 | - | - | - | - | x | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00218 | - | - | x | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00219 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | - | - |
| 00222 | - | - | - | - | - | - | - | - | - | - | - | x | - | - | x | - | - | - | - | - | - | - | - | - | - | - |
| 00231 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00232 | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00233 | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | x | - | - | - |
| 00401 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00403 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00402 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00404 | | | | | | | | | | | | | | | | | | | | | | | | | | |

**IMPERIAL BATTLE LAKE NO. 1**

| | 5520-30 | 5507-17 | 5503-07 | 5490-5503 | 5486-93 | 5479-86 | 5477-79 | 5475-76 | 5473-75 | 5465-70 | 5452-62 | 5447-58 | 5440-47 | 5430-40 | 5420-25 | 5415-20 | 5411-16 | 5409-11 | 5389-99 | 5385-90 | 5375-85 | 5365-70 | 5342-45 | 5327-37 | 5319-27 | 5309-19 | 5304-09 | 5294-5304 | 5284-94 | 5274-84 | 5265-74 | 5259-65 | 5249-59 | 5239-49 | 5234-36 | 5226-34 | 5216-26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00501 | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | X | X | X | X | X | - | - | - | X | - |
| 00502 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 00503 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00507 | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - |
| 00508 | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00506 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00510 | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00601 | X | - | X | - | - | - | X | - | X | - | X | X | X | X | - | - | X | - | - | X | - | X | - | - | X | - | X | X | X | X | X | X | X | X | - | X | - |
| 00602 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - |
| 00603 | - | - | - | - | - | - | X | - | X | - | - | - | - | X | - | - | - | - | - | - | - | X | - | - | X | - | X | - | X | X | X | X | X | X | - | X | - |
| 00604 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00701 | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | X | - | X | X | - | X | - | X | - |
| 00704 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00705 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00702 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00703 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00751 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | X | - |
| 00752 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00301 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00302 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00304 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00305 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00951 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00901 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | X | X | - | - | - | - |
| 00902 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00907 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00903 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00904 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00905 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00130 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00753 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10001 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 10112 | X | - | X | - | - | - | X | - | - | - | - | X | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | X | X | - | X | - | - | X | - | - | - |
| 10101 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - |
| 10102 | - | - | X | X | - | - | X | X | X | X | X | - | - | - | - | - | X | - | - | X | - | X | - | - | X | - | X | X | X | X | X | X | - | - | X | - | - |
| 10103 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 10104 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 10105 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10106 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | - | X | - | X | X | X | - | - | - | - | - | - | - | - |
| 10107 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10120 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10121 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10122 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10108 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 10109 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10110 | - | - | - | - | - | - | X | - | - | - | X | X | X | - | X | - | - | - | - | - | - | X | - | - | - | - | X | X | X | - | X | X | - | - | X | - | - |
| 10111 | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | X | X | - | - | - | - | - | - | - | - | - |
| 10151 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10152 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10153 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10160 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10161 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 10162 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10155 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 10154 | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - |
| 10156 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10157 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | X | - | - | X | - | - | - | - | - |
| 10158 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10159 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10201 | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | X | X | X | - | X | - |

**KISSINGER IMPERIAL CHIGWELL**

| | 4943.1 | 4933.3 | 4925.3 | 4913.2 | 4903.3 | 4893.1 | 4883.7 | 4874.7 | 4862.9 | 4853.6 | 4846.2 | 4832.7 | 4823.5 | 4813.3 | 4803.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00501 | - | - | X | - | X | - | X | - | - | X | X | X | X | - | X |
| 00502 | | | | | | | | | | | | | | | |
| 00503 | | | | | | | | | | | | | | | |
| 00507 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 00508 | | | | | | | | | | | | | | | |
| 00506 | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - |
| 00510 | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - |
| 00601 | X | X | X | X | X | X | X | X | - | X | X | X | X | X | X |
| 00602 | - | X | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 00603 | X | X | X | - | X | - | - | - | X | X | X | X | X | - | X |
| 00604 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 00701 | - | - | - | - | X | - | - | - | - | - | - | - | X | X | X |
| 00704 | | | | | | | | | | | | | | | |
| 00705 | | | | | | | | | | | | | | | |
| 00702 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 00703 | | | | | | | | | | | | | | | |
| 00751 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| 00752 | | | | | | | | | | | | | | | |
| 00301 | | | | | | | | | | | | | | | |
| 00302 | | | | | | | | | | | | | | | |
| 00304 | | | | | | | | | | | | | | | |
| 00305 | | | | | | | | | | | | | | | |
| 00951 | | | | | | | | | | | | | | | |
| 00901 | | | | | | | | | | | | | | | |
| 00902 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 00907 | | | | | | | | | | | | | | | |
| 00903 | | | | | | | | | | | | | | | |
| 00904 | | | | | | | | | | | | | | | |
| 00905 | | | | | | | | | | | | | | | |
| 00130 | | | | | | | | | | | | | | | |
| 00753 | | | | | | | | | | | | | | | |
| 10001 | - | X | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 10112 | X | X | X | X | X | X | X | X | - | X | X | X | X | X | X |
| 10101 | - | - | - | - | - | X | - | - | - | X | - | - | X | - | X |
| 10102 | - | X | X | - | - | X | X | - | - | X | X | X | X | X | X |
| 10103 | X | X | - | - | - | - | - | - | - | - | X | - | - | - | X |
| 10104 | | | | | | | | | | | | | | | |
| 10105 | | | | | | | | | | | | | | | |
| 10106 | - | X | X | - | - | - | - | - | X | X | - | X | - | - | - |
| 10107 | X | - | X | - | - | X | - | - | - | - | - | X | - | - | - |
| 10120 | - | - | X | - | - | X | - | - | - | - | X | - | - | - | - |
| 10121 | | | | | | | | | | | | | | | |
| 10122 | | | | | | | | | | | | | | | |
| 10108 | - | - | - | - | - | - | - | - | X | X | X | X | - | - | X |
| 10109 | | | | | | | | | | | | | | | |
| 10110 | X | X | X | - | X | X | - | - | - | X | - | X | X | X | X |
| 10111 | X | X | X | - | - | - | X | - | - | X | X | - | - | - | X |
| 10151 | - | - | X | - | - | - | - | - | - | - | - | X | - | - | - |
| 10152 | | | | | | | | | | | | | | | |
| 10153 | | | | | | | | | | | | | | | |
| 10160 | | | | | | | | | | | | | | | |
| 10161 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 10162 | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 10155 | - | - | - | - | - | - | - | - | - | X | X | - | X | X | - |
| 10154 | - | - | X | - | - | - | - | - | - | - | - | - | - | X | X |
| 10156 | - | - | - | - | - | - | - | - | - | - | X | - | X | - | X |
| 10157 | - | - | - | - | - | - | - | - | - | - | X | X | X | - | - |
| 10158 | | | | | | | | | | | | | | | |
| 10159 | | | | | | | | | | | | | | | |
| 10201 | | | | | | | | | | | | | | | |

**ANGLO-CAN. WABAMUN**

| | 4622-32 | 4573-83 | 4558-68 | 4538-48 | 4494-4502 | 4469-4479 | 4439-49 | 4399-4409 | 4369-79 |
|---|---|---|---|---|---|---|---|---|---|
| 00501 | - | X | - | X | - | X | X | - | - |
| 00502 | | | | | | | | | |
| 00503 | | | | | | | | | |
| 00507 | | | | | | | | | |
| 00508 | | | | | | | | | |
| 00506 | - | X | - | - | - | X | - | - | - |
| 00510 | | | | | | | | | |
| 00601 | X | X | X | X | X | X | X | X | X |
| 00602 | - | - | - | - | - | X | - | - | - |
| 00603 | - | X | X | - | - | X | - | X | X |
| 00604 | | | | | | | | | |
| 00701 | - | X | - | - | - | X | X | X | X |
| 00704 | | | | | | | | | |
| 00705 | - | X | - | - | - | - | - | - | X |
| 00702 | | | | | | | | | |
| 00703 | | | | | | | | | |
| 00751 | X | - | - | - | - | X | X | X | X |
| 00752 | | | | | | | | | |
| 00301 | - | - | - | - | X | - | - | - | - |
| 00302 | - | - | - | - | X | - | - | - | - |
| 00304 | - | - | - | - | X | - | - | - | - |
| 00305 | | | | | | | | | |
| 00951 | | | | | | | | | |
| 00901 | - | - | - | - | - | - | - | X | - |
| 00902 | | | | | | | | | |
| 00907 | | | | | | | | | |
| 00903 | | | | | | | | | |
| 00904 | | | | | | | | | |
| 00905 | | | | | | | | | |
| 00130 | | | | | | | | | |
| 00753 | - | - | - | - | - | X | - | X | X |
| 10001 | X | X | - | X | X | X | X | X | X |
| 10112 | X | X | X | X | X | X | X | - | X |
| 10101 | | | | | | | | | |
| 10102 | - | X | X | X | X | X | X | X | X |
| 10103 | - | - | - | - | X | - | - | - | X |
| 10104 | | | | | | | | | |
| 10105 | - | X | - | - | X | - | - | - | X |
| 10106 | | | | | | | | | |
| 10107 | | | | | | | | | |
| 10120 | | | | | | | | | |
| 10121 | | | | | | | | | |
| 10122 | | | | | | | | | |
| 10108 | | | | | | | | | |
| 10109 | | | | | | | | | |
| 10110 | X | X | - | - | X | X | X | X | X |
| 10111 | - | - | - | - | X | - | - | - | X |
| 10151 | - | - | - | - | - | - | X | - | X |
| 10152 | - | - | - | - | X | - | - | - | - |
| 10153 | | | | | | | | | |
| 10160 | | | | | | | | | |
| 10161 | | | | | | | | | |
| 10162 | | | | | | | | | |
| 10155 | | | | | | | | | |
| 10154 | | | | | | | | | |
| 10156 | - | - | - | - | X | - | - | - | X |
| 10157 | | | | | | | | | |
| 10158 | - | - | - | X | - | X | - | - | - |
| 10159 | | | | | | | | | |
| 10201 | X | X | X | X | X | X | X | X | X |

**IMPERIAL GROSMONT**

| | 1573-74 | 1536-37 | 1521-28 | 1516-17 | 1510-15 | 1500-05 | 1486-90 | 1475-85 | 1469-74 | 1455-60 | 1429-38 | 1409-21 | 1403-08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00501 | - | - | - | - | - | - | X | - | - | - | - | X | X |
| 00502 | - | X | - | - | - | - | - | - | X | - | - | - | X |
| 00503 | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 00507 | | | | | | | | | | | | | |
| 00508 | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 00506 | - | - | - | - | - | - | - | - | X | - | X | - | - |
| 00510 | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 00601 | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 00602 | - | - | - | X | X | - | - | - | - | - | - | X | - |
| 00603 | - | - | - | X | X | X | X | X | X | X | X | X | X |
| 00604 | - | - | - | - | - | - | - | - | X | X | - | - | - |
| 00701 | X | X | X | X | - | - | X | X | X | - | X | X | X |
| 00704 | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 00705 | - | - | - | - | - | - | - | - | - | X | - | - | - |
| 00702 | - | - | - | - | - | - | - | - | - | - | - | X | - |
| 00703 | | | | | | | | | | | | | |
| 00751 | X | - | - | - | - | - | - | - | - | - | - | X | - |
| 00752 | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 00301 | | | | | | | | | | | | | |
| 00302 | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 00304 | | | | | | | | | | | | | |
| 00305 | - | - | - | - | - | - | - | - | - | X | - | - | - |
| 00951 | | | | | | | | | | | | | |
| 00901 | - | - | X | - | - | - | - | - | - | - | X | X | - |
| 00902 | X | X | - | - | - | - | - | - | - | - | - | - | - |
| 00907 | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 00903 | - | X | X | - | - | - | - | - | - | - | - | - | - |
| 00904 | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 00905 | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 00130 | | | | | | | | | | | | | |
| 00753 | | | | | | | | | | | | | |
| 10001 | - | X | X | - | - | - | - | - | - | X | X | X | X |
| 10112 | X | X | - | X | X | X | X | X | X | X | X | X | X |
| 10101 | - | X | X | - | - | - | - | - | - | - | - | - | - |
| 10102 | X | X | X | X | - | X | X | X | X | X | X | X | X |
| 10103 | - | - | - | - | - | - | - | - | - | - | X | X | - |
| 10104 | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 10105 | - | - | - | X | - | - | - | - | - | X | X | X | X |
| 10106 | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 10107 | - | - | - | - | - | - | - | - | X | - | X | X | X |
| 10120 | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 10121 | | | | | | | | | | | | | |
| 10122 | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 10108 | - | - | - | X | - | - | - | - | - | - | - | - | X |
| 10109 | X | - | X | - | - | - | - | - | - | - | - | - | - |
| 10110 | X | X | X | X | - | X | - | X | X | X | X | X | X |
| 10111 | X | - | X | - | - | - | - | X | - | - | - | X | X |
| 10151 | - | - | - | - | - | - | - | - | - | - | X | X | - |
| 10152 | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 10153 | - | - | - | - | - | - | X | - | - | - | - | - | - |
| 10160 | - | - | X | - | - | - | - | - | - | - | - | X | - |
| 10161 | - | - | - | - | - | - | - | - | - | - | - | X | - |
| 10162 | | | | | | | | | | | | | |
| 10155 | | | | | | | | | | | | | |
| 10154 | | | | | | | | | | | | | |
| 10156 | - | - | - | - | - | - | X | - | - | - | - | X | - |
| 10157 | - | - | - | - | - | - | - | - | - | - | X | X | - |
| 10158 | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 10159 | | | | | | | | | | | | | |
| 10201 | X | X | X | X | X | X | X | - | X | X | X | X | X |

**IMP GROUARD**

| | 1397-1402 | 1394-97 | 1389-94 | 1384-89 | 1379-84 |
|---|---|---|---|---|---|
| 00501 | X | X | X | X | X |
| 00502 | - | - | - | - | X |
| 00503 | | | | | |
| 00507 | | | | | |
| 00508 | | | | | |
| 00506 | - | - | - | X | - |
| 00510 | | | | | |
| 00601 | X | X | X | X | X |
| 00602 | | | | | |
| 00603 | X | X | - | X | X |
| 00604 | X | - | - | - | - |
| 00701 | - | - | - | X | - |
| 00704 | | | | | |
| 00705 | | | | | |
| 00702 | | | | | |
| 00703 | - | - | - | X | - |
| 00751 | | | | | |
| 00752 | | | | | |
| 00301 | - | - | - | - | X |
| 00302 | | | | | |
| 00304 | | | | | |
| 00305 | | | | | |
| 00951 | - | - | X | - | - |
| 00901 | | | | | |
| 00902 | | | | | |
| 00907 | | | | | |
| 00903 | | | | | |
| 00904 | | | | | |
| 00905 | | | | | |
| 00130 | | | | | |
| 00753 | | | | | |
| 10001 | - | X | X | X | X |
| 10112 | X | X | X | X | X |
| 10101 | | | | | |
| 10102 | X | X | X | X | X |
| 10103 | - | - | X | X | - |
| 10104 | - | - | - | X | - |
| 10105 | X | X | - | X | X |
| 10106 | - | X | - | X | - |
| 10107 | - | X | - | X | X |
| 10120 | | | | | |
| 10121 | | | | | |
| 10122 | | | | | |
| 10108 | - | - | - | - | X |
| 10109 | - | X | - | - | - |
| 10110 | X | X | X | X | X |
| 10111 | - | X | - | X | - |
| 10151 | | | | | |
| 10152 | X | - | X | X | - |
| 10153 | | | | | |
| 10160 | | | | | |
| 10161 | | | | | |
| 10162 | | | | | |
| 10155 | | | | | |
| 10154 | | | | | |
| 10156 | - | - | - | X | - |
| 10157 | - | X | X | X | - |
| 10158 | | | | | |
| 10159 | - | - | X | - | - |
| 10201 | X | X | X | X | X |

**IMPERIAL SPIRIT RIVER NO. 1**

| | 2670-80 | 2650-60 | 2625-35 | 2600-10 | 2590-2600 | 2570-75 | 2555-60 | 2540-45 | 2535-38 | 2515-20 | 2490-2500 | 2470-80 | 2450-60 | 2420-30 | 2380-90 | 2350-60 | 2330-40 | 2284-94 | 2249-59 | 2221-31 | 2191-2202 | 2161-71 | 2132-42 | 2103-13 | 2074-82 | 2045-55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00501 | - | X | X | X | X | - | - | - | - | - | X | X | - | - | - | X | X | - | - | - | - | X | X | X | X | X |
| 00502 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00503 | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00507 | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - |
| 00508 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00506 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - |
| 00510 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00601 | X | X | X | X | X | X | X | X | - | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | - |
| 00602 | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | X | - | - | - | - | - | - | X | - | - |
| 00603 | - | - | - | - | - | - | - | - | - | X | X | X | X | - | X | X | X | - | X | X | X | X | X | X | X | X |
| 00604 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00701 | X | X | - | - | X | - | - | - | - | X | X | X | - | - | X | X | X | X | X | X | X | X | X | X | X | X |
| 00704 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00705 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00702 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | - | - | - | - | - | - | - | X | - | - |
| 00703 | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | X | X | - | - |
| 00751 | - | X | - | - | X | - | - | - | - | - | - | - | - | - | X | X | X | - | X | X | X | X | X | - | X | - |
| 00752 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00301 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - |
| 00302 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - | - | - | - | - | - |
| 00304 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00305 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00951 | X | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00901 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - |
| 00902 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00907 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00903 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00904 | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 00905 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00130 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 00753 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - |
| 10001 | - | X | X | X | X | - | - | - | - | X | X | - | X | X | X | - | - | - | X | - | - | - | - | X | X | - |
| 10112 | X | X | X | X | X | - | - | - | - | X | X | X | - | X | X | X | - | - | X | X | X | X | X | - | X | - |
| 10101 | - | X | X | X | X | - | - | - | - | - | - | - | - | - | X | - | X | - | - | X | - | - | - | - | X | - |
| 10102 | X | X | X | X | X | X | - | - | - | X | X | X | X | X | X | X | X | X | X | X | - | X | X | X | X | X |
| 10103 | - | - | - | X | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - | - | - |
| 10104 | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10105 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10106 | - | X | - | X | X | - | - | - | - | - | - | X | - | X | X | - | X | X | - | - | - | X | X | X | X | - |
| 10107 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10120 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10121 | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10122 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10108 | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10109 | - | - | X | X | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10110 | X | X | X | X | X | - | - | - | - | X | X | X | X | X | X | X | X | X | X | - | X | X | X | X | X | - |
| 10111 | - | - | X | X | X | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 10151 | - | - | - | - | X | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | X | - | - |
| 10152 | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10153 | - | - | - | X | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10160 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10161 | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10162 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 10155 | - | - | - | - | X | - | - | - | - | - | - | X | - | - | X | - | - | - | - | - | - | - | - | - | - | X |
| 10154 | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 10156 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 10157 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 10158 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10159 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10201 | - | - | - | - | - | - | - | - | - | X | X | - | - | - | X | X | X | - | X | X | - | X | X | - | X | - |

|  | IMPERIAL BATTLE LAKE NO. 1 | KISSINGER IMPERIAL CHIGWELL | ANGLO-CAN WABAMUN | IMPERIAL GROSMONT | IMP GROUARD | IMPERIAL SPIRIT RIVER NO. 1 |
|---|---|---|---|---|---|---|
|  | 5520-30 5507-17 5503-07 5490-5503 5486-90 5479-86 5477-79 5475-76 5473-75 5465-70 5459-65 5447-52 5440-47 5430-40 5420-25 5415-20 5411-16 5409-11 5389-99 5385-90 5375-85 5365-70 5342-45 5327-37 5319-27 5309-19 5304-09 5294-5304 5284-94 5274-84 5265-74 5259-65 5249-59 5239-49 5234-36 5226-34 5216-26 | 4943.1 4933.3 4925.3 4913.2 4903.3 4893.1 4883.7 4874.7 4862.9 4853.6 4846.2 4832.7 4823.5 4813.3 4803.0 | 4622-32 4573-83 4558-68 4538-48 4494-4502 4469-79 4439-49 4399-4409 4369-79 | 1573-74 1536-37 1521-28 1516-17 1510-15 1500-05 1486-90 1475-85 1460-74 1455-60 1429-38 1409-21 1403-08 | 1397-1402 1394-97 1389-94 1384-89 1379-84 | 2670-80 2650-60 2625-35 2600-10 2590-2600 2570-75 2555-60 2540-45 2525-30 2515-20 2490-2500 2470-80 2450-60 2420-30 2380-90 2350-60 2330-40 2284-94 2240-50 2221-31 2191-2202 2161-71 2132-42 2103-13 2074-84 2045-55 |
| 10202 | ------XXX-XXX---X----X--X------------ |  | -X--XXXXX | XXXXX-XX-XXX- | XX-XX | XXXXXX-X-XX--------------- |
| 10203 | ---------XXXXX-X--------------------- | XXXXXX----XX--X | -----X--- | ---X-X------- |  | ---XX-------X-X-X------X-X |
| 10210 |  |  | --------X |  |  |  |
| 10204 | ----------X--X----------------------- | -XX--------XX-X | X---X---- |  | -X-X- | -X-------------X---------- |
| 10301 | -X------------------------------X---- | XXX--X--X--X--X | -XX---X-X | --------X-XX- | X--XX | --X--------X-------------- |
| 10302 | ------------------------------XX----- | -X---X---X--X-X | X-X---XX- | --------X-X-- | ---X- | X-X------X---------------- |
| 10351 |  | X-------------- |  |  |  |  |
| 10401 |  | XX------------- | ------X-- | ---X-----XX-- | X---- | ----------------X--X------ |
| 10402 | ------------------------------X------ | -XX------------ | ------X-X | -X-----X-X-X- | --XX- | X---X------XX------X--X-X- |
| 10403 |  |  |  | --X---------- |  |  |
| 10404 |  |  |  | -----X---X--- | X---X |  |
| 10405 |  |  | ------XX- |  | ---X- | ------------X------------- |
| 10501 | --X-------X----X----------XX-X-----X- | XXX-XX----XX--X | -X------- | XX----------- | ---X- | X---X-----XXXX-XXXXXXXX-X- |
| 10502 | --X-------X--------------------X----- | -X--X------X--- |  |  |  | -----------------X------X- |
| 10503 | ---------X----------------X------X--- | -X---X---X----- |  |  |  |  |
| 10504 |  |  | --------X |  |  | ---XX--------------------- |
| 10505 |  |  |  |  |  | ---X-------X-------------- |
| 10506 |  |  |  |  |  | -----------------------X-- |
| 10507 |  | --XX----------- |  |  |  | -----------X-------------- |
| 10508 |  | -X---X--------- |  |  |  |  |
| 10704 | ----------XX------------------X-X---- | XXX--X----X---X | -X--X-XXX | -----XXXXXXXX | -XXXX | -------X-XX--XXX--XX-XX--- |
| 10702 |  | -X------------- | -----XX-- | -----X---X--- | --X-X | -------X-------XX--X-XX--X |
| 10705 |  |  |  |  | ---X- | ----------X--------------X |
| 10709 |  |  |  | ----------X-- |  |  |
| 10701 | ------------------------------X-X---- | ----------XX--X | XX--XXXXX | ---X-X-XXXXX- | ---XX | ------------X-X-X----XXXX- |
| 10703 | --------------------------------X---- | -----------X--- |  | ----------X-- | --X-X | ------------------------X- |
| 10707 |  |  |  | ------XX-XXX- |  |  |
| 10708 |  |  |  | ----------X-- | X---- |  |
| 10706 | --------------------------------X---- |  |  |  |  | -----------------------X-- |
| 10710 |  |  |  |  | X---- |  |
| 10711 |  |  |  |  |  | ------------------------X- |
| 10712 |  | --------------X |  |  |  |  |
| 10713 |  |  | -------X- | ----------X-- |  |  |
| 10714 |  |  |  |  |  | ------------X------------- |
| 10801 | ------------------------------X------ | X-X-------X---- | -----X--X |  | -X--- | --XX--------------X------- |
| 10803 | -------------X-X--------------------- | XX------------- | -----X--- | XX---XX-XXXXX |  | ----------------X--------- |
| 10806 |  |  |  | ---------X--- |  |  |
| 10807 |  |  |  |  |  | -----------------------X-- |
| 10805 | --------------------------X---------- |  | ----X---- | -XX---------- |  |  |
| 10902 |  |  | -X------- | --------X---- |  |  |
| 20001 |  |  |  |  |  | ---X------------X--------- |
| 20102 | ----------------X-------------------- |  |  |  |  | -----------------------X-- |
| 20404 | --------------------------XX-----X-X- | --------------X |  |  |  | ---X----------------X----- |
| 20401 | -------XX--XX-------------X-----X---- | XXX-X--XX--X--X |  | ---XX-------- |  | ---------------X-X---X---- |
| 20402 | --------X-X-------------------------- | --X--X--------- | X-------X | ---XXXX---X-X | --X-X | -X------------X-X-X------- |
| 20403 | --------------------------X-XXX--X--- | -X------X---XX- | ------X-- | -------XX-XX- | ---X- | -------X-------XXX---X-X-- |
| 20406 | ------X-X-X-----------------X-X-XX-X- | XXX--------XXXX | XXX-XXXXX | ---XXXXXXXXXX | -X--X | ----X------X--XXXXXXXXXXXX |
| 20407 |  |  |  |  |  | ---------------------XXX-- |
| 20405 | ------X--X----------------X-X-------- | -X------X--X--- | ---X----- |  |  |  |
| 20503 |  |  | -------XX |  |  | ----------------------XXXX |
| 20502 | ------XXXXX-X------------------------ | -------X------- | XX------- | ---XXXX--XX-- |  | ---------------------XX--- |
| 20510 |  |  | -----XX-- | ----X-------- |  | ------------------X------- |
| 20505 | -------X--XX---------X------X---X--X- | -X---X-----XXXX | XX--X---- | ---X-XX------ | -XXX- | ---------X---X-XXX-X------ |
| 20504 | -------X-XXXX------------------------ | XXX---X-X---X-- | XX--X---- | ---XX-X--X--- | --X-- | ----------------XX-------- |
| 20501 | ----------X-------------------------- |  |  | ------X------ |  |  |
| 20506 | ---------------------X--------------- | --X------------ |  | -----X------- |  |  |
| 20507 | ------X---X-------------------------- |  | ----X---- | ---XX-X------ |  |  |
| 20508 | ---------------------X--------------- | --X---X-------- |  |  |  |  |
| 20703 | --------------------------------X---- | --------------X | ---XX---- | ----X-----X-- | --X-X | ------------------------X- |
| 20704 | ----------X-----------------X-X------ | -----X--------- |  | | | ---X------------------X-X- |

**IMPERIAL BATTLE LAKE NO. 1**

| | 5520-30 | 5507-17 | 5502-07 | 5499-5503 | 5486-93 | 5479-86 | 5477-79 | 5475-76 | 5472-75 | 5465-70 | 5452-62 | 5447-52 | 5440-47 | 5430-40 | 5420-25 | 5415-20 | 5411-16 | 5409-11 | 5389-99 | 5385-90 | 5375-85 | 5365-70 | 5342-45 | 5327-37 | 5319-27 | 5309-19 | 5304-09 | 5294-5304 | 5284-94 | 5274-84 | 5265-74 | 5259-65 | 5249-59 | 5239-49 | 5234-36 | 5226-34 | 5216-26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20702 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - |
| 20705 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20751 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 20752 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20753 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20754 | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20755 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20756 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20801 | - | - | - | - | - | - | X | X | X | - | X | X | X | X | X | X | X | X | X | - | - | - | - | - | X | - | X | X | X | X | X | X | X | X | - | X | - |
| 20802 | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | X | - | X | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - |
| 20803 | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | X | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | - |
| 20804 | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - |
| 20805 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | X | X | - | X | - | - | X | - | - | - |
| 20806 | - | - | - | - | - | - | X | X | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - |
| 20807 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | X | X | - | - | - | - | - | - |
| 20901 | - | - | - | - | - | - | - | - | X | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | X | - | X | - | X | X | - | - | - |
| 20906 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20903 | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 21001 | - | - | - | - | - | - | - | X | X | - | - | - | - | X | X | X | X | - | - | - | - | X | - | - | X | - | X | X | X | X | X | X | X | X | - | X | - |
| 21002 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | - | - | - | - |
| 21101 | - | - | - | - | - | - | - | X | - | X | - | - | - | X | X | X | X | X | - | - | - | X | - | - | X | - | X | X | X | X | X | X | X | X | - | X | - |
| 21102 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - | - |
| 21104 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | X | X | X | X | X | X | X | X | - | X | - |
| 21103 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | - | - | - |
| 21105 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21201 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | - | X | - | X | X | - | X | X | X | X | X | - | X | - |
| 21202 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 21206 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | X | - | - | - | - | - |
| 21207 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21208 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - |
| 21205 | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | X | - | - | - | - | - | X | - | - | X | - | X | X | X | - | X | - | - | - | - | - | - |
| 22952 | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21301 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - | X | - | X | X | X | X | X | X | - | X | X | - | - |
| 21302 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | X | X | - | X | - | X | - | - | - |
| 21303 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | X | - | - | X | - | X | X | - | - | - | - | - | X | - | - | - |
| 21304 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | - | - | - | X | X | X | - | X | - | X | X | - | - | - |
| 21309 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | X | - | - | - |
| 21305 | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21310 | - | - | - | - | - | - | - | X | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 21308 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21307 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - |
| 21406 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | - |
| 21407 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - |
| 21702 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - |
| 21706 | - | - | - | - | - | - | - | X | X | - | - | - | - | X | X | X | X | X | - | X | - | - | - | - | - | - | X | X | X | X | X | X | X | X | - | X | - |
| 21703 | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - |
| 22001 | - | - | - | - | - | - | - | X | - | X | X | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 22006 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | X | X | X | X | X | - | X | - |
| 22005 | - | - | - | - | - | - | X | - | - | X | - | X | - | - | X | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - | - |
| 22008 | - | - | - | - | - | - | X | X | X | X | X | X | X | X | X | X | X | - | - | X | - | X | - | - | X | - | X | X | X | X | X | X | - | X | - | X | - |
| 22012 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | - | - | - | - | - | - | X | - | - | X | X | - | X | - |
| 22011 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22029 | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22003 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | - | - | - | - |
| 22010 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - |
| 22009 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | X | - | - | - | - | - | - | - | - | - |
| 22015 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | X | X | X | - | - |
| 22014 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 22013 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**KISSINGER IMPERIAL CHIGWELL**

| | 4943.1 | 4933.3 | 4925.3 | 4913.2 | 4905.3 | 4893.1 | 4883.7 | 4874.7 | 4862.9 | 4853.6 | 4846.2 | 4832.7 | 4823.5 | 4813.3 | 4803.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | - | - | - | - | X | - | - | X | - | X | - | - | - | - | - |
| 20702 | - | - | X | - | - | - | - | - | - | - | - | - | - | X | - |
| 20705 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 20751 | | | | | | | | | | | | | | | |
| 20752 | | | | | | | | | | | | | | | |
| 20753 | | | | | | | | | | | | | | | |
| 20754 | | | | | | | | | | | | | | | |
| 20755 | | | | | | | | | | | | | | | |
| 20756 | | | | | | | | | | | | | | | |
| 20801 | X | X | X | X | X | X | X | - | X | X | X | X | X | X | X |
| 20802 | | | | | | | | | | | | | | | |
| 20803 | - | X | - | - | X | - | - | X | - | - | - | X | X | - | - |
| 20804 | - | X | - | X | - | X | X | - | - | - | - | X | - | - | X |
| 20805 | - | - | X | - | - | - | - | - | - | - | - | X | - | - | - |
| 20806 | | | | | | | | | | | | | | | |
| 20807 | - | - | - | - | - | - | - | - | - | - | - | X | X | - | X |
| 20901 | | | | | | | | | | | | | | | |
| 20906 | | | | | | | | | | | | | | | |
| 20903 | X | X | X | X | X | - | - | - | X | - | X | - | X | X | X |
| 21001 | X | - | X | - | - | X | - | - | - | - | - | - | X | - | - |
| 21002 | X | X | X | - | X | X | - | - | - | - | X | X | X | X | X |
| 21101 | - | - | X | - | - | X | - | - | - | - | - | - | - | - | - |
| 21102 | | | | | | | | | | | | | | | |
| 21104 | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 21103 | | | | | | | | | | | | | | | |
| 21105 | - | - | - | - | - | X | - | - | - | X | X | - | - | X | X |
| 21201 | | | | | | | | | | | | | | | |
| 21202 | X | X | X | - | X | - | X | - | - | X | X | X | X | X | X |
| 21206 | | | | | | | | | | | | | | | |
| 21207 | - | - | X | - | - | - | - | - | - | - | X | X | X | - | - |
| 21208 | X | X | X | - | - | X | - | - | - | - | - | X | X | - | X |
| 21205 | X | X | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 22952 | - | X | X | X | - | - | - | - | - | - | - | - | - | - | X |
| 21301 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - |
| 21302 | - | X | X | - | - | X | - | - | - | - | - | - | - | - | - |
| 21303 | - | X | X | - | - | - | - | - | - | - | X | X | X | X | X |
| 21304 | X | - | - | - | - | X | - | - | - | - | - | - | X | - | X |
| 21309 | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 21305 | | | | | | | | | | | | | | | |
| 21310 | | | | | | | | | | | | | | | |
| 21308 | | | | | | | | | | | | | | | |
| 21307 | | | | | | | | | | | | | | | |
| 21406 | | | | | | | | | | | | | | | |
| 21407 | - | - | - | - | - | - | - | - | - | X | - | X | X | - | - |
| 21702 | X | X | X | - | X | X | - | X | X | X | X | X | X | X | X |
| 21706 | | | | | | | | | | | | | | | |
| 21703 | X | X | - | X | X | - | - | - | - | - | - | X | - | - | - |
| 22001 | - | - | X | - | X | X | X | - | - | - | X | X | X | - | X |
| 22006 | - | X | X | - | - | - | - | - | X | - | - | - | - | - | X |
| 22005 | X | X | X | X | X | X | - | - | X | X | X | X | X | X | X |
| 22008 | - | X | X | X | - | X | - | - | - | X | X | - | - | - | X |
| 22012 | | | | | | | | | | | | | | | |
| 22011 | | | | | | | | | | | | | | | |
| 22029 | | | | | | | | | | | | | | | |
| 22003 | | | | | | | | | | | | | | | |
| 22010 | - | X | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 22009 | - | X | - | - | X | X | - | - | - | - | - | X | - | X | - |
| 22015 | - | X | X | - | - | - | - | - | - | - | - | - | - | X | - |
| 22014 | | | | | | | | | | | | | | | |
| 22013 | | | | | | | | | | | | | | | |

**ANGLO-CAN WABAMUN**

| | 4622-32 | 4573-83 | 4556-66 | 4538-48 | 4494-4502 | 4469-79 | 4439-49 | 4399-4409 | 4369-79 |
|---|---|---|---|---|---|---|---|---|---|
| 20701 | - | - | - | - | - | X | X | X | - |
| 20702 | | | | | | | | | |
| 20705 | | | | | | | | | |
| 20751 | - | X | - | - | - | - | X | - | X |
| 20752 | | | | | | | | | |
| 20753 | | | | | | | | | |
| 20754 | X | - | - | - | - | - | - | - | - |
| 20755 | | | | | | | | | |
| 20756 | | | | | | | | | |
| 20801 | X | - | - | - | - | X | X | X | - |
| 20802 | | | | | | | | | |
| 20803 | | | | | | | | | |
| 20804 | - | X | X | - | - | X | X | X | X |
| 20805 | | | | | | | | | |
| 20806 | | | | | | | | | |
| 20807 | X | X | X | X | X | X | X | X | X |
| 20901 | | | | | | | | | |
| 20906 | | | | | | | | | |
| 20903 | - | X | X | - | X | X | X | X | X |
| 21001 | | | | | | | | | |
| 21002 | X | X | - | - | X | X | X | - | X |
| 21101 | X | - | - | - | - | - | - | - | - |
| 21102 | X | - | - | X | - | X | X | X | X |
| 21104 | | | | | | | | | |
| 21103 | | | | | | | | | |
| 21105 | - | - | X | - | - | X | X | X | X |
| 21201 | - | X | - | - | - | - | - | X | - |
| 21202 | - | X | X | - | X | - | - | - | X |
| 21206 | | | | | | | | | |
| 21207 | | | | | | | | | |
| 21208 | | | | | | | | | |
| 21205 | | | | | | | | | |
| 22952 | - | - | - | - | - | X | - | X | - |
| 21301 | - | - | - | - | - | X | X | X | X |
| 21302 | | | | | | | | | |
| 21303 | X | X | X | X | - | X | X | X | X |
| 21304 | - | - | X | - | - | X | X | - | - |
| 21309 | | | | | | | | | |
| 21305 | | | | | | | | | |
| 21310 | | | | | | | | | |
| 21308 | | | | | | | | | |
| 21307 | | | | | | | | | |
| 21406 | | | | | | | | | |
| 21407 | | | | | | | | | |
| 21702 | X | X | X | X | X | X | X | X | X |
| 21706 | - | - | - | - | - | - | - | X | X |
| 21703 | X | X | - | - | - | - | - | - | - |
| 22001 | - | - | - | - | - | X | X | X | X |
| 22006 | - | - | - | - | X | - | - | - | X |
| 22005 | X | X | - | - | - | - | - | - | X |
| 22008 | - | X | - | - | - | - | - | - | - |
| 22012 | - | - | - | - | - | - | X | - | - |
| 22011 | X | X | - | - | - | - | - | - | - |
| 22029 | - | - | - | - | - | - | - | X | - |
| 22003 | - | - | - | - | - | - | - | X | - |
| 22010 | X | - | - | - | - | X | X | - | - |
| 22009 | - | X | - | - | X | - | X | X | X |
| 22015 | - | X | - | - | - | - | - | - | - |
| 22014 | - | - | - | - | - | - | - | - | X |
| 22013 | | | | | | | | | |

**IMPERIAL GROSMONT**

| | 1573-74 | 1536-37 | 1521-28 | 1516-17 | 1510-15 | 1500-05 | 1486-90 | 1475-85 | 1469-74 | 1455-60 | 1429-38 | 1409-21 | 1402-08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | - | - | - | - | - | - | X | - | X | - | - | - | - |
| 20702 | | | | | | | | | | | | | |
| 20705 | | | | | | | | | | | | | |
| 20751 | - | - | - | - | X | - | - | - | - | X | X | X | - |
| 20752 | | | | | | | | | | | | | |
| 20753 | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 20754 | | | | | | | | | | | | | |
| 20755 | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 20756 | - | - | - | X | - | - | X | - | - | - | - | - | - |
| 20801 | - | - | - | X | X | X | - | - | - | X | - | X | - |
| 20802 | | | | | | | | | | | | | |
| 20803 | - | - | - | - | - | - | X | - | - | - | - | - | - |
| 20804 | - | - | - | - | - | - | - | - | - | X | X | X | X |
| 20805 | | | | | | | | | | | | | |
| 20806 | | | | | | | | | | | | | |
| 20807 | - | - | - | - | - | X | X | X | X | X | - | X | X |
| 20901 | | | | | | | | | | | | | |
| 20906 | - | - | - | - | - | - | X | - | - | - | - | - | - |
| 20903 | - | - | - | - | X | X | X | - | - | - | X | - | - |
| 21001 | - | - | - | X | - | X | X | - | X | X | - | - | - |
| 21002 | - | - | - | X | X | X | X | - | - | X | X | X | X |
| 21101 | | | | | | | | | | | | | |
| 21102 | - | - | - | - | - | - | - | - | - | - | X | X | X |
| 21104 | | | | | | | | | | | | | |
| 21103 | | | | | | | | | | | | | |
| 21105 | - | - | X | - | - | - | X | - | X | - | - | - | - |
| 21201 | | | | | | | | | | | | | |
| 21202 | - | - | - | - | - | - | - | - | - | X | - | X | X |
| 21206 | | | | | | | | | | | | | |
| 21207 | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 21208 | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 21205 | | | | | | | | | | | | | |
| 22952 | - | - | - | - | X | - | X | X | X | - | - | X | X |
| 21301 | - | - | - | - | - | - | - | - | - | - | - | X | - |
| 21302 | - | - | - | - | X | - | X | X | X | X | - | X | X |
| 21303 | - | - | - | - | - | - | X | X | X | - | X | X | X |
| 21304 | - | - | - | - | - | - | - | - | - | - | X | - | X |
| 21309 | | | | | | | | | | | | | |
| 21305 | | | | | | | | | | | | | |
| 21310 | | | | | | | | | | | | | |
| 21308 | | | | | | | | | | | | | |
| 21307 | | | | | | | | | | | | | |
| 21406 | | | | | | | | | | | | | |
| 21407 | | | | | | | | | | | | | |
| 21702 | - | - | - | X | X | - | - | X | X | X | X | X | X |
| 21706 | - | - | - | - | - | - | - | X | - | - | - | - | - |
| 21703 | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 22001 | - | - | - | - | - | - | - | X | - | - | X | X | X |
| 22006 | - | - | - | - | - | - | - | X | - | X | - | - | - |
| 22005 | - | - | - | X | X | X | X | X | X | X | X | X | - |
| 22008 | - | - | - | - | X | - | - | - | - | X | X | X | X |
| 22012 | - | - | - | - | X | - | - | - | - | - | - | - | - |
| 22011 | - | - | - | - | - | X | - | - | - | - | - | - | - |
| 22029 | | | | | | | | | | | | | |
| 22003 | | | | | | | | | | | | | |
| 22010 | - | - | - | - | X | - | - | - | - | - | - | - | - |
| 22009 | | | | | | | | | | | | | |
| 22015 | | | | | | | | | | | | | |
| 22014 | | | | | | | | | | | | | |
| 22013 | | | | | | | | | | | | | |

**IMP GROUARD**

| | 1397-1402 | 1394-97 | 1389-94 | 1384-89 | 1379-84 |
|---|---|---|---|---|---|
| 20701 | - | X | - | - | - |
| 20702 | | | | | |
| 20705 | | | | | |
| 20751 | - | - | - | - | X |
| 20752 | | | | | |
| 20753 | | | | | |
| 20754 | X | - | - | - | - |
| 20755 | | | | | |
| 20756 | | | | | |
| 20801 | - | - | X | X | X |
| 20802 | | | | | |
| 20803 | | | | | |
| 20804 | | | | | |
| 20805 | X | X | - | X | - |
| 20806 | | | | | |
| 20807 | | | | | |
| 20901 | X | - | X | X | X |
| 20906 | | | | | |
| 20903 | | | | | |
| 21001 | - | X | - | - | - |
| 21002 | - | X | - | X | - |
| 21101 | X | X | - | X | X |
| 21102 | | | | | |
| 21104 | | | | | |
| 21103 | | | | | |
| 21105 | | | | | |
| 21201 | X | - | X | X | - |
| 21202 | X | X | X | - | - |
| 21206 | X | - | - | - | X |
| 21207 | | | | | |
| 21208 | | | | | |
| 21205 | | | | | |
| 22952 | | | | | |
| 21301 | X | X | X | X | X |
| 21302 | - | X | - | X | X |
| 21303 | - | X | X | - | - |
| 21304 | X | - | - | - | - |
| 21309 | X | X | - | - | - |
| 21305 | | | | | |
| 21310 | | | | | |
| 21308 | - | X | - | - | - |
| 21307 | | | | | |
| 21406 | | | | | |
| 21407 | - | - | - | X | - |
| 21702 | - | - | X | - | - |
| 21706 | X | X | X | X | - |
| 21703 | X | - | - | - | - |
| 22001 | - | - | X | X | - |
| 22006 | X | - | - | - | X |
| 22005 | X | - | - | - | - |
| 22008 | X | X | X | X | - |
| 22012 | X | X | - | - | - |
| 22011 | | | | | |
| 22029 | | | | | |
| 22003 | | | | | |
| 22010 | | | | | |
| 22009 | | | | | |
| 22015 | - | - | - | X | - |
| 22014 | | | | | |
| 22013 | | | | | |

**IMPERIAL SPIRIT RIVER NO. 1**

| | 2670-80 | 2650-60 | 2625-35 | 2600-10 | 2590-2600 | 2570-75 | 2555-60 | 2540-45 | 2535-38 | 2515-20 | 2490-2500 | 2470-80 | 2450-60 | 2420-30 | 2380-90 | 2350-60 | 2330-40 | 2284-94 | 2249-59 | 2221-31 | 2191-2202 | 2161-71 | 2132-42 | 2103-13 | 2074-82 | 2045-55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20702 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20705 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20751 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20752 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - |
| 20753 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20754 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20755 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - |
| 20756 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20801 | - | - | - | X | X | - | - | - | - | - | - | X | - | X | X | X | X | X | - | X | X | X | - | X | X | X |
| 20802 | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - | - | X | - | - |
| 20803 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X |
| 20804 | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20805 | - | X | X | - | X | - | - | - | - | - | X | - | - | X | X | - | - | - | - | X | X | - | - | - | - | - |
| 20806 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20807 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20901 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - | - | - | X | - | - |
| 20906 | - | - | - | - | - | - | X | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 20903 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - |
| 21001 | - | - | X | X | X | - | - | - | - | - | - | - | - | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 21002 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | X | - | X | - | X | - | - | X |
| 21101 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | X | X | X | X | X | X | X | X |
| 21102 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 21104 | - | - | - | X | - | - | - | - | - | - | - | X | - | X | X | X | - | - | - | - | - | - | - | - | - | - |
| 21103 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21105 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - |
| 21201 | - | X | - | X | X | - | - | - | - | - | - | - | - | X | - | X | X | - | - | - | - | - | X | X | - | - |
| 21202 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | X | - | - | - | - | - | - | - |
| 21206 | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | X | X | X | X | - | - |
| 21207 | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - |
| 21208 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| 21205 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | - | - | - | - | - | - |
| 22952 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21301 | - | - | - | X | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | X | - | - | - |
| 21302 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | - | - | - | - | X | - | - | - |
| 21303 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - | - | - | - | - |
| 21304 | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | X | - | X | - | X | - | - |
| 21309 | - | - | - | X | - | - | - | - | - | - | - | - | - | - | X | X | - | - | X | - | - | - | X | - | - | - |
| 21305 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21310 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21308 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - |
| 21307 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21406 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21407 | - | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | - | X | - | - | - | - | - | X | X | - |
| 21702 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 21706 | - | - | X | - | - | X | - | - | X | - | - | X | - | - | X | - | X | - | X | - | X | - | - | X | X | X |
| 21703 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| 22001 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | X | X | X | - | - | - | - | - |
| 22006 | - | - | - | - | - | - | - | - | - | X | - | - | - | X | X | X | X | - | X | X | - | - | X | X | - | X |
| 22005 | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - |
| 22008 | - | - | X | - | X | - | - | - | - | - | - | X | - | X | X | X | X | - | X | X | X | - | X | X | X | - |
| 22012 | - | X | - | X | X | - | - | - | - | X | - | - | - | - | - | - | X | - | - | - | X | - | - | - | - | X |
| 22011 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22029 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22003 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - |
| 22010 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | - | - | - | - | - |
| 22009 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22015 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | - | X | - | - | - | - | - | X | X |
| 22014 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X |
| 22013 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | X | - |

| IMPERIAL BATTLE LAKE NO. 1 | 5520-30 | 5507-17 | 5502-07 | 5499-5503 | 5486-93 | 5479-86 | 5477-79 | 5475-76 | 5472-75 | 5465-70 | 5452-62 | 5447-52 | 5440-47 | 5430-40 | 5420-25 | 5415-20 | 5411-16 | 5409-11 | 5389-99 | 5385-90 | 5375-85 | 5365-70 | 5342-45 | 5327-37 | 5319-27 | 5309-19 | 5304-09 | 5294-5304 | 5284-94 | 5274-84 | 5265-74 | 5259-65 | 5249-59 | 5239-49 | 5234-36 | 5226-34 | 5216-26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22016 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|x|-|-|-|
| 22018 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|
| 22017 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22020 |-|-|-|-|-|-|x|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22022 |-|-|-|-|-|-|-|-|x|-|x|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22023 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|-|-|-|-|
| 22025 |-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22026 |-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|
| 22027 |-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22028 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|-|x|-|-|x|-|-|-|-|-|-|-|-|-|-|-|x|-|x|-|
| 22301 |-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22302 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22303 |-|-|-|-|-|-|x|x|x|-|x|-|-|-|x|-|-|-|-|-|-|x|-|-|-|-|-|x|-|-|-|x|-|-|-|x|-|
| 22308 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22309 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22312 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22313 |-|-|-|-|-|-|-|-|x|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|-|x|-|
| 22501 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|x|-|
| 22506 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22502 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|
| 22504 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|
| 22503 |-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22951 |-|-|-|-|-|-|-|x|-|x|-|-|x|-|x|x|x|-|-|-|-|x|-|-|x|-|x|x|x|x|x|x|x|x|-|x|-|
| 22961 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22311 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21003 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|
| 23101 |-|-|-|-|-|-|-|x|-|x|x|-|x|-|x|-|-|-|-|-|-|x|-|-|x|-|x|-|x|x|x|x|-|x|-|x|-|
| 23102 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|x|-|-|-|-|-|-|-|
| 23201 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23202 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|x|-|-|-|
| 23203 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|
| 23252 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|x|-|-|-|-|
| 23301 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|x|-|-|-|x|x|-|x|-|
| 23310 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|x|x|x|x|-|x|x|-|-|x|-|
| 23311 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|
| 23312 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|
| 23313 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23302 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|-|-|x|-|-|-|-|x|-|
| 23501 |-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|x|x|x|x|x|x|x|x|-|-|x|
| 23502 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|x|-|x|x|x|x|x|x|x|-|x|-|-|
| 23503 |-|-|-|-|-|-|x|x|x|-|-|-|-|x|-|x|x|x|-|-|-|x|-|-|-|-|x|x|-|-|-|x|x|x|-|x|-|
| 23901 |-|-|-|-|-|-|-|-|-|-|-|x|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| F S |-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|x|-|-|-|-|-|-|-|-|-|-|-|x|
| C R S |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|x|x|x|x|x|x|x|x|-|x|-|
| F-T S |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|x|-|-|-|-|x|x|-|-|-|
| FORAM |-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|x|-|x|x|x|x|x|-|-|x|-|-|-|
| ALG |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|x|-|-|-|-|-|-|
| DISCO | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MEGAS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| KISSINGER IMPERIAL CHIGWELL | 4943.1 | 4933.3 | 4923.3 | 4913.2 | 4903.3 | 4893.1 | 4883.7 | 4874.7 | 4862.9 | 4853.6 | 4846.2 | 4832.7 | 4823.5 | 4813.3 | 4803.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22016 | | | | | | | | | | | | | | | |
| 22018 | | | | | | | | | | | | | | | |
| 22017 |x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22020 |-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|
| 22022 |-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|
| 22023 |-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|
| 22025 | | | | | | | | | | | | | | | |
| 22026 |x|x|x|x|-|x|-|-|-|-|x|-|x|-|-|
| 22027 | | | | | | | | | | | | | | | |
| 22028 |-|x|-|-|x|x|-|-|-|-|-|x|x|x|-|
| 22301 |x|x|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22302 | | | | | | | | | | | | | | | |
| 22303 |x|x|x|-|x|-|-|-|-|-|-|-|-|-|-|
| 22308 | | | | | | | | | | | | | | | |
| 22309 |-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|
| 22312 | | | | | | | | | | | | | | | |
| 22313 |x|x|x|-|-|-|-|-|-|-|-|x|x|-|-|
| 22501 |-|x|x|-|-|x|x|-|-|x|-|-|-|-|-|
| 22506 | | | | | | | | | | | | | | | |
| 22502 | | | | | | | | | | | | | | | |
| 22504 |-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|
| 22503 |x|x|-|-|-|-|-|-|-|-|-|-|-|-|-|
| 22951 |x|x|x|-|x|x|-|-|-|x|-|x|x|x|x|
| 22961 |x|-|-|-|x|-|-|-|-|-|-|-|-|-|-|
| 22311 | | | | | | | | | | | | | | | |
| 21003 |x|x|x|-|-|-|-|-|-|-|-|-|-|-|-|
| 23101 |x|x|x|-|-|x|-|-|x|-|-|x|x|-|x|
| 23102 | | | | | | | | | | | | | | | |
| 23201 |-|-|x|-|-|-|-|-|-|-|-|x|-|-|-|
| 23202 | |-|-|-|x|-|-|-|-|-|-|x|-|-|-|
| 23203 |-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|
| 23252 | | | | | | | | | | | | | | | |
| 23301 |-|-|-|-|-|-|-|x|-|-|x|-|-|x|x|
| 23310 |-|x|x|-|-|-|-|-|-|x|x|x|x|x|x|
| 23311 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|
| 23312 |-|-|-|-|-|x|-|-|-|x|-|-|-|-|-|
| 23313 | | | | | | | | | | | | | | | |
| 23302 |x|-|x|-|-|-|-|-|-|-|-|-|x|-|x|
| 23501 |-|-|-|-|x|-|-|-|-|-|x|x|x|x|-|
| 23502 | | | | | | | | | | | | | | | |
| 23503 |x|x|x|-|x|x|-|x|-|x|-|x|-|-|x|
| 23901 |-|x|x|-|-|-|-|-|-|-|-|-|-|-|-|
| F S | | | | | | | | | | | | | | | |
| C R S |-|x|x|-|-|-|-|-|-|x|x|x|x|x|x|
| F-T S |-|-|-|-|-|-|-|-|-|-|x|x|x|x|x|
| FORAM |-|-|-|-|-|-|-|-|-|-|-|x|x|-|-|
| ALG | | | | | | | | | | | | | | | |
| DISCO | | | | | | | | | | | | | | | |
| MEGAS | | | | | | | | | | | | | | | |

| ANGLO-CAN WABAMUN | 4622-32 | 4573-83 | 4558-68 | 4538-48 | 4494-4502 | 4469-79 | 4439-49 | 4399-4409 | 4369-79 |
|---|---|---|---|---|---|---|---|---|---|
| 22016 |-|-|-|-|-|x|-|-|-|
| 22018 | | | | | | | | | |
| 22017 | | | | | | | | | |
| 22020 | | | | | | | | | |
| 22022 | | | | | | | | | |
| 22023 |-|-|-|-|x|-|-|-|x|
| 22025 | | | | | | | | | |
| 22026 |-|-|x|x|x|-|-|-|-|
| 22027 | | | | | | | | | |
| 22028 |-|x|x|x|x|-|x|-|-|
| 22301 |-|x|-|-|-|-|-|-|-|
| 22302 | | | | | | | | | |
| 22303 |x|x|-|-|-|-|-|-|-|
| 22308 | | | | | | | | | |
| 22309 | | | | | | | | | |
| 22312 | | | | | | | | | |
| 22313 |x|-|-|-|-|-|-|-|-|
| 22501 |-|-|x|x|-|-|-|x|x|
| 22506 |-|-|-|-|-|-|-|-|x|
| 22502 |-|x|-|-|-|-|-|-|-|
| 22504 | | | | | | | | | |
| 22503 | | | | | | | | | |
| 22951 |x|x|-|x|x|x|x|x|-|
| 22961 |-|-|x|-|-|-|-|-|-|
| 22311 | | | | | | | | | |
| 21003 |-|x|-|-|-|-|-|-|-|
| 23101 |-|x|x|-|x|x|x|x|x|
| 23102 | | | | | | | | | |
| 23201 | | | | | | | | | |
| 23202 | | | | | | | | | |
| 23203 |x|-|-|-|-|-|-|-|-|
| 23252 |-|-|x|-|-|-|-|-|-|
| 23301 |-|-|-|-|-|x|x|x|x|
| 23310 |-|x|-|-|x|x|x|x|x|
| 23311 | | | | | | | | | |
| 23312 | | | | | | | | | |
| 23313 | | | | | | | | | |
| 23302 |-|-|-|-|-|-|x|x|x|
| 23501 |-|x|x|-|x|x|x|x|x|
| 23502 |-|x|x|-|-|x|x|x|-|
| 23503 |x|x|x|x|x|x|-|x|x|
| 23901 | | | | | | | | | |
| F S |-|-|x|x|-|-|-|-|x|
| C R S |-|-|-|-|-|x|x|x|x|
| F-T S |-|-|-|-|-|-|x|-|x|
| FORAM |-|x|-|-|-|-|x|x|x|
| ALG |-|-|-|-|-|-|-|-|x|
| DISCO |-|-|-|-|x|-|-|-|-|
| MEGAS | | | | | | | | | |

| IMPERIAL GROSMONT | 1573-74 | 1536-37 | 1521-28 | 1516-17 | 1510-15 | 1500-05 | 1486-90 | 1475-85 | 1469-74 | 1455-60 | 1429-38 | 1409-21 | 1402-08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22016 | | | | | | | | | | | | | |
| 22018 | | | | | | | | | | | | | |
| 22017 | | | | | | | | | | | | | |
| 22020 |-|-|-|-|x|-|-|-|-|-|-|-|-|
| 22022 |-|-|-|-|-|x|-|-|-|-|-|-|-|
| 22023 | | | | | | | | | | | | | |
| 22025 | | | | | | | | | | | | | |
| 22026 |-|-|-|-|-|x|x|-|-|-|-|x|-|
| 22027 |-|-|-|-|-|-|-|-|-|-|x|-|-|
| 22028 |-|-|-|-|-|-|-|-|-|-|-|x|x|
| 22301 | | | | | | | | | | | | | |
| 22302 | | | | | | | | | | | | | |
| 22303 |-|-|-|x|x|x|x|-|-|x|-|-|x|
| 22308 |-|-|-|-|-|-|-|-|-|x|-|-|-|
| 22309 | | | | | | | | | | | | | |
| 22312 | | | | | | | | | | | | | |
| 22313 |-|-|-|-|-|-|x|-|-|-|-|-|-|
| 22501 |-|-|-|-|-|-|-|x|x|x|x|x|x|
| 22506 |-|-|-|-|-|-|-|-|-|-|-|x|-|
| 22502 | | | | | | | | | | | | | |
| 22504 | | | | | | | | | | | | | |
| 22503 |-|-|-|-|-|-|x|x|x|-|x|-|-|
| 22951 |-|x|-|x|-|x|-|x|x|x|x|x|x|
| 22961 |-|-|-|-|-|-|x|-|x|-|x|x|x|
| 22311 | | | | | | | | | | | | | |
| 21003 | | | | | | | | | | | | | |
| 23101 |-|-|-|x|-|x|-|x|x|x|x|-|-|
| 23102 | | | | | | | | | | | | | |
| 23201 |-|-|-|x|-|-|-|-|x|-|-|x|x|
| 23202 |-|-|-|x|-|-|-|-|x|-|-|x|x|
| 23203 | | | | | | | | | | | | | |
| 23252 |-|-|-|-|-|-|-|x|-|-|x|-|-|
| 23301 |-|-|-|-|-|-|-|-|-|-|x|x|-|
| 23310 |-|-|-|-|-|-|x|-|-|x|-|-|-|
| 23311 | | | | | | | | | | | | | |
| 23312 | | | | | | | | | | | | | |
| 23313 | | | | | | | | | | | | | |
| 23302 |-|-|-|-|-|-|-|-|x|x|x|-|-|
| 23501 |-|-|-|-|-|-|-|-|-|x|x|x|x|
| 23502 | | | | | | | | | | | | | |
| 23503 |-|x|-|x|x|-|-|x|x|x|x|x|x|
| 23901 |-|-|-|-|x|-|-|-|x|-|x|-|-|
| F S |-|-|-|-|-|-|-|-|-|-|x|-|-|
| C R S |-|-|-|x|-|-|-|x|x|-|-|x|x|
| F-T S | | | | | | | | | | | | | |
| FORAM | | | | | | | | | | | | | |
| ALG | | | | | | | | | | | | | |
| DISCO | | | | | | | | | | | | | |
| MEGAS | | | | | | | | | | | | | |

| IMP GROUARD | 1397-1402 | 1394-97 | 1389-94 | 1384-89 | 1379-84 |
|---|---|---|---|---|---|
| 22016 | | | | | |
| 22018 | | | | | |
| 22017 | | | | | |
| 22020 | | | | | |
| 22022 | | | | | |
| 22023 | | | | | |
| 22025 | | | | | |
| 22026 |x|-|-|-|-|
| 22027 | | | | | |
| 22028 |x|x|-|-|-|
| 22301 | | | | | |
| 22302 | | | | | |
| 22303 |-|-|x|-|-|
| 22308 | | | | | |
| 22309 | | | | | |
| 22312 | | | | | |
| 22313 | | | | | |
| 22501 |x|x|-|-|-|
| 22506 | | | | | |
| 22502 | | | | | |
| 22504 | | | | | |
| 22503 | | | | | |
| 22951 |-|x|x|x|x|
| 22961 |x|-|-|-|-|
| 22311 | | | | | |
| 21003 |x|-|-|-|-|
| 23101 |x|x|x|-|-|
| 23102 |x|-|-|-|-|
| 23201 | | | | | |
| 23202 | | | | | |
| 23203 | | | | | |
| 23252 | | | | | |
| 23301 | | | | | |
| 23310 |-|x|x|x|x|
| 23311 | | | | | |
| 23312 | | | | | |
| 23313 |-|-|x|-|x|
| 23302 |-|-|-|x|-|
| 23501 |x|x|x|x|x|
| 23502 |x|-|-|x|-|
| 23503 |x|x|x|x|x|
| 23901 | | | | | |
| F S | | | | | |
| C R S |-|x|-|-|-|
| F-T S | | | | | |
| FORAM | | | | | |
| ALG | | | | | |
| DISCO | | | | | |
| MEGAS | | | | | |

| IMPERIAL SPIRIT RIVER NO. 1 | 2670-80 | 2650-60 | 2625-35 | 2600-10 | 2590-2600 | 2570-75 | 2555-60 | 2540-45 | 2535-38 | 2515-20 | 2490-2500 | 2470-80 | 2450-60 | 2420-30 | 2380-90 | 2350-60 | 2330-40 | 2284-94 | 2249-59 | 2221-31 | 2191-2202 | 2161-71 | 2132-42 | 2103-13 | 2074-82 | 2045-55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22016 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|x|x|-|
| 22018 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|
| 22017 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22020 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|
| 22022 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22023 |-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|
| 22025 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22026 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22027 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22028 |-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|x|x|x|x|-|-|-|-|-|-|x|
| 22301 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22302 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22303 |-|-|x|-|x|-|-|-|-|x|-|-|-|x|-|x|-|-|-|-|-|-|-|-|-|-|
| 22308 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22309 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22312 |-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|
| 22313 |-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|
| 22501 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|
| 22506 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22502 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|
| 22504 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22503 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22951 |-|-|x|x|x|-|-|-|-|-|x|x|-|x|x|x|x|x|x|x|x|x|-|x|x|x|
| 22961 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22311 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|x|-|-|-|-|-|-|-|
| 21003 |-|-|x|-|-|-|-|-|-|-|-|-|-|-|x|-|x|-|x|-|-|-|-|-|-|-|
| 23101 |-|-|x|x|x|-|-|-|-|-|-|x|-|-|x|-|x|-|x|x|x|x|x|x|x|x|
| 23102 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23201 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23202 |-|-|x|-|-|x|x|x|x|x|-|x|-|-|x|-|x|-|-|-|-|-|-|-|-|-|
| 23203 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|x|-|
| 23252 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23301 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|x|x|x|x|x|-|x|x|x|
| 23310 |-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|x|x|-|x|x|-|-|x|x|-|-|
| 23311 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|
| 23312 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|
| 23313 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|
| 23302 |-|x|x|x|-|-|-|-|-|-|-|-|-|-|x|x|x|x|x|x|x|x|x|x|x|x|
| 23501 |-|-|x|x|-|-|-|-|-|-|-|-|-|x|x|x|x|x|x|-|x|-|-|x|-|-|
| 23502 |-|-|-|x|-|-|-|x|-|-|-|-|-|-|-|x|x|-|x|x|x|-|x|x|x|x|
| 23503 |-|-|x|x|-|-|-|x|-|x|-|-|-|x|x|x|x|x|x|-|-|x|x|x|x|x|
| 23901 |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|
| F S |-|-|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|-|
| C R S |-|-|-|-|x|-|-|-|-|-|-|-|-|-|x|x|x|x|x|x|x|x|x|x|x|x|
| F-T S |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|-|x|x|x|x|x|x|x|-|
| FORAM |-|-|-|-|-|-|-|-|-|-|-|-|-|-|-|x|x|x|x|x|-|x|-|x|-|x|
| ALG |-|-|-|-|-|-|-|-|-|x|-|x|-|-|-|-|-|-|-|-|-|-|-|-|-|-|
| DISCO | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MEGAS |-|-|-|-|-|-|-|-|-|-|x|-|-|-|-|-|-|-|-|-|-|-|x|-|-|-|

Microplankton:

Leiosphaeridia sp. A.
Microdinium opacum sp. nov.
Palaeoperidinium cretaceum (Pocock) emend.
Oligosphaeridium complex
Cometodinium multispinosum (Singh) comb. nov.
Micrhystridium cf. M. piliferum
Chlamydophorella nyei
Dingodinium cerviculum
Odontochitina operculata

Most of the other species in the assemblages of the Lower Colorado Group appear to be more restricted in their distribution, either in a geographic sense, or vertically (stratigraphically), or both. There are many forms that occur rarely and which are found in only one, sometimes two, sections. Because of their restricted occurrence, these forms are not useful for biostratigraphic zonation, although they may prove useful in recognizing regionally restricted assemblages. Examples of species which are well represented but restricted to one section are very rare. One miospore species, Reticulitricolpites crassus sp. nov., occurring only in the Joli Fou-Viking units of the "Grosmont" section, exhibits this type of distribution.

Many species show restriction in vertical distribution but are found in nearly all of the sections investigated. Such vertical distribution may be of two forms: a type in which the species occurs within a restricted stratigraphic range that may be traced in all or nearly all of the sections; and a type in which species tend to recur throughout sections at certain intervals, often recurring with the same species. Species exhibiting the first type of restriction may have biostratigraphic significance in a regional zonation scheme.

Species which appear to recur consistently with the same forms at restricted levels may be part of recurring species groups. Both of these restricted distributions will be examined further in a later chapter. It is important to note that there is evidence suggesting their occurrence.

## RATIO CURVES AND OTHER DATA

In the preceding chapter, certain ratios were proposed involving several types of microfossil forms. Counts were made of these forms using the methods outlined in that chapter for certain selected sections or portions of these sections. The numerical results are presented in TABLE 4 and the ratios are plotted in Text-figures 5 and 6. Several values in these data produced very high ratios relative to those of nearly all other data. In order to accommodate all of these values on one graph, the log of the ratios was plotted rather than the arithmetic values.

Without making extensive interpretations of these results, it may be noted that general trends are evident in the plotted data. Cursory comparison of these trends with lithological and other data suggests that they may be correlative to some degree. This observation is explored and discussed further in a later chapter.

## RECYCLED MIOSPORES

Recycled miospores were common in many samples from the Lower Colorado Group and equivalents in west-central Alberta. Many of the forms were identifiable down to the species level and could be divided into assemblages of two different geological ages, Lower Carboniferous and Permo-Triassic. Below is a list of the identified forms. The

TABLE 4. Numerical results of counts of various groups of miospore and microplankton groups including calculations of the $\mathrm{Log}_{10}$ of the ratios: Total spores/Total pollen (TS/TP); Total acritarchs/Total dinoflagellates (TA/TD); and Total miospores/Total microplankton (TMS/TMP). Samples counted from Imperial Battle Lake No. 1 well, Imperial Grosmont No. 1 well, Imperial Grouard No. 1 well and Imperial Spirit River No. 1 well.

TABLE 4

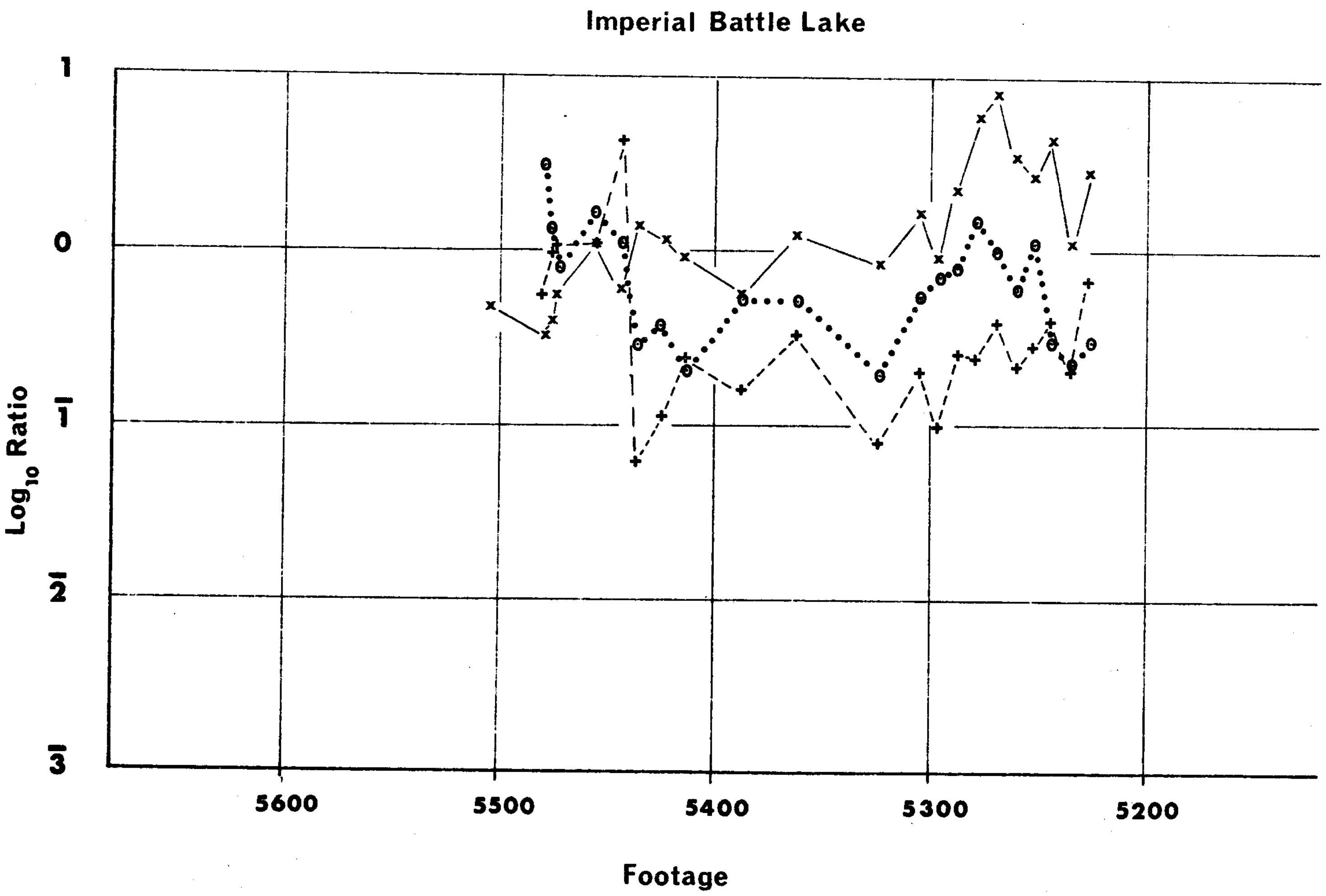
| SAMPLE NUMBER | TOTAL SPORES | TOTAL POLLEN | LOG$_{10}$ TS/TP | TOTAL ACRIT. | TOTAL DINOFL. | LOG$_{10}$ TA/TD | TOTAL MIOSP. | TOTAL MICROPL. | LOG$_{10}$ TMS/TMP |
|---|---|---|---|---|---|---|---|---|---|
| IMPERIAL BATTLE LAKE NO. 1 WELL | | | | | | | | | |
| BW 68 | 18 | 38 | $\bar{1}.67$ | 0 | 0 | ---- | 56 | ---- | ---- |
| BW 72 | 45 | 144 | $\bar{1}.49$ | 22 | 39 | $\bar{1}.75$ | 189 | 61 | 0.49 |
| BW 73 | 19 | 49 | $\bar{1}.59$ | 24 | 26 | $\bar{1}.96$ | 68 | 50 | 0.13 |
| BW 172 | 69 | 124 | $\bar{1}.75$ | 125 | 109 | 0.04 | 193 | 234 | $\bar{1}.91$ |
| BW 75 | 71 | 65 | 0.03 | 42 | 39 | 0.03 | 136 | 81 | 0.22 |
| BW 77 | 24 | 40 | $\bar{1}.78$ | 17 | 40 | 0.63 | 64 | 57 | 0.05 |
| BW 78 | 57 | 42 | 0.13 | 18 | 325 | $\bar{2}.78$ | 99 | 343 | $\bar{1}.46$ |
| BW 79 | 19 | 18 | 0.04 | 10 | 92 | $\bar{1}.04$ | 37 | 102 | $\bar{1}.56$ |
| BW 118 | 19 | 21 | $\bar{1}.96$ | 37 | 154 | $\bar{1}.38$ | 40 | 191 | $\bar{1}.32$ |
| IMP 11-454/2 | 24 | 42 | $\bar{1}.76$ | 16 | 107 | $\bar{1}.18$ | 66 | 123 | $\bar{1}.73$ |
| BW 131 | 106 | 88 | 0.08 | 96 | 293 | $\bar{1}.52$ | 194 | 389 | $\bar{1}.70$ |
| BW 132 | 69 | 85 | $\bar{1}.91$ | 55 | 729 | $\bar{2}.90$ | 154 | 784 | $\bar{1}.30$ |
| BW 120 | 80 | 49 | 0.21 | 44 | 190 | $\bar{1}.31$ | 129 | 234 | $\bar{1}.74$ |
| BW 121 | 103 | 112 | $\bar{1}.96$ | 28 | 270 | $\bar{1}.00$ | 215 | 298 | $\bar{1}.86$ |
| BW 122 | 149 | 60 | 0.39 | 52 | 198 | $\bar{1}.42$ | 209 | 250 | $\bar{1}.92$ |
| BW 123 | 280 | 48 | 0.77 | 45 | 179 | $\bar{1}.40$ | 328 | 224 | 0.17 |
| BW 124 | 228 | 30 | 0.88 | 71 | 182 | $\bar{1}.59$ | 258 | 253 | 0.01 |
| BW 125 | 158 | 47 | 0.53 | 60 | 274 | $\bar{1}.34$ | 205 | 334 | $\bar{1}.79$ |
| BW 126 | 149 | 54 | 0.44 | 41 | 144 | $\bar{1}.46$ | 203 | 185 | 0.04 |
| BW 127 | 70 | 16 | 0.64 | 78 | 196 | $\bar{1}.60$ | 86 | 274 | $\bar{1}.49$ |
| IMP 11-453/4 | 35 | 33 | 0.03 | 31 | 266 | $\bar{1}.08$ | 68 | 297 | $\bar{1}.36$ |

TABLE 4 CONT'D

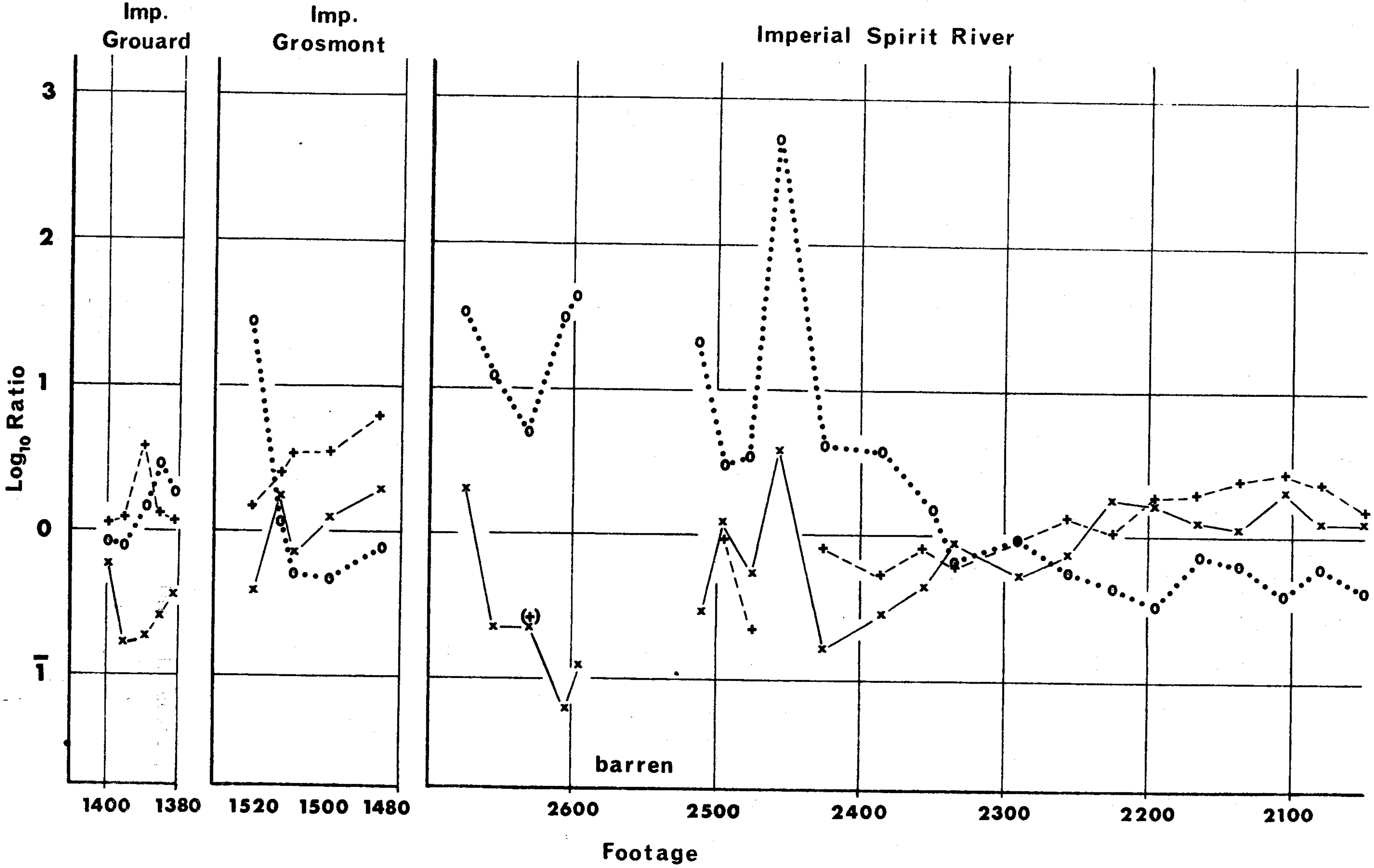
| SAMPLE NUMBER | TOTAL SPORES | TOTAL POLLEN | LOG$_{10}$ TS/TP | TOTAL ACRIT. | TOTAL DINOFL. | LOG$_{10}$ TA/TD | TOTAL MIOSP. | TOTAL MICROPL. | LOG$_{10}$ TMS/TMP |
|---|---|---|---|---|---|---|---|---|---|
| IMPERIAL BATTLE LAKE CONT'D | | | | | | | | | |
| BW 128 | 40 | 13 | 0.49 | 56 | 115 | $\bar{1}.69$ | 53 | 171 | $\bar{1}.49$ |
| IMPERIAL GROSMONT NO. 1 WELL | | | | | | | | | |
| BW 170 | 134 | 339 | $\bar{1}.60$ | 10 | 7 | (0.16) | 474 | 17 | 1.45 |
| BW 137 | 235 | 139 | 0.23 | 222 | 87 | 0.41 | 373 | 309 | 0.08 |
| BW 173 | 118 | 160 | $\bar{1}.86$ | 442 | 128 | 0.54 | 278 | 570 | $\bar{1}.69$ |
| BW 176 | 131 | 102 | 0.11 | 391 | 106 | 0.57 | 233 | 497 | $\bar{1}.67$ |
| BW 177 | 253 | 131 | 0.29 | 431 | 68 | 0.80 | 384 | 499 | $\bar{1}.89$ |
| IMPERIAL GROUARD NO. 1 WELL | | | | | | | | | |
| BW 174 | 244 | 415 | $\bar{1}.77$ | 413 | 362 | 0.06 | 659 | 775 | $\bar{1}.92$ |
| BW 169 | 53 | 312 | $\bar{1}.23$ | 244 | 191 | 0.11 | 365 | 435 | $\bar{1}.92$ |
| BW 168 | 69 | 350 | $\bar{1}.28$ | 226 | 58 | 0.59 | 429 | 284 | 0.18 |
| BW 167 | 112 | 410 | $\bar{1}.43$ | 104 | 76 | 0.14 | 532 | 180 | 0.47 |
| BW 166 | 117 | 326 | $\bar{1}.56$ | 123 | 102 | 0.08 | 443 | 225 | 0.29 |
| IMPERIAL SPIRIT RIVER NO. 1 WELL | | | | | | | | | |
| BW 153 | 424 | 184 | 0.36 | 5 | 8 | ---- | 608 | 13 | 1.67 |
| BW 133 | 105 | 443 | $\bar{1}.38$ | 26 | 14 | (0.27) | 548 | 40 | 1.14 |
| BW 154 | 129 | 512 | $\bar{1}.40$ | 24 | 93 | $\bar{1}.42$ | 641 | 117 | 0.74 |
| BW 134 | 52 | 752 | $\bar{2}.85$ | 13 | 10 | ---- | 804 | 23 | 1.54 |
| BW 135 | 83 | 612 | $\bar{1}.15$ | 3 | 12 | ---- | 695 | 15 | 1.67 |
| BW 159 | 66 | 203 | $\bar{1}.51$ | 4 | 8 | ---- | 269 | 12 | 1.35 |
| BW 160 | 121 | 92 | 0.12 | 32 | 33 | $\bar{1}.99$ | 213 | 65 | 0.52 |
| BW 136 | 173 | 286 | $\bar{1}.79$ | 24 | 103 | $\bar{1}.36$ | 459 | 127 | 0.56 |

TABLE 4 CONT'D

| SAMPLE NUMBER | TOTAL SPORES | TOTAL POLLEN | LOG$_{10}$ TS/TP | TOTAL ACRIT. | TOTAL DINOFL. | LOG$_{10}$ TA/TD | TOTAL MIOSP. | TOTAL MICROPL. | LOG$_{10}$ TMS/TMP |
|---|---|---|---|---|---|---|---|---|---|
| IMPERIAL SPIRIT RIVER NO. 1 WELL | | | | | | | | | |
| BW 161 | 977 | 212 | 1.66 | 3 | 2 | ---- | 1189 | 5 | 2.38 |
| BW 140 | 65 | 268 | $\bar{1}.25$ | 44 | 53 | $\bar{1}.92$ | 433 | 97 | 0.65 |
| BW 145 | 136 | 434 | $\bar{1}.49$ | 51 | 93 | $\bar{1}.74$ | 570 | 144 | 0.60 |
| BW 146 | 195 | 528 | $\bar{1}.57$ | 196 | 240 | $\bar{1}.92$ | 723 | 436 | 0.22 |
| BW 147 | 142 | 148 | $\bar{1}.98$ | 163 | 273 | $\bar{1}.78$ | 290 | 436 | $\bar{1}.82$ |
| BW 141 | 85 | 154 | $\bar{1}.74$ | 117 | 131 | $\bar{1}.95$ | 239 | 248 | $\bar{1}.98$ |
| BW 148 | 130 | 167 | $\bar{1}.89$ | 303 | 218 | 0.14 | 297 | 523 | $\bar{1}.76$ |
| BW 149 | 114 | 96 | 0.27 | 258 | 241 | 0.03 | 210 | 499 | $\bar{1}.64$ |
| BW 142 | 93 | 57 | 0.21 | 310 | 165 | 0.27 | 150 | 475 | $\bar{1}.51$ |
| BW 150 | 163 | 122 | 0.13 | 251 | 133 | 0.28 | 285 | 384 | $\bar{1}.87$ |
| BW 151 | 302 | 252 | 0.05 | 601 | 251 | 0.38 | 504 | 854 | $\bar{1}.77$ |
| BW 143 | 157 | 76 | 0.32 | 453 | 168 | 0.43 | 233 | 621 | $\bar{1}.58$ |
| BW 152 | 295 | 233 | 0.10 | 660 | 273 | 0.38 | 528 | 933 | $\bar{1}.76$ |
| BW 144 | 128 | 99 | 0.11 | 350 | 229 | 0.18 | 227 | 579 | $\bar{1}.59$ |



Text-figure 5. $\text{Log}_{10}$ of ratios listed in TABLE 4 plotted against footage in Imperial Battle Lake No 1 well. Ratio value plotted at mid-point of sample. TS/TP: (X———X) TA/TD: (+ - - - +) TMS/TMP: (0····0····0).



Text-figure 6. $Log_{10}$ of ratios listed in TABLE 4 plotted against footage for three wells in Central Alberta. Ratio value plotted at mid-point. Symbols as for Text-figure 5.

nomenclature is derived from a number of publications including Playford (1962, 1963a, 1963b), Hacquebard (1957), Hacquebard and Barss (1957), Hughes and Playford (1961), Jansonius (1962). Norris (1967) also lists a number of forms identified from Lower Colorado strata near Edmonton.

*Carboniferous Species*:

*Densosporites duplicatus* (Naumova) Pot. & Kr.; *D.* cf. *D. variabilis* (Waltz) Pot. & Kr.; *D. bialatus* (Waltz) Pot. & Kr.; *D. spitsbergensis* Playf.; *D.* cf. *D. striatiferus* Hughes & Playf.; *D.* cf. *D. aculeatus* Playf.; *Murospora aurita* (Waltz) Playf.; *M.* cf. *M. friendii* Playf.; *Monilaspora monilaformis* Hacqueb. & Barss; *Endosporites micromanifestus* Hacqueb.; *Annulatisporites* cf. *A. orbiculatus* (Waltz) Playf.; *Tripartites incisotrilobus* (Naumova) Pot. & Kr.; *Convolutispora tuberculata* (Waltz) Hoffm. *et al.* Unidentified species of the genera *Reticulatisporites*, *Stenozonotriletes*, *Knoxisporites*, *Tripartites* and *Densosporites*.

*Permo-Triassic Species*:

*Taeniasporites* cf. *T. hexagonalis* Jansonius; *T. gracilis* Jansonius. Various unidentified bisaccate grains belonging to the *Disaccate Striatiti*, and one unidentified monosaccate species.

Some of the species listed above were reported by Norris (1967) and others are listed for the first time as recycled forms present in the Lower Colorado Group and its equivalents. Most of the species preserved enough to be identified are cingulate or auriculate, although some Permo-Triassic species are striate bisaccate grains.

# V

# DISCUSSION AND INTERPRETATION OF PALYNOLOGICAL DATA

## PALYNOLOGICAL TIME-STRATIGRAPHIC CORRELATION OF THE LOWER COLORADO GROUP

One of the major objectives in the investigation of the palynology of the Lower Colorado Group and related deposits, was to assess the usefulness of the plant microfossil assemblages in providing a time-stratigraphic zonation and correlation of the sequence. The potential value of such an undertaking was outlined in an earlier portion of this account. Preliminary reports, indicating the presence of varied and abundant miospore and microplankton assemblages suitable for such an objective, have been confirmed by the taxonomic investigation (Part Two, Chapter Three). In the sections to follow, use is made of these data in developing a proposed time-stratigraphic division of the Lower Colorado Group and in correlation of the Group on a regional and continental level. The usefulness of the zonation developed in this account in answering stratigraphic questions posed earlier is also discussed.

## PALYNOLOGICAL ZONATION WITHIN THE LOWER COLORADO GROUP

### Correlation Methods

Time-stratigraphic zonation and correlation may be carried out on a number of geographic scales ranging from local, regional to continental or intercontinental. In all cases the fundamental data are the occurrence and geological ranges of the fossil species used in the correlation. Many methods of correlation have been evolved, using the total or regional geological range of a species, the acme of a species, or the acme or duration of an assemblage of fossil organisms. These are discussed critically by Shaw (1964) and need not be elaborated on further here. Shaw concludes, and the author concurs, that the only reliable time data a fossil species can supply is its partial or total geological range. Local and regional ranges of species are not useful in long distance correlation, but within a restricted geographical area may be of some value. Many correlation methods have been used in Cretaceous palynology including correlation by acme of species groups (Brown and Pierce, 1962) and the use of species ranges. Couper (1958), Pocock (1962) and Tschudy (1964) have presented discussions of palynological correlation methods, pointing out pitfalls and advantages of the various methods. The author thinks that correlation by acme does not lead to reliable results, and in any case the schemes are not valid except for very small geographic distances. Because of the many influences on deposition and preservation of palynological entities, some variation may be expected also in local and regional ranges of species. The evidence from a number of sections and for one or more groups of stratigraphically important species, however, is always more significant than the acme of these forms. The presence of recurrent species groups adds a further dimension to palynological stratigraphical correlation and zonation. This aspect will be discussed in a later portion of this chapter.

## Selection of Stratigraphically Significant Species

The basic unit of information on which the time-stratigraphic correlation of the Lower Colorado Group is based is the geological range of certain selected miospore and microplankton species. In some cases the range is necessarily local if the species is newly described and in other cases may be derived from previously reported worldwide occurrences. The zonation is based primarily on the first appearance of key species in the section although last appearances of a number of species are also utilized. In choosing the species considered to have stratigraphic significance, several criteria have been applied. Key species have a relatively restricted range, generally within the mid or late Albian. Longer ranging species are not considered in this context. These species are also distributed in the majority of all of sections examined. Other species with restricted ranges but with irregular distribution patterns are not considered. Some of these latter forms may be useful as accessory species, tending to appear with certain key forms in a few of the sections.

Local ranges of all the species described from the two complete sections were examined in detail. The criteria set out above were applied to these assemblages and then to assemblages present in the incomplete sections from other localities. Because the first appearance of any species in a section varies slightly in the level of appearance, it was decided to use groups of key species and work with assemblages rather than single species. The first appearance of a species in a cored section may sometimes be spurious because of caving or contamination from higher levels. The consistent occurrence of closely related first appearances of a group of species could not be traced to this possibility. The last appearance of a species is often more reliable where confirmatory evidence from previous stratigraphic work is available. Some species described in this investigation may be useful in this context, but the majority of Lower Colorado Group species range beyond the level at which palynological investigations were terminated.

In developing the stratigraphic zonation of the Lower Colorado Group, the miospore and microplankton assemblages were considered separately. The reasons for this procedure will be discussed more fully below. It is sufficient to suggest at this time that miospores were derived from parent plants inhabiting a land environment, while microplankton forms lived in a marine environment. Although both groups are subject to long term fluctuations in climatic and geological setting, the author suggests that each group is also subject to some degree to the separate primary environments. Both of the groups are utilized in the zonation scheme presented below.

## MIOSPORE ZONATION OF THE LOWER COLORADO GROUP

A total of 161 miospore species is described in the taxonomy section (Part Two, Chapter Three) from the Lower Colorado Group in central Alberta, the uppermost Mannville Group in central and south-central Alberta and the Peace River-Lower Shaftesbury Formations in west-central Alberta. Application of the criteria for choosing stratigraphically significant miospore species, and reference to the occurrence data presented in the charts of Text-figure 4a-e indicate that only 19 species have sufficiently restricted ranges and occur in the majority of sections examined. The ranges of these species in each of the six sections examined are presented for comparison in Text-figure 7a-b.

Of the 20 species, 9 species have significantly restricted ranges or definitive entrance levels and may be considered as reliable indicators of time-stratigraphic units within the Lower Colorado group and its equivalents. These species are: *Cirratriradites teter* Norris, *Tigrisporites scurrandus* Norris, *Reticulisporites norrisii* sp. nov., *Camarozonosporites insignis* Norris, *Reticulitricolpites sagax* (Norris) comb. nov., *Tricolpites vulgaris* (Pierce) comb. nov., *Rugubivesiculites rugosus* Pierce, *Rugubivesiculites* cf. *R. reductus* Pierce, and *Rugubivesiculites* sp. A.

*C. teter* appears near the base of most sections and is followed at a higher level by *T. scurrandus*. Further up in the sections *Tricolpites vulgaris* makes its first appearance accompanied closely by one or more of *Reticulisporites norrisii*, *C. insignis* and *Reticulitricolpites sagax*. In the higher levels of the more complete sections, the three species of *Rugubivesiculites* Pierce appear, accompanied in the "Grosmont" section by the first appearance of *Reticulitricolpites crassus* sp. nov. These entrance levels may be made the basis for a division of the Lower Colorado Group and its equivalents into three time segments.

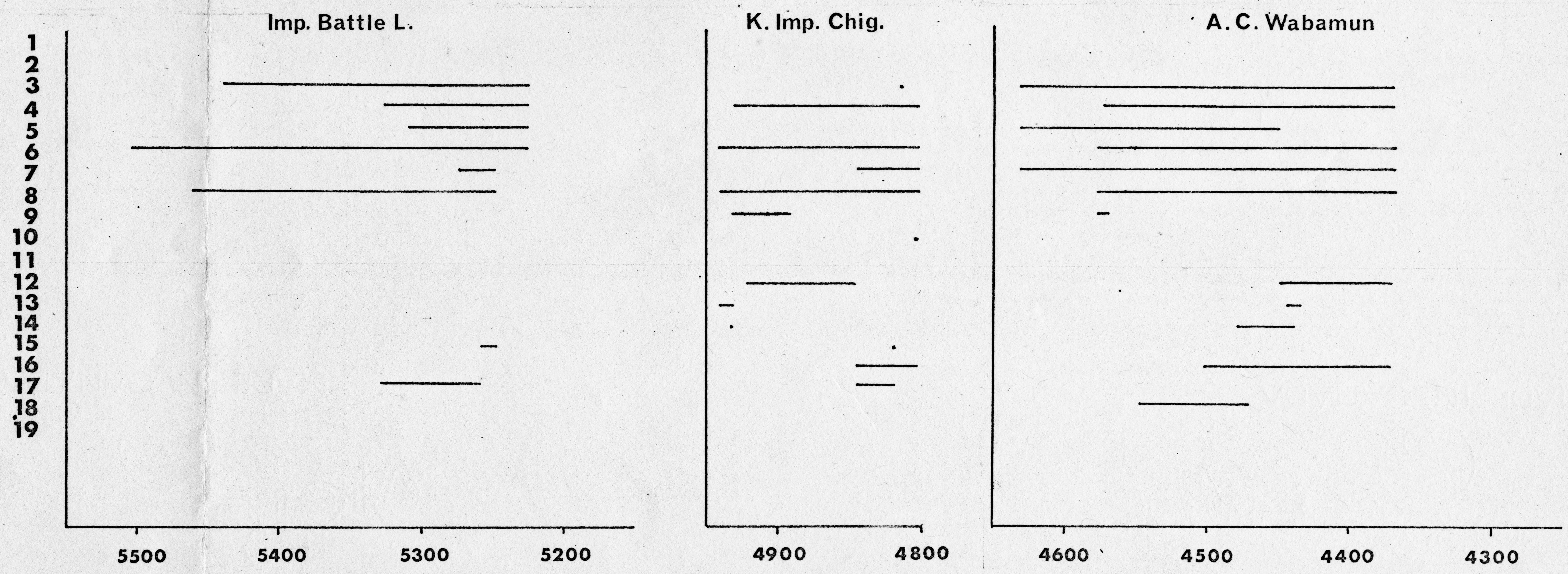
The base of the youngest unit, Unit III, is characterized by the first appearance of one or more of the following: *Rugubivesiculites rugosus* and *R.* cf. *R. reductus* and by *Rugubivesiculites* sp. A. The base

Text-figures 7a and 7b. Ranges of nineteen stratigraphically significant miospore species in six sections from the Lower Colorado Group and its equivalents in Central Alberta.

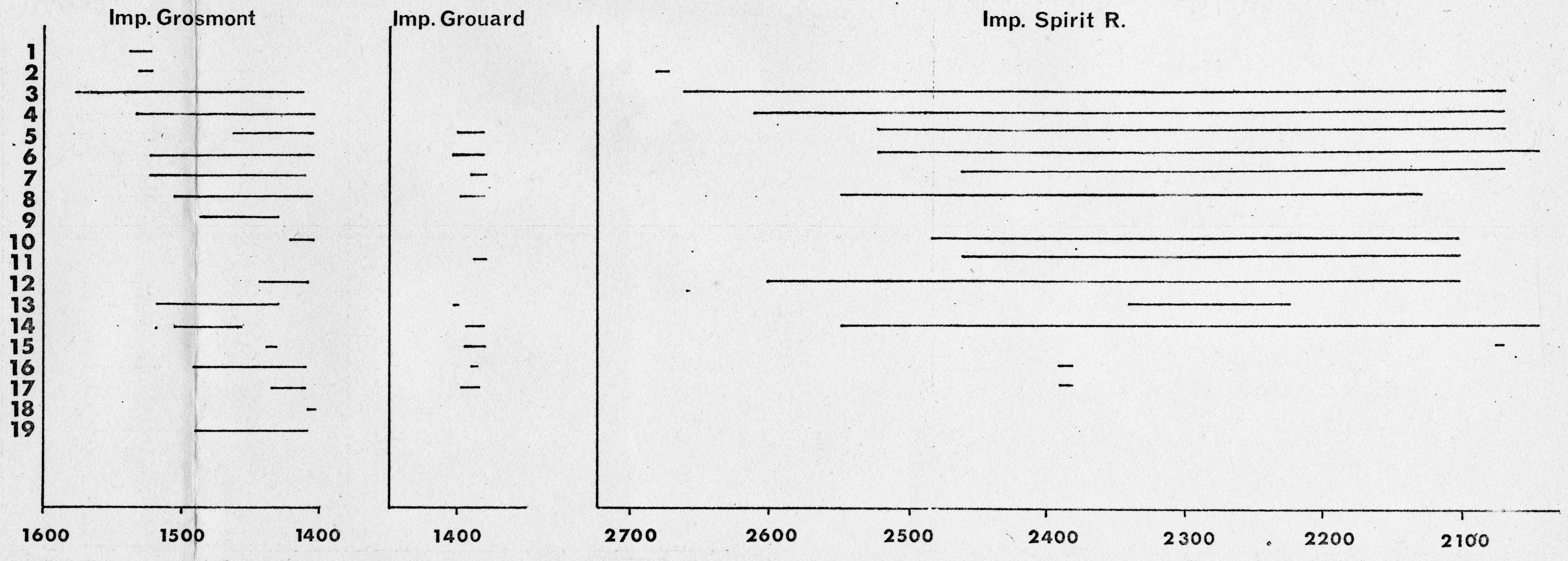
_Explanation of Symbols_:

1. _Rouseisporites_ _reticulatus_
2. _Rouseisporites_ _triangularis_
3. _Cirratriradites_ _teter_*
4. _Tigrisporites_ _scurrandus_*
5. _Reticulisporites_ _norrisii_*
6. _Camarozonosporites_ _insignis_*
7. _Reticulitricolpites_ _sagax_*
8. _Tricolpites_ _vulgaris_*
9. _Cicatricosisporites_ sp. A.
10. _Cingulatisporites_ sp. A.
11. _Cingulatisporites_ sp. B.
12. _Phyllocladidites_ sp. A.
13. _Clavatipollenites_ _minutus_
14. _Tricolpites_ _paraneus_
15. _Reticulitricolpites_ _georgensis_
16. _Rugubivesiculites_ _rugosus_*
17. _Rugubivesiculites_ cf. _R._ _reductus_*
18. _Rugubivesiculites_ sp. A.*
19. _Reticulitricolpites_ _crassus_

Species marked with an asterisk are key species.



Text-figure 7a



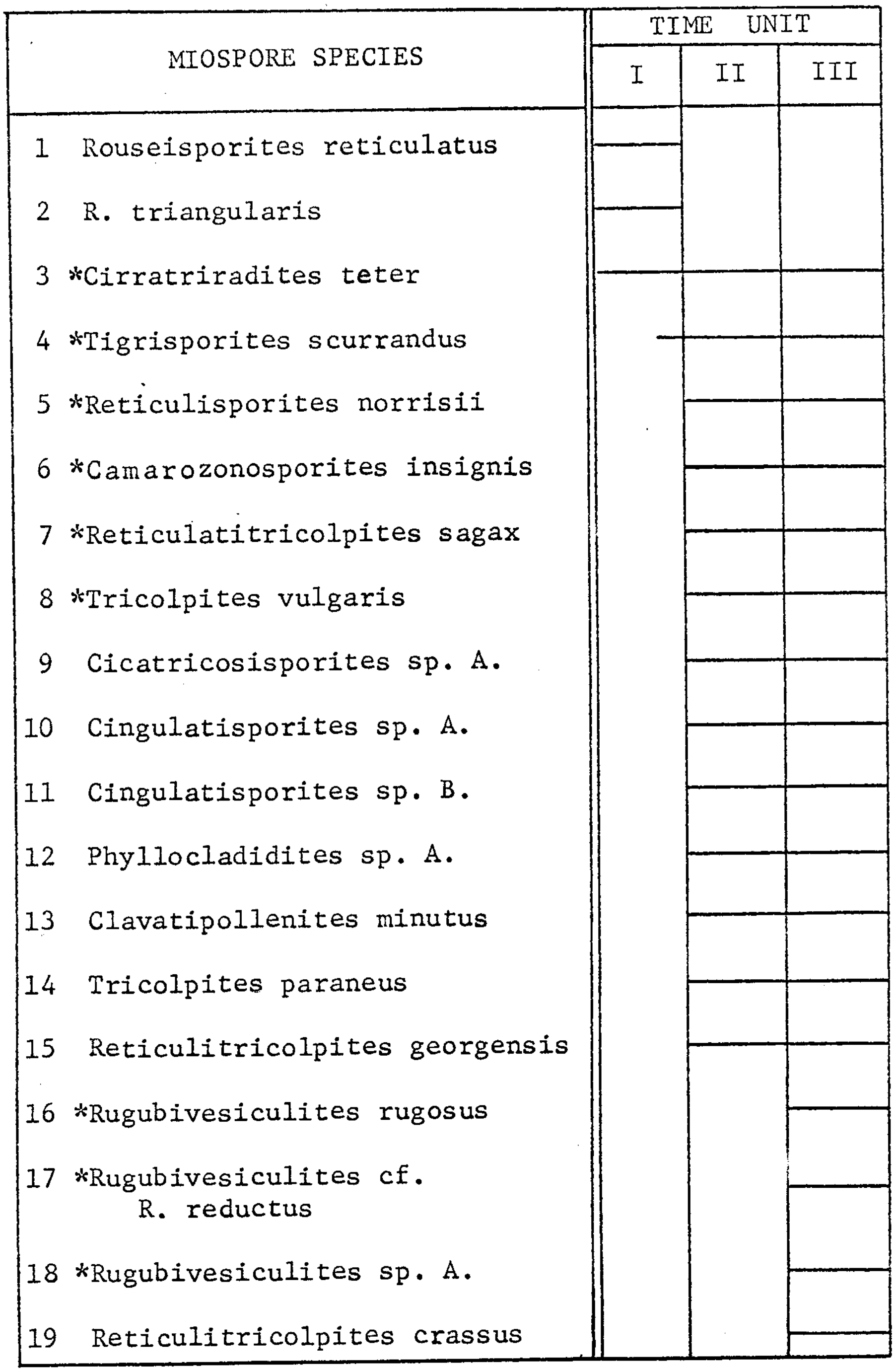
Text-figure 7b

of the next oldest unit, Unit II, is characterized by the first appearance of *Tricolpites vulgaris* and/or one or more of: *Camarozonosporites insignis*, *Reticulisporites norrisii* and *Reticulitricolpites sagax*. The oldest unit, Unit I, is less well defined and is characterized by the appearance of *Tigrisporites scurrandus* in its higher levels and *Cirratriradites teter* nearer the base. The three time units are outlined in Text-figure 8 with the ranges of the key species and other species whose local ranges are restricted to these units plotted in relation to the proposed subdivisions.

These time units are based on the appearance of groups of certain key species at approximately the same levels and in the same sequential relation to each other in the Lower Colorado Group deposits. The relatively constant order of first appearance and the wide geographical region over which the subdivision holds suggests that these time units may be considered as meaningful subdivisions not subject to the influence of local factors. Evidence from other investigations, partly summarized in the section on distribution given for each species in the taxonomic section, indicates that the time-stratigraphic value of some of the key species is not limited to the central Alberta region. Further discussion of this is given below.

### The Time-Stratigraphic Significance of the Key Species

Several of the key species used in subdividing time units in the Lower Colorado Group have been described only from the immediate region of investigation. These are: *Cirratriradites teter*, *Tigrisporites scurrandus*, *Reticulisporites norrissii*, *Reticulitricolpites*



Text-figure 8. Ranges of stratigraphically significant miospore species in the Lower Colorado Group arranged in order of first appearance with respect to Miospore Time Units I-III.

*sagax* and *Rugubivesiculites* sp. A. Four other species have been described elsewhere in uppermost Lower Cretaceous deposits from North America.

*Camarozonosporites insignis* has been found only in late Albian deposits of Maryland (Brenner, 1963), in the late Albian of western Canada (Norris, 1967; this study) and in younger deposits (Stanley, 1965) of Maestrichtian age. Singh (1964) and Pocock (1962, 1964) do not report the form from deposits of Middle Albian age. Thus, in North America at least, this species appears in the late Albian and ranges upwards.

Species of *Rugubivesiculites* Pierce also appear to be confined to Upper Albian and younger deposits. *Rugubivesiculites reductus* Pierce *sensu* Brenner, synonymous with the form *Rugubivesiculites* cf. *R. reductus* described in this investigation, appears only in the late Albian of Maryland (Brenner, 1963). This species occurs in Subzone B-2 of Zone II of Brenner (1963) and, significantly, as in Lower Colorado deposits, appears consistently above *Camarozonosporites insignis* (described as *Lycopodiacidites cerniidites auct. non* Ross, Brenner) in the Maryland deposits. Davis (1963) reports the first appearance of species of *Rugubivesiculites* in the lower part of the Newcastle Formation and in the lower Skull Creek Shale of Montana. As in the Lower Colorado Group in central Alberta and in Maryland (Brenner, 1963), the first appearance of species of *Rugubivesiculites* occurs after the appearance of the first angiosperm tricolpate grains. In Montana, significantly, the Newcastle and Skull Creek Shale occur stratigraphically below the base of the Mowry Shale. The base of the

Upper Cretaceous is usually taken near the middle of the Mowry Shale in the North American stratigraphic column in the northwestern United States (Cobban and Reeside, 1952). Further evidence comes from a palynological investigation by Pannella (1966) of the Dakota Group and Graneros Shale in the Denver Basin of Colorado. Here again species of *Rugubivesiculites*, probably *R. reductus* and *R. rugosus*, first appear above the level at which angiosperm pollen grains make their first appearance. *Rugubivesiculites* occurs in Zones III and IV of Pannella (1966), in the Fall River Formation, while the angiosperms first occur in the Glencairn Formation in his Zone I. Finally, Tschudy and Veach (1965) figure a specimen of *Rugubivesiculites* from near the base of the Thermopolis Shale in Montana (Tschudy and Veach, 1965; pl. 1, fig. 54), perhaps *R.* ? *reductus*, 34 feet above the base of this Formation.

The stratigraphic significance of *Rugubivesiculites rugosus*, *R. reductus* and similar forms in the correlation of Albian deposits in North America thus seems to be well established. The first appearance of one or more of these species may be taken as an indication of late Albian age for the enclosing deposits, and the presence of this genus indicates a late Albian or younger age.

The fourth key species, which has more than local stratigraphic significance is *Tricolpites vulgaris* (Pierce) comb. nov. This form has not been reported elsewhere in North America from deposits older than late Albian. The form was first described from the Cenomanian of Minnesota (Pierce, 1961) and has been reported in western Canada only from Late Albian deposits (Norris, 1967 and others). Pannella (1966) reports this form from his Zones I and II (as *Tricolpopollenites virgeus*) and similar and probably synonymous forms have been figured from the Thermopolis Shale by Tschudy and Veach (1965; pl. 1, fig. 78 and pl. 3, fig. 170). In the uppermost Lower Cretaceous of Maryland (Brenner, 1964), this species also occurs (as *Retitricolpites virgeus* (Brenner) *auct. non* Groot *et al.*) and its entrance level is below that of *Rugubivesiculites reductus* Pierce *sensu* Brenner.

From this evidence, it appears that the incoming of the species *Camarozonosporites insignis* and *Tricolpites vulgaris* precedes that of *Rugubivesicultíes rugosus* and *R. reductus* and related species in late Albian miospore assemblages available for comparison from North America. This evidence supports the use of these species as key forms in the time-stratigraphic subdivision of the Lower Colorado Group in central Alberta. It also suggests that the base of the first appearance of *Rugubivesiculites* is an important time marker in North America. Information on the stratigraphic distribution of these species outside of North America is not forthcoming. A recent paper by Muller (1968) reports the species *Rugubivesiculites reductus* from deposits of Senonian to Palaeocene age in Borneo, but not from older deposits in the region. To the writer's knowledge, this is the only report of this species outside of North America to date.

## The Time-Stratigraphic Significance of Associated Species

Norris (1967) in an investigation of the Lower Colorado Group in the Fort Augustus No. 1 well near Edmonton, east-central Alberta, compared the miospore assemblages of that Group with those of the underlying Mannville Group. A number of species were shown to be limited in this section to Mannville strata. Results of the present investigation confirm that some of the species have such a restricted range. Norris (1967, Table 4) showed the following species as not ranging above the Mannville Group-Lower Colorado Group contact: *Microreticulatisporites uniformis*, *Concavissimisporites punctatus*, *C. variverrucatus*, *Appendicisporites crimensis*, *A. erdtmanii*, *A. crickmayii*, *A. sellingii*, *Trilobosporites minor*, *T. apiverrucatus*, *Pilosisporites trichopapillosus*, *Rouseisporites triangularis*, *Januasporites spiniferus*, *Pteruchipollenites thomasii*, *Podocarpidites multesimus*, and *Leioaletes calvatus*.

Further evidence gained from the extension of palynological investigations to several other sections containing the boundary between the Mannville and Lower Colorado Groups has revealed that some of the species listed above do occur in strata of the Lower Colorado Group. Of the 15 species listed by Norris (1967), only the following are restricted to pre-Lower Colorado Group strata: *Microreticulatisporites uniformis*, *Appendicisporites erdtmanii*, *A. crickmayii*, *A. crimensis*, *Trilobosporites minor*, *Rouseisporites triangularis*, *Leioaletes calvatus* and *Pteruchipollenites thomasii*. In addition, the following 5 species were also found to be restricted to pre-Lower Colorado Group deposits: *Rouseisporites reticulatus*, *Cooksonites variabilis*, *Cingulatisporites reticingulus*, *Pilosisporites verus* and *Pityosporites constrictus*.

The last appearance of these miospore species provides a means of recognizing a clear stratigraphic break between the Mannville Group and Lower Colorado Group in eastern and south-central Alberta. Some of these species also occur in west-central Alberta in the lower level of the Peace River-Lower Shaftesbury succession and allow further understanding of the changes in the composition of the miospore assemblages in Alberta in the mid- and late Albian. Further discussion of these points is deferred to a later section dealing with miospore succession in the late Cretaceous of western Canada.

Other species, while occurring too irregularly to be of use in subdivision of the Lower Colorado Group, nevertheless have a certain stratigraphic significance. *Concavissimisporites punctatus* and *C. variverrucatus* have not been reported previously from the late Albian and do not range into the Cenomanian. *Taurocusporites segmentatus* and *Taurocusporites minor* likewise do not range into the Cenomanian and are probably making their last appearances in the Cretaceous of western Canada. Other species which are probably making final appearances are *Sestrosporites pseudoalveolatus*, *Densoisporites velatus*, *D.* cf. *D. balmei*, *Eucommiidites minor* and *Clavatipollentites hughesi*. *Parvisaccites amplus* and *Clavatipollenites minutus* have previously been reported only from the Upper Albian of Maryland (Brenner, 1963) and the Upper Albian of western Canada (Norris, 1967, this study). Norris (1967, p. 83) gives a more comprehensive list of miospore species reported either from Albian strata or making their final appearance in Albian strata.

The angiosperm tricolpate pollen species merit consideration also. While only a few of the forms are useful in defining time-stratigraphic units in the Lower Colorado Group, the other forms also have stratigraphic significance. On a worldwide basis, tricolpate angiosperm pollen grains have not been reported before the late middle or early Upper Albian (Groot and Groot, 1961, Brenner, 1963, 1967). Thus the appearance of tricolpate angiosperm grains in the upper Cadotte Member, Peace River Formation and in the basal deposits of the Lower Colorado Group marks a significant change in the miospore assemblages in western Canada, as well as in the parent floras contributing to the miospore assemblages. This latter point will be discussed further in a later section. It is thus significant that no angiosperm grains have been reported from deposits belonging to the Mannville Group or in deposits stratigraphically below the Peace River Formation. Besides the key species discussed earlier, *Tricolpites paraneus* (Norris) nov. comb., *T. prosimilis* (Norris) nov. comb., *Reticulitricolpites georgensis* (Brenner) nov. comb. and *Cornaceoipollenites parvulus* (Groot and Penny) nov. comb. all appear at some point above the Mannville-Lower Colorado Group boundary. Of stratigraphic interest also is the occurrence of several angiosperm grains of a structure previously found only in deposits of Cenomanian or younger age. Several grains of what appears to be a tricolpate grain (Tricolporate Forma A) were found in Unit III of the "Wabamun" and "Grosmont" sections. A more doubtful form, Periporate? Forma A., was noted in deposits referred to the Paddy Formation in the "Spirit River" section. Such forms according to Couper (1964) have not been reported previously from pre-Cenomanian strata on a worldwide basis. The occurrence of this type in two different sections, the preservation of the grain, which is similar to other forms in the samples, and the lack of any indication of contamination from younger deposits in any of the samples examined combines to support the belief of the author that the occurrence is not spurious. The presence of such a grain suggests that the Upper part of the Lower Colorado Group, while not basal Cenomanian is probably very late Albian.

## Miospore Zonation and Western Canadian Lower Cretaceous Stratigraphy

Relationships of Lithological Units and Time-Stratigraphic Units - The discussion up to this point has been concerned with the development of time-stratigraphic units without reference to established lithological boundaries, except with respect to the Mannville-Lower Colorado Group boundary. Text-figure 11 diagrams the relationship of the miospore Units I-III in relation to the various Formations concerned. For emphasis, and because of the significance of the base of the appearance of *Rugubivesiculites*, the base of Unit III is taken as a time datum line.

The base of Unit III occurs in the basal part of the Lower Shaftesbury Formation in west-central Alberta, the Cadotte Member-Joli Fou Formation boundary in the "Grouard" section, near the top of the Joli Fou in the "Grosmont" section and in the East-Fort Augustus Well (Norris, 1967), and near the top of the Viking Formation in the wells examined in south-central Alberta.

The base of Unit II is defined in the "Spirit River" section where the first appearances of key species of that Unit appear near the middle of the Cadotte Member. The Paddy Member in this section and a few tens of feet of the basal Lower Shaftesbury are also included in this Unit. The uppermost portion of the Cadotte Member in the "Grouard" section is considered as being in Unit II. In all the other wells examined, the Joli Fou and a varying portion of the Viking or Pelican Formations belong to Unit II.

The base of Unit I and the top of this Unit are defined only in the "Spirit River" section. The first appearance of the two key species of Unit I occurs near the base of the Harmon Member. In addition a few of the species, earlier listed as restricted to the pre-Lower Colorado strata also occur in Unit I in this section. Unit I is also defined in the Mannville strata examined from the "Grosmont" and "Battle Lake" sections in south-central Alberta. No angiosperm grains or any of the key species signalling the base of Unit II have been noted in the Mannville Group (uppermost Grand Rapids Formation). Furthermore, none of the species restricted to pre-Lower Colorado strata range into Unit II in the "Spirit River" section. Thus the three time-stratigraphic units are relatable to the lithological units and suggest that answers to certain stratigraphical problems may be provided by the sequence of miospore assemblages in western Canada.

Extent of Diachronism - From the change in the level of the base of Unit III in relation to the lithological boundaries, it is evident that the deposition of the Joli Fou and Viking Formations and the Pelican Formation in the central Alberta region began later than the deposition in south-central Alberta. The base of Unit III occurs near the top of the Viking Formation in south-central Alberta, but in deposits lithologically equivalent to the Joli Fou Formation in central Alberta and in Imperial Grouard No. 1 Well. The base of the Lower Shaftesbury Formation is equivalent in time to the top of the Viking Formation in the southeast and to the basal Joli Fou and uppermost Cadotte in the "Grouard" section. The upper half of the Cadotte and the Paddy Members in the "Spirit River" section are equivalent in time to the Joli Fou and Viking Formations in the southeast but are younger in time than deposits lithologically similar in the "Grouard" section. Thus the lithological correlations of Workman (1959) and Glaister (1959) are not correct in terms of time relationships. The scheme of Stelck (1958) is somewhat more equivalent to the time relationships suggested by palynological data but does not indicate the nature and extent of the diachronism within the various lithological units of the Peace River-Lower Shaftesbury succession and the Lower Colorado Group in central and south-central Alberta.

<u>Peace River Formation-Mannville Group Time Relationships</u> - Based on the evidence supplied by the miospore assemblages of these lithological units, it appears that the Harmon Member is at least partly equivalent in time to the upper Grand Rapids Formation in central and east-central Alberta. In the "Grouard" section where the Harmon and Cadotte Members come to underlie the Joli Fou Formation, and no strata lithologically equivalent to the Grand Rapids Formation are developed, the age relationship must necessarily change. Here only the lower part of the Harmon Member can be time equivalent to the upper Grand Rapids Formation. The top of the Cadotte Member is in Unit II and the basal Joli Fou Formation belongs to Unit III.

Mannville Group - Lower Colorado Group Hiatus - Mellon and Wall (1963) suggested that a regional disconformity existed between the Mannville Group and the overlying Lower Colorado Group. Norris (1967) concurred with this view, citing the sharp change in miospore assemblages across the Mannville-Joli Fou boundary in the "Fort Augustus" section. Further evidence for this sharp change has been presented here in sections approximately 100 miles west of the Fort Augustus well and 75 miles south of this site ("Grosmont" and "Battle Lake" sections respectively). Besides the appearance of the angiosperm species in the Joli Fou Formation, as well as the appearance of several other key species, thirteen other species are not recorded from post-Mannville deposits in central and southern Alberta. In addition, many species previously thought to make their last appearance in the top of the Mannville Group, while occurring in the Lower Colorado Group are much reduced in frequency and their distribution becomes sporadic. Most of these forms do not range into Unit III, or are last noted only in the basal part of this time stratigraphic unit. The evidence for a regional disconformity based on palynological data is thus considerable.

The extent of this hiatus is difficult to determine. The species Cirratriradites teter and Tigrisporites scurrandus are present along with Rouseisporites triangularis, Appendicisporites cf. A. crimensis and Pilosisporites verus in the Harmon and lower Cadotte Members in the "Spirit River" section and in the "Grosmont" section. The two key species, however, were not reported by Norris from the uppermost Grand Rapids Formation of the Edmonton region (Norris, 1967) or by Singh (1964) and are absent also from the upper

Grand Rapids Formation in the "Battle Lake" section. Possibly the hiatus is diachronous or perhaps was of different duration in different areas. The miospore assemblages do not provide a definitive answer to this question.

Relationship of Faunal Zones and Miospore Assemblage Time Units - A brief description of ammonite and foraminiferal zones in central and west-central Alberta has been presented earlier (see Part I, Chapter II). It is possible now to discuss the relationship of the faunal zones and the miospore assemblage time-stratigraphic units. Reference to Text-figure 11 shows that the base of Unit III roughly coincides with the development of the "Miliammina manitobensis" foraminiferal microfaunal zone. This microfauna has been dated as late Albian (Wall, 1967) and is developed both in the basal and middle portions of the Lower Shaftesbury Formation in the Peace River district and in the basal portion of the Upper Shale Unit in east-central Alberta. The Neogastroplites zone (Warren and Stelck, 1958; Jeletzky, 1968) occurs near the top of the Lower Shaftesbury Formation in the Peace River District, above the appearance of Rugubivesiculites Pierce, and is considered to be near the top of the Lower Cretaceous in western Canada (Jeletzky, 1968; Figure 1). Thus, miospore assemblage Unit III is late Albian in age, and the upper portion is probably very late Albian and is not basal Cenomanian, as has been suggested by Norris (1967).

Unit II of the miospore time-stratigraphic division occurs below the "Miliammina manitobense" microfauna and includes near the base, the microfauna of the Haplophragmoides gigas Cushman foraminiferal zone in east-central and south-central Alberta (Stelck, et al., 1956). Unit II occurs above the Gastroplites zone, which is considered to mark the top of the Middle Albian in England (Stelck, 1958). Thus the key species of Unit II represent the earliest forms of the Upper Albian miospore assemblage in Alberta. The diachronism of the lithological units revealed by Unit III, and the evidence for an extensive hiatus presented in this account and by other authors between the Mannville Group and the Lower Colorado Group, suggest that the basal Joli Fou Formation in south-central Alberta may be slightly younger than the strata of the Cadotte Member at the level of the base of Unit II. The boundary of Units I and II lies at or just above the Gastroplites zone in west-central Alberta and thus Unit I is possibly uppermost Middle Albian in age. This determination concurs with the views of Pocock (1962) and Singh (1964) who consider the uppermost Mannville deposits to be no younger than Middle Albian. In summary, the Lower Colorado Group is probably entirely Upper Albian in age as are the Lower Shaftesbury Formation, the Paddy Member and part of the Cadotte Member in west-central Alberta. The Harmon and the lower part of the Cadotte Members in the Peace River district are latest Middle Albian in age.

Significance of Miospore Assemblages in the late Albian of Western Canada - The miospore assemblages in the late Lower Cretaceous of the western Canada basin are particularly useful in understanding the time relationships of the lithological subdivisions in this region. They allow an estimate of the diachronism across lithological boundaries and provide a useful means of zonation and correlation where micro- or macrofaunal remains are scarce or absent. Their abundance and variation and small size make them excellently suited for correlation studies using cored sections. While the faunal remains provide a broad basis for understanding broad time relationships, only the miospore assemblages are abundant and widespread enough to provide such information over the whole of the basin. Their potential usefulness, suggested in earlier discussions in this account, has been fully realized.

## COMPARISON OF LOWER COLORADO GROUP MIOSPORE ASSEMBLAGES WITH OTHER ASSEMBLAGES

Miospore assemblages from the Lower Colorado Group and lithological equivalents in west-central Alberta contain many species found in common with almost all Lower Cretaceous miospore assemblages described from Europe, North and South America and Australia. Several of these assemblages, however, deserve some comment, although an exhaustive survey of specific similarities will not be attempted here.

Miospore assemblages from the Arundel and Patapsco Formations in Maryland described by Brenner (1963) show many similarities. Over 40 species described in this investigation, along with others noted by Norris (1967) from the Edmonton region, have also been described from the Maryland deposits. The close similarity in the sequence of first appearances of angiosperm grains and other species of Unit II and Unit III in the Lower Colorado Group and Zone II of Brenner (1963) in Maryland has been noted previously. As with the Maryland assemblage, approximately 8% of the species described from the Lower Colorado Group are tricolpate angiosperm grains.

Dettmann (1963) has described a large and varied assemblage of miospores from southeastern Australia, dividing the species into three assemblages, the "Stylosus", "Speciosus" and "Paradoxa" assemblages. The first of these, considered by Dettmann (1963) to be of Neocomian-Aptian age contains only a few long ranging forms in common with the Lower Colorado assemblages. The "Speciosus" assemblage contains many forms confined in Alberta to Upper Mannville or strata of the Peace River Formation assigned to Unit I. The "Paradoxa" assemblage has elements in common with both Mannville and Lower Colorado Group assemblages but contains no angiosperms. Dettmann (1963) suggests these latter two assemblages are Aptian-Albian and Albian in age respectively. Based on observations discussed earlier concerning the age of Unit I in Alberta, it is possible that Dettmann's "Paradoxa" assemblage is no younger than late Middle Albian. Dettmann (1963, p. 115) reports the occurrence of an angiosperm tricolpate grain in the uppermost portion of one section containing that assemblage, but no further mention of angiosperm pollen types is made.

Pierce (1961) describes a Cenomanian assemblage from Minnesota. Although comparison is difficult on a specific level because of the nomenclatural approach, brief description and often inadequate illustrations, there appear to be about 20 species in common with assemblages of Unit II and III of the Lower Colorado assemblages. Pierce's miospore assemblage also contains many Cenomanian elements which are not found in the Lower Colorado assemblages.

A recently described miospore assemblage of Barremian-Aptian age from Patagonia (Archangelsky and Gammero, 1967) contains 20 species in common with Lower Colorado assemblages, including some confined to

Unit I or upper Mannville strata.

In summary, miospore assemblages from the Lower Colorado and equivalents in west-central and central parts of Alberta show affinity with Lower Cretaceous miospore assemblages from many parts of the world but particularly with those assemblages described from the late Lower Cretaceous of Maryland. The Lower Colorado assemblages contain many species which are useful in correlation on a local and regional as well as long distance basis.

## MICROPLANKTON ZONATION OF THE LOWER COLORADO GROUP

### General Considerations

Development of a time-stratigraphic subdivision of the Lower Colorado Group based on microplankton assemblages is more difficult than with miospore assemblages for two reasons. Firstly, there are a number of previous investigations of relevant miospore assemblages on which to base the development of a miospore zonation in the Lower Colorado Group. In the case of microplankton assemblages, however, few papers relating to Cretaceous microplankton assemblages in North America have been published. Pocock (1962) and Singh (1964) provide the only such data from western Canada. Drugg (1967) and Stanley (1965) deal with uppermost Cretaceous and Palaeocene assemblages. A number of papers are available for reference on Australian, British and European assemblages, but the data are scattered. Several investigations of Albian and younger strata are now in progress in western Canada, but results are not yet available for comparison. Secondly, many of the species considered stratigraphically significant in the Lower Colorado assemblages are newly described or have been described only from the western Canada region. Only their local ranges are available for stratigraphic work.

The procedure in the valuation of microplankton species for purposes of time-stratigraphic subdivision is essentially that used for the miospore species. More dependence has had to be placed on the local ranges for the reasons discussed above. The procedure of correlation by first appearance of key groups of species is followed as in the miospore zonation.

### Subdivision Using Microplankton Assemblages

A total of 122 microplankton species is described in the taxonomic section (Part Two, Chapter III). Application of the criteria for choosing stratigraphically significant species to this assemblage suggests that 15 of the species are reliable indicators of time-stratigraphic subdivisions. From the discussion of the stratigraphic significance of the miospores and their relations to previously established faunal zones, it has been concluded that the basal portions of the Peace River Formation represent the oldest strata investigated. It is in this section, near the base of the Harmon Member, that the first group of stratigraphically significant species make its first appearance. This group consists of: Gonyaulacysta globosa sp. nov., Hystrichodinium sp. A., Oligosphaeridium complex, Hystrichosphaera ramosa and Chlamydophorella nyei.

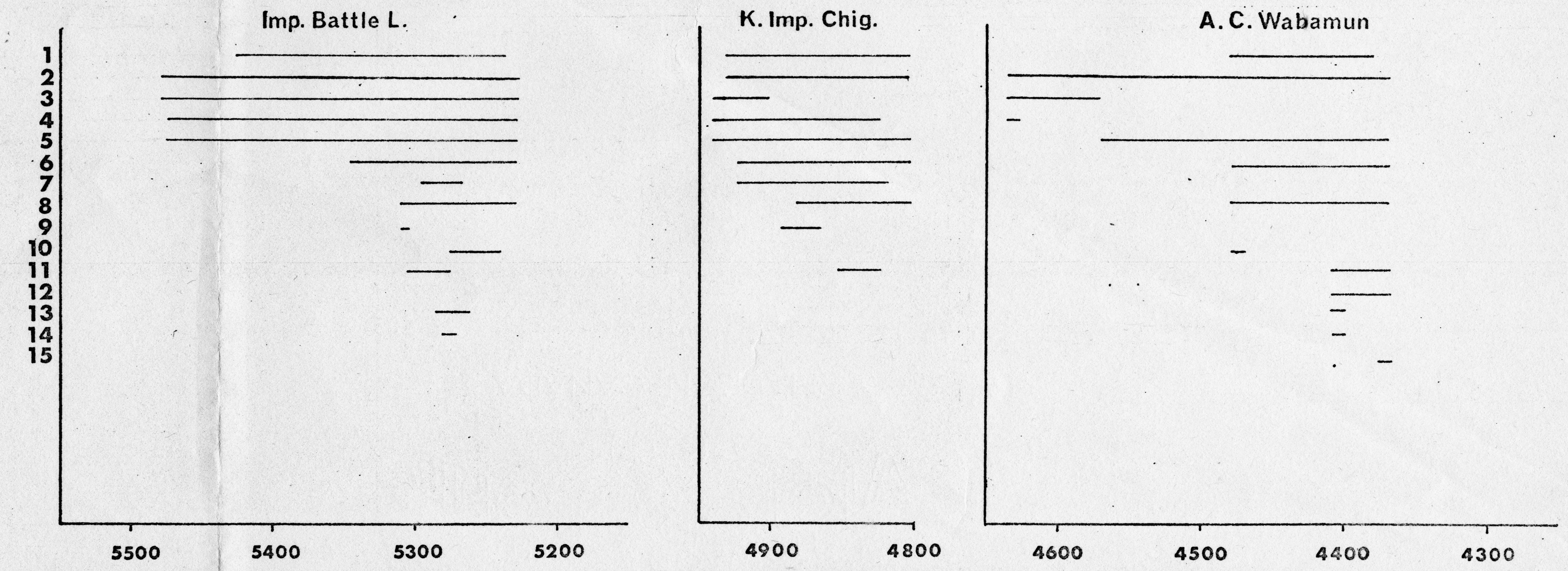
Later in this section and in the basal portions of the Lower Colorado Group in other sections examined, the species Oligosphaeridium totum sp. nov. and Tenua? sp. B. first appear, accompanied in some sections by associated species including Palaeostomocystis fragilis and *Hexagonifera*? sp. A. At a still higher level, a third group appears for the first time, consisting of *Deflandrea dignitosa* sp. nov., *Spinidinium* sp. B., *Hystrichosphaeridium* sp. B. and Proximate Cyst Forma A. A final group of four species makes its first appearance in higher levels of the three complete sections examined in this investigation ("Spirit River", "Wabamun" and "Battle Lake") from the basal Colorado Group to the Fish Scale Horizon. These are: *Veryhachium iniquum* sp. nov., *Oligosphaeridium* sp. A., *Oligosphaeridium* sp. B., and *Hystrichosphaeridium* sp. A. The ranges of these species are shown for each section examined in Text-figures 9a and 9b.

The sequence of first appearances of the microplankton species listed above allows subdivision of the Lower Colorado Group and its equivalents into three time-stratigraphic units, labelled A to C to distinguish them from the miospore Units I-III. The base of Unit A is defined by the first appearance of *Gonyaulacysta globosa* sp. nov. and one or more of the other four species of that group. Unit B is marked at the base by the first appearance of *Oligosphaeridium totum* and *Tenua*? sp. B. Unit C may be subdivided into two sub units, designated Unit C-1 and C-2. The base of Unit C-1 (Unit C) is distinguished by the first appearances of one or more of *Deflandrea dignitosa* and the other three species mentioned above. Unit C-2 is marked by the first appearances of *Veryhachium iniquum* sp. nov. and one or more of the other species, *Oligosphaeridium* sp. A., *O.* sp. B. and *Hystrichosphaeridium* sp. A. The stratigraphic ranges of these key forms arranged in relation to the time-stratigraphic units defined above are given in Text-figure 10.

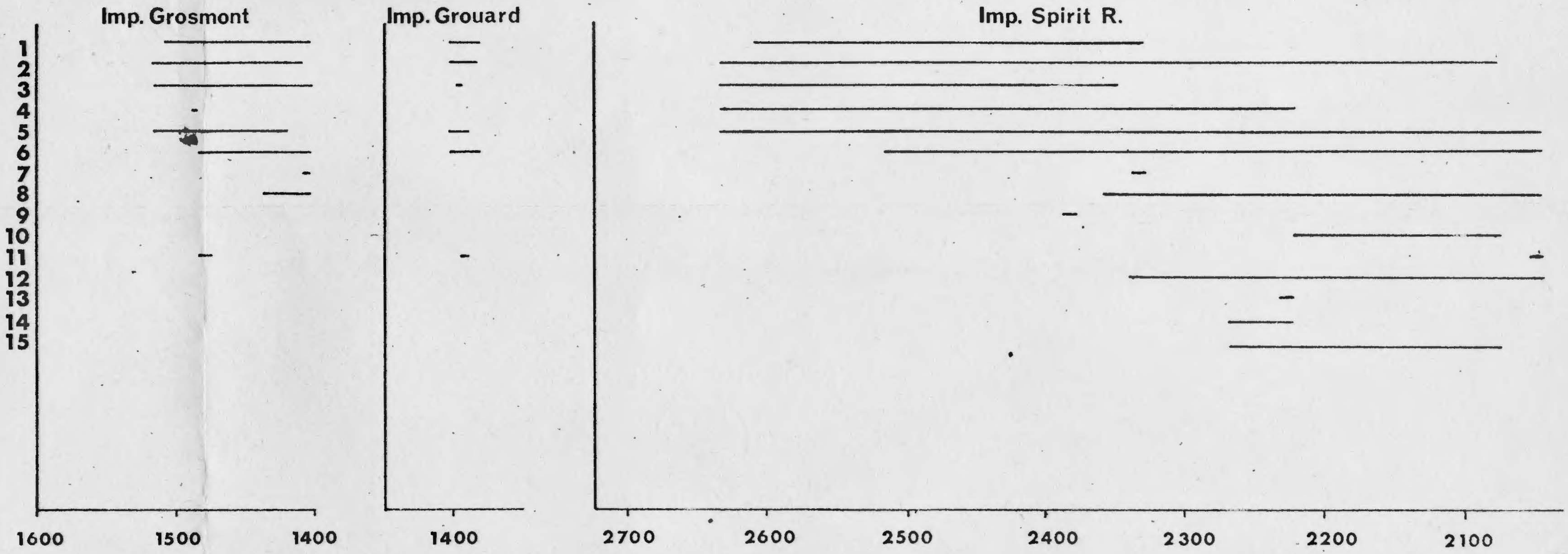
Text-figures 9a and 9b. Ranges of fifteen stratigraphically significant microplankton species in six sections from the Lower Colorado Group and its equivalents in Central Alberta.

*Explanation of Symbols*:

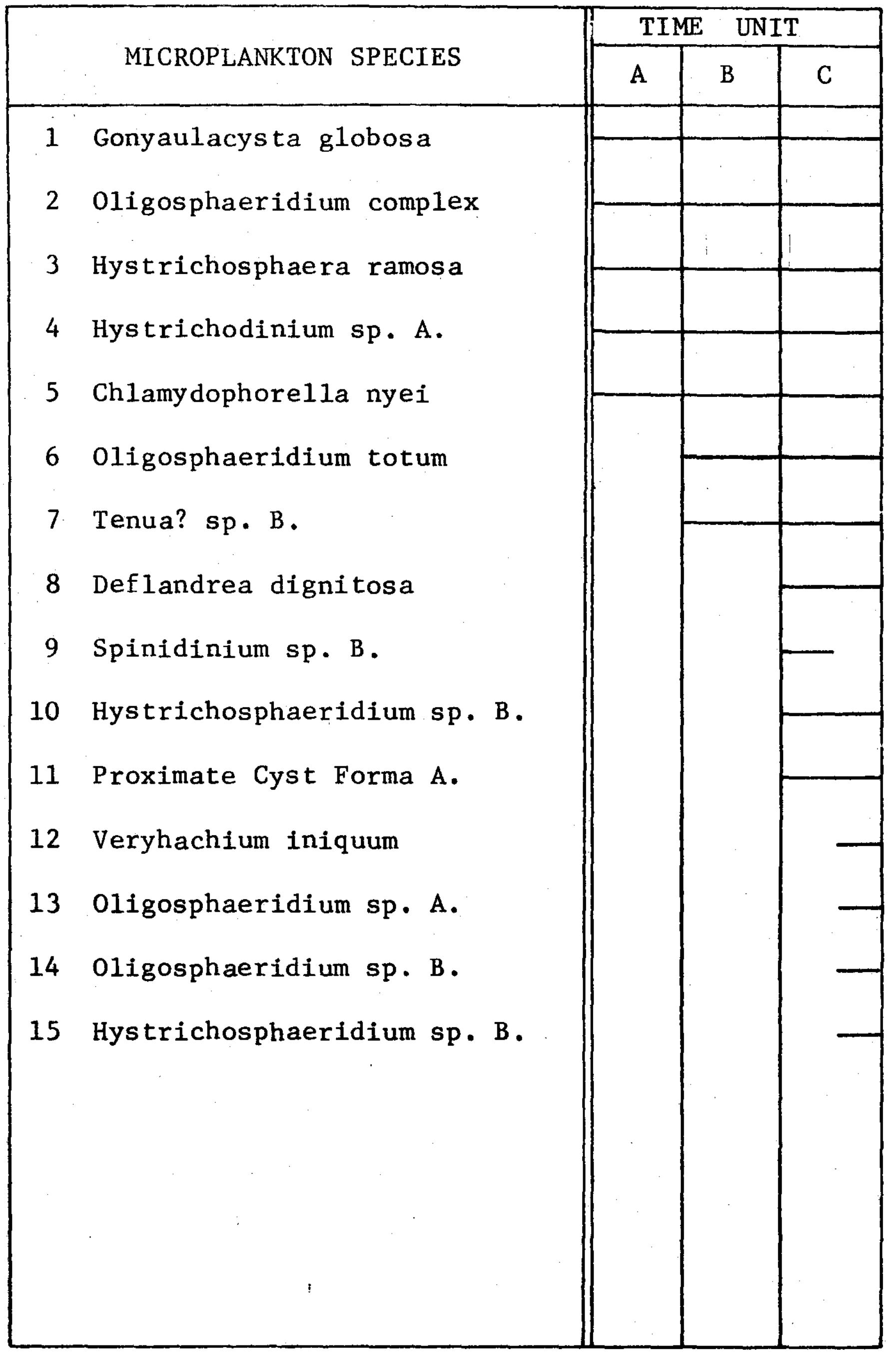
1. *Gonyaulacysta globosa*
2. *Oligosphaeridium complex*
3. *Hystrichosphaera ramosa*
4. *Hystrichodinium* sp. A.
5. *Chlamydophorella nyei*
6. *Oligosphaeridium totum*
7. *Tenua?* sp. B.
8. *Deflandrea dignitosa*
9. *Spinidinium* sp. B.
10. *Hystrichosphaeridium* sp. B.
11. Proximate Cyst Forma A.
12. *Veryhachium iniquum*
13. *Oligosphaeridium* sp. A.
14. *Oligosphaeridium* sp. B.
15. *Hystrichosphaeridium* sp. A.



Text-figure 9a



Text-figure 9b



**Text-figure 10.** Ranges of stratigraphically significant microplankton species in the Lower Colorado Group, arranged in order of first appearance with respect to Microplankton Time Units A-C.

## Time-Stratigraphic Significance of Key Microplankton Species

In contrast to the miospore assemblage, key species of the microplankton assemblages nearly all have only a local range available for stratigraphic work. Four species used as key forms in this investigation have been described or reported on elsewhere. Oligosphaeridium complex and Hystrichosphaera ramosa have total ranges from the Barremian to the Eocene. Chlamydophorella nyei ranges from the Aptian to Turonian. Veryhachium iniquum sp. nov. is very similar and perhaps is synonymous with a form reported from the Upper Albian in Manitoba and Saskatchewan by R. L. Cox of the Geological Survey of Canada, Calgary (pers. comm.). Except for the latter form, the other species are long-ranging, although they appear to be useful as stratigraphic markers within the Lower Colorado Group and equivalents in Alberta. The significance on other than a local level of the species Gonyaulacysta globosa sp. nov., Deflandrea dignitosa sp. nov. and Oligosphaeridium totum sp. nov. has yet to be demonstrated.

## Time-Stratigraphic Significance of Associated Species

Most of the species of the Lower Colorado microplankton assemblages previously described from other localities are long-ranging and have little stratigraphic value in the context of the present investigation. Six species however, deserve special comment because they do have ranges significant for this study.

Palaeostomocystis fragilis has been reported previously only from Cenomanian or younger strata. Hystrichosphaeridium stellatum has not previously been reported from Albian strata and thus makes its earliest appearance in the Upper Albian Lower Colorado Group. A group of species occurring in the Lower Colorado Group and equivalent deposits makes its last reported appearance. The species are: *Oligosphaeridium anthophorum*, *O. irregulare*, *Aptea* cf. *A. polymorpha* and *Cometodinium multispinosum* (Singh) comb. nov.

There are also species in the Lower Colorado microplankton assemblage which, although they occur too irregularly to be useful as reliable key species, do have stratigraphic significance. These are species which have not been reported from older deposits in the western Canada basin and whose ranges are only known from this region. They are: *Baltisphaeridium rallum*, *B. planispinum*, *B. turbinatum*, *Microdinium? cristatum*, *Canningia crassa*, *Tenua longispina*, *Gonyaulacysta obesa*, *G. auctifica*, *G. villosa*, *G. fragosa*, *Oligosphaeridium minor*, *Hystrichosphaeridium cylindratum*, *Coronifera admixta*, *Toolongia alata*, *Spinidinium vestitum* and *Pseudoceratium expolitum*, all new species. In addition, there are many species not listed here and given no formal species name which are not found in older deposits in western Canada. There is thus a considerable influx of new microplankton forms in the late Albian of the western Canada Basin. Distribution of these species and other forms excepting key forms are given in Text-figure 12 for selected regions and Formations in the late Lower Cretaceous of Central Alberta.

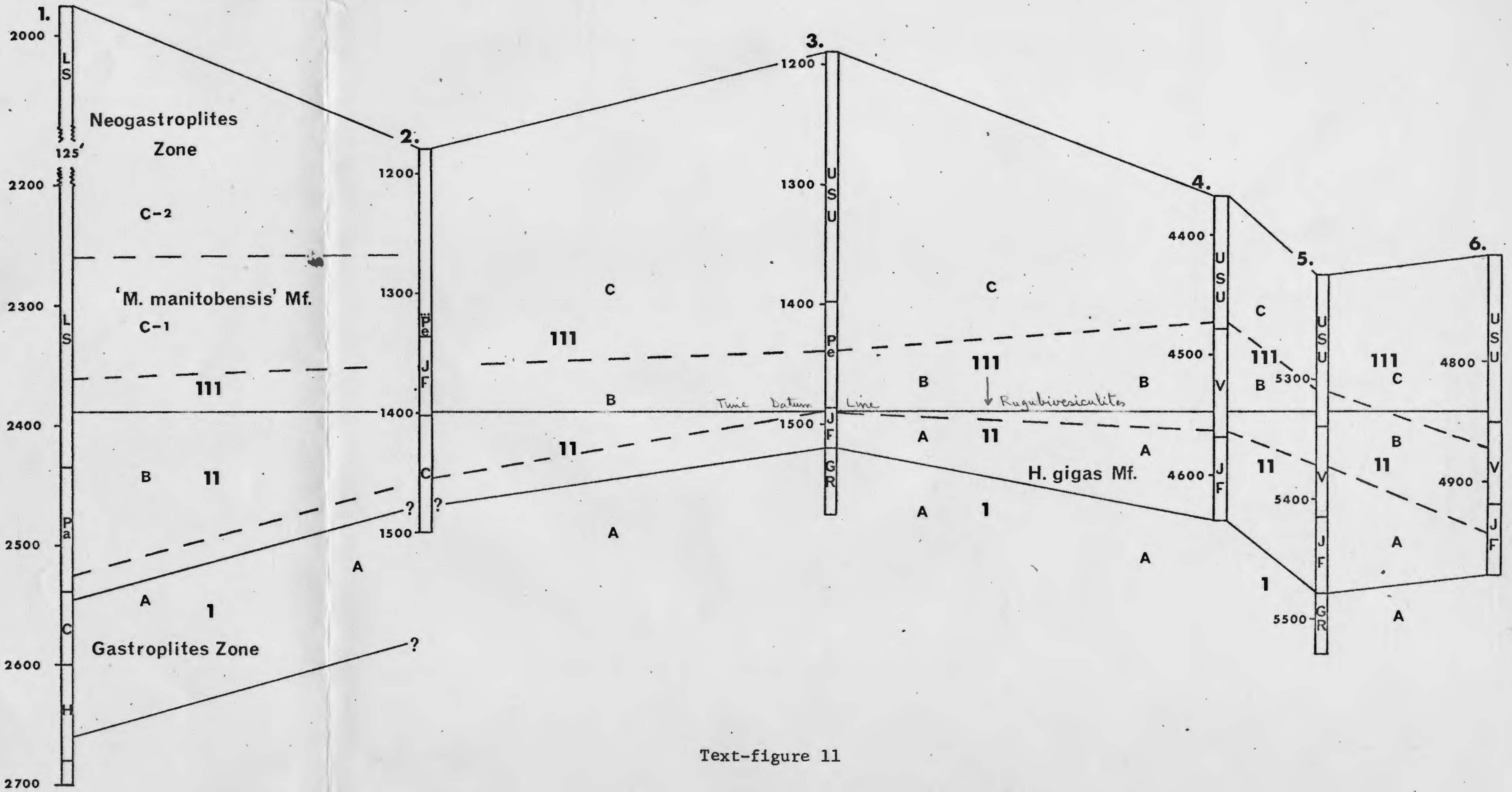
## Microplankton Zonation and Western Canadian Stratigraphy

*Microplankton Time-Stratigraphic Units and Miospore Units* - Text-figure 11 summarizes the relationships of microplankton time Units A-C and shows their relationship to the miospore time Units I-III in the six sections examined. The sequence of time units of the microplankton and the miospore assemblages appears in this order: A and I, II, B, III, C-1, Text-figure 11. Diagram showing relationship of miospore and microplankton time units to lithological units and to each other in the six well cores. Dashed lines and letters indicate the base and extent of microplankton units; full lines and numbers indicate base and extent of miospore time units.

Explanation of Other Symbols:

1. Imperial Spirit River No. 1.
2. Imperial Grouard No. 1.
3. Imperial Grosmont No. 1.
4. Anglo-Canadian Wabamun No. 1.
5. Imperial Battle Lake No. 1.
6. Kissinger Imperial Chigwell No. 1.

| | |
|---|---|
| H | Harmon Member |
| C | Cadotte Member |
| Pa | Paddy Member |
| LS | Lower Shaftesbury Formation |
| JF | Joli Fou Formation |
| Pe | Pelican Formation |
| V | Viking Formation |
| USU | Upper Shale Unit |



Text-figure 11

Text-figure 12. Occurrence of microplankton species important to western Canadian late Lower Cretaceous stratigraphy excluding key microplankton species in the Lower Colorado Group and Peace River-Lower Shaftesbury succession. Presence in Formation marked by an X. Species marked with an asterisk are described as new.

| LOCALITY | EAST-CENTRAL ALBERTA | | | SOUTH-CENTRAL ALBERTA | | | | WEST-CENTRAL ALBERTA & WESTERN GREAT SLAVE LAKE REGION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LITH. UNIT / SPECIES | McMURRAY FORMATION | CLEARWATER FORMATION | GRAND RAPIDS FORMATION | GRAND RAPIDS FORMATION | JOLI FOU FM. | VIKING FM. | UPPER SHALE UNIT | HARMON MEM. | CADOTTE MEM. | PADDY MEM. | LOWER SHAFT. FM. |
| Palaeoperidinium cretaceum | X | X | X | X | X | X | X | X | X | X | X |
| Odontochitina operculata | X | X | X | X | X | X | X | X | X | X | X |
| Cometodinium multispinosum | | X | X | | X | X | X | X | X | X | X |
| Gonyaulacysta granulata | | X | X | | X | | | | | | |
| Oligosphaeridium irregulare | | X | X | | X | X | | | | | |
| Microdinium opacum* | | | X | | X | X | X | X | X | X | X |
| Oligosphaeridium anthophorum | | | | | X | X | X | X | X | X | X |
| Fromea amphora | | | | | | X | X | X | X | | |
| Tenua longispina* | | | | | X | X | X | X | | | X |
| Dingodinium cerviculum | | | | | X | X | X | X | | | X |
| Cf. Leiofusa sp. B. | | | | | X | | | | X | | |
| Toolongia alata* | | | | | X | X | | | X | | |
| Microdinium? cristatum* | | | | | X | X | X | X | X | | X |
| Canningia crassa* | | | | | X | X | X | X | X | | X |
| Gonyaulacysta obesa* | | | | | X | X | X | | | | X |
| G. auctifica* | | | | | X | X | X | | X | | X |
| G. villosa* | | | | | X | X | X | | X | | X |
| G. fragosa* | | | | | X | X | | | | | |
| Oligosphaeridium minor | | | | | X | X | X | | X | X | X |
| Hystrichosphaeridium cylindratum* | | | | | X | X | X | | X | | X |
| Coronifera admixta* | | | | | X | X | X | | X | | X |
| Litosphaeridium? sp. A. | | | | | X | X | X | | X | | X |
| Spinidinium vestitum* | | | | | X | X | X | | X | | X |
| Pseudoceratium expolitum* | | | | | X | X | X | X | X | | X |
| Aptea cf. A. polymorpha | | | | | X | X | X | X | | | X |
| Palaeostomocystis fragilis | | | | | | X | X | | | | X |

Text-figure 12

C-2 in all but the section in Kissinger Imperial Chigwell No. 1 well. Here Unit C precedes Unit III. It should be noted that microfloras are sparse in this 30' of section, several samples showing very poor microfloras. Thus the writer thinks the anomaly is not due to a change in the relation of time units in this well, but to the absence of varied and well-preserved assemblages. Reference to this diagram also shows that the tops of Units III and C-2 cannot be determined without study of younger strata in these sections. It is also to be noted that the base of microplankton Unit A in south-central Alberta coincides with the base of the Lower Colorado Group. Evidence from the miospore assemblages indicates, however, that this is due to a hiatus and does not represent the same time as the base of Unit A in west-central Alberta.

### Microplankton Units and Lithological Boundaries

In west-central Alberta (see Text-figure 9) Unit A includes most of the Harmon and Cadotte Members and the basal portion of the Paddy Member in the "Spirit River" section. Elsewhere Unit A includes the Joli Fou and a varying part of the Viking or Pelican Formations. Unit B includes the upper part of the Paddy Member and the basal Lower Shaftesbury Formation in the "Spirit River" section. Eastwards, all of the uppermost Cadotte Member and the basal Joli Fou Formation of the "Grouard" section are included within this unit. East and southeast, Unit B includes perhaps the upper part of the Joli Fou Formation in the "Grosmont" section and only a portion of the Viking Formation or Pelican Formation. The base of Unit C occurs in west-central Alberta above the base of the Lower Shaftesbury Formation and about 30' above the base of miospore Unit III. Unit C is not present in the part of the "Grouard" section available for study, includes the upper part of the Pelican Formation in the "Grosmont" section, and appears near or at the top of the Viking Formation in south-central Alberta. It is interesting to note that the microplankton time Unit C occurs as expected in the "Chigwell" section while the miospore Unit III occurs higher than would be expected from other sections close to that one. An explanation of this point has been offered in the preceding section in connection with relations of miospore and microplankton units.

Significance of Microplankton Assemblages of late Albian Age in Western Canada - From the discussion presented above, it is apparent that the microplankton assemblages have stratigraphic significance for western Canadian stratigraphy. The consistent relationship of miospore and microplankton time-stratigraphic units indicates the value of the microplankton assemblages in subdivision of the Lower Colorado Group and its lithological equivalents. It also indicates that the zonation scheme may have validity in the absence of confirmatory data from miospore assemblages or faunal zones. The paucity of data on older microplankton assemblages, and on North American Cretaceous microplankton assemblages in general, does not allow their use in determining the extent of diachronism or in understanding regional disconformities as is the case with the miospore assemblage. However the great influx of species in the late Middle and early Upper Albian in Alberta indicates an extensive change in microplankton assemblages occurred. The application of this knowledge outside the immediate region of investigation should prove useful in stratigraphic subdivision of deposits in other regions where microplankton assemblages are abundant. Finally, consideration of the known total ranges of the species previously described from other assemblages indicates that the assemblage could be used without supporting data from other fossil groups to date the deposits in central Alberta. Analysis of the ranges of the 32 species previously described from other assemblages shows that the age of the Lower Colorado Group and its equivalents in west-central Alberta is likely no older than early or mid-Albian and no younger than late Albian. This determination is in accord with the evidence from miospore assemblages and faunal zones in Alberta.

## Comparison of Microplankton Assemblages with Other Assemblages

Of the 122 microplankton species described in the Lower Colorado assemblage, only 32 species (approximately 26%) have been described previously from other localities. Twenty-nine of these species have been described from assemblages other than those reported from western Canada. Most of these species are also recorded in assemblages of Hautervian to Turonian age from Germany (Alberti, 1961) and Senonian to Turonian age from Australia (Deflandre and Cookson, 1955; Cookson and Eisenack, 1958 and later; and other papers). A few species in common with the assemblage from the Speeton Clay of Hauterivian-Barremian age (Neale and Sarjeant, 1962; Sarjeant, 1966) of England also occur.

A small number of species recorded from Lower Colorado strata has been previously described only from Eocene deposits or from Upper Cretaceous strata. Specimens of these forms are rare in the Lower Colorado Group but indicate that ranges of many species previously thought to be more restricted are more extended. Sarjeant (1967) points out that this is to be expected considering the many uninvestigated deposits or poorly dated strata used in earlier studies of microplankton assemblages.

## RECURRENT SPECIES GROUP ANALYSIS

### THE VALUE OF SPECIES OCCURRENCE DATA

Data on microplankton species occurrence in samples from the Lower Colorado Group, summarized in Text-figures 4a to 4e (Part One, Chapter IV), represents a considerable investment in time and a considerable refinement in expression of a great amount of information. Yet, except for use in stratigraphic investigations, these data are virtually ignored in most palynological accounts.

Approximately 75% of the microplankton species described in this account are fossilized remains of dinoflagellate cysts, the other 25% being acritarch forms. These remains represent a dinoflagellate-acritarch assemblage living during Upper Albian time in sea arms in interior Alberta. Although the assemblage has been filtered through many preservational and sedimentological processes, it remains the only record of those assemblages available for study. It must be remembered that these organisms once existed in marine communities which developed and changed in time and space. It is thus reasonable to assume that the occurrence data, viewed on a broad basis, are not fortuitous, but reflect at least an estimation of the differences and changes in this Upper Albian assemblage. By extension of this argument, it seems reasonable to believe that there may be discernable patterns in the occurrence of the microplankton species. Certain intuitive observations made during the scanning of slides and compilation of the occurrence data further support this hypothesis. But evidence of a quantitative and qualitative nature is needed to truly investigate the validity of such a possibility.

The question of recurrent species groups of microplankton may be resolved into several steps. If there is a basis on the intuitive level for supposing that such groups exist, is there a method, independent of the observer, which will allow recognition of these patterns? if there are patterns, what sort are they and how are they related to other factors observed in this palynolgical investigation? Finally, given the existence of recurrent species groups, to what extent can they be used in the understanding of fossil microplankton assemblages and in the development of stratigraphic palynology? The following section will be concerned with the first question, the elucidation of a method for recognition of recurrent species group patterns in fossil microplankton assemblages.

## THE RECOGNITION OF RECURRENT GROUPS

### A Method for Defining Significantly Associated Species Pairs

Consider, for example, the case of two species, A and B. In a given number of samples, N, species A will occur x times and species B, x' times. The question may be posed: given that the occurrence of species A is independent of species B, is there a method to determine whether species A and B occur together in a significant association, that is, more than chance alone would be expected to produce? It is possible to express the occurences of the two species in N samples as a probability. Thus the probability that A will occur in a given sample is $p(A) = x/N$ and that B will occur in a given sample is $p(B) = x'/N$. The probability that both A and B will occur in a given sample is given by the expression $p(A \text{ and } B) = (x/N).(x'/N)$, according to elementary probability theory (Mills, 1955). The expected number of joint occurrences, X, can be found by the expression $(N).(x.x'/N^2)$ or $(x.x'/N)$. The observed number of joint occurrences, X, may be determined from occurrence data for the species.

On a statistical level, a Null Hypothesis may now be formulated. Given an expected number of joint occurrences of two species in N samples, calculated from the occurrence data, and the actual number of joint occurrences, is the difference between the two due to chance alone or is it significant at a chosen probability level and explainable only by factors other than chance? The Null Hypothesis thus stated is: there is no significant difference between the observed and expected number of joint occurrences of species A and B at the significant probability level chosen. The testing of this Null Hypothesis requires an independent, non-parametric statistical test.

## Choice of Test

In modern studies of species group association, many workers have used the Chi-square ($X^2$) test (Cole, 1949; and others). Fager (1957) introduces a refinement of this procedure, which eliminates some of the contradictions of earlier methods. $X^2$, however, is not suitable for the data discussed here. The $X^2$ test requires a relatively large sample number and a minimum expected theoretical value in each of the cells making up the contingency table.

A second non-parametric test which might be applied here is the Binomial Test. Such a test does not depend on continuous distribution of data and can be applied to discrete data such as the occurrence or non-occurrence of a species in a palynological sample. While the number of variates available influences the results of the significance tests to some degree, a low size of sample does not prohibit the use of the test as with $X^2$. Hence this method of testing significance of the departure of the observed number of joint occurrences from the expected number for species pairs in a sample of size N is used in this case.

Given a theoretical and observed value for the joint occurrence of two species in N palynolgical samples, the probability, p', that the given observed occurrence would occur is calculated by using a standard Binomial expression:

$$p' = \frac{N!}{(N-X)!(X)!} \cdot p(X)^{N-X} \cdot p(1-X)^{X}$$

In the case in point, however, it is also desirable to calculate not only the probability of obtaining exactly X number of joint occurrences, but also to calculate the remaining probabilities of values even more extreme (Siegal, 1956), that is for $X \pm 1...2...3...n$. To do this all the possible values of p' are summed and we have:

$$p'' = \sum_{X=0}^{n} \frac{N!}{(N-n)!(n)!} \cdot p(n)^{N-n} \cdot p(1-n)^{n}$$

Because it has been predicted which category has the smaller frequency, the test is a one-tailed test. The Null Hypothesis is accepted if the value of p" exceeds a significance level of 0.05 and must be rejected if the value of p" is 0.05 or less. In the latter case the number of joint occurrences of the pair of species in question must be regarded as not due to chance alone. The explanation must be sought in some other factors and the association, whether positive or negative must be considered statistically significant. This statement makes no comment on why the species are significantly associated but merely states that statistically they are associated in the same sample more than chance alone could account for.

## Application of the Method to Lower Colorado Assemblages

The solution of the equation given above, for more than a few species pairs, would involve an immense amount of calculation. It was therefore decided to develop a computer program which would solve this equation for a large number of species pairs. The complete program, written in Fortran IV, is given in Appendix IV at the end of the account. Included also in this Appendix are the data sheets for the two sections used and a sample page of the data print-out. On the data print-out, M and N stand for the number of occurrences of each of the species in the species pair (M,N) being tested. The next column shows the probability of joint occurrence of the two species in a given sample, the next the expected number of joint occurrences, then the observed number of joint occurrences, p' and finally p" for a positive association and p" for a negative association.

Choice of Species - Two sections were used; these were Imperial Battle Lake No. 1 well and Imperial Spirit River No. 1 well. They were chosen because they afforded a complete section of the strata investigated in this account. Further, they were also the most widely separated sections, being about four hundred miles apart. Out of 122 species, 74 species occurring in the "Battle Lake" section and 68 species occurring in the "Spirit River" section were chosen for examination. Most of the species from the two wells were the same, although each section contained a few species not present in the other. Most of the species chosen occurred relatively frequently. Some species chosen, however, occurred in only a few samples but were abundant in that sample. While reliability and usefulness of a significant positive association decreases with decreasing frequency of occurrence of the species pair, it was decided to do as many species as possible. Later analysis showed that these rarely occurring species did not enter into significant pairings to any extent and did not occur in any of the recurrent groups. 31 samples over 260 feet of section were used from the "Battle Lake" section; 26 samples covering 560' of section were available from the "Spirit River" section.

Results of Species-Pair Determinations - The data print-out sheets, amounting to several hundreds of pages are deposited with the Department of Biology, McMaster University. In addition, sheets with an analysis of the significantly associated species pairs arranged on a grid are also deposited with that department. Out of 2701 possible pairs of species from the "Battle Lake" section, 103 pairs proved significantly positively associated, or about 3.7%. Out of the 2278 possible species pairings from the "Spirit River" section, 54 pairs showed significant positive association, or about 2.4%.

The results of the species pair determinations based on application of the non-parametric Bionomial Test show then that a small percentage of the species in two widely separated wells passing through Lower Colorado strata are significantly associated in pairs. The results confirm that there are patterns of association within the microplankton assemblages of this Group. Furthermore, there does not appear to be any objection to applying the method described above to other microplankton assemblages in different geographical localities and in strata of different geological age.

The results of this determination suggest that further investigation using methods outlined by Fager (1957) might reveal not only significantly associated species pairs but also groups of species which recur in part of or the whole of the Lower Colorado strata. It is to the investigation of this possibility that attention is now turned.

## Formulation of Species Groups

Fager (1957) discusses at length a method by which species pairs showing positive association may be grouped into recurrent species groups. Fager (1957, p. 589) gives four criteria which a recurrent group must meet and these are briefly summarized below:

1. All species pairs within a recurrent group show a positive affinity for each other at the 0.05 probability level.
2. The greatest possible number of species is included.
3. Of several possible groups having the same number of members, the groups giving the greatest number of groups without members in common are selected.

4. Of two or more groups having the same number of species, and with members in common, the one occurring as a unit in the greatest number of samples is chosen.

Fager's (1957) method cannot be discussed at length here. Essentially, it consists of arranging species in order of decreasing numbers of affinities and enlarging groups until a group satisfying the requirements outlined above can be formed. The remaining species are then subjected to the same process until all groups of three or more members have been formed.

Not all species may belong to recurrent groups and various degrees of affinity beyond the species pair level are possible. Solitary species may have positive affinity with one or several members of a recurrent group but not with all of them. Such species are termed associate members of a recurrent group. One or more species in one recurrent group may show affinity with one or more species in a second recurrent group, but each of these species belongs in a separate group satisfying the four requirements outlined by Fager (1957).

## Application of Fager's Method to Lower Colorado Species Pairs

The application of Fager's method to the species pairs from both sections examined was not entirely successful. In both cases, the procedure outlined by Fager could be used to show that no recurrent groups satisfying all four requirements possessed more than five members. In each of the wells, however, Fager's method failed to indicate immediately recurrent groups because of the multiplicity of choices available. Thus criteria 3 and 4 have to be applied by analysis of the data from grids. The method applied was necessarily tedious and involved and the development of the groups will not be repeated in this account. This original compilation is available along with other data from the Biology Department, McMaster University, Hamilton, Ontario. The final results of the recurrent group analysis, translated into recurrent groups and associate species and represented diagrammatically, are given in Text-figures 13 and 14.

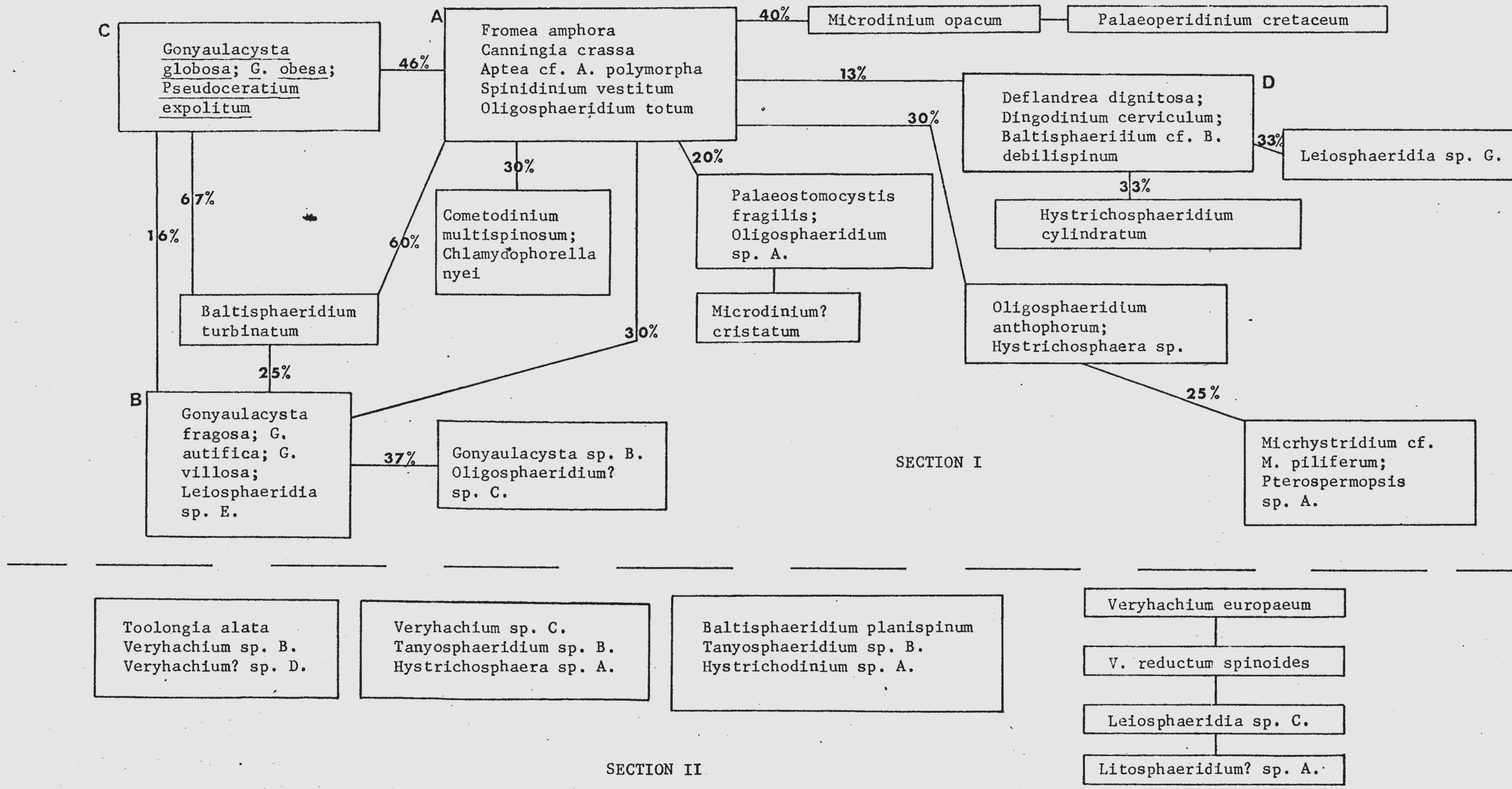
It is apparent from Text-figures 13 and 14 that well defined recurrent species group patterns exist in microplankton assemblages from the Lower Colorado Group. This constitutes strong evidence in favour of the hypothesis proposed earlier in the discussion that such patterns of occurrence exist and points out that species occurrence data, at least with reference to microplankton assemblages, has been greatly underestimated. Fager's method, while useful in ruling out combinations of species failing to meet the necessary criteria for recurrent groups, is not successful in all situations. It is possible that the relatively small number of samples may contribute to difficulty in applying his method successfully. A second difficulty might also arise in the nature of the species concept, which is, of necessity, subjective.

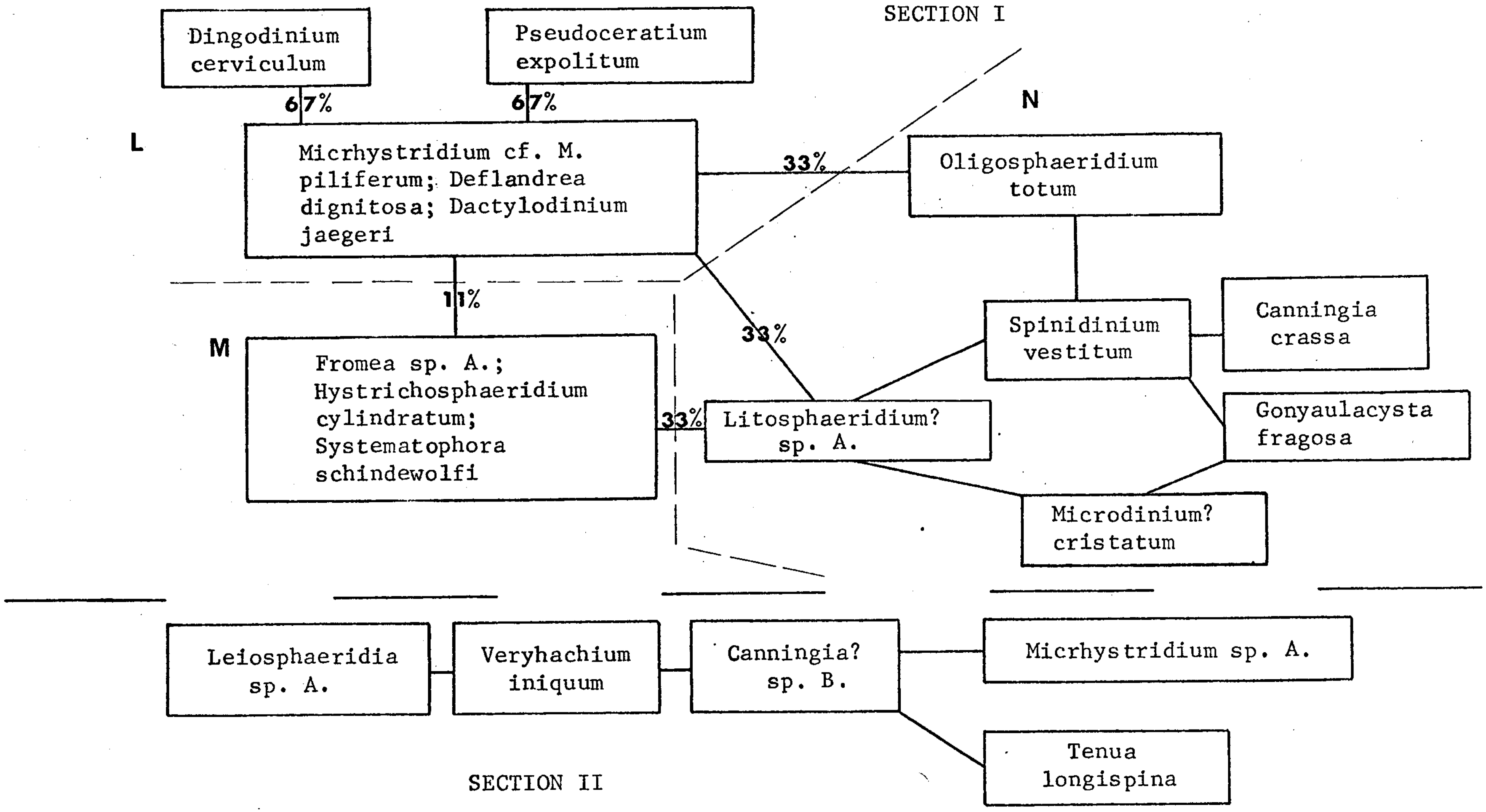
## DISCUSSION OF RECURRENT GROUPS IN LOWER COLORADO STRATA

### Comparison of Recurrent Groups at Two Sites

Examination of Text-figures 13 and 14 shows that microplankton species from the "Battle Lake" locality are more clearly grouped and form more groups of three or more species than the species from "Spirit River". The relationships of major groups and associate

Text-figure 13. Diagram of relationships between recurrent microplankton species groups in Imperial Battle Lake No. 1 Well. Percentage of possible species pairs showing positive association between groups are indicated on lines joining associated groups. 31 samples used.


A
Fromea amphora
Canningia crassa
Aptea cf. A. polymorpha
Spinidinium vestitum
Oligosphaeridium totum
40%
Microdinium opacum
Palaeoperidinium cretaceum
C
Gonyaulacysta globosa; G. obesa; Pseudoceratium expolitum
46%
13%
D
Deflandrea dignitosa; Dingodinium cerviculum; Baltisphaeridium cf. B. debilispinum
30%
33%
Leiosphaeridia sp. G.
33%
Hystrichosphaeridium cylindratum
30%
20%
Cometodinium multispinosum; Chlamydophorella nyei
Palaeostomocystis fragilis; Oligosphaeridium sp. A.
Microdinium? cristatum
Oligosphaeridium anthophorum; Hystrichosphaera sp.
67%
16%
60%
Baltisphaeridium turbinatum
30%
25%
B
Gonyaulacysta fragosa; G. autifica; G. villosa; Leiosphaeridia sp. E.
37%
Gonyaulacysta sp. B. Oligosphaeridium? sp. C.
25%
Micrhystridium cf. M. piliferum; Pterospermopsis sp. A.
SECTION I
Toolongia alata
Veryhachium sp. B.
Veryhachium? sp. D.
Veryhachium sp. C.
Tanyosphaeridium sp. B.
Hystrichosphaera sp. A.
Baltisphaeridium planispinum
Tanyosphaeridium sp. B.
Hystrichodinium sp. A.
Veryhachium europaeum
V. reductum spinoides
Leiosphaeridia sp. C.
Litosphaeridium? sp. A.
SECTION II



Text-figure 14. Diagram of relationships between recurrent microplankton species groups in Imperial Spirit River No. 1 Well. Percentage of possible species pairs showing positive associations between groups are indicated on lines joining associated groups. 26 samples used. Groups L, M, and association chain N indicated by dashed lines.

species at "Battle Lake" are also more complex than those at "Spirit River". Each locality is similar in that recurrent groupings may be divided into two Sections, I and II. But at "Battle Lake", Section II also shows several groups of three, as compared to an association chain of species in Section II at "Spirit River". At both sites, none of the species in the two sections has any connections outside its section.

At "Battle Lake", there are four major groups in Section I, headed by Fromea amphora, Gonyaulacysta fragosa, Gonyaulacysta globosa and Deflandrea dignitosa. A curious feature is the central position of the species Baltisphaeridium turbinatum, which, although it has no affinity with any of the groups, is an associate of three main groups and several smaller ones. A number of other species, including the long-ranging and ubiquitous species, Microdinium opacum sp. nov. and Palaeoperidinium cretaceum (Pocock) comb. nov. among others, are associate members of one or more groups. In section II at "Battle Lake", there are three groups of three species and one association chain. None of the three groups has any affinity with the other.

In the "Spirit River" section, by contrast, there are only two recurrent groups of three species in Section I. Many species grouped at "Battle Lake" are arranged in the "Spirit River" site as members of a chain association or as associate members of the two main groups. Three members of the major group of five at "Battle Lake", Canningia crassa sp. nov. Spinidinium vestitum sp. nov. and Oligosphaeridium totum sp. nov. are associated as part of a chain in the "Spirit River" section. At "Spirit River" also, there is a conspicuous absence of groupings of species of *Gonyaulacysta* and a trend, although not well marked, to groupings involving acritarchs or members of the Hystrichosphaeridiaceae.

### Association between Recurrent Groups

The extent to which recurrent groups are associated with each other may be estimated by a simple means. Given two groups with X and Y members respectively, it follows that there are XY possible combination of pairs between them. The actual number of species pairs showing positive affinity between the two groups may be expressed as a percentage of the total XY pairings. For example in Text-figure 13, recurrent group A has five members and recurrent group D has 3 members. Of the 15 possible positive associations between these species only 2 occur (from species pairs data), or approximately 13% of the total. The two major recurrent groups in the "Spirit River" section have only 11% of the possible pairings possible. It follows that the species within a recurrent group show 100% in accordance with criterion 1 of Fager (1957). Percentages of possible pairs between groups and between groups and associate species are indicated in each case in Text-figure 13 and 14.

## RECURRENT SPECIES GROUPS IN RELATION TO OTHER DATA

### Stratigraphic Time-Units, Lithology and Recurrent Groups

Of the species contained in the major recurrent groups of the "Battle Lake" section, only a few species, including *Oligosphaeridium totum* and *Deflandrea dignitosa*, are considered key species in the microplankton time units. All of the other forms show irregular distribution or are not confined to restricted ranges in this and other sections examined.

When the local range of species in these groups in the "Battle Lake" section alone are examined in detail, certain patterns become evident. For convenience, the major recurrent groups are labelled A to D in Text-figure 13. Their relation to time and lithology units is outlined below:

Group A: Species appear first from the basal Joli Fou to the lower Viking Formation. The majority of forms is present by the lower Viking Formation. The range of the group is Unit A to C.

Group B: Species appear from the top of the Joli Fou to the middle Viking Formation. The majority of forms is present by the middle Viking. The range of the group is the top of Unit A to C.

Group C: All species appear by the top of the Joli Fou Formation. The group ranges from the top of Unit A to C.

Group D: All species appear near the base of the Upper Shale Unit. The range of the group is Unit C only. The associated species, Hystrichosphaeridium cylindratum sp. nov. also occurs only in Unit C in this section.

Three recurrent groups are separated in Section II of the "Battle Lake" assemblage. One group, including the species Toolongia alata occurs only in one sample. A second, including Tanyosphaeridium sp. A. and a third, containing Baltisphaeridium planispinum occur only in the basal part of the Joli Fou Formation. These groups do not have any associations with each other or with those of Section I. Their restriction, in the case of the last two groups, should be noted. Little may be said about the group occurring in one sample. It is also interesting to note that Litosphaeridium? sp. A. occurs in an association chain of Section II in the "Battle Lake" section, but is present as a linking species between the association chain and the two major recurrent groups of Section I in the "Spirit River" section.

The recurrent groups in the "Spirit River" section may be examined in the same manner. In Text-figure 14, the two major groups are labelled L and M, with the association chain referred to as "Group" N for convenience. Group L also has two associated species which are included as part of that major division. The relation of species groups L, M, and N to lithology and time-units are outlined below:

Group L: The associated species and *M*. cf. *M*. *piliferum* appear only in the Harmon Member and the Lower Shaftesbury Formation. The other two species appear at the base of the Lower Shaftesbury Formation in the lowest part of Unit C.

Group M: All of the species occur first in the Lower Shaftesbury Formation. The group ranges from the top of Unit B to C.

"Group" N: This is not strictly a group, but rather an association chain of species, most of which occur first in the Lower Shaftesbury Formation. *Oligosphaeridium totum* occurs in the lower part of the Paddy Member and *Gonyaulacysta fragosa* occurs in the Harmon Member. The range of all species in this association chain is thus Unit A to C, with most of the forms ranging from the top of Unit B to C.

## Sequential Appearance of Recurrent Groups

If the point in the section at which the majority of forms of a recurrent group are present is taken as a reference marker, a sequence of recurrent groups can be demonstrated at both sections. Thus in the "Battle Lake" section, Group C appears by the top of the Joli Fou Formation, Group A in the Lower Viking and Group B in the mid-Viking. In terms of time-units, these groups span time units A to C. Group D appears and is present only in the uppermost Viking and in the Upper Shale Unit; it is confined to time Unit C.

In the "Spirit River" section, a slightly different pattern emerges. The associate species of Group L are present in the Harmon, and all are present in the Lower Shaftesbury Formation. A few of the species of the association chain, loosely termed "Group" N, occur in the Harmon or Paddy Members, but all are present in the Lower Shaftesbury. The species of Group M do not appear until the base of the Lower Shaftesbury Formation and range in this section from the top of Unit B to C.

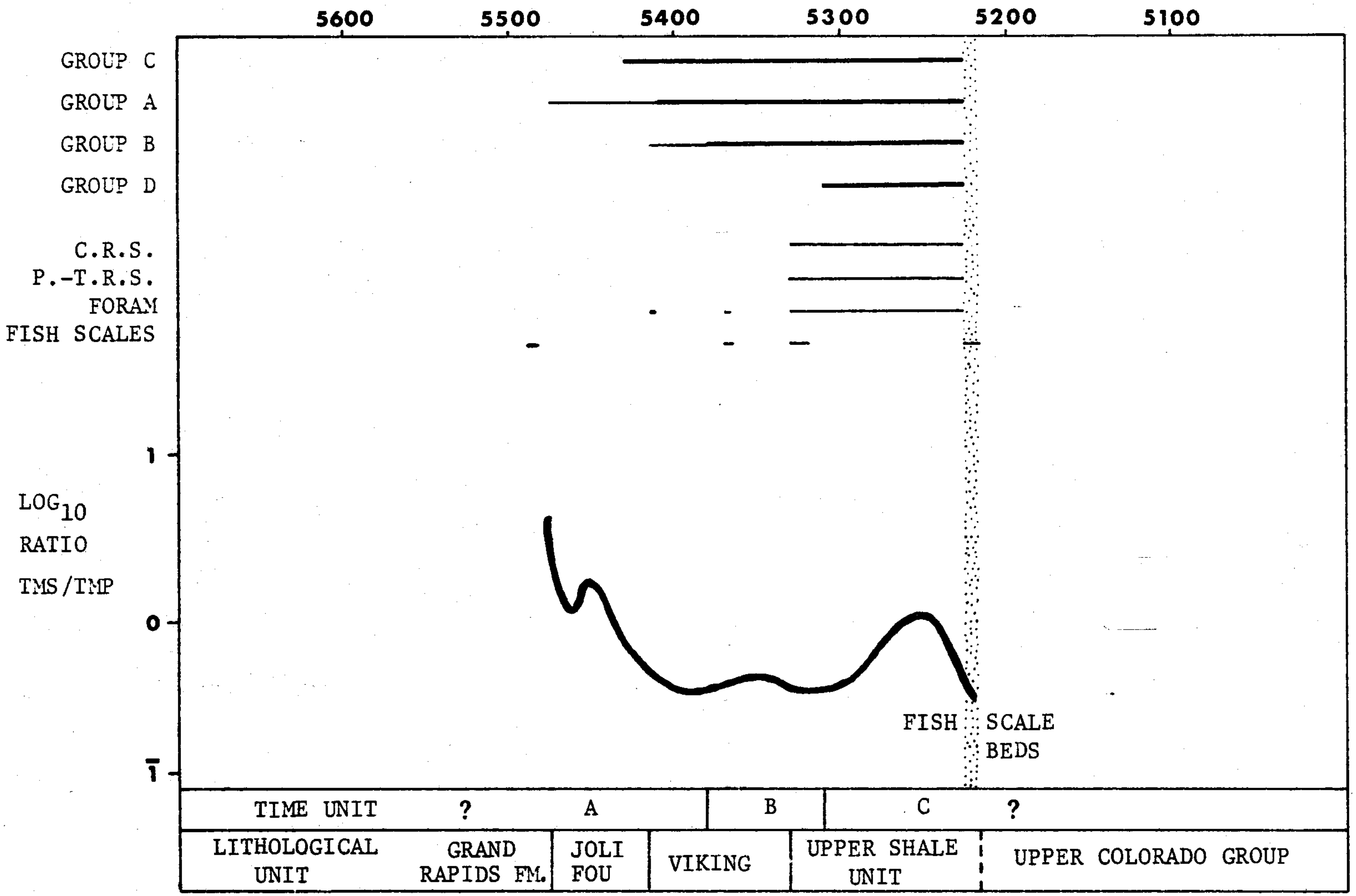
In connection with these points, in the "Battle Lake" section Dingodinium cerviculum is present in a group with Deflandrea dignitosa (Group D) and there is confined to Unit C. In the "Spirit River" section, this species occurs in the Harmon Member (Unit A) and again in the Lower Shaftesbury Formation. Gonyaulacysta fragosa first appears in the top of the Viking Formation in the "Battle Lake" section but in the Harmon Member in the "Spirit River" section. This and other evidence to be presented suggests that these recurrent species and associated forms may be responding to factors of an environmental nature and that their "irregular" appearance levels in different regions are part of an overall pattern. The sequence of recurrent species groups A to D and the changes in Groups L–N in the two sections also supports this possibility. With this background, it is now possible to review other data and information presented in Chapter IV and see if there are any correlations which may be made.

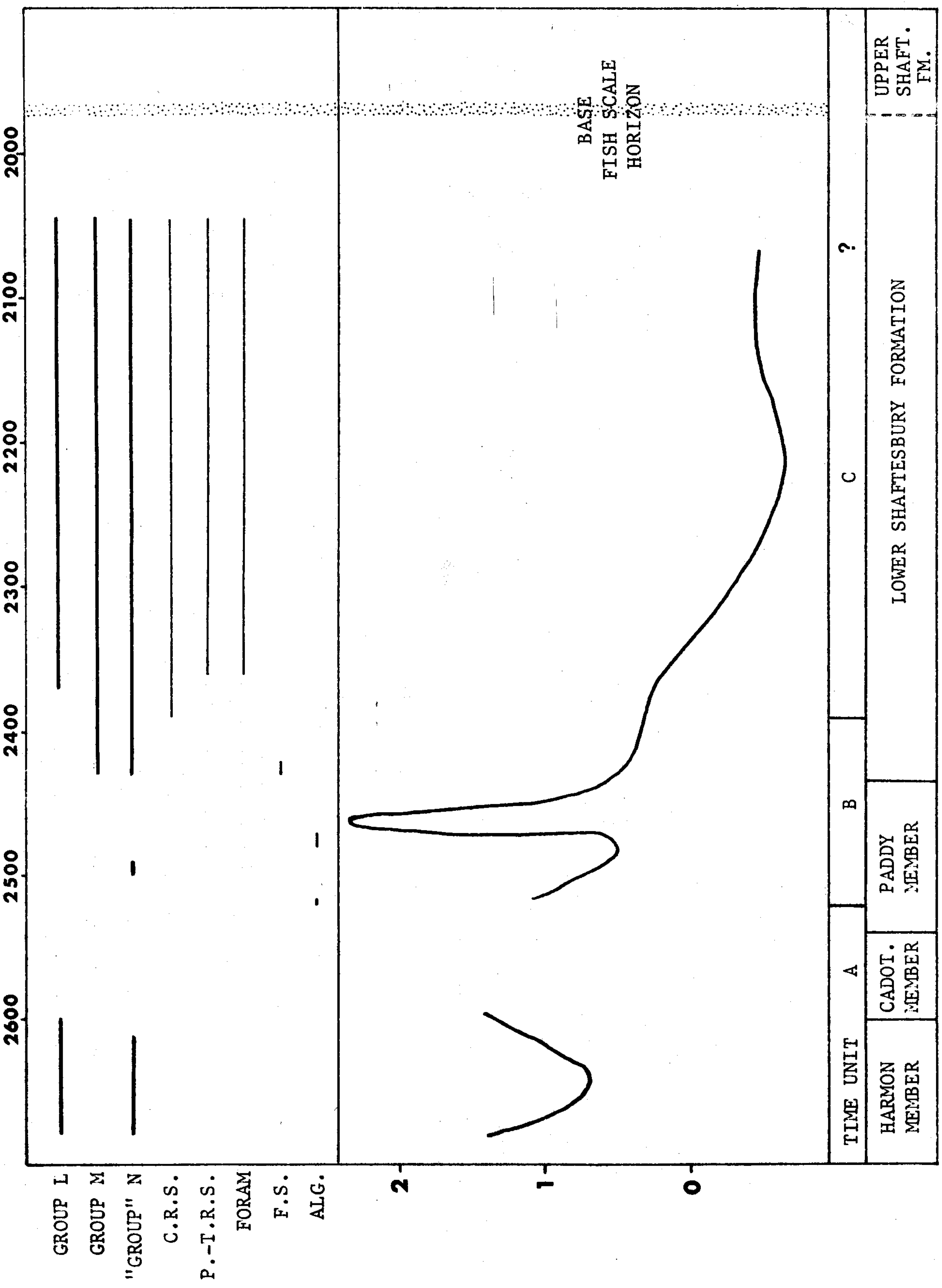
## Correlation of Recurrent Species Group Patterns With Other Data

Text-figures 15 and 16 summarize the times of appearance and complete development of the recurrent species groups of Section I in the "Battle Lake" and "Spirit River" sections. The ranges of other microfossil forms, including recycled miospores, chitinous inner linings of foraminifera and fish scales are also noted. For reference, formation boundaries and time unit boundaries based on the microplankton assemblages are also included.

In the "Battle Lake" section, the first members of recurrent groups appear near the base of the Joli Fou Formation, co-incident with the change from fine-grained, sometimes pyritic, sandstones of the uppermost Grand Rapids Formation to dark grey or black shales. At the top of the Joli Fou Formation and continuing to the mid-Viking Formation, three of the four major recurrent groups of Section I become evident. By mid-Viking strata, Groups A, B and C are all present and fully developed. The enclosing strata during this interval from the upper Joli Fou to the mid-Viking have become more silty and are often cross-laminated. Occasional samples in these strata contain fish scales or foraminifera. About the 5330' level in this well, the lithology returns to dark grey or black fissile shales and recycled spores and foraminifera become common in almost all samples. About 20 feet higher in the section, members of the recurrent Group D appear. It may also be noted that the ratio of

Text-figure 15. Appearance (thin lines) and final development levels (thick lines) of four major recurrent groups in Imperial Battle Lake No. 1 Well, related to lithological and time units and other data. The $\text{Log}_{10}$ ratio curve for TMS/TMP smoothed from points of Text-figure 5. Symbols: CRS: Carboniferous recycled spores, P-TRS: Permo-Triassic recycled spores, FORAM: Foraminiferal test linings, FS: Fish Scales.


5600
5500
5400
5300
5200
5100
GROUP C
GROUP A
GROUP B
GROUP D
C.R.S.
P.-T.R.S.
FORAM
FISH SCALES
1
LOG$_{10}$
RATIO
TMS/TMP
0
$\bar{1}$
FISH SCALE
BEDS
TIME UNIT
?
A
B
C
?
LITHOLOGICAL UNIT
GRAND RAPIDS FM.
JOLI FOU
VIKING
UPPER SHALE UNIT
UPPER COLORADO GROUP



Text-figure 16. Appearance of major recurrent groups in Imperial Spirit River No. 1 Well, related to lithological and time units and other data. Symbols as for Text-figure 15 except ALG: Algal fragments.

miospores to microplankton, which previously had dropped sharply at the Grand Rapids-Joli Fou contact, now begins to rise again, reaching a peak before falling as the Fish Scale Horizon is approached. At the Fish Scale Horizon, microplankton assemblages disappear, as do the miospore assemblages. No samples higher than this interval were processed. Throughout most of the "Battle Lake" section, except for the basal strata of the Joli Fou Formation, the total acritarch/dinoflagellate ratio remains very low.

In the "Spirit River" section, recurrent groups are partly in evidence in the middle part of the Harmon Member, coincident with a decrease in the total miospore/total microplankton ratio. The lithology of the strata in the Harmon Member changes from claystone and coal stringers at the base, to shales, and then near the top of the Member, to protoquartzites. At the top of the member, the microplankton decrease in importance and do not reappear again in significant numbers, except sporadically in several samples of the Cadotte and Paddy Members, until the base of the Lower Shaftesbury Formation.

The base of the Lower Shaftesbury Formation is marked by reappearance of the association chain N and by the first appearance of Group M. Somewhat higher in the section, recurrent Group L is reestablished with several new members added including _Deflandrea dignitosa_, one of the diagnostic species for time Unit C. At the base of the Lower Shaftesbury Formation, the total miospore/total microplankton ratio decreases from relatively high values recorded in samples of the Paddy Member. Recycled miospores and foraminifera appear in the samples and the lithology changes from a succession of claystones and protoquartzites to dark grey or black fissile shales. The changes in lithology in the Harmon and through the Cadotte and Paddy Members, from sandstones to shales and then protoquartzites and finally back to black shales, are very suggestive of regressive and transgressive movements of the shoreline relative to the well site. Further work would be needed at other localities to confirm or disprove this hypothesis. The interpretation is supported by the disappearance and reappearance of microplankton groups and the general predominance of miospores in the basal Harmon and in the Cadotte and Paddy Members, compared to the upper Harmon Member and Lower Shaftesbury Formation.

## Interpretation of Recurrent Species Group Patterns

Foraminiferal linings, fish scales and relatively low total miospore/total microplankton ratios have been taken as indications by many workers of marine depositional conditions (Muller, 1959; Sarmiento, 1957; and Upshaw, 1964). Williams and Sarjeant (1967) suggest that the presence of recycled miospores and other entities has some connection with proximity of shoreline. Norris (1967) suggests that the recycled miospores in the Lower Colorado Group may represent reworking and recycling of Palaeozoic and Permo-Triassic deposits in the region of the depositional basin. The general correlation of recurrent species group occurrence with the appearance of these acid-insoluble groups and changes in the miospore/microplankton ratio and lithology suggest that the recurrent groups at both sites may be responding to changes in sedimentological or environmental factors.

Reference to the occurrence charts in Text-figures 4a to 4e, show that the acanthomorph and polygonomorph acritarch subgroups show greatest diversity in the lower Joli Fou Formation and again at the base of the Upper Shale Unit in the "Battle Lake" well. They also show their greatest diversity at various intervals in the lower and middle portions of the Lower Shaftesbury Formation in the "Spirit River" well. If the interpretations of Wall (1965) are correct, and the interpretations of the changes in lithologies are correct as set out in this account, this pattern of acanthomorph-polygonomorph occurrence would seem to confirm a transgressive interpretation for basal Joli Fou, Upper Shale Unit and Lower Shaftesbury deposits. Thus the development of some recurrent groups, especially those containing *Deflandrea dignitosa* and other associated forms probably occurred under transgressive marine conditions, while development of other groups, especially in the Upper Joli Fou-Viking portion of the "Battle Lake" section, occurred in relatively stable conditions.

## Recurrent Species Groups and Stratigraphy

All but a few of the species forming the major recurrent groups of Section I from "Battle Lake" and "Spirit River" were not suited to use as stratigraphic markers for microplankton time units. This majority of species belonged to recurrent groups whose appearance appeared to be controlled by factors other than evolutionary change in the assemblage. Because of this it would appear that recurrent species groups are not useful as time stratigraphic markers except on a local scale.

Two of the species, *Oligosphaeridium totum*, a key species in recognition of Unit B and Deflandrea dignitosa, a key species for marking the base of Unit C, also belonged to recurrent species groups in one or both of the sections examined. Their ranges were more restricted than those of the recurrent groups to which they belonged. The significance of this cannot be assessed with any certainty, but perhaps it confirms the meaningfulness of the restricted ranges. Two other species, Gonyaulacysta globosa and Chlamydophorella nyei appear at the base of Unit A in the Harmon Member and the basal Joli Fou Formation in the "Battle Lake" section. These two species, considered as key species for the definition of the base of time Unit A, appear along with their respective groups and do not have ranges more restricted than the recurrent groups to which they belong.

## SUMMARY AND CONCLUSIONS ON RECURRENT GROUPS

In general it is possible to demonstrate the presence and the distribution of recurrent species groups in the Lower Colorado Group. These groups appear to be responsive to changes in the sedimentary or environmental regime. They have value in that they allow a more refined correlation of occurrence data with other palynological indices present in the same section. Recurrent species groups do not appear to have stratigraphic value in themselves but may confirm the usefulness, as stratigraphic markers, of certain species contained in the groups.

## SIGNIFICANCE OF MICROFOSSIL RATIOS

### General Comments

Earlier in this account (Part One, Chapter III) it was proposed to make counts of various groups of microfossils in a number of sections and plot ratios of certain groups. Such counts have been made for complete sections at the "Battle Lake" site, and "Spirit River" site. In addition, counts of these microfossil groups were made in samples from the "Grouard" section and from the uppermost Grand Rapids and Joli Fou Formations cored in the "Grosmont" section. Not all of the samples from "Battle Lake" and "Spirit River" were counted, but a representative suite throughout each site was used. In total, 54 samples were counted. The $\log_{10}$ of ratios calculated from these microfossil groups was presented as Text-figures 5 and 6 and Table 4 in Part One, Chapter IV. The results of this work are now analyzed and commented on in relation to other data and evidence presented and discussed in previous sections of this chapter.

### Total Spore/Total Pollen Ratios

The curves plotted from the ratios of these two plant microfossil types show no definite trends. The value of the ratio fluctuates in samples from as low as 0.07 at one point in the "Spirit River" section to as high as 7.60 in the "Battle Lake" section. In the "Battle Lake" section, the ratio drops just at the base of the Joli Fou Formation, and thereafter follows a general increasing trend, reaching a sudden peak near the middle of the Upper Shale Unit and then fluctuating again but following a downward trend. A sudden influx of hilate spores, nearly all belonging to *Januasporites spiniferus* occurs at this point. In the "Spirit River" section, the ratio is high near the base of the Harmon, falling to the value 0.07 near the top of the Member. Samples of the

Cadotte Member and lower portions of the Paddy Member are barren. In the mid- and upper part of the Paddy Member, the ratio increases to high values, fluctuating relatively widely as well. Then, at the base of the Lower Shaftesbury Formation, the ratio drops markedly, thereafter following a slowly rising trend to a high value, again coinciding with a moderate influx of Januasporites spiniferus. At the time this rising trend is occurring, the miospore/microplankton ratio is slowly falling after a peak value in the upper part of the Paddy Member of 237.8 ($\log_{10}$ approximately 2.38).

In the "Grouard" section, this ratio is relatively stable and very low, fluxtuating over a range of 0.17 to 0.59. In the "Grosmont" section, there is a rise across the Grand Rapids-Joli Fou boundary, followed by a drop and then a rise again near the top of the Joli Fou Formation.

While there are no marked trends associated with this ratio in the sections examined, it is to be emphasized that after the establishment of marine conditions in both the "Spirit River" and "Battle Lake" sections, a general increase in the number of spores recorded in the assemblages occurred while the pollen grains decreased. The influx of the hilate species Januasporites spiniferus marks a return of hilate spores to the assemblage after absence since the uppermost part of the Mannville Group, where the species in those strata belonged to Aequitriradites, Cooksonites, and Rouseisporites. This along with a general decrease in the pollen fraction suggests that spore-producing parent floras may have been in closer proximity to the depositional sites or that current directions might have been conducive to directing spores into this area of the basin; causing an overshadowing of the pollen fraction. Only intensive and detailed studies of this aspect of the palynology of the Lower Colorado Group could prove or disprove this speculation. High values of the spore/pollen ratio at the base of the Harmon Member and again at various points in the Paddy Member might be explainable by postulating a closer proximity to shoreline or at least to spore-producing vegetation at certain stages. This interpretation is supported by the enclosing lithologies and the relatively high miospore/microplankton ratio at these levels.

Thus, while the total spore/total pollen ratio shows some relation to lithological changes and to proximity of shoreline, much more detailed work needs to be done to assess the value or non-value of compiling this type of ratio in palynological studies. It is perhaps more meaningful to look at ratios of spores or pollen grains within these major categories, as has been done with the hilate grains in this account.

## Total Acritarch/Total Dinoflagellate Ratio

There is in this ratio a certain element of subjectivity arising from the opinion of the observer as to what constitutes a dinoflagellate and what must be considered an acritarch. The ratios presented, for example, might have differed markedly if this work had been done several years earlier, before the work of Evitt (1961 and later) and Davey, *et al*. (1966). However, the ratios in this work have been derived from numerical data based on certain concepts of what constitutes a dinoflagellate and what constitutes an acritarch. These are set out in Part Two, Chapter One. Hence the ratios have some internal consistency. Of more import is the distinction made between thin-walled acritarchs assigned to the Leiospheres, particularly Leiosphaeridia sp. A. and L. sp. B. Such microfossils are similar in general appearance to thin-walled pollen grains assigned to the genera Laricoidites and Inaperturopollenites (particularly the species I. dubius). Differentiation of these forms is given in the appropriate sections in Part Two, Chapter III on Taxonomy of the assemblages. With these points advanced, an examination of the ratios as plotted in the sections investigated can now be undertaken.

In the "Battle Lake" section (Text-figure 5), the ratio rises steadily in the lowest strata of the Joli Fou Formation and then decreases rapidly at about the 5440-47' level and drops to a low value of 0.06 at the 5330-40' level. This drop is coincident with a sudden influx at the 5330-40' level of almost complete domination by one species of the microplankton fraction, Palaeoperidinium cretaceum, and with the continued slow decrease of the miospore/microplankton ratio. From this point onward, the ratio fluctuates from values around 0.1 and never exceeds 0.5.

In the "Spirit River" section (Text-figure 6), the microplankton count is very low in all but two samples from the Peace River Formation. The actual values obtained fluctuate rapidly, probably because of the low frequencies of microplankton in the samples and are thus not very reliable. In the Lower Shaftesbury Formation where the miospore/microplankton ratio slowly declines, the acritarch/dinoflagellate ratio shows a definite upward trend in value, reaching a peak near the top of the section examined at the 2103-2113' level. This also coincides with the peak of the total spore/total pollen ratio in that sample.

In the five samples from the "Grouard" section (Text-figure 6) the ratio increases to a peak about the Cadotte-Joli Fou boundary and then decreases. In the "Grosmont" section (Text-figure 6) the ratio value rises slowly to a maximum near the top of the Joli Fou Formation in that well. No further samples were counted in this well.

Again, as with the total spore/total pollen ratio, this acritarch/dinoflagellate ratio produces results which are not indicative of any particular trend. In one well, onset of marine conditions with black shales and decreasing miospore/microplankton ratios is concomitant with an increase followed by a sharp decrease. In another section ("Spirit River"), onset of black shales and decreasing miospore/microplankton ratios coincide with a slow increase in the ratio. One other factor may be noted. The high ratios in the "Battle Lake" section result from an influx of acanthomorph-polygonomorph forms, and similarly in the "Grosmont" section. In the "Spirit River" section and the "Grouard" section, in contrast, the leiospheres form the main acritarch fraction, with the acanthomorph-polygonomorph fraction being relatively insignificant in total numbers, although not necessarily in species diversity.

This ratio, like the total spore/total pollen ratio remains of doubtful value in the understanding of changes in the microplankton assemblages associated with lithological and environmental factors. Certain trends discussed above, however, suggest that this ratio might be explored using a closely set network of wells and much closer sample control, such as is present in the basal Lower Colorado section of Imperial Battle Lake No. 1 well, where there are three samples in the first 8' of section, or in the "Grouard" section.

## PALAEOBOTANICAL SIGNIFICANCE OF THE MIOSPORE ASSEMBLAGES

### Botanical Affinities of the Miospore Species

The miospore species described in this account are based on dispersed specimens recovered from an enclosing rock matrix. The precise botanical affinity cannot be determined for any of these species. Evidence from investigations of modern spore and pollen types in relation to natural groups and from fossilized sporangia and strobili, suggests that the morphology of a dispersed spore species may often be used to determine its affinity, at least down to familiar level. Such determinations should be made with caution, however, for some morphological types may be associated with more than one major plant group. The list of affinities given below is derived from previous work on the botanical relationships of Mesozoic miospores by Couper (1958), Potonié (1962), Dettmann (1963), Singh (1964), Pocock (1962, 1964) and Norris (1967). Where a species is confined in stratigraphic range to the Mannville Group, this is indicated by an asterisk.

Bryophyta

Musci (4)

*Stereisporites antiquasporites*
*S.* sp. A.
*S.* sp. B.
*Cingutriletes clavus*

Hepaticae (6)

*Aequitriradites spinulosus*
*A.* sp. A.*
*Januasporites spiniferus*
*Rouseisporites reticulatus**
*R. triangulatus**
*Cooksonites variabilis**

*Pteridophyta*

*Equisetales* (1)

*Inaperturopollenites dubius* (pars)

*Lycopodiales*: *Lycopodiaceae* (5)

*Lycopodiumsporites austroclavatidites*
*L. reticulumsporites*
*L. marginatus*
*L.*? sp. A.
*Sestrosporites pseudoalveolatus*

*Lycopodiales*: *Selaginellaceae* (5)

*Acanthotriletes varispinosus*
*Neoraistrickia truncata*
*Densoisporites microrugulatus*
*Densoisporites* cf. *D. balmei* (?)
*D.* sp. A. (?)

*Filicales*: *Osmundaceae* (4)

*Todisporites major*
*T. minor*
*Osmundacidites wellmanii*
*Baculatisporites comauensis*

*Filicales*: *Shizaeaceae* (18)

*Kukisporites variegatus*
*K. pseudoreticulatus*
*Cicatricosisporites minutaestriatus*
*C. australiensis*
*C. hughesi*
*C. pseudoreticulatus*
*C. perforatus*
*C.* cf. *C. sewardi*
*C.* sp. A.
*C.* sp. B.
*C.* sp. C.

*Appendicisporites sellingii*
*A.* cf. *A. crimensis*
*A.* cf. *A. matesovai*
*A.* cf. *A. unicus*
*A.* sp. A.
*A.* sp. B.
*A. perplexus* (?)

*Filicales: Gleicheniaceae* (1)

*Gleicheniidites senonicus*

*Filicales: Cyathaceae* (?) (2)

*Cyathidites australis*
*C. minor*

*Pteridophyta*

*Incertae sedis* (46)

*Deltoidospora hallei*; *D. psilostoma*; *D. juncta*
*Undulatisporites* cf. *U. undulapollis*
*Biretisporites potoniae*; *B.* cf. *B. deltoidus*
*Dictyophyllidites* sp. A.
*Concavissimisporites punctatus*; *C. variverrucatus*
*Neoraistrickia*? sp. A.
cf. *Raistrickia* sp. A.
*Acanthotriletes* sp. A.; *A.* sp. B.
*Pilosisporites trichopapillosus**; *P. verus**
*Cyclogranisporites* sp. A.
*Apiculatisporis*? sp. A.
*Converrucosisporites* sp. A.; *C.* sp. B.; cf. *C.* sp. C.
*Foveosporites* cf. *F. canalis*
*Lycopodiacidites* sp. A.
*Taurocusporites reduncus*; *T. segmentatus*; *T. minor*
*Tigrisporites scurrandus*; *T.* sp. A.
*Reticulisporites norrisii*
*Dictyotriletes* sp. A.
*Microreticulatisporites uniformis**
*Trilobosporites apiverrucatus*; *T. marylandensis*; *T.* cf. *T.*
    *trioreticulosus*; *T.* sp. A.
*Camarozonosporites insignis*, *C.* sp. A.
*Cingulatisporites reticingulus**; *C.* ? *saevus*; *C.* sp. A.; *C.* sp. B.
*Cirratriradites teter*
cf. *Kraeuselisporites* sp. A.
cf. *Cyclosporites* sp. A.
*Laevigatosporites ovatus*
Genus undetermined sp. A. and sp. B.

*Cycadophyta*: *Caytoniales* (2)

*Vitreisporites pallidus*
*Alisporites minutus* (pars) (?)

*Cycadophyta*: *Cycadales* or *Bennettitiales* (6)

*Cycadopites fragilis*; *C. follicularis*; *C. carpentieri*; *C. formosus*; *C.* sp. A.; *C.* sp. B.

*Coniferophyta*

*Coniferales*: *Araucariaceae* (1)

*Araucariacites australis*

*Coniferales*: *Taxodiaceae* (4)

*Sequoiapollenites* sp. A.
*Inaperturopollenites hiatus*; *I. dubius* (pars)
*Laricoidites magnus*

*Coniferales*: *Podocarpaceae* (14)

*Podocarpidites* cf. *P. ellipticus*; *P. canadensis*; *P. multesimus*; *P. biformis*; *P.* sp. A.; *P.* sp. B.
*Phyllocladidites* sp. A.; *P.* sp. B.
*Rugubivesiculites rugosus*; *R.* cf. *R. reductus*; *R.* sp. A.; *R.* sp. B.

*Parvisaccites amplus*; *P. radiatus*

*Coniferales*: *Pinaceae* (15)

*Alisporites grandis*; *A. robustus*; *A. minutus* (pars); *A. microsaccus*
*Abietineaepollenites aequisaccus*; *A. auritus*; *A.* sp. A.; *A.* sp. B.
*Pityosporites constrictus*
*Pinuspollenites* sp. A.
*Piceaepollenites*? sp. A.
*Cedripites cretaceus*; *C. canadensis*
*Cerebropollenites mesozoicus* (?)

*Coniferophyta*

*Incertae sedis* (9)

*Eucommiidites troedsonii*; *E. minor*
*Monosulcites* sp. A.; *M.* sp. B.
*Circulina* cf. *C. parva*
*Classopollis torosus*; *C.* cf. *C. minor*; *C.* cf. *pflugii*
*Exesipollenites tumulus*

*Ephedrales* (1)

*Ephedripites patapscoensis*

*Spores incertae sedis* (1)

*Schizosporis reticulatus*

*Angiospermophyta*: *Monocotyledonae* (?) - *Incertae sedis* (5)

*Liliacidites* cf. *L. textus*; *L.* sp. A.
*Clavatipollenites hughesi*; *C. minutus*; cf. *C.* sp. A.

*Angiospermophyta*: *Dicotyledonae* - *Incertae sedis* (14)

*Tricolpites vulgaris*; *T. paraneus*; *T. prosimilis*; *T.* sp. A.
*Reticulitricolpites sagax*; *R. georgensis*; *R. crassus*; *R.* sp. A.
*Cornaceoipollenites parvulus*; *C.* sp. A.
*Tricolpate* Forma A; *Tricolpate*? Forma B.
*Tricolporate*? Forma A.
*Periporate*? Forma A.

The dispersed miospore species assigned to the major plant groupings are distributed in this manner:

| PLANT GROUP | NUMBER OF SPECIES | CUMULATIVE TOTAL |
|---|---|---|
| Bryophyta | 10 | 10 |
| Lower Vascular Groups | 11 | 21 |
| Filicales | 25 | 46 |
| Pteridophyta - Incertae | 46 | 92 |
| Cycadophyta | 8 | 100 |
| Coniferales | 34 | 134 |
| Ephedrales | 1 | 135 |
| Coniferophyta - Incertae | 9 | 144 |
| Angiospermophyta | 19 | 163 |
| Spores incertae | 1 | 164 |

A total of 161 miospore species were described from the six sections examined. The discrepancy of 3 in the cumulative total arises because several miospore species have morphological characteristics which have led investigators to assign them to different botanical groups.

## Comparison with the Mannville Group

The natural affinities of miospore species in the Mannville Group and in the Lower Colorado Group show many similarities as far as major plant groups are concerned. In each, species belonging to the Filicales, Coniferales and lower vascular forms, are important constituents. Within the Filicales, the Schizaeaeceae are the dominant constituents while in the species assigned to the Coniferophyta, those having probable affinity with the Pinaceae and the Podocarpaceae are the most numerous. There is a decline in the number of species assigned to the Schizaeaceae in the Lower Colorado Group assemblage compared to the Mannville assemblage.

Certain differences occur in the two assemblages, the most obvious being the appearance of tricolpate angiosperm grains in the Lower Colorado Group assemblage. Almost 12% of the species described from the Lower Colorado Group are allied with the Angiospermophyta compared to none in the Mannville Group. This incoming of angiosperm grains occurs in the Harmon Member and by the middle Cadotte Member and the basal Joli Fou Formation, tricolpate grains have also made their appearance. Near the top of the Lower Colorado Group, several rare tricolporate grains also occur for the first time. Several other minor changes may also be noted. The number of species assignable to hepatic groups decreases, as does the number assignable to the Ephedrales. These observations, with one exception, confirm those of Norris (1967). Norris (1967) recorded only one species assignable to a cycadophyte affinity in the "East Fort Augustus" section near Edmonton, where evidence from six other sections indicates no real decline in representation of these forms.

### Composition of Parent Floras within the Region of Investigation

The miospore assemblages from the six sections examined in this account and the section examined by Norris (1967) in the Edmonton region indicate that the parent floras remained relatively similar throughout central Alberta in Upper Albian time. In all of the wells examined, the dominant constituents remained nearly constant with the exception of a few components. In the "Grosmont" well, the cycadophyte species are few in number and the angiosperm forms show their greatest diversity. Other minor differences occur but these cannot be demonstrated to have any significance. They are more likely due to influences other than changes in the regional composition of the parent vegetation.

## PROBLEMS FOR FUTURE RESEARCH IN THE PALYNOLOGY OF ALBERTA

In this account the taxonomy of a varied and abundant assemblage of miospores and microplankton from the Lower Colorado Group and its equivalents in central and west-central Alberta has been described. The assemblages have been shown to be useful in establishing a time-stratigraphic subdivision of these strata, in understanding the time relationships of lithological units and in developing new methods to analyze the occurrence patterns of microplankton assemblages. The value of miospore assemblages in developing a conception of the parent floras in the depositional region has been demonstrated again. The success in fulfilling these objectives suggests that these studies might be extended to other palynological problems in Alberta and elsewhere. Some of these are now discussed below.

### Time-Stratigraphic and Taxonomic Projects

Description of assemblages and understanding of the changes with time of palynological assemblages remains a fundamental pursuit in this field. There are many such projects which could be undertaken in Cretaceous palynology of Alberta that are a direct extension of the present investigation. Further detailed investigation of the well preserved assemblages contained in wells spanning the zero edges of deposition of the Peace River and south-central Lower Colorado successions would fill in gaps in the knowledge of assemblages in this region and give a clearer picture of the time relationships within the Members of the Peace River Formation. This study might also elucidate the depositional environments and position of shorelines in this region throughout the time of deposition of the Peace River Formation. Palynological investigation has not been carried out in this thesis beyond the base of the Fish Scale Horizon. This means that between the base of the Cenomanian and the base of the Maestrichtian Srivastava (1966, 1967a, 1967b, 1968) in Alberta, no published investigations of miospore and microplankton assemblages are available. Study of representative sections in this part of the Alberta Cretaceous would provide further stratigraphic subdivision of the Upper Cretaceous, help relate microplankton assemblages in western Canada to those of other regions, and would give a comprehensive picture of the differentiation of angiosperm pollen assemblages, and through them the parent angiosperm floras in the Upper Cretaceous of western Canada. It would be useful, for example, to correlate such information in western Canada with that reported by Brenner (1967) for the early Upper Cretaceous of Maryland. It may be remembered that late Lower Cretaceous miospore assemblages from

Maryland showed great similarity to those from central Alberta.

Related to the above projects would be investigations designed to place the Fish Scale Horizon, the First and Second White Specks and other marker horizons in the Upper Cretaceous in relation to time-stratigraphic units based on miospore and microplankton assemblages. A further project would be the extension of palynological studies to the thick succession of strata of the Blairmore Group. Information gained from other palynological investigations in the Lower Cretaceous of western Canada (Pocock, 1962; 1964; Singh, 1964; Norris, 1967, and the present account) would supplement previous palaeontological investigation of this Group (Mellon and Wall, 1963; Bell, 1956).

### Non-Stratigraphic Projects

The results of this investigation in areas not directly involved with stratigraphic palynology have been encouraging. The disclosure and relation of recurrent species groups in microplankton with other data has confirmed that occurrence data is of much value in understanding the relationships in such assemblages. Application of the methods outlined in this thesis to other microplankton assemblages, not necessarily those disclosed from deposits in Alberta, might reveal hitherto undetected relationships in microplankton assemblages.

Although the results of the counts for determination of the total spore/total pollen ratio and the total acritarch/total dinoflagellate ratio did not reveal any definite trends or principles of application, as in the case of the total miospore/total microplankton ratio (Sarmiento, 1957; Upshaw, 1964), results were encouraging. If a single lithological unit were explored throughout much of its extent, for example the Joli Fou Formation, using a dense network of wells and all aspects of palynological, lithological, and other data were recorded, a comprehensive picture might result and these ratios might then be seen to have some value as environmental or other indicators. It might be possible to apply some of the techniques used in the study of modern sediments and their palynology (Muller, 1959; de Jekowsky, 1963; Traverse and Ginsberg, 1966, and others). The tentative efforts of this investigation have shown that such a project is feasible and may produce results of significance beyond the immediate region under study.

# PART TWO

# SYSTEMATIC PALYNOLOGY OF THE MIOSPORE AND MICROPLANKTON ASSEMBLAGES OF THE LOWER COLORADO GROUP

# I

# MORPHOLOGY AND TAXONOMY OF FOSSIL DINOFLAGELLATES AND ACRITARCHS

## BASIC MORPHOLOGY OF DINOFLAGELLATES

Modern dinoflagellates belong to the order Dinoflagellata. The members of this order possess two flagella, have a body which is either fixed, or more rarely irregular, in form, and may or may not be enclosed by outer layer forming a distinct plate pattern. Most dinoflagellates are one-celled (acellular) and reproduce by binary fission. Sexual reproduction may occur, but has not yet been observed (Hyman, 1940). Many species encyst in response to seasonal or short-term fluctuations in living conditions. The old theca is destroyed and the cyst opens by splitting or rupturing along certain plate sutures, the organism excysting and developing into a new individual. This process has been observed only recently (Rossignol, 1963; Wall and Dale, 1967).

Most modern dinoflagellates are recovered from their habitat as motile forms. In contrast, with few exceptions (Evitt, 1961), fossil dinoflagellates are recovered as abandoned cyst forms. Consequently, the morphology of the cyst form is of considerable interest to the palynologist. The morphology of the cyst form may closely parallel that of the motile stage or it may be very different. This variation in cyst form, sometimes within genera or species (Wall, 1965b), has created a number of problems in the interpretation of fossil dinoflagellate remains. Some of these difficulties have been resolved only recently (Evitt, 1961; Evitt and Davidson, 1964). An understanding of the basic morphology of motile and cyst forms is essential to the comprehension of the taxonomy of fossil dinoflagellates. The following sections present a brief outline, but the reader is referred to Chatton (1952), Fritsch (1956) and other reference works for more detailed treatments.

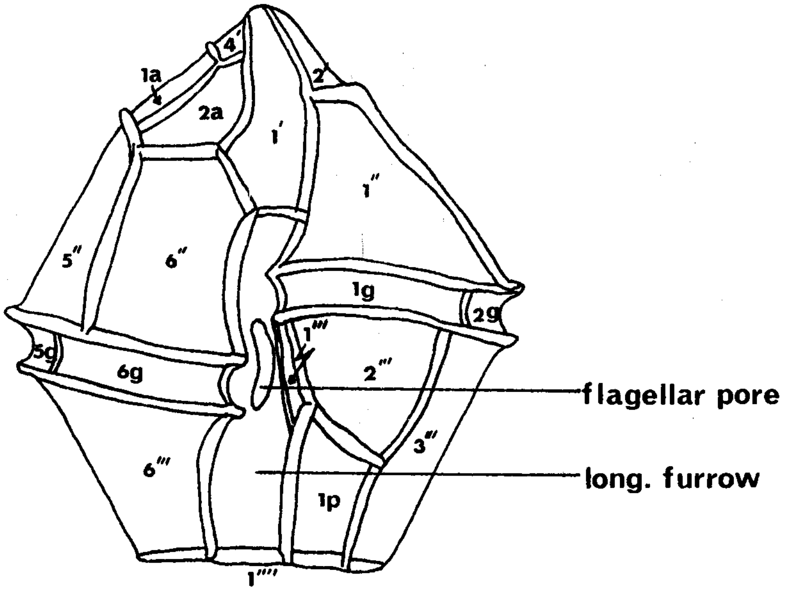
### The Motile Stage

The modern dinoflagellate cell is either naked, enclosed in a simple membrane, or provided with a system of plates referred to as the theca. The theca may be pentagonal, ovoid, or rounded; it possesses structures which allow a conventional orientation of the cell. The first of these is the transverse furrow (synonyms: girdle, groove; cingulum in cyst forms) which runs about the theca approximately at the mid-line. The ends of the furrow may be opposite or displaced with respect to one another. In life this transverse furrow carries the transverse flagellum. A second furrow, the longitudinal furrow (reflected as the sulcus in cyst forms) is generally visible and is oriented approximately at right angles to the transverse furrow, although it may follow a winding course. These two furrows provide a means of orienting the theca with respect to apex and antapex (See Text-figs. 17a and 17b) and with respect to dorsal and ventral sides. The longitudinal furrow is considered as being developed on the ventral theca and runs from near the mid-line to the antapex. The part of the theca bearing the longitudinal furrow and antapex is termed the hypotheca while the portion of theca between the apex and the transverse furrow is called the *epitheca*. The transverse and longitudinal furrows merge on the ventral surface, and at this point, the flagella emerge from a flagellar pore to lie in their respective furrows.

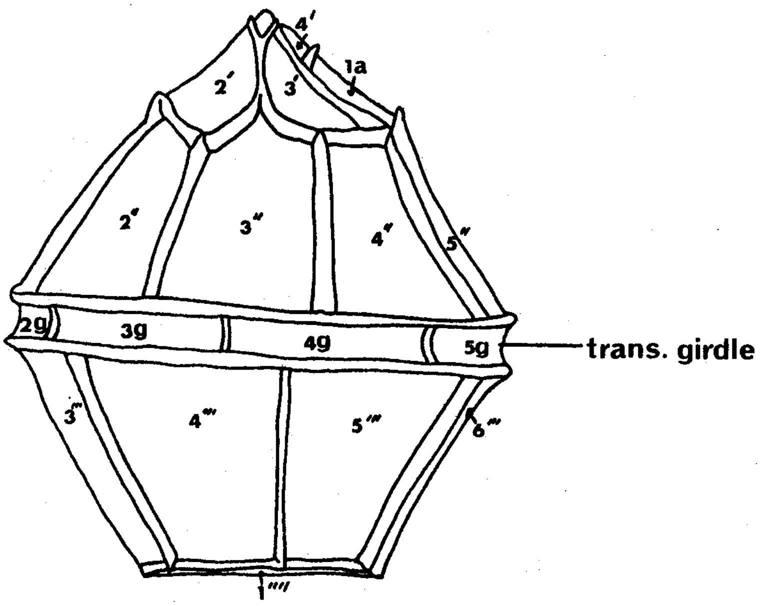
The apical portion of the theca may be rounded or possess an apical prominence or horn. The antapex may be flattened, rounded, or variously indented and prolonged into one or more equally to unequally developed antapical horns. Many variations of this simple basic plan exist (Hyman, 1940; Chatton, 1952; and others).

Many dinoflagellate thecae develop well-defined plate systems on the thecal membrane. Such forms are often termed the "armoured" dinoflagellates in contrast to the "unarmoured" forms such as *Gymnodinium*. Norris (1966) has given a brief and useful account of these forms. A typical plating pattern for a generalized modern dinoflagellate is shown in Text figs. 17a and 17b. These plate systems are of diagnostic value (Bursa, 1964) and a shorthand formula has been devised to convey the plate system in short form. The main divisions of the plate system, applicable to both motile and cyst forms bearing plates includes the following: an apical series (n'), an apical intercalary series (0 - na); a precingular series (n"); a cingular series developed on cysts (0 - 6c); a post-cingular series (n"); a posterior intercalary series (0 - np); a posterior-ventral series (0 - n pv); and an antapical series (n""). Not all the series may be present on a given species.

The morphological characters constitute the major criteria available for taxonomic division based on external features. Bursa



Text-figure 17a



Text-figure 17b

Text-figure 17a and 17b. Outline diagram of *Gonyaulax polyhedra* Stein 1883, a modern armoured dinoflagellate, showing tabulation pattern and other details mentioned in the text. 17a, ventral view. 17b, dorsal view. Apex at the top. Redrawn after Sarjeant (1967, Text-fig. 2, p. 251).

(1964) outlines some of the internal features useful in the taxonomy of modern forms. These are of interest, but of little use to the palynologist who must deal with the fossilized remains of an outer cyst wall, or more rarely a motile form having no internal structure preserved. The morphology of the cyst form thus assumes great importance in fossil dinoflagellate studies.

## The Cyst Stage

General Considerations - The morphology of fossil dinoflagellate cysts is highly variable. Many cysts so resemble a motile stage in appearance that they were thought to be quite possibly motile stages (Evitt, 1961). In these, the original plate boundaries and positions of furrows are easily recognizable; the transverse furrow may not show septa, which would in life impede the course of the flagellum. Other dinoflagellate cysts resemble motile stages in general construction and may preserve external structural features of motile thecae, but possess features which preclude their being motile forms. Evitt (1961) discusses this point in detail. Other dinoflagellate cysts like those of the fossil genera *Hystrichosphaeridium* and *Hystrichosphaera* were long thought to be organisms unrelated to the dinoflagellates. The former genus, with its open tubular processes, and the latter with its crests bearing spiny, trifucate processes, seemed remote from dinoflagellate morphology. Over a century after their first discovery (Ehrenberg, 1838; and later), workers were still debating their position (Eisenack; 1954, and later; Deflandre, 1947). Only recently has positive evidence been offered of the dinoflagellate affinity of these fossil cysts (Evitt, 1961; and later). These studies by Evitt and his co-workers provided much fundamental knowledge about dinoflagellate cysts and enabled palynologists to make interpretations of their fossil material in the light of evidence from modern dinoflagellates. Some of these findings are discussed below.

Evitt and Davidson (1964) demonstrated conclusively that many resting cysts of modern dinoflagellates closely resemble fossil forms allied with the hystrichospheres, as well as those already recognized as dinoflagellates. They showed that these cysts are smaller than the motile theca and are formed at a variable distance from the bounding thecal layer. It has further become apparent from their work, that many cysts formed closer to the thecal wall are likely to reflect more of the original thecal morphology. Cysts formed at a relatively greater distance from the thecal wall often develop complex processes which may be interpreted as supportive structures acting to maintain the cyst rigidly within the theca. Evitt and Davidson (1964) specifically showed that the cyst of the modern dinoflagellate *Gonyaulax digitale* (Pouchet) Kofoid could not be distinguished from the fossil genus *Hystrichosphaera*. The cyst was observed in the position hypothesized by Evitt (1961). They further were able to isolate the cyst of *Peridinium leonis* Pavillard and show that it resembled the type of cyst which, if found as a fossil, would be classed as a dinoflagellate. Other authors have isolated and observed the actual excystment of modern dinoflagellates and confirmed that the cyst gives rise to a new motile thecal stage (Rossignol, 1963; Wall and Dale, 1966; Wall *et al.*, 1967).

These results of investigations of modern dinoflagellates have enabled a reappraisal of the structure and morphology of many fossil organic-walled microplankton previously thought to be unrelated to the dinoflagellates. The structure of the genus, Hystrichosphaera, for example, has been re-interpreted as representing a fossil dinoflagellate cyst bearing reflected tabulation of the motile plate system. The boundaries of the plates are outlined by crests or sutures, and the spines arising at the junctions of the crests as well as along them are interpreted as supportive processes for the cyst body. Other fossil genera have been re-interpreted, an important, common form being Hystrichosphaeridium, a genus long the subject of discussion as to taxonomic position (Ehrenberg, 1838; Eisenack, 1954; 1963; Deflandre and Deflandre-Rigaud, 1961). The long tubular processes are suggested as being supportive cyst structures arranged so as to reflect tabulation of the original motile theca, there being one intratabular process per plate (Evitt, 1961). Recently, Davey and Williams (1966a; 1966b) have presented a comprehensive treatment of many of the fossil species assigned to the two genera mentioned above, based on the theoretical and demonstrated evidence of Evitt (1961) and Evitt and Davidson (1964). It should be noted, however, that caution must be exercised in using these criteria in the absence of other supportive evidence. Cyst forms also possess certain other unique features. These structures often provide a more reliable basis for assigning fossil forms to the dinoflagellates.

Archaeopyle Structure - In addition to the reflected tabulation, the processes and the shape of the fossil form, an important feature of the dinoflagellate cyst is the opening through which the organism excysts to form a new motile stage. Many earlier workers observed these characteristic openings, but ignored them or even attempted to reconstruct forms without the archaeopyle in order to figure undamaged forms (Evitt, 1967, p. 3). Evitt (1961) introduced the term archaeopyle to mean the opening in a dinoflagellate cyst left when the cyst ruptures to allow the organism to excyst. Other workers have used various terms in their publications, for example the "Schlüpfloch" of Eisenack (1961), the "okoshchechko" of Vozzhennikova (1965), and the pylome of many authors. Most authors today have adopted the term, archaeopyle, preferring to use the term, pylome, where dinoflagellate affinity is not suggested. Evitt (1967) discusses this point at greater length.

In a recent series of papers, Evitt (1961; 1963a; 1963b; 1967) has conclusively demonstrated that the archaeopyle is not a fortuitous structure, but that it represents an opening formed by the rupture and often the complete loss of certain portions of the cyst wall. The ruptures tend to occur along certain defined sutures, enabling a consistent classification of archaeopyle structures to be developed. Evitt (1967) has outlined more than a dozen varieties and shown that, even in cases where no evident reflected tabulation is present, the archaeopyle opening manifests a characteristic polygonal chape which may be related to certain characteristic plate shapes and positions present on motile thecae. Evitt calls the portion of the cyst wall lost or detached wholly or partially during archaeopyle formation, the operculum. The sutures, along which rupture and formation of the operculum occur, are termed primary, while those resulting from partial rupture of the surrounding plates are called accessory sutures (Evitt, 1967). Where an operculum is divided into two or more opercular pieces, it is termed a compound operculum. Accessory sutures may thus divide the operculum as well as radiate away from the primary suture(s). Evitt (1967, p. 14-16; text-figures. 16-21) discusses other archaeopyle terminology.

While Evitt (1967) has been able to demonstrate the existence of more than a dozen varieties of archaeopyle formation, there are three main types which are found most commonly in fossil dinoflagellate cysts as well as modern cysts. These are: (1) an apical archaeopyle formed by the loss of one or more apical plates; (2) an intercalary archaeopyle formed by the loss of plate 2a, or perhaps plates 1a, 2a and 3a, the compound intercalary archaeopyle type; and (3) a pre-cingular archaeopyle formed by the loss of plate 3". Norris (1965) first noted the presence of the epithecal archaeopyle, where the whole epitheca is lost. A related form is the cingular archaeopyle where the epitheca and cingulum are lost and form the operculum, as in Downie and Sarjeant (1966). Downie and Sarjeant (ibid.) have recently proposed that the terms epitract and hypotract be used when cyst forms are involved, restricting the terms epitheca and hypotheca to motile stages. Thus these archaepyle types are now referred to as epitractal and cingular archaeopyles. Evitt (1967) describes a number of new archaeopyle forms in addition to those mentioned above. Evitt (1967) also defines reduced archaeopyles where the opening is smaller than the boundaries of the reflected thecal suture surrounding it, as well as enlarged archaeopyles where the opposite condition occurs. The reader is referred to Evitt's (1967) paper on archaeopyle and operculum structure for a more comprehensive and detailed discussion of this important feature of dinoflagellate cysts.

The most important conclusion to be drawn from Evitt's work (1961, and later) is that archaeopyle formation and operculum structure are extremely useful diagnostic features in the taxonomy of fossil dinoflagellate cysts. Recognition of an archaeopyle structure in a fossil microplankton form constitutes one of the most important criteria for interpreting this form as a dinoflagellate cyst. The presence of this feature also assures the worker, that no matter how similar the form is to a motile theca in other respects, it must be a cyst form. No thecal stage has ever been observed to possess this structure (Evitt, 1967; other workers).

Wall Structure - Investigations by Evitt (1961, and later) and Evitt and Davidson (1964) have shown that modern cysts have a two-layered wall. Downie and Sarjeant (1966) have proposed the terms periphragm and endophragm to indicate the outer and inner layers of the cyst wall respectively. These authors further state that the processes of most cysts are formed by extensions of the periphragm, although few sections have been produced to substantiate this view. The author feels that some dinoflagellate cysts found as fossils may have a two-layered wall and that some may exhibit processes formed in this manner. However, the extension of Evitt and Davidson's (1964) findings to all fossil cysts is not yet warranted. Sections, separation along layers, and sometimes the observation that processes do not communicate with the interior cyst cavity, may demonstrate the presence of a double layered wall in a fossil form. Some fossil cysts, termed cavate by Downie and Sarjeant (1966) show a marked separation of layers. In this case, the inner layer has also been called the capsule by Evitt (1961). This condition is characteristic of many fossil genera, for example *Deflandrea*. In some fossil genera, the inner layer may bear supporting rods which connect the inner layer to an outer generally thinner layer; such forms, typified by the genus *Chlamydophorella* are termed membranate (Davey, *et al*. 1966). Other variations in wall structure are summarized in Davey, *et al*. (1966).

Little is known about the actual chemical composition of the cyst wall. Eisenack (1963), in a review of the hystrichosphere forms, noted that the wall is not chitinous, pseudochitinous or cellulosic, and suggests that it may be a polyterpene or a condensate of unsaturated organic acids. Evitt and Davidson (1964) suggest that the cyst wall is formed of some organic material, probably not cellulose, although they noted faint birefringence under polarized light in some cysts of the modern material they examined. Cellulose structure produces a characteristic birefringence under crossed nichols, and in contrast to cysts, is probably the main constituent of thecal walls.

Process Emplacement and Tabulation - In many fossil dinoflagellate cysts, the reflected tabulation is indicated directly by sutures which correspond to the original outline of the plates on the motile form. Some modern cysts of *Gonyaulax* also exhibit this type; similar fossil forms are referred to the genus *Gonyaulacysta* Deflandre 1964.

Cysts of this type have been termed *proximate* by Downie and Sarjeant (1966). The fossil genus, *Hystrichosphaera* retains the sutures reflecting plate boundaries but has in addition, complex processes arising from the sutures at the junction of suture crests (*gonal processes*) and along the sutures. Downie and Sarjeant (1966) propose the term *proximo-chorate* for these cysts.

Many fossil cysts, however, bear processes which are not so easily related to plate boundaries. These may be divided into two main categories: the *intertabular* type where processes are arranged along reflected plate boundaries; and the *intratabular* type (Evitt, 1963a) where the processes occur in part or in whole within the central area of the plate. Evitt (1963a) has also introduced the term *sutural* and his term corresponds to the intertabular processes of this thesis. Because of the confusion of sutural processes with sutures, the author proposes that intertabular be substituted. Thus the sutures of *Gonyaulacysta* and *Hystrichosphaera* are intertabular. Intertabular processes may also develop as isolated, to partly or wholly connected spines, cones, and other processes. Intratabular processes may be distributed one per plate and open, tubular, flared or unflared as in many species of *Hystrichosphaeridium*, or spine-like, closed and greater than one per plate in number. In the later case, the reflected plate boundary may be marked by narrow to broad barren regions on the cyst wall. Other forms like *Aeroligera* may possess membranous or fenestrate complexes arranged in various ways and paralleling the plate boundaries in part or whole. A comprehensive summary of the common types of intratabular processes is given in

Downie and Sarjeant (1966). Finally, mention may be made of *trabeculate* cysts in which processes arising from the cyst wall are interconnected at the distal ends to form a fenestrate canopy of variable density (for example, *Cannosphaeropsis*).

This discussion is intended to be no more than an introduction to the major features of dinoflagellate cyst morphology. For further details and more comprehensive treatments, the reader is referred to Evitt (1961, and later) and to the papers contained in Davey, *et al.* (1966). Taxonomy of fossil dinoflagellate cysts is based for the most part on the characters described above. Thus a discussion of dinoflagellate morphology has of necessity preceded a discussion of taxonomic questions occasioned by fossil cyst forms.

## THE RECOGNITION OF FOSSIL DINOFLAGELLATE CYSTS

In the preceding section certain general aspects of the morphology of fossil and modern dinoflagellate thecae and cysts were discussed. These morphological features provide a basis for recognition of fossil dinoflagellate cysts and thecae in the fossil record. In the following paragraphs, some indication of the diagnostic value of certain morphological characteristics in the recognition of fossil dinoflagellate cysts is presented.

### Archaeopyle and Operculum Structure

The presence of archaeopyle and operculum structure is one of the most important criteria for distinguishing fossil specimens as dinoflagellate cysts. Recognition of archaeopyle structure is based on the outline of the opening, the shape of the opening and the presence of primary and secondary sutures (accessory sutures). Where the operculum is still partially attached, the type of archaeopyle may be determined quite readily. When the operculum is completely detached and missing, the shape of the archaeopyle opening often allows precise determination of the type of archaeopyle developed. Such a determination helps in the orientation of the cyst and in the interpretation of other features present on the cyst. For example, an apical archaeopyle may show a zig-zag outline corresponding to an operculum formed of one to four apical plates, accessory sutures, and a sulcul notch indicating the junction of the longitudinal furrow (sulcus) and plate 1' of the apical series (Evitt, 1967; Fig. 16). A simple intercalary archaeopyle, formed by the loss of plate 2a, has a characteristic hexagonal shape, the "hoof-shaped pylome" of Cookson and Eisenack (1958, and later), in part. It must be emphasized that irregularity of outline exhibited by an opening does not constitute evidence of an archaeopyle structure. These outlines must be related to other evidence, determined from presence of reflected tabulation, development of accessory sutures, and from position of the opening with respect to other cyst structure.

The archaeopyle is the most useful feature for separating dinoflagellate cysts from other similar microplankton forms, and from thecal stages (Evitt, 1967; Evitt and Davidson, 1964). The confirmed presence of this feature alone is sufficient to assign the specimen to the dinoflagellates. The writer thinks, based on evidence presented in Evitt (1967), that when a population of specimens having identical morphology is found, some with and some without recognizable archaeopyle structure, this alone is sufficient to assign all the specimens to the same species. Further, where specimens having otherwise identical morphology differ in archaeopyle formation, the writer thinks that this is a sufficient indication that two different cyst taxa are involved. These views are supported tacitly or explicitly in many recent papers (Norris, 1965; Drugg, 1967; Davey, *et al*. 1966; and others). Such a view of the archaeopyle as being so important has only recently developed, mainly as the result of the detailed investigations of Evitt (1961, and later).

### Evidence from Tabulation

Fossil dinoflagellates may not exhibit archaeopyle structure. They may, however, possess other features which aid in their assignment to that group. One important criterion is the presence of some form of reflected tabulation. Fossil forms with well developed intertabular sutural crests and those with intratabular processes closely paralleling reflected plate boundaries may be referred to the dinoflagellates with reasonable confidence. In all likelihood they represent cysts of fossil dinoflagellate forms. Where the processes can be correlated with tabulation patterns consistent with dinoflagellate affinity, even though discretely arranged (as in type *23310* of this thesis), assignment to the dinoflagellates is not likely to prove incorrect. However, as the processes dwindle in number, whether they are gonal and intertabular as in *Achomosphaera* or intratabular as in *Oligosphaeridium*, or where they become great in number as in *Polysphaeridium*, assignment may have to be made in conjunction with other criteria. Although the position and type of process may give some evidence as to the orientation of the fossil entity, or some indication that the entity is a cyst with processes reflecting tabulation, the risk of assigning such forms to the dinoflagellates without confirmatory evidence, usually archaeopyle structure, becomes great.

## Presence of Cingulum and Sulcus Structure

The presence of furrow structures is a reliable criterion for assigning fossil organic-walled microplankton to the dinoflagellates. Where a complete reflected tabulation is preserved on a cyst, the cingulum and sulcus are easily recognized. In many specimens, the reflected sulcul plate sutures may be noted. As with tabulation, furrow structures may be outlined by raised sutural crests, ridges, rows of processes or process complexes, or by barren regions corresponding to the position of a cingulum or sulcus, as in *Cyclonephelium* and many fossil genera. The cingulum may also have plate septa or, as in *Achomosphaera*, processes corresponding to reflected tabulation present in the cingular region. In some forms like *Oligosphaeridium*, processes are absent from the cingular region. In other cysts, like *Fromea amphora* Cookson and Eisenack 1958, the position of the reflected cingulum may be represented only by a change in colour or thickness of the wall. Other types may possess only a consistently folded region in the expected position of the cingulum, which taken in conjunction with other evidence may suggest the interpretation of a reflected transverse girdle.

## Shape of the Cyst

Shape is perhaps the least reliable character on which to base an identification of dinoflagellate affinity. In the absence of other characters, it may be possible however to assign a specimen to the dinoflagellates on this basis alone. The cyst of the modern dinoflagellate Peridinium leonis Pavillard as illustrated in Evitt and Davidson (1964, pl. 1, fig. 9), were it to possess no girdle or archaeopyle, might be recognizable as a dinoflagellate stage. The cyst of Protoceratium reticulatum Claparède & Lachmann, however, without an archaeopyle, would not be recognizable as having definite dinoflagellate affinity (ibid.; pl. 1, fig. 12). It must also be remembered, using this latter case as an example, that one may also discard the possibility that an entity may belong to the dinoflagellates because of its shape. This would also be in error.

Fossil dinoflagellate genera like Canningia possess a pentagonal or rhomboidal outline with the usual apical and often two antapical prominences. In contrast, genera like Muderongia or Chlamydophorella exhibit a different organization. Shape is probably more of a confirming characteristic than a diagnostic feature.

## THE GROUP ACRITARCHA EVITT 1963

The question arose: what is to be done with those forms considered as marine microplankton but not assigned to the dinoflagellates? As many earlier workers had pointed out, these incertae sedis forms probably belonged to many unrelated or only remotely related groups (Deflandre 1947), although Eisenack (1954) suggested a monophyletic origin. Included in this grouping were the genera, Hystrichosphaera and Hystrichosphaeridia and related forms, and this complex became known general as the "hystrichospheres". Evitt (1963a), basing his views on his detailed earlier studies (Evitt, 1961), placed these <u>hystrichospheres sensu stricto</u> in the Dinoflagellata, creating and emending respectively, two new families, the Hystrichosphaeridiaceae and the Hystrichosphaeraceae, and restricting the term "hystrichospheres" to these families. For the "residue" of forms, not considered dinoflagellates but commonly treated with organic-walled microplankton, Evitt (1963b) proposed an informal Group, the Acritarcha, the term being derived from the greek roots meaning "uncertain origin". In a related paper, Downie, Evitt and Sarjeant (1963) classified all of the genera then referred to this group into thirteen subgroups, each based entirely on morphological criteria. At that time, the members of the fossil algal group, the Tasmanaceae, were also included but have since been referred to the Chlorophyceae by Wall (1962) and in Norris and Sarjeant (1965). It is thus incorrect to speak of "acritarchous hystrichospheres" as is done in the paper by Staplin, Jansonius and Pocock (1965).

Certain problems exist involving taxonomy and nomenclature in the Group Acritarcha, but discussion of these points will be deferred to later sections. These difficulties involve both dinoflagellates and acritarchs and are better treated with reference to fossil microplankton as a whole.

## Morphology of the Acritarcha

As may be expected of an informal Group of unrelated or remotely related entities, the morphology of the acritarchs is very variable. A complete diagnosis of each morphological subgroup may be found in Downie, *et al.* (1963). The writer presents below, his own key to the various subgroups, based on diagnostic morphological characters drawn from the diagnoses of Downie, et al. (1963):

Key to the Subgroups of the Acritarcha

A' With an inner body..........................................A"

a' Non-flattened, spherical...........DISPHAEROMORPHITAE

a" Flattened or fusiform.................................b'

b' Flattened, non-fusiform............PLATYMORPHITAE

b" Fusiform shape....................DINETROMORPHITAE

A" Without an inner body.

c' Ornamented with distinct processes....................c"

d' Processes concentrated at particular regions...........d"

e' Processes present at two poles......DIACROMORPHITAE

e" Processes present at one pole.......OOMORPHITAE

d" Processes not concentrated at particular regions.......f'

f' Processes consisting of crests or corona..............f"

g' With crests subdividing fields......HERKOMORPHITAE

g" With corona and other occasional processes....STEPHANOMORPHITAE

f" Processes discrete or only slightly fusing............h'

h' Test spherical or ovoid............ACANTHOMORPHITAE

h" Test polygonal.....................POLYGONOMORPHITAE

c" Without distinct processes............................k'

k' With equatorial development of flange or lamella.......k"

l' Test flanged, prismatic or polygonal.........PRISMATOMORPHITAE

l" Test spherical, ovoid, polygonal with lamella..PTEROMORPHITAE

k" Without equatorial development........................m'

m' Fusiform or elongate test..........NETROMORPHITAE

m" Spherical or ovoid test............SPHAEROMORPHITAE

### Other Observations

In the diagnoses of these subgroups, Downie, *et al*. (1963) refer to the acritarch bodies as *tests*. In this thesis, the term *vesicle* will often be used, and means the same as test.

## TAXONOMY OF FOSSIL DINOFLAGELLATES AND ACRITARCHS

### Classification - Dinoflagellates

Modern dinoflagellates present a wide variety of characters to the taxonomist. There are morphological characters for both the motile and cyst stages, cytological, physiological and ecological criteria on which to base a classification (Bursa, 1964; and others). In contrast, fossil dinoflagellates occur as cysts, and perhaps in a few rare cases as fossil thecae. The taxonomic characters are thus essentially derived solely from the morphology of the cyst.

Some cysts appear very similar to modern motile thecae. The cyst genus *Gonyaulacysta* for example closely resembles the modern genus *Gonyaulax*. Other cysts like *Aeroligera* or *Pareodinia* are not immediately relatable to modern genera. Furthermore, it has been demonstrated (Evitt and Davidson, 1964; Wall, 1966) that modern genera such as *Gonyaulax* possess many varieties of cyst forms corresponding to several fossil genera (*Hystrichosphaera*, *Leptodinium* and *Nematosphaeropsis*, to name several). It is also of importance to note that the genus *Hystrichosphaera*, which has been made the type genus for the family Hystrichosphaeraceae (Wetzel) Evitt 1963a, is also a member of the modern family Gonyaulaceae, belonging to *Gonyaulax*. These considerations raise a problem of classification which has not yet been satisfactorily dealt with. Should fossil cysts be classified according to modern families or should they be classified under a separate system, somewhat analogous to the morphographic system adopted for dispersed miospores and megaspores by Potonié and Kremp (1954, and later)? This question, discussed by Deflandre (1964), Sarjeant and Downie (1966), and other workers, occupies much of the discussion presented below in the subsequent sections. Several procedures in response to this question are outlined below.

Eisenack (1958, and later) has classified all forms he considers to be fossil dinoflagellates under existing modern families where possible. Eisenack (1961) also added a number of families based on fossil material, thus following the practice initiated by earlier authors (Deflandre, 1936; Eisenack, 1954; Gocht, 1957). Vozzhennikova (1961; 1965) has developed a somewhat similar classification to that presented by Eisenack (1961; 1962; 1964). Her classification scheme presents several new families and in addition proposes a superfamilial framework.

On the other hand, Sarjeant and Downie (1966) have stated a case for classifying fossil cysts in terms of "cyst-families", based on the morphology of the cysts, and having fossil type genera. These authors suggest that such a scheme would avoid the problems raised by such genera as Hystrichosphaera, mentioned earlier, and would provide a clear distinction between groupings of cysts and groupings of motile forms.

It may be noted here that nomenclatural considerations further complicate those of classification. This aspect of the taxonomy of fossil dinoflagellates, while interrelated with the foregoing discussion, is deferred for convenience to a later section.

## Classification - Acritarcha

Evitt (1963a) left no doubt that he considered the Acritarcha to be an informal grouping of unrelated entities. He also pointed out that such a policy seemed the best course in order to avoid future confusion in taxonomic practice. This informal group thus forms a convenient resting place for organic-walled microplankton of unknown affinities. Downie, et al. (1963) enlarged upon this procedure, erecting thirteen informal subgroups based on the morphology of the test. In deliberately avoiding the designation of type genera for each group, they left ample room for further rearrangement or reassignment of genera elsewhere as further evidence of affinity accumulated. The writer is in complete agreement with the views expressed by Evitt (1961a) and Downie, et al. (1963) and follows their classification in this thesis. It should be noted that while these subgroups are informal, the writer thinks that they should be treated in a systematic manner. Proposals of change in interpretation, erection of new groups, or rearrangement of genera within existing groups should be carried out in an orderly fashion. An analogy would be the treatment of suprageneric categories used in the classification of miospores (Dettmann, 1963).

Eisenack (1938; 1954) proposed several formal families, based on type fossil genera which are also included in several subgroups of the Acritarcha by Downie, et al. (1963). These include the Leiofusidae Eisenack 1938 and the Leiosphaeridiaceae Eisenack 1954 among others. Recently, Combaz, et al. (1967) reviewed the genera assigned to the Leiofusidae and made reference to analogous subgroups of the Acritarcha. These families exist apart from the Acritarcha as formally proposed units, but because the acritarch subgroupings are informal, there is no difficulty involved in terms of synonymy and priority. This example serves as a practical demonstration of the usefulness and convenience of such a system as the Acritarcha. It also serves to point out that Eisenack, like many other authors, has shifted from a zoological to a botanical classification for formal units, the ending -idae being a zoological one and -aceae being a botanical form. It leads also to the next part of the discussion, which concerns both acritarchs and dinoflagellates in its implications.

### Nomenclature of Fossil Microplankton

A review of the extensive literature on the taxonomy of fossil microplankton indicates that past authors have classified their material at various times under the International Code of Zoological Nomenclature (hereafter abbreviated to ICZN) and under the International Code of Botanical Nomenclature (ICBN). Eisenack (1961), for example, indicated that he preferred to use the ICZN and used zoological endings for his fossil dinoflagellate and modern dinoflagellate families. Later, Eisenack (1964) published a classification using botanical endings for all the families according to the ICBN. Many examples of similar procedure could be cited.

Modern dinoflagellates are classified under the ICBN (Chatton, 1952; other workers) and are subject to the articles of that Code. Downie, Williams and Sarjeant (1961) recognized this and proposed for this and other reasons that all fossil microplankton be treated under the ICBN. Downie, Evitt and Sarjeant (1963) in proposing informal subgroups for the Acritarcha, re-iterated that position and advanced further arguments to support the view. Most papers published subsequently have adopted these proposals.

Although the ICBN has been adopted as the framework of classification for fossil microplankton, nomenclatural problems created by the transfer from one Code to the other have not always been satisfactorily resolved. Minor problems, such as the formulation of a junior homynym created by transferal of a genus valid under the ICZN to the ICBN system, may be easily rectified. An example of this is the acritarch genus, *Diplotesta* Cookson & Eisenack 1958, valid under the ICZN, but a junior homynym to the form-genus for seeds, *Diplotesta* Brongniart 1874 under the ICBN. Recently, Loeblich and Loeblich (1968) proposed a new name, *Wallodinium*, for *Diplotesta sensu* Cookson & Eisenack and thereby resolved the conflict. Other problems raised by the transfer of forms from the ICZN to the ICBN system are not always so easily solved. The ICZN and ICBN differ markedly with respect to their articles on typification, validly published taxa and in other details. Finally, there is a legitimate objection to be voiced to the removal of all forms of the Acritarcha to the ICBN system. It must be remembered in connection with this that in all probability the Acritarcha comprise in part forms which are animal in origin. A valid argument exists against their removal to a botanical code, even though acritarch forms cannot be related with certainty to the animal kingdom.

The views of the writer, however, parallel those of Downie, et al. (1963), and in this thesis, the Acritarcha will be treated under the ICBN. In connection with this, it is appropriate to quote Principle I of the International Code of Botanical Nomenclature (Lanjouw, ed., 1966; p. 16):

> "Botanical nomenclature is independent of zoological nomenclature.
>
> The Code applies equally to names of taxonomic groups treated as plants whether or not these groups were originally assigned to the plant kingdom."

The situation with regard to the question of fossil dinoflagellate nomenclature is considerably more complicated. Article 3 of the ICBN (Edinburgh, 1966) makes provision for what are termed "organ-genera" and "form-genera". An organ-genus is defined as being assignable to a family. A form-genus, "artificial" to a varying degree, cannot be assigned to a family but is often assignable to a higher taxon. In the ICBN (Montreal, 1961), Recommendation 18A also proposed that a form-genus could not be used to typify a family. This recommendation has not been adopted in the Edinburgh Code (Stafleu, 1966; p. 41) and appears nowhere in the text (Lanjouw, ed., 1966). The problems envisaged by Sarjeant and Downie (1966), when form-genera are used to typify fossil families, does not exist in view of the rejection of Recommendation 18A. Thus the procedure of Eisenack (1961; 1964) and other authors, of creating fossil families with form-genera as types must remain valid. The question of the status of genera created for fossil cyst forms, on the other hand, remains unanswered.

Some fossil dinoflagellate cyst genera, like Hystrichosphaera, have been found in part to be cysts of modern motile forms of Gonyaulax (Evitt and Davidson, 1964). In contrast, some cyst genera cannot be confidently assigned to any "natural" taxon below the rank of order. The cyst genus Pareodinia may be considered as an example of this type. Hence Hystrichosphaera, created as a fossil genus, and type of the fossil family Hystrichosphaeraceae (Wetzel) Evitt, is assignable to a natural family, the Gonyaulaceae. It should be considered then, by definition of the ICBN to be an organ-genus. Pareodinia, on the other hand, another fossil cyst genus cannot be assigned to a natural family and must be considered to be a form-genus by definition. It may be used, as practice has shown, to typify a fossil family, the Pareodiniaceae (Gocht) Norris and Sarjeant; it is therefore assignable to a fossil family. Does this then make it an organ-genus? Another genus, Deflandrea, provides a further illustration of the complicated nature of this problem. Some species of Deflandrea, identical in all other respects to the genus diagnosis, show evidence of reflected tabulation identical to that of the modern genus, Peridinium (Manum, 1962), while other species do not possess this character. By extension of the reasoning above, part of this genus is made up of species which would allow its definition as an organ-genus and part which would characterize it as a form-genus. Many cases similar to this exist (Sarjeant and Downie, 1966).

Sarjeant and Downie (1966) adopt a different interpretation of the terms organ-genus and form-genus with respect to fossil dinoflagellate cysts. They observe that (Ibid., 1966: 508):

> "The Code nowhere suggests that the cysts of unicellular organisms would constitute organ-genera; and in no case has any fossil dinoflagellate genus been specifically stated to be an organ-genus.
>
> Thus most specialists would agree that genera based wholly on dinoflagellates must of necessity be regarded as form-genera..."

In an attempt to resolve the anomalies of the present classification systems outlined above, Sarjeant and Downie (1966) proposed an alternative system consisting of what they termed "cyst-families". These authors left no doubt that these were formally proposed families, as they took care to typify each family with a cyst genus. The families thus created must be considered in a different light to those subgroupings of the Acritarcha (Downie, et al., 1963), although both schemes are based solely on the morphology of the cyst or vesicle respectively. In the writer's opinion, this point alone seriously undermines the major advantage of such a cyst-family classification, which is the provision of a resting place for fossil cyst genera of unknown affinity, a purpose analogous to the one served for organic-walled microplankton of unknown affinity by the informal Group, Acritarcha. Unfortunately, as tacitly recognized by the authors in their citation of many cyst-families, partial synonyms exist and in addition, previously recognized families which were validly published (such as the Microdiniaceae Eisenack 1964) are retitled "cyst-families". The author thinks that had this system been proposed as a collection of informal groups, based on cyst morphology, rather than as formally typified families, the contribution to the solution of the problems discussed earlier would have been much greater.

It has become apparent from the preceding discussion that the solution to the problems relating to the status of fossil cyst genera and their assignment to existing or newly proposed families, cannot be solved readily at this time. Fossil cyst forms may not always be confidently assigned to modern dinoflagellate families. Placing a fossil cyst genus into a modern family presupposes that there is compelling evidence for so doing. Referring the cyst form to a modern genus must therefore require even more rigorous evidence. Yet examples have been cited which demonstrate that all shades of confidence actually exist in relation to such assignments.

Some modern forms have been shown to possess several types of cysts assignable to more than one fossil cyst genus. The question arises: what is the phylogenetic significance, if any, of different cyst forms occurring in the life cycle of genus? Are these differences phenotypic or do they indicate that such "natural" entities as Gonyaulax are themselves a convenient combination of closely related types having a similar motile stage? A corollory to this question may be asked: which stage is in fact the most significant in terms of taxonomy? The motile stage has always been tacitly considered as the important one, but is this necessarily so? This question has also been discussed by Wall and Dale (1967) in their paper on resting cysts of modern dinoflagellates. Wall (1966) offers a different possibility, that several cyst stages may be present in the life cycle of any given motile species. The answers to such questions cannot be formulated at this time, nor is it possible within the scope of this thesis to do so. The writer feels, however, that it is important to state these queries explicitly. Their solution is properly the ultimate goal of all fossil and modern dinoflagellate studies.

## Taxonomic Procedures Adopted in this Thesis

Previous sections have been concerned with the discussion of relevant problems in the taxonomy of fossil dinoflagellates and acritarchs and the relation of these groups to modern dinoflagellates. The points raised in that discussion have led the author to adopt these procedures in taxonomy in this thesis:

1) Organic-walled microplankton (fossil dinoflagellate cysts and acritarch tests of unknown affinity) encountered in this investigation will be classified under the articles of the International Code of Botanical Nomenclature (Lanjouw, ed., 1966).

2) The informal classification of the Acritarcha proposed in the papers of Evitt (1963a) and Downie, _et al_. (1963) will be employed here.

3) Genera based on the morphology of dinoflagellate cysts and acritarch tests are considered as form-genera subject to all the provisions of the ICBN.

4) The ICBN (Edinburgh Code, 1966) does not explicitly state that form-genera may not be the types of fossil families. It states that the form-genera are those unassignable to families. No provision is made for unicellular organisms like the dinoflagellates. Hence, the author proposes to consider families based on fossil cyst genera as valid taxa, subject to the future clarification of the contradiction contained in Article 3 of the ICBN (Edinburgh Code, 1966).

5) Where considerations of priority and synonymy do not obtain, the "cyst-families" proposed in Sarjeant and Downie (1966) must be considered valid according to point (4). Such families will be termed "family" rather than "cyst-family" in this thesis.

6) The writer thinks that one of the more plausible solutions to the problems of classification and nomenclature discussed earlier would be the introduction of an informal cyst classification, similar in intent to the Acritarcha, but constructed on the basis of dinoflagellate cyst morphology. Such action seems, in the view of the writer, to have been the intent of the scheme introduced by Sarjeant and Downie (1966), but this intention was incorrectly developed.

# II

# THE TAXONOMY OF DISPERSED MIOSPORES

## DESCRIPTIVE MORPHOLOGY OF DISPERSED MIOSPORES

The morphological characteristics of spores and pollen grains are the concern of every phase of palynology, whether the investigator be engaged in a biostratigraphic study of a Mesozoic dispersed miospore assemblage, or in the preparation of a monograph on the pollen of a modern angiosperm family. The increased interest in all phases of palynology has led to a proliferation of terms, definitions and morphological classification schemes having reference to spores and pollen grains. These are scattered throughout the literature in papers dealing with miospores of all geological ages. It would be beyond the scope of this thesis to present even a simple outline of all of the common terms and definitions now in common contemporary usage. Detailed glossaries treating these terms may be found in many publications including Potonié and Kremp (1954 and later), Harris (1955), Dettmann (1963), and particularly in The Morphologic Encyclopedia of Palynology (Kremp, ed., 1965). This latter publication collects in one volume most of the terminology of palynology with reference to miospores and megaspores published before 1965, and includes reproductions of many of the original illustrations of morphological terminology.

It is useful here to indicate the major features of miospores which form the basis of descriptive schemes, and which may or may not have taxonomic value in individual cases for the allocation of grains in a natural system of parent plants. The major morphological characters, which must be considered in any description of spores and pollen grains are: the type of germinal aperture and its structure; the structure of the wall layer(s) and their relation to each other; the sculpture elements present on the wall layer(s); the shape of the grain in polar, equatorial or other orientation; and the diameter of the grain and size ranges of other sculptural and structural features exhibited by the grain. Palynologists also make a fundamental distinction between the structure of the spore or pollen grain, the form and arrangement of the elements within the sclerine (sporoderm excepting the intine) and the sculpture, the form and arrangement of elements external to the sclerine.

The following sections of this chapter will be devoted to a critical discussion of aspects of the classification and nomenclature of dispersed miospores, taking into account the points mentioned above.

## CLASSIFICATION OF DISPERSED MIOSPORES

Classification as opposed to nomenclature of dispersed miospores is essentially concerned with suprageneric groupings or frameworks designed to bring some order to the vast amount of data accumulated from the proliferation of dispersed miospore form-genera. The following paragraphs perhaps have more bearing on generic than on suprageneric classification but are included in this section because they set forth the essential background necessary to understand the need for a morphological classificatory and nomenclatural system.

## Provenance of Dispersed Miospores and Classification

Fossil spores and pollens of all geological ages are most commonly found dispersed in an enclosing matrix of rock, coal, peat, salt, or other consolidated to unconsolidated sedimentary deposit. It is only relatively rarely that reproductive organs, bearing spores or pollen grains, and attached to an identifiable macrofossil plant, are recovered and described. The literature contains a vast quantity of descriptions of miospore genera, but few of these are relatable to their parent plant. Many fossil miospores of Tertiary or younger age are often assignable with some confidence to living families and genera, particularly if use may be made of a modern reference collection made up of relevant material. In contrast, the majority of pre-Tertiary miospores are rarely assignable on this basis to a taxon lower than family. The risk of serious error increases as the age of the enclosing matrix becomes older and the parent plant groups are formed more and more of extinct forms. Evidence from reproductive structures of these extinct groups often provides a means of assigning some of these pre-Tertiary miospores to contemporary plant groups. In most cases, however, the only solution to classification of these miospores is an artificial system based on their morphology.

Despite the uncertainty and risk of serious error involved, many authors have persisted in placing fossil miospore species recovered from early Tertiary and pre-Tertiary deposits into modern genera. Examples of this procedure may be found papers by Bolkhovitina (1953), Samoilovich, et al. (1961), Stanley (1965) and many others. Such practice has often resulted in needless confusion and necessitated numerous nomenclatural changes. There are both advantages and disadvantages where this approach is used to classify late Tertiary miospores. The paper by Traverse (1955) on the Brandon Lignite of Vermont illustrates this point. Traverse, using a modern reference collection of pollen and spore types was able to make assignments of his dispersed species with some confidence to living genera. Then, making the assumption that ecological preferences had not appreciably changed between the time the Brandon lignite was deposited and the present day, he was able to suggest an ecological interpretation of his data based on the affinities of the miospore assemblages. The danger inherent in this type of approach remains that the investigator must base his assignments of generic status solely on the similarity of miospore morphology. Incorrect assignments could lead to mis-leading results. The writer also questions the validity of creating new fossil species assigned to modern genera, based only on fossil pollen grains. Nevertheless, this study remains an example of the extent to which modern material may be used in the interpretation of fossil miospore assemblages in Tertiary and pre-Tertiary deposits.

An alternative approach used by many workers has been to erect classification schemes based entirely on the morphology of dispersed miospores. Some of these schemes have been of great value in reducing the vast amount of data to some useful order. Other schemes, by virtue of their extreme nature, and because of the disregard of the authors of the rules of nomenclature contained in the ICBN, have created as much confusion as the placing of dispersed miospore species into modern genera.

Many such schemes have been proposed in the literature and these are discussed in Dettmann (1963), Pierce (1961) and other papers. Three of these are discussed in the following section in order to indicate desirable and undesirable approaches to the question of morphological suprageneric classifications.

## Discussion of Some Suprageneric Classification Schemes

Van der Hammen (1956a; 1956b) recognized the difficulties and potential sources of mis-information inherent in the practice of assigning fossil miospore species to modern genera and families. He therefore proposed than an entirely artificial scheme be adopted based on the morphology of the miospores and using the terminology of Iversen and Troels-Smith (1950). Van der Hammen diagnosed a number of form genera and form subgenera, providing each genus with a type form species and each species with a holotype. The position of the form genus in a general scheme was indicated by a key. Unfortunately van der Hammen's work suffers from a lack of observance of the rules of the ICBN. His systematic section ignored all earlier genera which had been validly published and his type species were typified by a pollen or spore specimen of a modern living plant species. In doing so, he in fact referred his type species and therefore genus to the modern genus and species, the names given to his miospore form genera being superfluous when published (ICBN; Lanjouw, ed., 1966; Article 63 and also cf. Article 58). Van der Hammen (1956a, p. 69) stated: "...we give our spore-system here only as a proposal, not describing the genera on the basis of type-species, and leaving acceptance or rejection of this system to specialists..." By saying this, van der Hammen apparently thought that this made his proposals informal and not validly published or legitimate. But later, he states (Ibid., p. 77): "The following section includes the type-descriptions of the artificial genera...and the description of their type-species...." Further, as already noted, each form species is typified explicitly by a holotype. Thus van der Hammen's proposals must be taken as intended and not invalid under Article 34 of the ICBN (Lanjouw, ed., 1966).

Pierce (1961), after an extensive review of various classification schemes and nomenclatural procedures, proposed the adoption of a purely artificial classification system similar in intent to that of van der Hammen (1956a; 1956b). Pierce provided a more formally arranged suprageneric classification divided into Sporites and Pollenites. The former was subdivided into Triletes and Monoletes and the latter was divided into seven sub-classes. Pierce provided each newly proposed form-genus with a diagnosis, a type species and the type species was diagnosed and described on the basis of a type specimen. Unfortunately, Pierce disregarded the rules of priority contained in the ICBN and it is now apparent that many of his genera and species are synonymous with earlier validly published genera and species. Pierce did use, however, fossil material for his typification of species and some of his nomenclature has been retained by later authors. A second shortcoming arises from the lack of a comprehensive suprageneric framework. A third stems from the belief of Pierce that his system could be used to classify any type of dispersed miospore. Pierce, however, failed to take into account the extremely diverse construction of fossil miospores, especially many of the pre-Mesozoic forms, and thus his system fails from a lack of flexibility. Finally, many of his generic diagnoses are so broad as to overlap many earlier suprageneric categories put forward by other authors.

A further disadvantage in the schemes of van der Hammen (1956a; 1956b), Pierce (1961), Pant (1954) and other authors is their failure to erect a suprageneric framework based on some logical system, preferably the basic differences in morphology contained under the sculpture, wall structure and aperture among other features. Thus a means is not provided whereby all types of fossil miospores may be fitted into a system regardless of morphology.

The final classification system to be discussed here was first formulated by Potonié and Kremp (1954) and subsequently revised and expanded in later publications by Potonié and Kremp (1955a, 1955b, 1956), Potonié (1956, 1958, 1960 and 1966) and Dettmann (1963). While inconsistencies exist in this system, removed in part by the revisions of Dettmann (1963), it remains in the opinion of the writer, the most comprehensive and logically constructed suprageneric classification of fossil miospores presented in the literature.

In developing the scheme, Potonié and Kremp (1954, and later) attempted to follow the rules of the ICBN with regard to priority and typification, a practice not always followed by palynologists before that time. Some of the opinions of the authors, and later of Potonié alone, have not always been accepted by later workers. Certain nomenclatural proposals and choice of lectotypes were not always agreed upon. The use of the term Triletes as a turma in the classification, for example, is disputed by several authors (Winslow, 1959) who consider it to be a validly published genus of fossil spores. However, the basic concept of the classification scheme has not really been disputed.

The strength of this classification system lies in its flexibility, its ability to absorb useful components of other schemes (Pant, 1954; Naumova, 1939; 1953), and the comprehensive and logically constructed suprageneric framework provided for the classification of the gamut of dispersed miospores from Silurian to sub-fossil deposits.

The original suprageneric framework, unlike other schemes, incorporated the basic features of all miospore types outlined at the beginning of this chapter. There were inconsistencies in the manner in which these were employed, but these did not prove to be serious defects, and have in large part clarified by the work of Dettmann (1963). Dettmann (1963) pointed out that some of the suprageneric categories set out in Potonié and Kremp (1954, and later) were based on more than one diagnostic character. One result of this was that spores of similar morphology could be classified in

TABLE 5. A comparison of the diagnostic features used to delineate ranks in the morphographic system of Potonié and Kremp (1954) compared to those used in Dettmann (1963).

| RANK | DIAGNOSTIC FEATURES (SPORITES) | |
|---|---|---|
| | Potonié & Kremp | Dettmann |
| Turma | Aperture, lip and equatorial features | Aperture |
| Suprasubturma | ---------- | Wall stratification |
| Subturma | Stratification, lip, and equatorial features | Equatorial features |
| Infraturma | Sculpture, lip, and equatorial features | Sculpture<br>Equatorial features |

separate categories depending on the view of the author. Her criticism was limited to the anteturma Sporites and there are doubtless similar inconsistencies contained in the anteturma Pollenites, but this question cannot be pursued here.

Dettmann (1963) established the suprageneric categories on the basis of one morphological feature (See TABLE 5.) and erected a new suprageneric category, the suprasubturma, in order to accommodate the character of wall stratification. Only in the infraturma did she allow more than one character to remain as a diagnostic feature. Dettmann (1963) proposed the creation of suprasubturmas incorporating the term "cavate", as in Acavatitriletes and Cavatitriletes. Unfortunately the term "cavate" has also been used by Faegri and Iversen (1950) to mean the space left by separation of the ektexine (sexine) from the endexine (nexine) in saccate pollen grains. Harris (1955) has extended the use of this term to spore wall layers and Dettmann (1961; 1963) also has used it in this sense. Cavate as used in this thesis describes an asaccate spore which exhibits partial to complete separation of wall layers, _sensu_ Dettmann (1961).

The suprageneric categories proposed by Potonié and Kremp (1954, and later) and those adopted from other classifications have been treated by these authors as though they were formally proposed taxa, although they recognize that they are informal and not subject to the rules of priority under the ICBN. Other authors have also followed this trend, although some workers (Kosanke, 1967) have criticized this procedure. The writer welcomes this restraint on the proliferation of suprageneric categories. While the procedure is not under formal rules of the ICBN, it does have the effect of imparting a certain stability to the suprageneric system. Such a policy will be followed in this thesis.

## NOMENCLATURE OF DISPERSED MIOSPORES

### Organ- and Form-taxa

Nomenclature of dispersed miospores operates at the generic and species level. It is here that the rules of the ICBN dealing with priority, typification, valid publication and other procedures are applicable. The ICBN recognizes two types of genera in relation to fossil plants: the organ-genus, assignable to a family; and the form-genus, unassignable to a family but often assignable to a taxon of higher rank. It may be recalled that these types of genera were discussed in relation to dinoflagellate cysts and modern motile thecae. The situation with respect to miospores is somewhat different. Miospores represent only some of the sporogenous cells of a complex multicellular plant body. Dinoflagellate cysts comprise the complete stage of one part of the life cycle of an acellular (unicellular) organism.

The various extremes of procedure in treating fossil miospore genera and species have been discussed earlier. Those workers who assign miospore species to a living genus or family are essentially creating "organ-taxa". On the other hand, those who create new generic and specific taxa without reference to botanical relations at the familial or lower level are proposing form-taxa according to the definitions of the ICBN. The writer points out that it is conceivable that some workers may create species and assign them to families while others may not <u>within</u> the same generic concept (compare the treatment of Singh (1964) with that of Norris (1967) of the genus, <u>Cicatricosisporites</u>). In essence, however, both procedures must take into account the morphology of the fossil miospore species. The worker in either case must make a decision based on morphology and in reality is creating a "form-taxon" in both cases. What is actually being indicated is the confidence with which a given miospore species is being assigned or not assigned to a living family. The writer poses this question: is it not more arbitrary to decide when a miospore species becomes part of an organ-taxon rather than a form-taxon, then it is to create a so-called "artificial" form-taxon? While the organ-taxon concept may have validity where multicellular components of a fossil plant are concerned, does it strictly apply to single-celled representatives of sporogenous tissue? In the view of the writer, the only true miospore organ-genus is one described on the basis of a population of spores or pollen grains derived from an attached reproductive organ. Here the recovered miospores may be referred to the fossil plant and the limits of morphological variation of this miospore population may be determined with respect to the sample from that plant. Dispersed miospores, in the opinion of the writer, recovered from deposits of Silurian to late Tertiary age, are properly assignable only to form-taxa, accompanied by an indication of their botanical affinity if this may be stated. The similarity to spores or pollen grains of a natural familial or generic taxon should not be assessed in the naming of the form. A few examples of misleading names should suffice to indicate the confusion engendered by this procedure. Equisetosporites (Daughtery) Scott 1960 is more likely allied to the Ephedrales than the Equisetales; the original material was mis-interpreted (Daughtery, 1941; Scott, 1960). Eucommiidites (Erdtman) Couper 1958 is not a pollen genus related to the modern angiosperm genus, Eucommia, as the name might suggest. Couper (1958) and Hughes (1961) have since shown that pollen grains of this type are probably related to a gymnosperm form.

Many authors have suggested that a morphological system of form-genera cuts across and obscures natural affinities. Chaloner (1959) cites the case of the finding of spores assignable to two different form species in a sporangium of *Sigillaria*. The writer can see no conflict here. There is nothing to prevent an author from stating that the form species he is dealing with has been noted in reproductive organs of a given fossil plant or is very similar in morphology to spores or pollen grains of a living form. Conversely, there is nothing to prevent authors from describing miospores *in situ* and noting that they belong to one or more form species (Brush and Barghoorn, 1965; Bonamo and Banks, 1966). The difficulty results from the failure of many workers to separate the concepts of natural affinity and morphological classification and to define which one they are speaking of at any given time. This failure or reluctance on the part of many workers led to a great nomenclatural tangle which very nearly caused a breakdown of palynological nomenclature with respect to miospores.

## The Naming of Genera and Species

Potonié (1931) began the modern phase of miospore nomenclature by defining a second extremely broad fossil miospore genus, *Pollenites*, in addition to the two existing ones, *Triletes* Reinsch 1881 and *Sporites* H. Potonié 1893. It may be noted here that, except for *Triletes*, these genera have ceased to be used in generic assignments, except in an informal sense. All three names were used by Potonié and Kremp (1954) as names of informal ranks in their morphological classification system. *Triletes* (Reinsch) Schopf 1938 is still used as a genus for megaspores (Singh, 1964).

Ibrahim (1933), working with Palaeozoic material rather than Tertiary material as did Potonié, elaborated on Potonié's terms, prefixing descriptive morphological roots to "Sporites". He created such names as *Reticulatisporites* (the "i" for trilete), *Punctatosporites* (the "o" for monolete), and *Punctatasporites* (the "a" for alete). Wodehouse (1933) contracted the word "Pollenites" to "-pites" and named many of his forms from the Eocene in this manner: *Cedripites*, *Peltandripites* and *Smilacipites*. Meanwhile, Raistrick and Simpson (1933), Knox (1938) and other workers used alphabetical designates to group their Palaeozoic dispersed spore species. This procedure was revived by Radforth and Rouse (1954) in connection with Cretaceous material. Another method of naming Tertiary material was introduced by Simpson (1936); he indicated affinities with living taxa by using the term "*Cf.*" in conjunction with a modern family or genus name. This designation was translated in the German literature as "Typus" and then abbreviated to "Typ." (Thiergart, 1949). A different contraction of "Sporites" was used by Miner (1935) who prefixed a morphological root to "-spora", as in *Deltoidospora*. Thus, within five years after Potonié's initial (1931) paper, at least five other methods of naming dispersed fossil miospore genera had been published. No author commented on the status of *Triletes*, *Sporites* or *Pollenites*, nor was the status of any of the other genera clarified. Schopf (1938) published a discussion and emendation of Triletes Reinsch 1881, but other forms were not considered.

Schopf, Wilson and Bentall (1944) published a comprehensive paper concerned with the current generic types proposed for Palaeozoic spores. These authors introduced yet another manner of naming miospore genera by giving such commemorative names as Raistrickia. They also considered some of the earlier described genera and concluded that many of them should be synonymized. For example, Punctati-sporites was defined to include Ibrahim's (1933) genera, Verrucosi-sporites and Apiculati-sporites, a procedure with which the writer, and others (Potonié and Kremp, 1954), do not agree.

Proposals for nomenclature in the mid-1940's and early 1950's continued the trend to proliferation of various types of roots or endings. The attempt to indicate not only the botanical affinity of the taxon but also the degree of confidence in this assignment nearly resulted in nomenclatural chaos. Potonié, Thomson and Thiergart (1950) proposed that no less than three nomenclatural procedures might be used concurrently: a modification of a system first suggested by Erdtman (1947) integrated with an artificial system; a "half-natural" system whereby a possible botanical affinity could be indicated (e.g.: Sequoidites); and a natural system wherein material would be placed if it could be positively identified with a living taxon. Finally, Potonié (1951) subsequently modified endings in the half-natural system to make "-oidae" indicate familial affinity and "-oisporites" and "-oipollenites" indicate generic affinity. The confusion was complete.

Realizing the serious consequences of this tangle of names, Thomson and Pflug (1953) and later Potonié and Kremp (1954) returned to a morphological classification system. The task was begun of sorting out the status of the various nomenclatural proposals and of determining the genera having priority under the ICBN. While this task still continues today, there is a relatively orderly system prevailing compared to that of the early 1950's. This order dates from the decision of these workers to return to the morphological classification method.

A few years later, Rouse (1957) proposed a system of nomenclature almost as equally confusing as Potonié's "half-natural" system, often prefixing not only the generic but also the specific epithet (as for example, Gleichenia concavisporites and Gingko labiapollenites). This proposal has not met with much use. With the exception of Rouse's (1957) proposal and the Russian and American papers cited earlier, most workers have now adopted a morphological classification system and exercise restraint in their indication of affinity in the generic epithet. In the fifteen years since the introduction of a more unified procedure of naming miospore taxa, the confusion caused by the proliferation of nomenclatural procedure has been largely dispersed. The major problem in contemporary miospore nomenclature is the vast amount of taxonomic literature currently being published. Many generic epithets are proposed that become synonymous on publication with other genera independently proposed and published as little as a month or a week previously. Contemporary palynologists, however, are still left with the problem of disregarding the misleading botanical allusions of a large number of generic epithets. Much thought as well needs to be devoted to the best way to incorporate material introduced into the literature by van der Hammen (1956a; 1956b) and Pierce (1961). Finally, the problem of the Russian literature remains. Many Russian workers continue to refer fossil miospore species to modern genera and combine validly published species placed under form genera with modern genera solely on the basis of morphology.

### Taxonomic Procedures Adopted in this Thesis

The discussion of classification and nomenclature of dispersed miospores suggests the following taxonomic policies for this thesis:

1) Previously described dispersed miospore genera and species will be considered form-taxa. Newly proposed taxa will be considered as form-taxa.

2) The ICBN (Lanjouw, ed., 1966) will be the nomenclatural guide adopted in this thesis.

3) The possible affinities of the dispersed spore species will be indicated in a separate section (see Part I - Chapter V) and are not to be taken as meaning the taxa included are organ-taxa.

4) The suprageneric classification of Potonié and Kremp (1954 and later) subsequently modified by Potonié (1956 and later) and Dettmann (1963) will be used throughout the thesis.

# III

# SYSTEMATICS

## MIOSPORES

All of the miospores species described in this investigation are classified, where possible, under the morphographic system of Potonié and Kremp (1954 and later), Potonié (1956 and later), and include the revisions of Dettmann (1963). The categories are arranged for convenience in much the same order found in Potonié (1956 and later) and Dettmann (1963). The genera within these categories are not arranged in any particular order, nor are the species with the exception that species proposed as new are described first under their generic headings.

All of the spores recovered in this investigation are dispersed and cannot be identified with a given species. However, other workers have shown certain species to have affinity with natural groups on a generic or higher level. These affinities, where known, are summarized at the end of this taxonomic section.

Many of the synonymies given below are partial synonymies designed to reflect the major nomenclatural changes associated with a given genus or species. In many cases a reference to a more comprehensive listing is given, if that list is in accordance with the views of the writer. In all cases, no attempt has been made to synonymize poorly described and inadequately figured material. Only a complete revision of the original material, in these cases, can hope to make clear the taxonomic position of such forms.

The writer stresses that not all of the forms encountered in the samples have been described below. Many species concepts are poorly defined because of inadequate material or unsuitable orientation of specimens. These concepts, being of doubtful biostratigraphic and taxonomic significance, have not been included. Well-preserved single specimens of morphological or stratigraphical interest have been described briefly as have previously described species represented by only a few but well preserved specimens.

Where the term "cf." is used before a name, the writer considers the form to be closely comparable if not synonymous to a previously described form. However, the writer does not wish to indicate synonymy without further evidence to support that view. Where a question mark is used, the writer is indicating an even greater degree of uncertainty with regard to synonymy. The numbers in brackets after the species names refer to code numbers used in various places through the text of the thesis. These code numbers will be found listed in Appendix III at the end of the thesis.

Anteturma SPORITES H. Potonié 1893

Turma TRILETES (Reinsch) Dettmann 1963

Suprasubturma ACAVATITRILETES Dettmann 1963

Subturma AZONOTRILETES (Luber) Dettmann 1963

Infraturma LAEVIGATI (Bennie & Kidston) Potonié 1956

## Genus STEREISPORITES Pflug 1953

Selected syn.

1937 Sphagnumsporites Raatz, p. 9. (nom. nud.)

1953 Stereisporites Pflug in Thomson and Pflug, p. 53.

1953 Sphagnites Cookson, p. 453.

1956 Sphagnumsporites Raatz ex Potonié, p. 17.

Type species: Stereisporites (al. Sporites) stereoides (Pot. & Ven.) Pflug 1953.

### Stereisporites antiquasporites (Wilson & Webster) Dettmann 1963 (01)

Plate 1, fig. 1

Selected syn.

1946 Sphagnum antiquasporites Wilson & Webster, p. 273; fig. 2.

1961 Sphagnumsporites apulori Reinhardt, p. 705; pl. 1, fig. 13.

1962 Sphagnumsporites antiquasporites (Wilson & Webster) Pocock (pars), p. 32; pl. 1, figs. 1-3.

1963 Stereisporites antiquasporites (Wilson & Webster) Dettmann, p. 25; pl. 1, figs. 20-21.

Description: Amb subcircular to subtriangular. Trilete; laesurae simple and extending about 1/2 spore radius. Exine thickened equatorially and sometimes showing a distal polar dark spot; otherwise thin. Laevigate. The equatorial thickening is uniform and about 2-3μ wide.

Dimensions: Equatorial diameter 16 to 28μ.

Distribution: Present in most samples from the Lower Colorado Group and Peace River-Lower Shaftesbury Formations. Worldwide distribution in Mesozoic and Tertiary strata.

### *Stereisporites* sp. A. (02)

Plate 1, fig. 2

*Description*: Amb subcircular. Trilete; laesurae simple and about 1/2 spore radius. Exine laevigate, thickened equatorial with the radial equatorial region slightly more thickened. A distal polar darkened region is present.

*Dimensions*: Equatorial diameter on 1 specimen, 21µ.

*Remarks*: Dettmann (1963, p. 25) includes similar forms in the species *Stereisporites antiquasporites*.

*Distribution*: Viking Formation, "Chigwell", Lower Colorado Group.

### *Stereisporites* sp. B. (03)

Plate 1, fig. 3

*Description*: Amb subcircular to subtriangular. Trilete; laesurae ridge-like, extending to the equator. Exine thickened uniformly equatorially; laevigate. The laesurae sometimes appear to be connected by faint lines (curvaturae) joining the radial extremities.

*Dimensions*: Equatorial diameter on 5 specimens, 18-24µ.

*Distribution*: Lower Shaftesbury Formation and Viking Formation.

## Genus TODISPORITES Couper 1958

Type species: *Todisporites minor* Couper 1958.

### *Todisporites minor* Couper 1958 (04)

Plate 1, fig. 11

*Description*: Amb subrounded to circular. Trilete; laesurae simple extending about 4/5 spore radius; exine thin and laevigate, occasionally folded about the commissure.

Dimensions: Equatorial diameter on 12 specimens, 29-50μ.

Distribution: Present throughout the Upper Mannville and Lower Colorado Groups. Ranges from Middle Jurassic to Cenomanian (Norris, 1967).

### *Todisporites major* Couper 1958 (05)

Plate 1, fig. 9

Dimensions: Equatorial diameter on 3 specimens, 56-64μ.

Remarks: *Todisporites major* Couper is similar to *T. minor* Couper but larger (Couper 1958).

Distribution: Rare in Viking Formation and Upper Shale Unit.

## Genus CYATHIDITES Couper 1953

Type species: *Cyathidites australis* Couper 1953.

### *Cyathidites australis* Couper 1953 (06)

Plate 1, fig. 10

Description: Amb triangular; sides concave or weakly concave; apices rounded. Trilete; laesurae simple, extending 2/3 to 3/4 spore radius, commissures sometimes gaping. Exine thin and laevigate.

Dimensions: Equatorial diameter on 13 specimens, 52-69μ.

Distribution: Present in various units of the Lower Colorado Group and in the Peace River-Lower Shaftesbury Formations; rare in the Upper Mannville Group. Lower Jurassic to Upper Cretaceous in the northern and southern hemispheres.

### Cyathidites minor Couper 1953 (07)

Plate 1, fig. 12

Dimensions: Equatorial dimensions, 20-49µ.

Remarks: C. minor is similar to C. australis but smaller (Couper, 1953).

Distribution: Present throughout the Lower Colorado, Upper Mannville and Peace River-Lower Shaftesbury. Worldwide distribution in the Lower Jurassic to Upper Cretaceous.

## Genus DELTOIDOSPORA (Miner) Potonié 1956

Type species: Deltoidodspora hallei Miner 1935.

Remarks: The genus Leiotriletes Naumova is probably a partial or complete synonym of Deltoidospora (See Pocock, 1962).

### Deltoidodspora hallei Miner 1935

Plate 1, fig. 13

Selected syn.

1935 Deltoidospora hallei Miner, p. 618; pl. 24, fig. 7.

Description: Amb triangular; sides weakly convex to convex; apices rounded. Trilete; laesurae simple, extending 2/3 to 3/4 spore radius. Exine thin and smooth.

Dimensions: Equatorial diameter on 26 specimens, 22-43µ.

Remarks: Specimens agreeing with the description given above, but possessing concave or weakly concave sides are placed in Cyathidites minor Couper 1958.

Distribution: Present throughout the Upper Mannville and Lower Colorado Groups, Peace River and Lower Shaftesbury Formations; common in the Jurassic and Cretaceous of North America. Similar forms, as Leiotriletes Naumova, have been recorded from Europe and the U.S.S.R.

### Deltoidospora psilostoma Rouse 1959 (09)

Plate 1, fig. 26

Selected syn.

1959 Deltoidospora psilostoma Rouse, p. 311; pl. 2, figs. 7-8.

1964 Deltoidospora psilostoma Rouse; Singh, p. 80; pl. 9, fig. 15.

1967 Deltoidospora psilostoma Rouse; Norris, p. 86; pl. 1, fig. 8.

Description: Amb triangular; sides strongly to weakly convex; apices broadly rounded. Trilete; laesurae simple, commissure often gaping, extending 2/3 to 3/4 spore radius. Exine about $1\frac{1}{2}\mu$ thick and laevigate.

Dimensions: Equatorial diameter on 24 specimens, 45-73µ.

Comparison: Deltoidospora psilostoma Rouse is distinguished from D. hallei Miner by its larger size and slightly thicker exine.

Distribution: Jurassic and Cretaceous of North America; present throughout the Upper Mannville and Lower Colorado Groups and in the Peace River and Lower Shaftesbury Formations (Singh, 1964; Norris, 1967).

### Deltoidospora juncta (Kara-Murza) Singh 1964 (10)

Plate 1, fig. 4

Selected syn.

1956 Cibotium junctum Kara-Murza; Bolkhovitina, p. 37; pl. 3, figs. 25a-e.

1964 Deltoidospora junctum (Kara-Murza) Singh, p. 81; pl. 9, fig. 16 and fig. 8.

1967 Deltoidospora juncta (Kara-Murza) Singh; Norris, p. 86; pl. 10, figs. 4-5.

Description: Amb triangular, sides straight or very weakly concave along one side; apices slightly pointed to rounded. Trilete; laesurae ridge-like, extending to the equator. Near each apex, the exine is folded on the distal side, perpendicular to the laesurae.

Dimensions: Equatorial diameter on 13 specimens, 22-42μ.

Distribution: Present in the Lower Colorado Group and in the Upper Peace River Formation and Lower Shaftesbury. Present in the Lower Jurassic to Lower Cretaceous of Siberia (Bolkhovitina, 1959) and in the Lower Cretaceous of Alberta (Singh, 1964; Norris, 1967).

## Genus UNDULATISPORITES Pflug 1953

Type species: Undulatisporites microcutis Pflug 1953 in Thomson and Pflug 1953.

### Undulatisporites cf. undulapollis Brenner 1963 (011)

Plate 1, fig. 14

Cf. 1963 Undulatisporites undulapollis Brenner, p. 72; pl. 24, fig. 1.

1967 Undulatisporites sp. cf. U. undulapollis Brenner; Norris, p. 87; pl. 10, figs. 6-7.

Description: Amb triangular, sides nearly straight to convex, apices rounded. Trilete; laesurae undulating, extending 2/3 to 3/4 spore radius, bordered by folded exine. Exine thin and laevigate.

Dimensions: Equatorial diameter on 3 specimens, 38-49µ.

Remarks: The specimens recovered in this investigation are identical to Undulatisporites sp. of Norris (1967); they appear similar to Brenner's species but too few well-preserved specimens are available for comparison to make identification certain.

Distribution: Rare in the Uppermost Mannville Group and in the Joli Fou and Viking Formations of the "Chigwell" section.

### Genus BIRETISPORITES (Delcourt & Sprumont) Delcourt, Dettmann & Hughes 1963

Selected syn.

1955 Biretisporites Delcourt & Sprumont, p. 40.

1963 Biretisporites (Delcourt & Sprumont) Delcourt, Dettmann & Hughes, p. 283.

See also Delcourt, Dettmann and Hughes (1963, p. 283).

Type species: Biretisporites potoniaei Delcourt & Sprumont 1955.

### Biretisporites potoniaei Delcourt and Sprumont 1955 (012)

Plate 1, figs. 19-21

Selected syn.

1955 Biretisporites potoniaei Delcourt and Sprumont, p. 40; fig. 10.

1963 *Biretisporites* cf. *B*. *potoniaei* Delcourt & Sprumont; Dettmann, p. 26; pl. 2, figs. 1-2.

1967 *Biretisporites potoniaei* Delcourt & Sprumont; Norris, p. 87; pl. 10, figs. 12-13.

See also Norris (1967, p. 87).

Description: Amb triangular, sides convex, apices rounded. Trilete; laesurae bordered by raised membranous lips, 2-4µ high; laesurae extend about 3/4 spore radius; commissure bordered by slightly thickened exine. Exine smooth; about 2µ thick, 3µ thick about the commissure.

Dimensions: Equatorial diameter on 25 specimens, 28-60 ; polar diameter on 31 specimens, 21-56µ.

Remarks: The size range of the specimens recovered in this investigation overlap both those of Dettmann's (1963, p. 26; 34-56µ) and Delcourt & Sprumont's (1955, p. 40; 48-67µ). In view of the similar morphology of these types, the forms are considered synonymous.

Distribution: Present in all units investigated in this work. Lower Cretaceous of France, Belgium, Australia and Alberta, Canada (see Norris, 1967; Dettmann, 1963).

### *Biretisporites* cf. *B*. *deltoidus* (Rouse) Dettmann 1963 (013)

Plate 1, fig. 24

1957 *Hymenophyllumsporites deltoidus* Rouse, p. 363; pl. 3, figs. 54-56.

1963 *Biretisporites deltoidus* (Rouse) Dettmann, p. 26.

Dimensions: Equatorial dimension, on 1 specimen, 80µ.

Remarks: *Biretisporites deltoidus* (Rouse) Dettmann is larger than

B. potoniaei and has shorter laesurae. Only one specimen was isolated, from the Upper Shale Unit, "Chigwell" section, and this is considered insufficient for definite assignment to B. deltoidus.

### Genus DICTYOPHYLLIDITES (Couper) Dettmann 1963

Selected syn.

1958 Dictyophyllidites Couper, p. 140.

1963 Dictyophyllidites (Couper) Dettmann, p. 27.

Type species: Dictyophyllidites harrisi Couper 1958.

### Dictyophyllidites sp. A. (015)

Plate 1, fig. 5

Description: Amb triangular, apices rounded, sides nearly straight. Trilete; laesurae raised into membranous lips, 4μ high and bordered by a thickened margo, 5μ wide; laesurae extend 3/4 spore radius. Exine laevigate and about 1μ thick, thicker about the laesurae.

Dimensions: Equatorial diameter on 1 specimen, 23μ.

Distribution: Upper part of Joli Fou Formation, "Chigwell" section.

## Infraturma APICULATI (Bennie & Kidston) Potonié 1956

### Genus CONCAVISSIMISPORITES (Delcourt & Sprumont) Delcourt, et al. 1963

Selected syn.

1955 Concavissimisporites Delcourt & Sprumont, p. 25.

1962 Concavisporites Pocock (pars) auct. non Concavisporites Pflug 1953.

1963 Concavissimisporites (Delcourt & Sprumont) Delcourt, Dettmann & Hughes, p. 284.

Type species: Concavissimisporites verrucosus Delcourt & Sprumont 1955, p. 25.

Concavissimisporites punctatus (Delcourt & Sprumont) Singh 1964 (101)

Plate 1, fig. 25

For synonymy, see Singh (1964, p. 77).

Description: Amb triangular, sides concave, apices rounded. Trilete; laesurae simple, extending 2/3 spore radius, often gaping. Exine 1-2μ thick; ornament consisting of scabrate elements or closely packed minute grana.

Dimensions: Equatorial diameter on 4 specimens, 60-70μ.

Distribution: Reported for the first time in the Lower Colorado Group, occurring rarely in the Lower Shaftesbury Formation and the Upper Shale Unit. Reported previously in Berriasian to Albian strata in western Canada (Singh, 1964; Pocock, 1962), from the Barremian-Albian strata of Maryland (Brenner, 1963) and from the Lower Cretaceous of Belgium, France and England (Delcourt & Sprumont, 1955; Couper, 1958) among other occurrences. Not yet found in Cenomanian strata so far as the writer knows.

Concavissimisporites variverrucatus (Couper) Singh 1964 (121)

Plate 1, fig. 16

Selected syn.

1958 Concavisporites variverrucatus Couper, p. 142; pl. 22, figs. 4-5.

1961 Lygodium variverrucatus (Couper) Bolk., p. 100; pl. 36, fig. 5.

1964 Concavissimisporites variverrucatus (Couper) Singh, p. 78; pl. 9, figs. 9-11.

Description: Amb triangular, sides concave, apices rounded. Trilete; laesurae extending about 3/4 spore radius. Proximal and distal faces ornamented with densely spaced, low, sculpture elements, 1-2μ high and 1-4μ in diameter (low grana and verrucae).

Dimensions: Equatorial diameter on 6 specimens, 48-83μ.

Remarks: The writer feels that separation of the few specimens available into two species on size alone is not warranted. The specimens described are identical to figured specimens in Couper (1958) and Singh (1964).

Distribution: Common in the uppermost Grand Rapids Formation, Upper Mannville Group, "Grosmont" site, and rare in strata of the Lower Colorado Group and Lower Shaftesbury Formation. Range from Bajocian to Upper Albian; Singh (1964, p. 79) gives additional locations.

## Genus OSMUNDACIDITES Couper 1953

For synonymy, see Dettmann (1963, p. 31).

Type species: Osmundacidites wellmanii Couper 1953, p. 20.

### Osmundacidites wellmanii Couper 1953 (104)

Plate 1, fig. 34

Selected syn.

1953 Osmundacidites wellmanii Couper, p. 20; pl. 1, fig. 5.

1959 Baculatisporites wellmanii (Couper) Krutzsch, p. 142.

1962 Osmundacidites wellmanii Couper; Pocock (pars), p. 35; pl. 1, fig. 15.

Description: Amb circular. Trilete; laesurae indistinct or distinct, extending 3/4 spore radius. Exine thin; more or less densely ornamented with small grana (1µ wide) and occasional coni or papillae.

Dimensions: Equatorial diameter on 16 specimens, 30-58µ.

Remarks: This species is broadly defined and contains specimens with variable sculpture elements. However, intermediate forms exist and the species cannot be further subdivided without adopting highly arbitrary criteria.

Distribution: Present in various units of all strata investigated; worldwide distribution in the Jurassic and Cretaceous.

### Genus BACULATISPORITES Thomson and Pflug 1953

Selected syn.

1934 Osmundasporites primarius Wolff, p. 66; pl. 5, fig. 8.

1953 Baculatisporites primarius (Wolff) Thomson and Pflug, p. 56.

Type species: Baculatisporites primarius (Wolff) Thomson and Pflug 1953.

### Baculatisporites comaumensis (Cookson) Potonié 1956 (114)

Plate 1, fig. 15

Selected syn.

1953 Triletes comaumensis Cookson, p. 470; pl. 2, figs. 27-28.

1956 Baculatisporites comaumensis (Cookson) Potonié, p. 33.

1957 Osmundacidites comaumensis (Cookson) Balme, p. 25; pl. 4, figs. 54-56.

Description: Amb subcircular to circular, occasionally very weakly subtriangular. Trilete; laesurae often indistinct, extending 2/3 spore radius, simple. Exine ornamented with a relatively dense, evenly distributed cover of bacula and with occasional setae, 1-3μ high and basally 1/2 to 1μ wide. Where elements are corroded, they may appear as stout coni.

Dimensions: Equatorial diameter on 7 specimens, 34-52μ.

Distribution: Rare in the Upper Mannville Group and the Joli Fou and Viking Formations in the samples investigated. Range from Upper Triassic to Lower Cretaceous (Norris, 1967). Dettmann (1963, p. 35) mentions that similar spores occur in the Quaternary of Victoria, Australia.

### Genus NEORAISTRICKIA Potonié 1956

Selected syn.

1949 Cepulina Malyavkina (pars), p. 73.

1956 Neoraistrickia Potonié, p. 34.

1959 Reticulatisporites? Ibrahim; Krutzsch, p. 162.

Type species: Neoraistrickia truncatus (Cookson) Potonié 1956.

Remarks: Raistrickia S. W. & B. 1944 possesses bacula but also has interspersed spines and cones. Baculatisporites has baculate sculpture but is rounded and has a dense distribution of elements. Neoraistrickia has bacula which are stouter and more widely dispersed and is subtriangular.

### Neoraistrickia truncata (Cookson) Potonié 1956 (115)

Plate 1, fig. 6

Selected syn.

1953 Triletes truncatus Cookson, p. 471; pl. 2, fig. 36.

1956 Neoraistrickia truncatus (Cookson) Potonié, p. 34; pl. 3, fig. 32.

1957 Baculatisporites truncatus (Cookson) Balme, p. 18; pl. 1, fig. 21-22.

1958 Lycopodiumsporites gristhorpensis Couper, p. 135; pl. 15, figs. 14-15, (?fig. 16).

1959 Reticulatisporites? truncatus (Cookson) Krutzsch, p. 162.

1962 non Lycopodiumsporites gristhorpensis Couper; Pocock, p. 33; pl. 1, fig. 9.

Description: Amb subtriangular, apices well-rounded. Trilete; laesurae ridge-like and extending 3/4 spore radius. Proximal exine scabrate, distal exine with small, widely spaced bacula; the bacula sometimes extending onto the equatorial region, 2-5μ high. Wall 1-2μ thick.

Dimensions: Equatorial diameter on 5 specimens, 27-42μ.

Remarks: Specimens having slightly corroded sculpture elements may appear to differ from the diagnosis, but uncorroded elements show the usual outline (cf. Dettmann 1963, pl. 5, figs. 4-5 and fig. 4m).

Distribution: Ranges from Middle Jurassic to Lower Cretaceous (Couper, 1958; Balme, 1957; Dettmann, 1963). Present in the Viking and Upper Shale Unit (this study) and the Upper Jurassic and Lower Cretaceous of western Canada (Pocock, 1962).

### Neoraistrickia? sp. A. (122)

Plate 1, fig. 7

Description: Amb weakly subtriangular. Trilete; laesurae simple and extending 3/4 spore radius. Distal surface and equatorial region ornamented with relatively widely spaced bacula of variable length, 1-7μ, and about 2-3μ wide at the base. Wall about 2μ thick.

Dimensions: Equatorial diameter on 1 specimen, 42μ.

Distribution: Present in one sample from the upper part of the Viking Formation, "Chigwell" section.

## Genus RAISTRICKIA (Schopf, Wilson & Bentall 1944)

Pot. & Kr. 1954

Type species: Raistrickia grovensis Schopf in S. W. & B. 1944

### cf. Raistrickia sp. A. (113)

Plate 1, fig. 18 and Text-fig. 18a

Description: Amb circular to subcircular. Trilete; laesurae simple, often obscured by ornament, extending about 2/3 to 3/4 spore radius. Wall thin; sculpture densely packed, consisting of grana, occasional verrucae, thin bacula, with some specimens also possessing occasional spines and bastionate bacula; sculpture elements 1-4μ high, verrucae up to 4μ wide.

Dimensions: Equatorial diameter on 5 specimens, 35-48μ.

Remarks: This form is tentatively assigned to this genus because it possesses spines and other ornament as well as bacula. It differs from the concept of the genus Raistrickia by also having verrucae and grana as ornament.

Distribution: Present rarely in the Harmon Member, Upper Mannville Group and Viking Formation.

Genus ACANTHOTRILETES (Naumova) Pot. & Kr. 1954

Selected syn.

1937 *Acanthotriletes* Naumova, p. 60-61.

1950 *Spinoso-sporites* Knox, p. 313.

1954 *Acanthotriletes* (Naumova) Potonié & Kremp, p. 83.

Type species: *Acanthotriletes* (al. *Spinoso-sporites*) *ciliatus* (Knox) Potonié & Kremp, p. 83.

*Acanthotriletes varispinosus* Pocock 1962 (118)

Plate 1, fig. 17

1962 *Acanthotriletes varispinosus* Pocock, p. 36; pl. 1, figs. 18-20.

1964 *Acanthotriletes varispinosus* Pocock; Singh, p. 43; pl. 1, figs. 17-18.

1967 *Acanthotriletes varispinosus* Pocock; Norris, p. 89; pl. 10, fig. 22.

Description: Amb subcircular to subtriangular. Trilete; laesurae simple and indistinct or with exinal folds about the commissure; laesurae extend 4/5 spore radius. Proximal surface scabrate in the contact area; equatorial and distal exine ornamented with simple spines of variable length or with spines set on bulbous, expanded bases; spines relatively densely spaced, discrete; 3-10μ long.

Dimensions: Equatorial diameter on 14 specimens, 20-41μ.

Distribution: Sparsely distributed throughout the Mannville and Lower Colorado Groups and in the Peace River-Lower Shaftesbury

Formations (Pocock, 1962; Singh, 1964; Norris, 1967; this study).

### *Acanthotriletes* sp. A. (117)

Plate 1, figs. 22-23 and 28 and Text-fig. 18b

*Description*: Amb triangular, sides straight or weakly concave to convex; apices rounded. Overall outline deltoid. Trilete; laesurae extending 3/4 spore radius; commissure bordered by a narrow smooth margo, about 2μ wide and an outer thickened exinal border bearing spines. The proximal and distal surfaces also ornamented with spines or spinose processes, the latter often formed of acute-tipped papillae set on expanded, bulbous bases or acute-tipped spines set on bosses. Sculpture elements discrete or occasionally set on low ridges; length of elements, 2 to 6μ. On two specimens, weakly to strongly developed sets of interradial crassitudes appear to be present, although these may be distal sets of folds parallelling the amb which simulate crassitudes. Specimens without the ?crassitudes are otherwise indistinguishable from those with these structures.

*Dimensions*: Equatorial diameter on 8 specimens, 24-35μ.

*Remarks*: Too few specimens are available to assess the range of variation within this form. If two populations of specimens were found, one with interradial crassitudes and one without, then the former population would be separated as a distinct species and placed in the Tricrassati Dettmann 1963. Spinose spores with interradial crassitudes are similar to forms described under the genus *Ornamentifera* Bolkhovitina 1966.

*Distribution*: Specimens recorded from the Joli Fou, Viking and Lower

Shaftesbury Formations, and in the Upper Shale Unit. Not previously reported from Lower Cretaceous deposits in Canada; doubtfully in Lower Cretaceous deposits from Russia (Bolkhovitina, 1966).

### Acanthotriletes sp. B. (116)

Plate 1, fig. 8

Description: Amb triangular; sides straight or weakly convex, apices rounded. Trilete; laesurae simple, extending the spore radius. Proximal surface smooth; distal surface with discrete, small spines, 2-3μ long.

Dimensions: Equatorial diameter on 3 specimens, 34-39μ.

Distribution: Rare in the Harmon and Paddy Members of the Peace River Formation, west-central Alberta, Canada.

## Genus PILOSISPORITES Delcourt & Sprumont 1955

Selected syn.

1949 Sporites Potonié (pars); Thiergart, p. 22.

1955 Pilosisporites Delcourt & Sprumont, p. 34.

1961 Lygodium Swartz; Bolkhovitina (pars), p. 102.

Type species: Pilosisporites (al. Sporites) trichopapillosus (Thiergart) Delcourt & Sprumont, p. 34.

### Pilosisporites trichopapillosus (Thiergart) Delcourt & Sprumont 1955 (120)

Plate 1, fig. 27 and Plate 2, fig. 1

For synonymy, see Singh (1964, p. 74)

Dimensions: Equatorial diameter on 6 specimens, 52-75μ.

Remarks: For the diagnosis of this species, see Singh (1964. p. 75).

The specimens recovered in this study correspond in all respects to those described in earlier publications.

Distribution: Reported here for the first time from late Albian strata. Previously recorded from Upper Jurassic to Middle Albian strata in England, Belgium and western Canada (Singh, 1964). Norris (1967) does not report this species from the Lower Colorado Group of east-central Alberta; recovered in this study from samples of the Viking Formation in the "Chigwell" and "Grosmont" sections, and from the uppermost Grand Rapids Formation of the "Grosmont" section.

### Pilosisporites verus Delcourt & Sprumont 1955 (119)

Plate 1, fig. 35

Selected syn.

1955 Pilosisporites verus Delcourt & Sprumont 1955, p. 35; pl. 4, fig. 1.

1961 Lygodium verus (Delcourt & Sprumont) Bolkhovitina, p. 103; pl. 38, figs. 3a,b.

1964 Pilosisporites verus Delcourt & Sprumont; Singh, p. 75; pl. 9, fig. 5.

Description: Amb triangular; sides weakly concave or convex. Apices rounded. Trilete; laesurae extend 3/4 spore radius, simple. Exine ornamented with spines which are concentrated on the proximal and distal apices, otherwise scabrate except for small scattered spines present distally in the interradial regions. Spines 5-10μ long.

Dimensions: Equatorial diameter on 1 specimen, 48μ.

Distribution: No specimens of this species have been found in post-Mannville strata (Norris, 1967; this study). The species appears to be confined to Upper Jurassic to Middle Albian strata (Singh, 1964).

### Genus CYCLOGRANISPORITES Pot. & Kr. 1954

Type species: C. leopoldi (Kremp 1952) Pot. & Kr. 1954.

### Cyclogranisporites sp. A. (106)

Plate 1, fig. 29

Description: Amb circular to subcircular. Trilete; laesurae simple, extending 1/2 to 2/3 radius of spore. Exine ornamented with mixture of small and large grani (1 to $1\frac{1}{2}\mu$ in diameter) and a few coni 1-2μ high. Sculpture elements discrete and not crowded.

Dimensions: Equatorial diameter on 5 specimens, 25-39μ.

Distribution: Rare in samples from the Harmon Member, Viking and Lower Shaftesbury Formations and the Upper Mannville Group.

### Genus APICULATISPORIS Pot. & Kr. 1956

Types species: Apiculatisporis (al. Apiculatisporites) aculeatus (Ibrahim 1933) Pot. & Kr. 1956

### Apiculatisporis? sp. A. (112)

Plate 2, fig. 17

Description: Amb circular to subcircular. Trilete; laesurae with commissure bordered by slightly raised and thickened exine forming a margo; margo edge irregular: laesurae extend 3/4 spore radius. Wall 2-3μ thick, sculptured with coni, and occasional spines and grana 1-4μ high; densely spaced sculpture elements, except in the contact region.

Dimensions: Equatorial diameter on 4 specimens, 31-45μ.

Remarks: This form bears some similarity to Conosmundasporites othmari Klaus 1960, p. 128; pl. 28, fig. 4, in possessing a mixed sculpture and raised laesurae, but differs in the distribution and size range of the sculpture elements.

Distribution: Present rarely in samples from the Viking Formation in south-central Alberta.

### Genus CONVERRUCOSISPORITES Pot. & Kr. 1954

Type species: Converrucosisporites triquetrus (Ibrahim 1933) Pot. & Kr. 1954.

### Converrucosisporites sp. A. (109)

Plate 1, fig. 30

Description: Amb subtriangular or nearly subcircular. Trilete; laesurae simple, often obscured by sculpture elements, and extending 3/4 spore radius. Proximal ornament often of smaller verrucae or grana in the contact region, otherwise similar to a distal ornament of polygonal to rounded verrucae, sometimes slightly elongate, 3-8μ in maximum diameter, closely spaced.

Dimensions: Equatorial diameter on 4 specimens, 32-38μ.

Remarks: Species similar to this form have been assigned to Leptolepidites Couper 1953 by Couper (1953) and Dettmann (1963) and to Matthesisporites Döring 1964 by Döring (1964). These two genera and Converrucosisporites have very similar diagnoses and it is possible that synonymy exists.

Distribution: Present rarely in samples from the Harmon Member, Joli Fou and Viking Formations.

### *Converrucosisporites* sp. B. (111)

Plate 1, fig. 36

*Description*: Amb triangular, apices rounded, sides nearly straight. Trilete; laesurae extend 3/4 spore radius, bounded by a smooth, often dissected, thickened margo. Sculpture proximally of grana and occasional verracae, grading into distal polar verrucae or irregular rugulae. Grana 1-2μ wide and 1-$1\frac{1}{2}$μ high; verrucae 3-6μ wide and about 2μ high.

*Dimensions*: Equatorial diameter on 4 specimens, 27-36μ.

*Remarks*: The Aptian species, *Selaginella* (*Lophotriletes*) *granata* Bolkhovitina 1953, p. 31; pl. 3, figs. 9-10, is similar to this form but is illustrated only by drawings and cannot be accurately compared. *Converrucosisporites* *proxigranulatus* Brenner 1963, p. 60; pl. 15, figs. 1-3 is more rounded in outline and has larger distal verrucae, but is otherwise similarly constructed.

*Distribution*: Rare in samples from the Harmon Member, Viking and Lower Shaftesbury Formations.

### cf. *Converrucosisporites* sp. C. (110)

Plate 1, figs. 31 and 37

*Description*: Amb triangular, apices rounded, sides straight to weakly concave. Trilete; laesurae sinuous and bordered by a raised margo about 2μ high and 6-9μ in total width; laesurae extend 2/3 spore radius. Proximal exine smooth; distal exine smooth except for closely packed, irregularly shaped verrucae present in a distal polar triangular region, mirroring the proximal contact region; the verrucae may be replaced by an irregularly shaped, dissected distal thickening in this area.

Dimensions: Equatorial diameter on 2 specimens, 31 and 34µ.

Distribution: Found only in the Viking Formation in south-central Alberta.

### Infraturma MURORNATI Potonié and Kremp 1954

### Genus FOVEOSPORITES Balme 1957

Type species: Foveosporites canalis Balme 1957.

### Foveosporites cf. F. canalis Balme (201)

Plate 1 , fig. 32

Description: Amb subcircular to triangular. Trilete; laesurae indistinct, extending to the periphery. Foveolate, the foveae small ($\frac{1}{2}\mu$) and subcircular or elongated, spaced 1-2µ apart.

Dimensions: Equatorial diameter on 4 specimens, 42-50µ.

Remarks: The specimens described here differ in not having a preponderance of elongate foveae but are otherwise identical to those described by Balme (1957, p. 17; pl. 1, figs. 15-17).

Distribution: Present rarely in the Pelican and Lower Shaftesbury Formations and in the Upper Shale Unit. Foveosportes canalis is reported from the Cretaceous of Australia (Balme, 1957; Dettmann, 1963).

### Genus LYCOPODIACIDITES (Couper) Potonié 1956

Type species: Lycopodiacidites bullerensis Couper 1953.

### *Lycopodiacidites* sp. A. (234)

Plate 1, fig. 38

*Description*: Amb subcircular. Trilete mark not visible. Proximal(?) surface smooth; distal surface with closely spaced hamulate sculpture elements, $1-1\frac{1}{2}\mu$ wide and about $1\mu$ high. Wall uniformly thick, $1\frac{1}{2}\mu$.

*Dimensions*: Equatorial diameter on 1 specimen, $38\mu$.

*Remarks*: Species of *Camarozonosporites* with hamulate distal sculpture described elsewhere in this thesis are tricrassate and thus differ in structure from similar spores assignable to *Lycopodiacidites*.

*Distribution*: Present in the Viking Formation, "Wabamun" section.

## Genus TAUROCUSPORITES Stover 1962

1953 *Chomotriletes* (pars) Naumova 1939 ex Naumova, p. 31.

1962 *Taurocusporites* Stover, p. 55.

1965 *Polycingulatisporites* (pars) (Simonscics & Kedves) Playford & Dettmann, p. 143.

Type species: *Taurocusporites segmentatus* Stover 1962.

*Remarks*: Playford and Dettmann (1965, p. 143 and p. 145) emended the genus *Polycingulatisporites* Simonscics and Kedves 1961 as well as *Taurocusporites* Stover 1962. Both genera were interpreted to be cingulate and the latter form was restricted to species showing proximal ornament. The writer agrees with the emendation of *Polycingulatisporites* but not with the interpretation of *Taurocusporites*.

### *Taurocusporites reduncus* (Bolk.) Stover 1962 (223)

Plate 1, fig. 39

Selected syn.

1953 Chomotriletes reduncus Bolkhovitina, p. 35; pl. 3, figs. 23-24.

1962 Taurocusporites reduncus (Bolk.) Stover, p. 57; pl. 1, figs. 15-21.

1965 Polycingulatisporites reduncus (Bolk.) Playford & Dettmann, p. 143.

Dimensions: Equatorial diameter on 1 specimen, 39μ.

Remarks: One specimen of this species was found in a sample from the Pelican Formation, "Grosmont" section.

Distribution: Geological range from Middle Jurassic to Upper Cretaceous (Norris, 1967). Reported from Pakistan, Denmark, Russia (Bolkhovitina, 1953; Obonitskaya, 1966), Maryland, U.S.A. (Stover, 1962). In western Canada, previously reported from the Mannville Group (Singh, 1964) and the Upper Shale Unit (Norris, 1967).

### Taurocusporites segmentatus Stover 1962 (202)

### Plate 1, fig. 33

Selected syn.

1962 Taurocusporites segmentatus Stover, p. 56; pl. 1, figs. 1-14; text-fig. 1.

Dimensions: Equatorial diameter on 3 specimens, 38-50μ.

Distribution: Middle Albian of western Canada (Pocock, 1962; Singh, 1964); Barremian to Albian of Maryland (Stover, 1962; Brenner, 1963); Lower Cretaceous of Central Kizilkum and the southern Pre-Arals (Obonitskaya, 1966); present in samples from the Harmon Member and the Joli Fou and Pelican Formations of the "Grosmont" section.

### Taurocusporites minor Singh 1964 (203)

Plate 2, fig. 5

1964 Taurocusporites minor Singh, p. 87; pl. 11, fig. 7-11.

Dimensions: Equatorial diameter on 4 specimens, 29-32μ.

Remarks: Taurocusporites cf. T. minor Singh in Norris (1967, p. 91; pl. 11, fig. 9) differs in the lack of a thin distal polar region and in having shorter laesurae according to Norris (1967).

Distribution: Aptian to Middle Albian of western Canada (Singh, 1964); present rarely in the Upper Mannville Group, uppermost Cadotte Member in the "Grouard" section, and in the Lower Shaftesbury Formation and Upper Shale Unit; range thus extended to Upper Albian.

## Genus TIGRISPORITES Klaus 1960

Type species: Tigrisporites halleinis Klaus 1960, p. 140.

### Tigrisporites scurrandus Norris 1967 (204)

Plate 2, figs. 9-10 and Text-fig. 18c

1967 Tigrisporites scurrandus Norris, p. 91; pl. 11, figs. 3-7.

Description: Amb triangular; sides straight or weakly convex to concave; apices rounded or slightly flattened. Trilete; laesurae raised 3-5μ and extending about 3/4 spore radius. Wall 1-2μ thick. Proximal surface smooth or with a few narrow, low rugulae, occasionally radially arranged. Distal surface bearing a prominent polar thickening, with smooth or crenulated edge and about 1/4 to 1/4 of the spore radius in extent; the rest of the distal surface ornamented with irregularly shaped, lobed, occasionally anastomosing to form an imperfect reticulum, or narrow, sinuous rugulae, from 1/2 to 2μ wide and 3-7μ long. Where shorter sculpture elements (2-4μ wide) predominate, they may often be more properly termed verrucae. The density of the rugulae vary; their presence may give the amb an irregular outline.

Dimensions: Equatorial diameter on 17 specimens, 28-45μ; diameter of distal polar thickening, 7-15μ. Many more specimens observed.

Remarks: The specimens agree in all respects with those described by Norris (1967), with the exception of the few specimens showing an imperfect distal reticulum formed of anastomosing rugulae.

Distribution: Uppermost Harmon Member, Cadotte, Paddy Members, Lower Shaftesbury Formation in the "Spirit River" section; uppermost Grand Rapids Formation, Joli Fou, Viking Formations and the Upper Shale Unit in central and south-central Alberta. The stratigraphic range and geographical distribution of this species, first described from the Edmonton region (Norris, 1967), is considerably extended.

### *Tigrisporites* sp. A. (230)

Plate 2 , fig. 12

Description: Amb triangular, sides convex or nearly straight, apices rounded. Trilete; laesurae ridge-like and extending about 4/5 to the complete spore radius. Proximal surface smooth; distal surface ornamented with a trelliswork of long, narrow (about 1/2μ wide), sinuous to gently arcing rugulae, having many projections and side branches; occasional rugulae extend onto the periphery of the proximal surface. A distal polar crassitude always present, from 1/5 to 2/5 of the spore radius. Rugulae radiate from this thickening.

Dimensions: Equatorial diameter on 2 specimens, 33 and 39μ; diameter of thickening, 7 and 15μ respectively.

*Comparison*: *Tigrisporites scurrandus* Norris 1967 has shorter and generally wider rugulae which are more widely spaced, branch less and sometimes grade into verrucae.

*Distribution*: Found only in one sample from the Cadotte Member, "Spirit River" section.

## Genus RETICULISPORITES Potonié & Kremp in Weyland and Krieger 1953

Type species: *Reticulisporites parvogranulatus* Weyland and Krieger 1953.

*Remarks*: *Dictyotriletes* (Naumova) Potonié and Kremp 1954 is distinguished from this genus by possession of a distinctly convexly triangular amb. *Microreticulatisporites* (Knox) Potonié and Kremp is circular and has a distinctive microreticulation. *Reticulatisporites* (Ibrahim) Butterworth *et al*. is cingulate.

### *Reticulisporites norrisii* sp. nov. (207)

Plate 2, figs. 19-20

1967 *Reticulisporites* sp.; Norris, p. 91; pl. 11, figs. 10-11.

*Holotype*: BW 143/1 at 532 - 934; equatorial diameter, 36μ.

*Description*: Amb triangular; apices broadly rounded and sides straight to concave or weakly concave. Trilete; laesurae ridge-like and extending nearly to the equator. Proximal surface smooth. Equatorial and distal surface ornamented with a low perfect to occasionally imperfect reticulum; muri narrow, 1/2 to 1μ wide and lumina rounded or polygonal, nearly equidimensional to elongate; 3-7μ in longest diameter. Reticulum may extend just onto the proximal surface in the radial regions in some specimens. A distal polar darkening is almost always present; a distal polar crassitude is never present.

Dimensions: Equatorial diameter on 23 measured specimens, 29-43μ.

Remarks: The 7 specimens described by Norris (1967) as *Reticulisporites* sp. conform to the description of *R. norrisii* sp. nov. except that they possess more consistently elongate lumina which range up to 10μ in diameter.

Comparison: *Retitriletes parvimurus* Döring 1965, p. 45; pl. 21, figs. 5-7 is similar to *Reticulisporites norrisii* sp. nov. but possesses shorter, simple laesurae which are not raised and has a reticulum extending well onto the proximal surface and not just present near the apices.

Distribution: Noted in samples from all strata investigated in this thesis except the Harmon and Cadotte Members and the Upper Grand Rapids Formation. Previously reported from the Upper Shale Unit of the Edmonton region, east-central Alberta, by Norris (1967).

### Genus DICTYOTRILETES (Nauomova) Pot. & Kr. 1954

Type species: *Dictyotriletes bireticulatus* (Ibrahim in Potonié, *et al.*, 1932) Pot. & Kr. 1954.

### *Dictyotriletes* sp. A. (205)

Plate 2, figs. 6-7

Description: Amb triangular; sides straight or convex; apices rounded. Trilete; laesurae raised about 2-4μ and extending from 3/4 to the complete spore radius. Proximal surface smooth. Distal surface ornamented with a low reticulum surrounding a distal polar crassitude of variable thickness. Muri narrow, about 1/2-1μ wide and low, 1/2μ high, enclosing rounded to polygonal lumina, 3-6μ in diameter; distal polar thickening from 1/4 to 1/3 spore radius in extent.

Dimensions: Equatorial diameter on 7 specimens, 29-35μ; distal polar crassitude, 9-13μ in diameter.

Remarks: This species is placed in Dictyotriletes because it possesses a low reticulum and straight to convex sides. Lycopodiumsporites has higher muri; Reticulatisporites is cingulate.

Comparison: This species is distinguished from Tigrisporites scurrandus Norris 1967 by its perfect reticulum and lack of any indication of radial orientation of the distal ornament, Reticulisporites norrisii sp. nov. possesses a perfect of nearly perfect, low, distal reticulum but without any distal polar thickening.

Distribution: Present rarely in the Upper Grand Rapids Formation, the Pelican, Viking, and Lower Shaftesbury Formations throughout west-central and central Alberta.

## Genus MICRORETICULATISPORITES (Knox) Pot. & Kr. 1954

Type species: Microreticulatisporites lacunosus (Ibrahim) Knox 1950.

### Microreticulatisporites uniformis Singh 1964 (208)

Plate 2, fig. 36

1964 Microreticulatisporites uniformis Singh, p. 97; pl. 13, figs. 5-7.

Dimensions: Equatorial diameter on 2 specimens, 43 and 44μ.

Distribution: Present in the Upper Mannville Group, "Grosmont" section. Reported previously from the Mannville Group, from Aptian to Albian by Singh (1964). No specimens were found in this investigation or by Norris (1967) from strata belonging to the Lower Colorado Group or its equivalent.

### Genus KLUKISPORITES Couper 1958

Type species: Klukisporites variegatus Couper 1958

Selected syn.

1958 Klukisporites Couper, p. 137.

1964 Klukisporites (Couper) Pocock, p. 193.

Remarks: The genus Klukisporites Couper 1958 is characterized by foveolate or foveo-reticulate sculpture. Dictyotriletes (Naumova) Potonié and Kremp 1954 possesses a very low reticulum.

### Klukisporites variegatus Couper 1958 (209)

Plate 2, fig. 2

Selected syn.

1958 Klukisporites variegatus Couper, p. 137; pl. 19, figs. 6-7.

Dimensions: Equatorial diameter on 4 specimens, 48-74μ.

Remarks: Klukisporites variegatus Couper is distinguished from K. pseudoreticulatus Couper 1958 by its irregular foveolate to foveo-reticulate sculpture on the distal surface, by its more rounded-triangular shape and generally larger size.

Distribution: Recovered rarely from samples of the Upper Grand Rapids, Viking and Lower Shaftesbury Formations. Couper (1958) reports this species in beds of Middle Jurassic age from England.

### Klukisporites pseudoreticulatus Couper 1958 (210)

Plate 2, fig. 35

Selected syn.

1958 Klukisporites pseudoreticulatus Couper, p. 138; pl. 19, figs. 8-10.

1964 Klukisporites foveolatus Pocock, p. 194; pl. 7, figs. 5-6.

Dimensions: Equatorial diameter on 8 specimens, 39-53μ.

Remarks: Klukisporites foveolatus Pocock 1964 appears similar in all respects to K. pseudoreticulatus Couper 1958, although the size range for specimens described by Pocock (1964, p. 202) is smaller than that quoted by Couper (1958).

Distribution: Present in samples from the Upper Mannville Group, the Joli Fou, Pelican, Viking Formations and the Paddy Member. Previously reported by Couper (1958) from the Purbeckian to Wealden (Upper Jurassic to Lower Cretaceous) of England and by Pocock (1962; 1964) from strata of Barremian to Middle Albian age in western Canada.

## Genus LYCOPODIUMSPORITES Thiergart ex Delcourt & Sprumont 1955

Type species: Lycopodiumsporites agathoecus (Potonié) Thiergart 1938

### Lycopodiumsporites austroclavatidites

(Cookson) Potonié 1956 (211)

Plate 2, fig. 11

Selected syn.

1953 Lycopodium austroclavatidites Cookson, p. 469; pl. 2, fig. 35.

1956 Lycopodiumsporites austroclavatidites (Cookson) Potonié, p. 46.

See Dettmann (1963, p. 45) for a more complete synonymy.

Dimensions: Equatorial diameter on 10 measured specimens, 24-49μ; muri 2-7μ high; lumina 4-12μ in maximum diameter.

Distribution: Worldwide distribution in the Jurassic and Cretaceous.

Present in strata from Barremian to Upper Albian age in western Canada (Pocock, 1962; 1964; Singh, 1964; Norris, 1967).

### Lycopodiumsporites reticulumsporites (Rouse) Dettmann 1963 (212)

Plate 2, fig. 13

Selected syn.

1959 Lycopodium reticulumsporites Rouse (pars), p. 309; pl. 2, figs. 1-2 only.

1963 Lycopodiumsporites reticulumsporites (Rouse) Dettmann, p. 45, pl. 7, figs. 4-7.

Description: Amb subcircular to subtriangular. Laesurae indistinct, extending about 2/3 spore radius and raised 1-2μ. Exine thin, with proximal radial and fully developed distal ornament. Sculpture reticulate; the muri narrow, about 1μ wide, and 1-3μ high; lumina 3-7μ wide; polygonal to elongate distally, more irregularly shaped proximally.

Dimensions: Equatorial diameter on 7 measured specimens, 25-38μ.

Remarks: This species is distinguished by the presence of radially developed, low proximal muri as well as the low distal reticulum.

Distribution: Upper Jurassic of British Columbia (Rouse, 1959); Lower Cretaceous of Australia (Dettmann, 1963); mid to upper Albian (Norris, 1967). Present rarely in samples from the Harmon and Paddy Members, the Viking and Lower Shaftesbury Formations and the Upper Shale Unit investigated in this thesis.

## Lycopodiumsporites marginatus Singh 1964 (213)

Plate 2, fig. 18

1964 Lycopodiumsporites marginatus Singh, p. 41; pl. 1, figs. 7-10.

1967 Lycopodiumsporites marginatus Singh; Norris, p. 90; pl. 10, figs. 24-26.

Description: Amb subcircular to circular. Trilete; laesurae bordered by narrow exine folds and extending about 3/4 spore radius. Proximal face smooth in the contact region; otherwise proximal and distal faces ornamented with a reticulum; the muri $1\text{-}1\frac{1}{2}\mu$ wide and 6-10μ high; the lumina polygonal and from 4-10μ wide.

Dimensions: Equatorial diameter on 8 measured specimens, 36-54μ.

Remarks: Singh (1964, p. 41) mentions only a few irregular proximal ridges. However, his photographs suggest (pl. 1, fig. 9) that proximal muri may also be present and the specimens recorded here, identical in all other respects, support this possibility.

Comparison: This species is distinct from Lycopodiumsporites reticulumsporites (Rouse) Dettmann 1963 in having high muri and larger lumina, as well as a more extensively developed proximal reticulum.

Distribution: Previously reported from the Mannville Group of east-central Alberta (Singh, 1964) and from the lower part of the Lower Colorado Group in the same region (Norris, 1967). Present rarely in samples from the Harmon and Paddy Members, the Joli Fou, Viking, Lower Shaftesbury Formations and Upper Shale Unit.

### Lycopodiumsporites? sp. A. (206)

Plate 2 , figs. 32-33

Description: Amb triangular; apices rounded; sides convex or weakly convex. Trilete; laesurae simple and extending about 3/4 spore radius, with wall gaping or slightly folded about the commissure. Proximal surface smooth or with peripheral rugulae. Equatorial and distal surface ornamented with a reticulate sculpture which surrounds a distal polar crassitude, distinctly to indistinctly developed. Muri of reticulum narrow, about 1/2µ wide, about 2-3µ high, sinuous; lumina irregular in shape to rounded or polygonal, isodiametric to elongate, 3-13µ in longest diameter. Wall about 2µ thick.

Dimensions: Equatorial diameter on 7 specimens, 33-38µ.

Remarks: This form is doubtfully referred to Lycopodiumsporites Thiergart ex Delcourt & Sprumont 1955 because of the presence of a distal polar thickening on most of the specimens.

Comparison: The lumina of the distal reticulum are larger and the muri are higher than on Reticulisporites norrisii sp. nov. and the reticulum is fully developed and polygonal unlike the imperfect type developed on some specimens of Tigrisporites scurrandus Norris 1967.

Distribution: Present in samples from the Viking, Pelican and Lower Shaftesbury Formations and the Upper Shale Unit.

### Genus CICATRICOSISPORITES Potonié & Gelletich 1933

Type species: Cicatricosisporites dorogensis Potonié & Gelletich 1933.

Selected syn.

1950 Mohrioidites Thiergart, p. 84.

1951 Mohrioisporites Potonié, p. 114.

1954 *Mohriosporites* Cookson, p. 122.

1962 *Costatoperforosporites* Deák, p. 230.

*Remarks*: Deák (1962, p. 230) distinguished *Costatoperforosporites* from *Cicatricosisporites* by the possession of exclusively canaliculate sculpture and pitted ribs (muri). Many species of *Cicatricosisporites* possess pitted muri and the same specimen of a given species may exhibit both canaliculate or cicatricose or gradational muri patterns. The writer thinks that the genus proposed by Deák is thus synonymous with *Cicatricosisporites* Potonié & Gelletich.

### *Cicatricosisporites* (al. *Pelleteria*) *minutaestriatus*
### (Bolkh.) comb. nov. (218)
### Plate 2, figs. 18 and 29

1958 *Cicatricosisporites dorogensis auct. non* Potonié & Gelletich; Couper, p. 137; pl. 17, fig. 11 only.

1961 *Pelleteria minutaestriata* Bolkhovitina, p. 68; pl. 20, figs. 1a-f; pl. 21, figs. 3a-d; and pl. 39, fig. 19.

1963 *Cicatricosisporites venustus* Deák, p. 252; pl. 2, figs. 7-8 and 12-13.

1963 *Cicatricosisporites hallei auct. non* Delcourt & Sprumont; Brenner, p. 49; pl. 9, fig. 2.

1964 *Cicatricosisporites dorogensis auct. non* Potonié & Gelletich; Leopold & Pakiser; pl. 3, figs. 3-7.

1966 *Cicatricosisporites dorogensis auct. non* Potonié & Gelletich; Hedlund, p. 18; pl. 3, figs. 2a-b.

1967 *Cicatricosisporites hallei auct. non* Delcourt & Sprumont; Norris, p. 92; pl. 11, figs. 15-20.

1968 Cicatricosisporites hallei auct. non Delcourt & Sprumont; Hedlund, p. 579; pl. 1, fig. 1a,b.

Description: Amb triangular; sides convex or weakly convex, apices rounded. Trilete; laesurae simple, extending 3/4 spore radius, with a smooth margo and occasionally upturned exine about the commissure. Muri and canaliculi nearly equal in width, 1μ; muri 1-2μ high with rounded tops; canaliculi shallow, with rounded bottoms. Two proximal muri patterns, grading into each other. Less commonly, the muri arise from the distal surface so as to reach the proximal surface running at right angles to the amb; more commonly, the muri arise from the equatorial region of the interradial area at an angle, reaching the laesura clockwise to that side at right angles. Distally the muri pattern shows generally parallel muri which may curve about at the apices to move onto the proximal face.

Dimensions: Equatorial diameter measured on 31 specimens, 24-50μ; polar diameter measured on 5 specimens, 22-29μ.

Comparison: Cicatricosisporites hallei Delcourt and Sprumont 1955, p. 17; pl. 1, fig. 1; text-fig. 1 is distinguished from C. (al. Pelleteria) minutaestriatus (Bolk.) comb. nov. by possessing wider muri and a distinctly canaliculate sculpture pattern, as well as a different muri pattern.

Distribution: Lower Cretaceous of England, Maryland, Hungary and the Middle and Upper Albian of Alberta (Couper, 1958; Brenner, 1963; Deák, 1962; Norris, 1967); Cenomanian of Oklahoma (Hedlund, 1966; 1968); and the Upper Cretaceous of Alabama (Leopold and Pakiser, 1964). Present in moderate numbers in all units sampled for this investigation.

### Cicatricosisporites australiensis (Cookson) Potonié 1956 (216)

Plate 2, fig. 14

Selected syn.

1953 Mohriosporites australiensis Cookson, p. 470; pl. 2, figs. 31-34.

1956 Cicatricosisporites australiensis (Cookson) Potonié, p. 48.

1962 Cicatricosisporites dorogensis auct. non Potonié & Gelletich; Pocock (pars), p. 39; pl. 2, fig. 36 only.

1964 Cicatricosisporites dorogensis auct. non Potonié & Gelletich; Singh, p. 57; pl. 6, fig. 1.

See also Dettmann (1963, p. 53) for further synonymy.

Dimensions: Equatorial diameter on 12 measured specimens, 34-50μ; polar diameter on 1 specimen, 27μ.

Distribution: Cretaceous of Australia, India, Kazakhstan and Western Canada (Dettmann, 1963; Pocock, 1962; Singh, 1964; Norris, 1967). Common in the Upper Mannville Group; less common in the Lower Colorado Group in east-central and south-central Alberta, and in the Cadotte Member and Lower Shaftesbury Formation.

### Cicatricosisporites hughesi Dettmann 1963 (217)

Plate 2, fig. 23

1963 Cicatricosisporites hughesi Dettmann, p. 55; pl. 10, figs. 6-16; fig. 4p.

1967 Cicatricosisporites hughesi Dettmann; Norris, p. 93; pl. 11, figs. 21-22.

Description: Amb triangular; sides convex; apices rounded, but sometimes slightly pointed when the muri project at the radial extremities. Trilete; laesurae extending nearly to the equator, raised into membranous lips from 2-6μ high. Exine smooth in the contact region. Equatorial and distal sculpture of seven sinuous and crested muri, parallel to the amb and to each other, fusing in alternate pairs at the radial extremities of the laesurae. Muri 2-3μ wide, 3-4μ high; canaliculi 5-8μ wide. Sculpture pattern cicatricose.

Dimensions: Equatorial diameter on 5 specimens, 42-59μ.

Distribution: Aptian-Albian and ?Cenomanian of Australia (Dettmann, 1963); Upper Shale Unit (Norris, 1967) of the Edmonton region; present in samples from the Upper Mannville Group, the Peace River and Viking Formations investigated in this thesis.

Cicatricosisporites psuedotripartitus (Bolk.) Dettmann 1963 (218)

Plate 2, figs. 24 and 37

1961 Anemia pseudotripartita Bolkhovitina, p. 53; pl. 15, fig. 3a-c.

1961 Anemia tripartita Bolkhovitina; Markova in Samoilovich, et al., p. 69; pl. 17, fig. 4.

1963 Cicatricosisporites pseudotripartitus (Bolkhovitina) Dettmann, p. 54; pl. 10, figs. 1-5.

Description: Amb triangular; sides weakly convex or straight; apices rounded. Trilete; laesurae reach nearly to the equator, with raised membranous lips, 2-4μ high. Contact area smooth, otherwise with canaliculate sculpture pattern. Three sets of equatorial and distal muri parallel to the amb and to each other, meeting at the distal pole;

five to seven muri per set; muri 2-5μ wide, canaliculi about 1μ wide. Muri fuse and may sometimes coelesce at the distal pole, or form as well at the apices, a small triangular thickening at the extremities of the laesurae.

Dimensions: Equatorial diameter on 9 specimens, 36-62μ; polar diameter on 3 specimens, 36-41μ.

Comparison: *Cicatricosisporites pseudotripartitus* (Bolk.) Dettmann 1963 is distinguished from the very similar species, *C. hughesi* Dettmann 1963 by the canaliculate sculpture pattern.

Distribution: Reported previously from Albian strata of Australia (Dettmann, 1963) and Cenomanian strata of the U.S.S.R. (Bolkhovitina, 1961; Samoilovich, *et al.*, 1961). Found in samples investigated in this thesis from the Harmon Member, Uppermost Grand Rapids and Viking Formations, and from the Upper Shale Unit.

*Cicatricosisporites perforatus* (Baranov, et al.) Singh 1964 (219)

Plate 2, figs. 28 and 30

1957 *Anemia perforata* Baranov, Nemkova & Kondratiev, p. 202; pl. 2, fig. 22.

1961 *Mohria perforata* (Baranov, *et al.*) Markova, p. 85; figs. 3a,b.

1964 *Cicatricosisporites perforatus* (Baranov, *et al.*) Singh, p. 58; pl. 6, figs. 5-7.

? 1964 *Cicatricosisporites* sp.; Stover, pl. 1, fig. 24.

*non Anemia perforata* Markova 1961, p. 82; pl. 22, figs. 1a,b.

Description: Amb triangular; apices rounded; sides convex. Trilete; laesurae short and indistinct, simple construction. Proximal muri in three sets parallel to the amb and to each other; each pair of adjacent sets fusing along an angle-amb bisector; four to six muri per proximal pair, 2-4μ wide; canaliculi 1/2 to 1μ wide. Distal muri independent of proximal pattern, consisting of six to nine arcuate, partly fusiform muri, parallel to each other but oblique to the amb, more or less fusing at the apices of origin. Distal muri slightly wider than the proximal muri and canaliculi similar. All muri bear a single row of fossae.

Dimensions: Equatorial diameter on 6 specimens, 30-41μ; polar diameter on 2 specimens, 27 and 28μ.

Comparison: Cicatricosisporites sp. of Stover (1964; pl. 1, fig. 24) appears similar but apparently has laesurae meeting the proximal muri at a slight angle. Cicatricosisporites (al. Costaperforosporites) fistulosus (Deák 1962, p. 230; pl. 27, figs. 1-3) comb. nov. is also of similar construction but shows a different muri pattern.

Distribution: Aptian to Turonian (Singh, 1964); present rarely in several samples from the Pelican and Viking Formations and the Upper Shale Unit in east-central and south-central Alberta, doubtfully present in the Arundel Formation (Barremian-Aptian) of Maryland, U.S.A. Stover (1964).

### Cicatricosisporites cf. C. sewardi Delcourt & Sprumont 1955 (222)

Plate 2, fig. 34

Description: Amb broadly subtriangular, apices well-rounded. Trilete; simple laesurae extending 3/4 spore radius. Wall about 3μ thick. Proximal muri in three sets, each six to ten in number, 2-5μ wide and

3-6μ high, meeting the laesurae approximately at 30°; muri continuing distally to form a nearly uniform pattern oblique to the amb except at the convergence of the separate sets. Canaliculi from 1/2-3/4μ wide.

Dimensions: Equatorial diameter on 2 specimens, 41 and 49μ.

Remarks: The specimens recovered resemble closely *Cicatricosisporites sewardi* Delcourt & Sprumont 1955 but too few are present to make a definite assignment to that species.

Distribution: Rare specimens from the Lower Shaftesbury Formation and the Upper Shale Unit. Similar forms previously recorded from the Wealden of Belgium (Delcourt and Sprumont, 1955); Barremian to Aptian of Maryland, U.S.A. by Brenner (1963) and the Lower Colorado Group (Norris, 1967).

### *Cicatricosisporites* sp. A. (231)

Plate 2 , figs. 3-4

Description: Amb triangular, apices rounded, sides convex or weakly convex. Trilete; laesurae with raised membranous lips 4-6μ high, and extending 3/4 spore radius. Proximal muri six to eight in number, canaliculate, two sets continuing around the ends of the laesurae parallel to the amb, passing onto the distal surface as a series of parallel, occasionally anastomosing muri which then end at one side; a third set meeting the amb at an angle and passing onto the distal face to meet the parallel set at right angles. Muri 2-4μ wide and spaced about 1/2μ apart.

Dimensions: Equatorial diameter on 6 specimens, 38-53μ.

Comparison: This species is somewhat similar in arrangement and measurements of muri to Cicatricosisporites hallei Delcourt & Sprumont 1955, p. 17; pl. 1, fig. 1 but appears to differ in the distal arrangement of the muri.

Distribution: Present rarely in samples from the Pelican, Viking and Lower Shaftesbury Formations and the Paddy Member.

### Cicatricosisporites sp. B. (232)

Plate 2, fig. 31

Description: Amb triangular to subtriangular; sides convex; apices rounded. Trilete; laesurae simple and extending 3/4 spore radius. Cicatricose; the canaliculi 2 to 3 times wider than the muri; canaliculi 2-3μ wide with flat to slightly curved bottoms; muri about 1μ wide and with conical to rounded tops. Proximal muri parallel the amb; distal muri parallel each other, running in one direction and curving at the apices.

Dimensions: Equatorial diameter on 3 specimens, 41-45μ.

Distribution: Present in samples from the upper Grand Rapids and Viking Formation and the Upper Shale Unit.

### Cicatricosisporites sp. C. (233)

Plate 2, figs. 15-16

Description: Amb triangular; sides weakly convex to straight; apices rounded. Trilete; laesurae raised into membranous lips about 8μ high. Proximal muri in three sets, paralleling the amb, numerous and closely set, six to ten in number, and $1\text{-}1\frac{1}{2}\mu$ wide. Canaliculi very narrow, 1/2μ or less. Distal ornament distinctive; three sets of ornament, one perpendicular to one side, the other two parallel to the amb, consisting of rows of rugulae, occasionally united to form one continuous murum. At the junction of sets, the rugulae become twisted or anastomose to enclose small lumina; rugulae 1-2μ wide.

Dimensions: Equatorial diameter on 2 specimens, 39 and 43μ; polar diameter on smaller specimen, 34μ.

Remarks: The distal ornament on Cicatricosisporites sp. C. has not been, to the writer's knowledge, reported on any other species assigned to this genus.

Distribution: Rare in samples from the Harmon Member, "Spirit River" section and the basal Joli Fou Formation, "Grosmont" site.

### Subturma ZONOTRILETES Waltz 1935 sensu Dettmann 1963

### Infraturma AURICULATI (Schopf) Dettmann 1963

### Genus TRILOBOSPORITES Pant ex Potonié 1956

Type species: Trilobosporites (al. Concavisporites) hannonicus (Delcourt & Sprumont) Potonié 1956.

### Trilobosporites apiverrucatus Couper 1958 (401)

Plate 3 , fig. 2

Selected syn.

1958 Trilobosporites apiverrucatus Couper, p. 142; pl. 21, figs. 11-13.

1964 Trilobosporites apiverrucatus Couper; Singh (pars), p. 72; pl. 8, fig. 16 only.

Description: Amb triangular; apices well rounded; sides concave. Trilete; laesurae bordered by a margo of fused granules, and extending 3/4 spore radius. Exine 1-2µ thick and ornamented in the apical regions with grana or verrucae 3-6µ in diameter, occasionally so closely set as to form a negative reticulum; other portions of the exine ornamented with low grana, $1\text{-}1\frac{1}{2}$µ in diameter.

Dimensions: Equatorial diameter on 10 specimens, 57-80µ.

Remarks: Couper (1958, p. 142) quotes a size range for this species of 60-100µ, with a mean diameter of 75µ.

Comparison: Trilobosporites marylandensis Brenner 1963, p. 71; pl. 23, fig. 5 is similar but smaller in size and has smaller sculpture elements. The specimen illustrated by Singh (1964, pl. 8, fig. 18) belongs more properly in T. marylandensis Brenner than in T. apiverrucatus Couper.

Distribution: Present in various levels of the Mannville Group (Singh, 1964); occurs rarely in samples from the upper Grand Rapids, Viking, Pelican and Lower Shaftesbury Formations.

### Trilobosporites marylandensis Brenner 1963 (403)

Plate 3, fig. 3

Selected syn.

1962 Trilobosporites apiverrucatus auct. non Couper; Pocock (pars), p. 43; pl. 4, fig. 59 only.

1963 Trilobosporites marylandensis Brenner, p. 71; pl. 23, fig. 5.

1964 Trilobosporites apiverrucatus auct. non Couper; Singh (pars), p. 72; pl. 8, fig. 18 only.

1967 *Trilobosporites marylandensis* Brenner; Norris, p. 95; pl. 13,
figs. 3, 5.

*Description*: Amb triangular; apices rounded; sides concave. Trilete; laesurae bordered by a narrow margo ornamented with small closely packed granules, or nearly smooth. Radial equatorial regions ornamented with small grana or with verrucae which may be occasionally connected to form low irregular rugulae; sculpture elements 1-3μ high and 1-3μ wide. Exine otherwise ornamented with small grana about 1/2μ and 1/2μ wide.

*Dimensions*: Equatorial diameter on 7 specimens, 49-63μ.

*Remarks*: Brenner (1963, p. 71) gives a size range of 33-54μ; specimens here described conform in all respects but slightly exceed this maximum value.

*Comparison*: This species is distinguished from *Trilobosporites apiverrucatus* Couper 1958 by its smaller dimensions and smaller ornament, even on large specimens overlapping the size range of that species.

*Distribution*: Previously reported from portions of the Mannville Group and other strata of Lower Cretaceous age in Alberta (Pocock, 1962; Singh, 1964; Norris, 1967). Specimens occur in samples from the Viking and Upper Shale Units from south-central Alberta and in the Mannville Group, upper Grand Rapids Formation at the "Grosmont" site.

*Trilobosporites* cf. *T. trioreticulatus* Cookson & Dettmann 1958 (402)

Plate 3, fig. 4

*Description*: Amb triangular; apices rounded; sides convex. Trilete;

laesurae extend 2/3 spore radius, bordered by a narrow, low, thickened margo. Equatorial radial regions ornamented with a convolute to reticulate sculpture; exine otherwise scabrate and about 2μ thick.

Dimensions: Equatorial diameter on 1 specimen, 80μ.

Remarks: The specimen recorded here from the Upper Shale Unit, "Chigwell" section is similar to *Trilobosporites trioreticulatus* Cookson and Dettmann 1958, p. 109; pl. 17, figs. 1-3, but the writer thinks that one specimen is not sufficient material on which to base a synonymy.

### *Trilobosporites* sp. A. (404)

Plate 3, fig. 1

Description: Amb triangular; sides convex; apices rounded. Trilete; laesurae extending 3/4 spore radius without a margo but with a darkened region about the commissure. Ornamentation absent except for apical-equatorial grana, 1-2μ high and 1-3μ wide.

Dimensions: Equatorial diameter on 2 specimens, 56 and 56μ.

Comparison: This form is distinguished from *Trilobosporites marylandensis* Brenner 1963 by its lack of a margo and by confinement of ornament to apical regions.

Distribution: Present rarely in samples from the Viking Formation, "Chigwell" section.

## Infraturma APPENDICIFERI Potonié 1956

## Genus APPENDICISPORITES Weyland & Krieger 1953

Type species: *Appendicisporites tricuspidatus* Weyland & Krieger 1953.

## *Appendicisporites perplexus* Singh 1964 (501)

Plate 2, fig. 27

? 1958 *Cingulatisporites problematicus* Couper, p. 146; pl. 24, figs. 11-13.

1964 *Appendicisporites perplexus* Singh, p. 55; pl. 5, figs. 1-4.

1964 *Appendicisporites degeneratus auct. non* Thiergart 1949; Pocock, p. 172; pl. 4, figs. 16-18 (Fig. 18 not indicated in text by Pocock).

1967 *Contignisporites perplexus* (Singh) Norris, p. 98; pl. 14, figs. 1-4.

Dimensions: Equatorial diameter on 15 measured specimens, 34-50μ; width of cingulum 3-6μ.

Remarks: The specimens described as *Cingulatisporites problematicus* Couper 1958 appear similar to those described under the name, *Appendicisporites perplexus* Singh 1964. It is difficult, however, to determine definite assignment from the photographs of Couper (pl. 24, figs. 11-13) and Couper (1958, p. 146) describes the distal ornament as broad ridges sometimes forming a lophate pattern or merging into verrucate elements. This species does not belong in *Contignisporites* Dettmann 1963 as that genus is characterized by distal muri running in one direction only.

Distribution: Lower Cretaceous of western Canada (Singh, 1964; Pocock, 1964; Norris, 1967); also present in samples from the Peace River Formation and Lower Shaftesbury Formation.

### Appendicisporites sellingii Pocock 1964 (502)

Plate 3, fig. 18

1964 Appendicisporites sellingii Pocock, p. 163; pl. 3, figs. 5-7 only.

Dimensions: Equatorial diameter on 5 specimens, exclusive of appendices, 53-100μ; appendices, 5-14μ; total diameter, 58-114μ.

Remarks: Pocock (1964, p. 164) gives a total diameter range of 60-66μ. The specimens included herein are indistinguishable morphologically from Pocock's forms but range up to 114μ in total diameter. The grain illustrated by Pocock (1964, pl. 3, fig. 8) interpreted by that author as a "tetrachotomolete" grain is not included in the synonymy as the writer thinks its position is uncertain.

The species described as Appendicisporites jansonii Pocock 1964, p. 37; pl. 2, fig. 23, is also very similar to A. sellingii; Pocock gives no differential diagnosis for A. sellingii. The author has not compared the original material and thus hesitates to synonymize the two species at present.

Distribution: Previously reported from the Middle Albian of Saskatchewan by Pocock (1964); present rarely in samples from the upper Grand Rapids Formation, the Joli Fou and Pelican Formations in east-central Alberta and the Viking Formation in south-central Alberta. The range is thus extended to Upper Albian.

### Appendicisporites cf. A. crimensis (Bolk.) Pocock 1964 (503)

Plate 2, figs. 25-26

1961 Anemia crimensis Bolkhovitina, p. 55; pl. 15, fig. 8 and pl. 17, fig. 7.

1964 Appendicisporites cf. Appendicisporites crimensis (Bolkhovitina) Pocock, p. 168; pl. 4, figs. 1-3, 6.

1964 Appendicisporites crimensis (Bolkhovitina) Pocock; Singh, p. 49; pl. 2, figs. 11-12.

Description: Amb triangular; apices bearing appendices; sides convex or weakly convex. Trilete; laesurae raised and bordered by a thickened smooth margo which fuses at about 3/4 spore radius with the innermost proximal muri. Proximal muri in three sets paralleling the amb, the inner sets fusing with the margo and the outer sets fusing in adjacent pairs along an angle-amb bisector and continuing to form short rounded appendices 3-4µ long and 2-3µ wide; proximal muri five to seven per set with maximum width 2-3µ; canaliculi 1/2 to 3/4µ wide. Distal muri in three sets of which one or two may be underdeveloped, paralleling the amb, except oblique at the junctions of two adjacent sets; five to seven muri per set, or two or three in underdeveloped sets. Exine apparently thicker at the radial extremities, but this may be due to compression of the spore in the polar axis.

Dimensions: Equatorial diameter of body on 3 specimens, 41-53µ.

Comparison: Appendicisporites sellingii Pocock 1964 has more strongly developed, broader appendices and is generally larger.

Distribution: Confined in this thesis to samples from the Cadotte Member and upper Grand Rapids Formation; previously reported by Pocock (1964) from the Middle Albian of Saskatchewan, the Mannville Group (Singh, 1964) and the Hauterivian to Albian of the U.S.S.R. (Bolkhovitina, 1961).

### Appendicisporites cf. A. matesovai (Bolk.) Norris 1967 (507)

Plate 3, fig. 12

Description: Amb triangular; a multiple number of appendices present at the apices; sides convex. Trilete; laesurae raised into membranous lips and extending the spore radius. One set of proximal muri parallel to the amb extending as a set of appendices. Three distal sets of muri, three to four in number, parallel to the amb and extending at the apices into three to four sets of appendices. Muri 2-4μ wide, up to 4μ high and spaced 2-5μ apart.

Dimensions: Equatorial diameter excluding the appendices on 5 specimens, 48-53μ; appendices 2-4μ wide and 5-12μ long.

Remarks: The specimens of this form described above are tentatively referred to Appendicisporites cf. A. matesovai (Bolk.) Norris, p. 94; pl. 12, figs. 11,13-14. The specimens described by Norris are larger in diameter and have very thick polar extensions of the appendices. No equatorial views of any specimens were noted in this thesis and because of this and the smaller size, synonymy is not considered proven.

Distribution: Present rarely in samples from the Harmon Member, the Joli Fou, Viking and Lower Shaftesbury Formations in west-central and south-central Alberta.

### Appendicisporites cf. A. unicus (Markova) Singh 1964 (508)

Plate 3, figs. 15-16

Description: Amb triangular; sides convex or weakly convex; apices bear elongated appendices. Trilete; laesurae with raised membranous lips 4-7μ high, extending 3/4 spore radius. Three sets of proximal muri, parallel to the amb and fusing at the apices to form appendices with slightly swollen ends. Some specimens have only one murum per proximal set near the periphery. Three sets of distal muri, the muri somewhat lobed and parallel to the amb and to each other; two muri may be developed and the inner murum undeveloped for one or two sets.

Dimensions: Equatorial diameter exclusive of appendices on 2 specimens, 33 and 43μ; polar diameter on the latter specimen, 25μ; appendices 12μ and 8μ long respectively and 4-5μ wide.

Remarks: The specimens described above agree well with those described by Singh (1964, p. 53; pl. 4, figs. 4-6) as *Appendicisporites unicus* (Markova) Singh. Singh described only 2 specimens as well. The writer thinks that there is insufficient material to assign the specimens described above to *A. unicus*.

Distribution: Present in one sample from the upper Grand Rapids Formation, "Grosmont" section and the Joli Fou Formation, "Battle Lake" site. Singh (1964) reports rare specimens from the Grand Rapids Formation. Similar specimens are recorded by Markova (in Samoilovich, *et al.*, 1961) from the Cenomanian of Russia.

### *Appendicisporites* sp. A. (506)

Plate 3, fig. 7

Description: Amb triangular; sides convex; apices prolonged into appendices. Trilete; laesurae raised into membranous lips 2-3μ high, and extending 3/4 spore radius. Proximal muri in three sets, the muri parallel to the amb and to each other, fusing along an angle-amb bisector and prolonged into tapering, bluntly rounded appendices, 2-5μ wide and 9-28μ long. Two muri per proximal set, each 2-3μ wide. Distal muri in three sets, muri parallel to the amb and to each other; two muri per set always well developed, the inner set being incomplete or not reaching the angle-amb bisectors; muri straight to sinuous and 2-3μ wide. The distal muri fuse with each other and with the proximal muri to extend into one set of appendices per apical region.

Dimensions: Equatorial diameter on 11 specimens, exclusive of the appendices, 32-60μ; total diameter, 47-88μ.

Comparison: Only one set of appendices is developed at each apex in contrast to *Appendicisporites unicus* (Markova) Singh 1964. The very long appendices distinguish this species from other described in this thesis.

Distribution: Present in samples from the Joli Fou, Viking, Pelican and Lower Shaftesbury Formations and from the Upper Shale Unit.

### *Appendicisporites* sp. B. (510)

Plate 3, figs. 10-11 and Text-figs. 18d-e

Description: Amb triangular, sides convex, apices prolonged into short appendices. Trilete; laesurae raised into membranous lips, 2-4μ high, and extending about 2/3 spore radius. The proximal muri in three sets, running parallel to the amb and to the others in the set, fusing with the extremities of the lips of the laesurae, and with each other, to form an angle-amb bisector which projects as part of the appendices; muri 3-4μ wide, canaliculi about 1/2μ at their maximum width. Distally, one outer muri is present in each set of

Text-figures 18a to 18g. Camera lucida drawings of portions or complete specimens of selected miospore specimens illustrating ornament or structure. Magnifications approximate.

18a. Cf. *Raistrickia* sp. A. Portion of specimen showing varied sculpture elements. X 1250: BW123/1: 604 - 983.

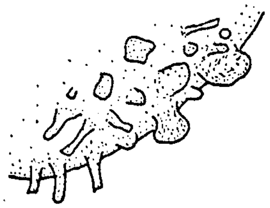
18b. *Acanthotriletes* sp. A. Complete specimen showing thickened spinose margo. BW145/1: 303 - 1013. X1100.

18c. *Tigrisporites scurrandus* Norris. Distal view of complete specimen. BW114/3: 189 - 978. X1200.

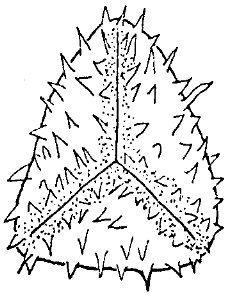
18d. and e. *Appendicisporites* sp. B. (d) Proximal and (e) distal views of complete specimen showing the muri pattern. BW72/1: 271 - 1072. X1400.

18f. Periporate? Forma A. Sketch showing general aspect of grain. BW161/1: 641 - 1024. Compare with Plate 8, fig. 7. X1500.

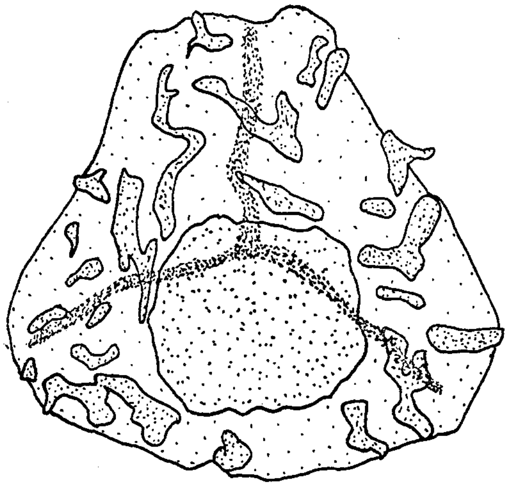
18g. *Circulina* cf. *parva* Brenner. Outline drawing of complete specimen showing trilete proximal scar and faint distal pore. BW124/1: 637 - 942. X1250.



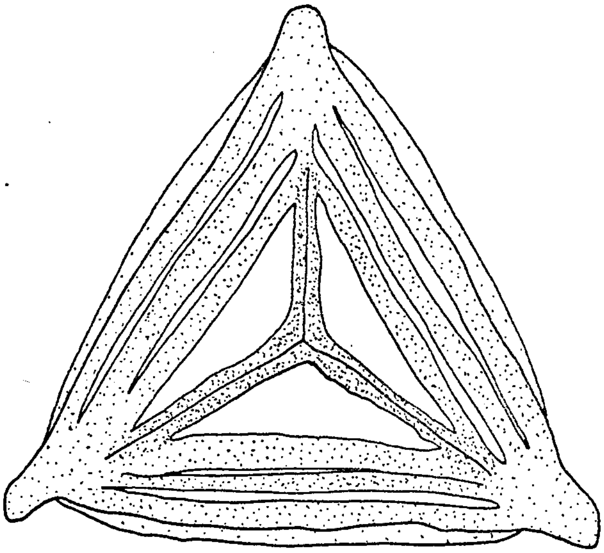
18a



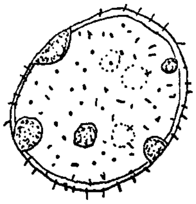
18b



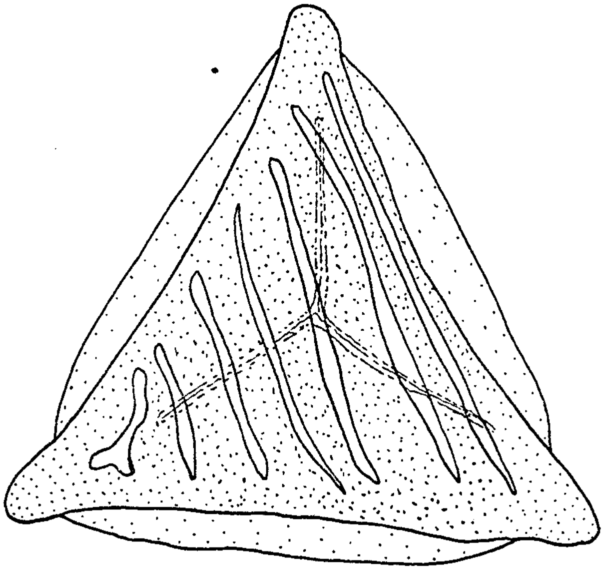
18c



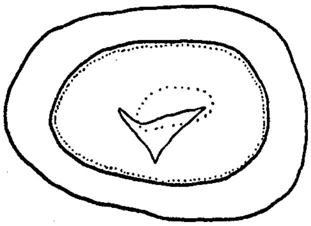
18d



18f



18e



18g

Text-figure 18

three while a second set is overdeveloped at the expense of the other two, the muri four to six in number and running parallel to one amb; near the apices the shorter muri may fuse leaving only a small fovea; these distal sets fuse at their extremities with the proximal extensions, forming part of the appendices. A few specimens have the other sets better developed, and the junction region forming the fovea shifts towards the distal pole. Exine thicker at the apices or appearing so because of polar compression.

Dimensions: Equatorial diameter on 4 specimens, exclusive of the appendices, 45-52μ; appendices 3-7μ; total diameter, 52-56μ.

Remarks: This species is distinguished from others described in this thesis by the combination of its distal muri pattern and the moderately developed appendices.

## Infraturma TRICRASSATI Dettmann 1963

### Genus GLEICHENIIDITES (Ross ex Delcourt & Sprumont) Dettmann 1963

Type species: *Gleicheniidites senonicus* (Ross) Skarby 1964.

Selected syn.

1949 *Gleicheniidites* Ross (*nom. nud.*), p. 31.

1955 *Gleicheniidites* Ross ex Delcourt & Sprumont, p. 26.

1957 *Triremisporites* Delcourt & Sprumont, p. 61.

1959 *Gleicheniidites* (Ross) Krutzsch, p. 109.

1961 *non Gleicheniidites* Grigorjeva in Samoilovich, *et al.*, p. 59
*non* Ross ex Delcourt & Sprumont.

1963 *Gleicheniidites* (Ross ex Delcourt & Sprumont) Dettmann, p. 64.

1964 *Gleicheniidites* (Ross ex Delcourt & Sprumont) Skarby, p. 61.

Remarks: Skarby (1964) gives a more lengthy and complete synonymy. The emendation of the genus by Dettmann (1963) and the diagnosis given by Skarby (1964) are in complete agreement and therefore Dettmann's (1963) emendation is retained.

### Gleicheniidites senonicus (Ross) Skarby 1964 (601)

Plate 3, figs. 13-14 and 17

Selected syn.

1949 Gleicheniidites senonicus Ross, p. 31; pl. 1, fig. 3.

Cf. 1953 Gleichenia circinidites Cookson, p. 464; pl. 1, figs. 5-6.

1957 Gleichenia concavisporites Rouse, p. 363; pl. 2, figs. 36-48 and pl. 3, fig. 49.

1959 Gleicheniidites (Toridistalisporis) toriconcavus Krutzsch, p. 112; pl. 12, figs. 110-111; text-fig. 25.

1961 Cingutriletes parvicingulus Pierce, p. 26; pl. 1, fig. 3.

1961 Cingutriletes interruptus Pierce, p. 26; pl. 1, fig. 5.

1961 Psilatriletes vulgaris Pierce, p. 27; pl. 1, fig. 9.

1961 Punctatriletes parvimundus Pierce, p. 28; pl. 1, fig. 13.

1963 Gleicheniidites senonicus Ross; Brenner, p. 53; pl. 11, fig. 6.

1963 Gleicheniidites circinidites (Cookson) Brenner, p. 53; pl. 11, figs. 4-5.

1964 Gleicheniidites senonicus (Ross) Skarby, p. 65; pl. 1, figs. 1-3; pl. 2, figs. 1-8, and pl. 3, figs. 1-11; text-fig. 1, 1-11.

Description: Amb triangular; sides concave, weakly concave to weakly convex or straight; apices rounded to slightly pointed. Trilete; laesurae raised into low membranous lips, 1-2μ high and extending nearly the complete spore radius. Exine thin and smooth, often folded into three distal arcuate folds. Tricrassate, the exine thickened in the interradial regions; the thickening sometimes extending almost to the apices.

Dimensions: Equatorial diameter on 50 specimens, 19-38μ.

Remarks: The treatment of this highly variable species follows that of Skarby (1964), who showed conclusively the wide variation of the form. All gradations of forms were noted in samples studied in this investigation. Forms with rounded to pointed corners intergraded with forms having concave to convex sides. From the observations of the writer and from the work of Skarby (1964) it may be concluded that there are in the literature many synonymns. Only a few were indicated here, however, and the reader is referred to Skarby (1964, pp. 65-66) for a more complete list.

Distribution: Worldwide distribution in the Jurassic and Cretaceous. Present in nearly all of the samples investigated in this thesis.

### Genus SESTROSPORITES Dettmann 1963

Type species: *Sestrosporites* (al. *Foveotriletes*) *irregularis* (Couper) Dettmann 1963.

1963 *Sestrosporites* Dettmann, p. 66.

1965 *Vallizonosporites* Döring, p. 60.

### *Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963 (602)

Plate 3, figs. 8-9

1958 *Cingulatisporites pseudoalveolatus* Couper, p. 147; pl. 25, figs. 5-6.

1963 *Sestrosporites pseudoalveolatus* (Couper) Dettmann, p. 66; pl. 13, figs. 11-16.

1964 *Hymenozonotriletes pseudoalveolatus* (Couper) Singh, p. 83; pl. 10, figs. 1-3.

1965 *Vallizonosporites pseudoalveolatus* (Couper) Döring, p. 60.

1967 *Sestrosporites pseudoalveolatus* (Couper) Dettmann; Norris, p. 96; pl. 13, figs. 8-10.

*Dimensions*: Equatorial diameter on 5 specimens, 42-56µ.

*Remarks*: The zonate appearance of some specimens results from rupture of the cavate interradial crassitudes, according to Dettmann (1963, p. 66-67).

It may be noted here that second species described by Döring (1965) probably belongs in *Sestrosporites* Dettmann. The following nomenclatural change is made:

*Sestrosporites* (al. *Vallizonosporites*) *vallifoveatus* (Döring, 1965, p. 60; pl. 13, figs. 1-2) comb. nov.

*Distribution*: Bajocian to Aptian of England (Couper, 1958); Lower Cretaceous of Australia (Dettmann, 1963); Grand Rapids Formation, east-central Alberta, Albian (Singh, 1964); Lower Cretaceous of Germany (Döring, 1965); rare in samples from the Lower Colorado Group, the Paddy Member and the Lower Shaftesbury Formation.

### Genus CAMAROZONOSPORITES (Pant ex Potonié) Klaus 1960

Type species: *Camarozonosporites cretaceus* (Weyland & Kreiger) Potonié 1956.

1954 *Camarozonosporites* Pant, p. 51; *nom. nud.*

1956 *Camarozonosporites* Pant ex Potonié, p. 65.

? 1959 Hamulatisporis Krutzsch, p. 157.

1960 Camarozonosporites (Pant ex Potonié) Klaus, p. 135.

1965 Hamulatisporis Krutzsch; Stanley, p. 241 (pars).

Remarks: The genus Camarozonosporites is characterized by development of interradial crassitudes, and often by possession of a distal hamulate sculpture pattern. The type species of the genus, Hamulatisporis Krutzsch, appears from the figures (Krutzsch, 1959; figs. 326-328) to be tricrassate, although Krutzsch states in the diagnosis that the walls are of uniform thickness about the spore. Klaus (1960, p. 134) places Hamulatisporis in synonymy with the genus Lycopodiacidites (Couper) Potonié. The writer prefers to record the synonymy as questionable because he has not seen any of the type material. Hamulatisporis Krutzsch sensu Stanley (1965, p. 241-243) is in part synonymous with Camarozonosporites. Stanley repeats the essentials of Krutzsch's (1959) diagnosis, but includes a species which is definitely tricrassate.

## Camarozonosporites insignis Norris 1967 (603)

Plate 3, figs. 5-6

1963 Lycopodiacidites cerniidites auct. non Ross; Brenner, p. 43; pl. 5, fig. 2.

1965 Hamulatisporis hamulatus auct. non Krutzsch 1959; Stanley, p. 242; pl. 29, figs. 7-8.

1967 Camarozonosporites insignis Norris, p. 96; pl. 13, figs. 12-16.

Dimensions: Equatorial diameter on 30 specimens, 24-53μ.

Remarks: The specimens included above from samples studied during this investigation show considerable variation in the distal hamulate pattern, the rugulae sometimes being so closely packed as to enclose occasional fossae, at other times being broad and relatively few in number. The rugulae may exhibit a sharply angular chevron pattern or be relatively rounded and slightly sinuous.

Comparison: A number of similar forms have been described by various authors but are not synonymous, although closely comparable. Camarozonosporites rudis (Leschik) Klaus 1960 is distinguished from C. insignis Norris by possession of labiate lips and broader distal sculpture elements. C. hammenii van Amerom 1965 has finer distal rugulae and lacks proximal sculpture. Lygodium reticulatiformis Bolkhovtina 1961 possess marked radial proximal rugulae.

A form illustrated by Stover (1964, pl. 2, fig. 6) as Lycopodiumsporites sp. is comparable to C. insignis but is not described. Upshaw (1964, pl. 1, fig. 4) also illustrates a similar form, as Lycopodimsporites sp., which is very close to C. insignis. A number of forms described briefly but insufficiently illustrated by Pierce (1961) are also comparable to C. insignis:

Rugutriletes rugosus, p. 31; pl. 1, fig. 23.
Retitriletes varius, p. 29; pl. 1, fig. 15.
Rugutriletes regularis, p. 30; pl. 1, fig. 19.

Krutzsch (1963) has subsequently placed these three species in the genus Camarozonosporites Pant ex Potonié.

Remarks: A comparative sample from the Hell Creek Formation, northwest of Mobridge, South Dakota, east of Stanley's (1965) locations, was obtained through the courtesy of Mr. F. W. Jordan. This sample contained specimens identical to those assigned to Camarozonosporites *insignis* Norris, and indistinguishable from the illustrations of *Hamulatisporis hamulatus auct. non* Krutzsch; Stanley (1965, pl. 29, figs. 7-8). It is on this basis that the writer synonymizes the latter form with *C. insignis* Norris 1967.

*Distribution*: Albian, probably Upper Albian, of Maryland (Brenner, 1963); restricted to the Viking and Upper Shale Unit (Norris, 1967); Upper Cretaceous (Maestrichtian) of South Dakota (Stanley, 1965); in this thesis, specimens restricted to the Paddy Member and Lower Shaftesbury Formations in west-central Alberta and the Lower Colorado Group in east-central and south-central Alberta.

### *Camarozonosporites* sp. A. (604)

Plate 4, fig. 1

*Description*: Amb triangular, apices rounded and sides convex. Trilete; laesurae bordered by a low, wide margo having a crenulated to gently sinuous margin; laesurae extend to the spore periphery. Tricrassate. Distally ornamented with a humulate pattern of rugulae, with slightly angular corners at the folded regions. Proximal surface appears smooth.

*Dimensions*: Equatorial diameter on 4 specimens, 42-49μ; width of the margo, 6-10μ.

*Comparison*: Distinguished from *Camarozonosporites insignis* Norris 1967 by the wide, low margo.

*Distribution*: Upper Shale Unit in south-central Alberta; "Chigwell" section; Pelican Formation in the "Grosmont" section, central Alberta.

## Infraturma CINGULATI Potonié & Klaus 1954

### Genus CINGUTRILETES (Pierce) Dettmann 1963

1961 _Cingutriletes_ Pierce, p. 20 (pars).

1963 _Cingutriletes_ (Pierce) Dettmann, p. 69.

Type species: _Cingutriletes congruens_ Pierce 1961.

### _Cingutriletes clavus_ (Balme) Dettmann 1963 (701)

Plate 4, fig. 4

Selected syn.

1957 _Sphagnites clavus_ Balme, p. 16; pl. 1, figs. 4-6.

1963 _Cingutriletes clavus_ (Balme) Dettmann, p. 69; pl. 14, figs. 5-8.

See Dettmann (1963, p. 69) and Norris (1967, p. 97) for more complete synonymies.

_Dimensions:_ Equatorial diameter on 14 measured specimens, 24-34μ; cingulum width 3-6μ.

_Comparison:_ This species is distinguished from other similar forms described in this thesis by possession of distal grana or grana and verrucae. Occasional specimens show only a few large verrucae situated near or at the distal pole.

_Distribution:_ Jurassic to Tertiary of Australia and the U.S.S.R. (Dettmann, 1963); Mannville Group and Lower Colorado Group of western Canada (Norris, 1967); present in the Peace River and Lower Shaftesbury Formations and in the Lower Colorado Group.

### Genus CINGULATISPORITES (Thomson in Thoms. & Pflug) Potonié 1956

Type species: _Cingulatisporites levispeciosus_ Pflug in Thoms. & Pflug 1953.

## Cingulatisporites reticingulus Brenner 1963 (704)

Plate 4 , fig. 2

1963 Cingulatisporites reticingulus Brenner, p. 42; pl. 4, figs. 2-3.

Description: Amb rounded-triangular, sides broadly convex, apices rounded. Trilete; laesurae bordered by raised lips, 1-2µ high, and extending to just short of the equator. Exine two-layered; nexine triangular and smooth-walled, extending about 1/2 spore radius; sexine smooth proximally, equatorially thickened to form a characteristically microreticulate cingulum, 3-5µ wide, and distally ornamented with spinose processes set on tubercular, expanded bosses; spinose processes 3-8µ long, bosses 2-4µ wide.

Dimensions: Equatorial diameter on 3 specimens, 35-36µ.

Remarks: Selaginella kemensis Khlonova 1960, p. 29; pl. 3, figs. 8-9, illustrated also in Khlonova (1961, pl. 2, fig. 9) is somewhat similar to Cingulatisporites reticingulus Brenner, but an accurate determination cannot be made from Khlonova's illustrations. Khlonova's form is from the Cenomanian of the Chulym-Yenissei region, Russia.

Distribution: Found only in one sample at the top of the Grand Rapids Formation, "Grosmont" section.

## Cingulatisporites ?saevus Balme 1957 (705)

Plate 4 , fig. 3

Dimensions: Equatorial diameter on 4 specimens, 32-42µ; width of cingulum, 7-10µ.

Remarks: Specimens found in the Lower Colorado Group are referred to

Cingulatisporites ?saevus on the basis of a wide, radially striated cingulum and occasional preservation of distal spinose ornament. The preservation and number of specimens is not sufficient to make a positive identification.

Distribution: Present rarely in samples from the Joli Fou and Pelican Formations and from the Upper Shale Unit.

### Cingulatisporites sp. A. (702)

Plate 4, figs. 13-14

Description: Amb triangular; apices rounded; sides convex. Trilete; laesurae with low, thickened margo, often obscured by sculpture elements or confluent with them; laesurae extend nearly or just onto a uniform, narrow cingulum, 3-4μ wide. Scattered proximal rugulae and occasional rugulae and verrucae on the cingulum; distally, rugulae anastomose and may enclose fossae or irregularly shaped lumina, but never form a reticulum; distal rugulae 2-5μ wide and about 1μ high, forming a lophate pattern.

Dimensions: Equatorial diameter on 5 specimens, 35-45μ.

Remarks: Species assigned to Camarozonosporites (Pant ex Potonié) Klaus 1960 are tricrassate; Lycopodiacidites (Couper) Potonié 1956 does not possess a cingulum.

Distribution: Rare in samples from the Paddy Member and Lower Shaftesbury Formations, and from the Pelican Formation and the Upper Shale Unit.

### Cingulatisporites sp. B. (703)

Plate 4, figs. 6 - 7

Description: Amb triangular; apices rounded; sides straight or weakly convex. Trilete; laesurae simple slits but surrounded by a thickened, wide margo, which may be straight edged or irregularly lobed; laesurae reaching to the margin of uniformly thick cingulum, 3-5μ wide. Proximal surface smooth. Distal surface and equatorial region ornamented with irregularly shaped broad, low rugulae which generally anastomose and enclose irregularly shaped lumina forming a dissected distal thickening.

Dimensions: Equatorial diameter on 5 specimens, 38-44μ.

Comparison: Cingulatisporites sp. B. is distinguished from Cingulatisporites sp. A. by its distal dissected thickening and by the thick, wide margo on the proximal surface and lack of proximal ornament.

### Infraturma ZONATI Potonié & Kremp 1954

### Genus CIRRATRIRADITES Wilson & Coe 1940

Type species: Cirratriradites saturni (Ibrahim) S. W. & B. 1944

### Cirratriradites teter Norris 1967 (751)

Plate 4, fig. 5

1967 Cirratriradites teter Norris, p. 98; pl. 14, figs. 6-10.

Dimensions: Equatorial diameter on 10 measured specimens, 22-49μ; diameter of zona, 3-7μ.

Remarks: Specimens from various units investigated conform to the diagnosis given for Cirratriradites teter Norris 1967. The zona is variable in morphology, sometimes entire, sometimes fully dissected; no specimens were found with the radial thickenings mentioned by Norris (1967, p. 98).

Comparison: Cingulatisporites scabratus Couper 1958, p. 147; pl. 25, figs. 3-4, is similar in some respects to Cirratriradites teter but lacks the larger grana or verrucae, the dissected zona and is more triangular.

Distribution: Previously reported from the Viking and Upper Shale Unit in east-central Alberta (Norris, 1967); recovered in this thesis in samples from the upper Grand Rapids, Peace River and Lower Shaftesbury Formations and from the Lower Colorado Group in central and south-central Alberta. Geological range thus late middle to late upper Albian in western Canada.

### Genus KRAEUSELISPORITES (Leschik) Jansonius 1962

Type species: Kraeuselisporites dentatus Leschik 1955.

1955 Kraeuselisporites Leschik, p. 36.

1958 Styxisporites Cookson & Dettmann, p. 114.

1963 Kraeuselisporites (Leschik) Jansonius, p. 46.

### cf. Kraeuselisporites sp. A. (752)

Plate 4 , figs. 11-12

Description: Amb triangular-rounded. Trilete; laesurae extend nearly to the periphery of the spore, bordered by raised membranous lips about 6μ high. Apparently three-layered construction, the outer layer forming a membranous zona. Within the circumference of the innermost layer but arising from the outermost layer, are broad-based, thick-columned, papillate processes, each occupying the central portion of a polygonal, slightly raised thickening. Processes 5-11µ high, and 3-5µ wide at the base; polygonal areas, 6-14µ in maximum diameter. The innermost layer appears to be thickened at the periphery, the medial layer is apparently slightly frilled along its circumference. All layers appear to be smooth-walled.

Dimensions: Diameters on 1 specimen: outer layer, 91µ; medial layer, 66µ; inner layer, 77µ.

Remarks: This specimen differs from Kraeuselisporites in having three wall layers and in having the distal processes set on polygonal raised areas.

Comparison: Selaginella speciosa Krasnova in Samoilovich, et al., 1961, p. 33; pl. 6, figs. 5a-c, possess distal spines, partially set on polygonal bases, with a smooth proximal surface, but differs in having the spines over the whole of the distal surface and in the construction of the spore.

Distribution: Present in one sample from the upper Grand Rapids Formation, "Grosmont" section.

### Suprasubturma PERINOTRILITES (Erdtman) Dettmann 1963

### Genus DENSOISPORITES (Weyland & Krieger) Dettmann 1963

Selected syn.

1953 Densoisporites Weyland & Krieger, p. 12.

1961 Selaginella Spring; Krasnova in Samoilovich, et al., p. 19 (pars).

1964 Lygodiidites Pocock, p. 180.

Type species: Densoisporites velatus (Weyland & Krieger) Krasnova 1961.

Densoisporites microrugulatus Brenner 1963 (301)

Plate 4 , fig. 8

1963 Densoisporites microrugulatus Brenner, p. 61; pl. 15, fig. 6 and pl. 16, fig. 1.

1967 Densoisporites microrugulatus Brenner; Norris, p. 99; pl. 14, fig. 11.

Description: Amb broadly triangular. Two layered construction, with an outer cingulate sculptine bearing microrugulate (vermiculate) sculpture, and an inner layer, smooth and thin walled. Inner layer bearing a trilete slit which is reflected by an outer folded triradiate mark reaching the periphery of the spore body. Some specimens show three faint distal interradial thickenings near the distal pole.

Dimensions: Diameters on 5 specimens; sculptine, 49-56µ; inner layer, 36-49µ.

Remarks: The terminology of Dettmann (1963, p. 83) is used in describing the forms in this genus.

Distribution: Upper Barremian to Albian of Maryland, U.S.A. (Brenner, 1963); Upper Shale Unit in east-central Alberta (Norris, 1967); present rarely in samples investigated in this thesis from the Paddy Member, Lower Shaftesbury, Joli Fou and Viking Formations.

## *Densoisporites* cf. *D.* (al. *Lygodiidites*) *balmei*

## (Pocock 1964) comb. nov. (302)

Plate 4 , fig. 17

1964 *Lygodiidites balmei* Pocock, p. 180; pl. 5, figs. 3/4.

*Description*: Amb rounded triangular. Two layered construction. Sculptine and inner layer smooth or scabrate. Sculptine bearing a triradiate mark which reaches the periphery of the spore, reflecting as a triradiate mark on the inner layer; sculptine with thickened periphery, about 4μ wide.

*Dimensions*: Diameters on 5 specimens; sculptine, 49-70μ; inner layer, 35-58μ.

*Remarks*: Pocock uses the terms "sexine" and "nexine" and these correspond to the terms "sculptine" and "inner layer" used by Dettmann (1963) and followed here. The other species described by Pocock (1964) under *Lygodiidites* also belongs in *Densoisporites* and is here transferred: *Densoisporites* (al. *Lygodiidites*) *laevigatus* (Pocock, p. 180; pl. 5, fig. 2) comb. nov.

*Comparison*: This species is distinguished by the possession of smooth or scabrate sculptine and inner layer from other species of *Densoisporites*.

*Distribution*: Mannville Group, middle Albian age, in Saskatchewan (Pocock, 1964); noted rarely in samples from the upper Grand Rapids Formation, the Viking and Lower Shaftesbury Formations, and the Paddy Member, Peace River Formation in this thesis. The range is thus extended to Upper Albian.

### Densoisporites sp. A. (304)

Plate 4 , fig. 18

Description: Amb rounded triangular. Two layered construction. Sculptine thickened at the periphery to form a cingulum and ornamented with low verrucae or grana, slightly radially disposed. Trilete; laesurae extend to the edge of the inner layer and reflected on the sculptine. Inner layer nearly equal in diameter to the sculptine.

Dimensions: Equatorial diameters on 1 specimen; inner layer, 50μ; outer layer, 56μ; cingulum width, 6μ.

Comparison: The ornament on the sculptine distinguishes this form from other species of Densoisporites.

Distribution: Present in one sample near the top of the Viking Formation, "Wabamun" section.

### Genus CYCLOSPORITES Cookson & Dettmann 1959

Type species: Cyclosporites hughesi (Cookson & Dettmann) Cookson & Dettmann 1959.

1958 Radiatisporites auct. non Potonié & Kremp 1954; Cookson & Dettmann, p. 103.

1959 Cyclosporites Cookson & Dettmann.

### cf. Cyclosporites sp. A. (305)

Plate 4, figs. 9-10

Description: Amb triangular; sides convex, apices rounded. Trilete; laesurae extend to the equator and bordered by raised lips about 7μ high. Two layered construction, the inner triangular layer extending about 2/3 spore radius. Outer layer smooth proximally, but ornamented distally with sinuous, sometimes irregularly shaped, broad rugulae, which may enclose irregular lumina of variable width and length, or may lie freely in a lophate pattern. Rugulae 2-4μ wide and 2-3μ high; lumina 1/2 to 3μ in width and 1-11μ in longest diameter.

Dimensions: Equatorial diameter on 1 specimen, 60μ; inner layer, 38μ.

Distribution: Present in one sample from the Pelican Formation, "Grosmont" section.

## Turma MONOLETES Ibrahim 1933

## Suprasubturma ACAVATOMONOLETES Dettmann 1963

## Subturma AZONOMONOLETES Luber 1935

## Infraturma LAEVIGATOMONOLETI Dybová & Jachowicz 1957

## Genus LAEVIGATOSPORITES Ibrahim 1933

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

### *Laevigatosporites ovatus* Wilson & Webster 1946 (951)

Plate 4, fig. 16

Dimensions: Length on 4 specimens, 32-45μ.

Distribution: Worldwide distribution in the Jurassic and Cretaceous. Occurs rarely in samples from the Paddy Member, Joli Fou and Lower Shaftesbury Formations. Present also in the Mannville Group and other parts of the Lower Colorado Group (Singh, 1964; Norris, 1967).

## Turma HILATES Dettmann 1963

## Genus JANUASPORITES (Pocock 1962) emend.

1962 Januasporites Pocock, p. 56.

1964 Januasporites (Pocock) Singh, p. 94.

Emended Diagnosis: Amb subrounded or subtriangular. Two layered construction. Hilate. Hilum developed as a distal polar opening in the inner wall and reflected by a similar opening or thinning of the outer wall layer. A distinct to indistinct vestigial trilete ridge, extending nearly the spore radius, developed on the outer proximal layer. Inner layer smooth; outer layer variously ornamented on both the proximal and distal faces with spines, clavate processes or an imperfect to perfect reticulum, among other types of sculpture. The outer layer extends beyond the equator to form a thin zonate margin around the inner layer.

Type species: Januasporites reticularis Pocock 1962, p. 56; pl. 8, figs. 121-123.

Remarks: Pocock (1962, p. 56) diagnosed the genus Januasporites as alete and distally porate. Singh (1964, p. 94) emended the genus and referred to thinning of the wall layers in the distal polar regions. The writer has recovered numerous specimens belonging to species described under this genus and nearly all show a distinctly developed distal hilum. For this reason the writer proposes an emendation of the genus and transfer it to the Hilates Dettmann 1963.

## Januasporites spiniferus (Singh 1964) emend. (901)

Plate 4 , figs. 15 and 23

1964 Januasporites spiniferus Singh, p. 94; pl. 12, figs. 8-12.

Emended Diagnosis: Amb circular to subcircular; outline smooth to polygonal where spinose processes show broadened bases. Trilete mark indistinct, occasionally present as a ridge-like mark extending nearly the complete spore radius. Hilate; the hilum present as a distal circular or subcircular opening in the inner wall layer and often reflected as a similarly shaped opening or thinning in the outer wall layer. Inner layer smooth or scabrate and about 1-2μ thick. Outer layer closely appressed to the inner layer and bearing clavate to spinose processes, occasionally with broadened bases; processes 3-8μ long, spaced 5-10μ apart and present both proximally and distally, but somewhat reduced in number on the proximal surface. Some specimens may show a low, highly imperfect reticulum joining the bases of some processes. Corroded processes may appear baculate.

Dimensions: Equatorial diameter on 40 measured specimens, 39-63μ.

Remarks: The species is emended to emphasize the hilate opening present in the species.

Comparison: *Januasporites spinulosus* Dettmann 1963, p. 50; pl. 10, figs. 17-20 has a well-developed distal reticulum and proximal spinules and is somewhat larger in size range.

Distribution: Middle Albian of east-central Alberta and common near the top of the Grand Rapids Formation (Singh, 1964). Present only in samples from the upper Grand Rapids Formation, the upper Viking, and Lower Shaftesbury Formations and the Upper Shale Unit. Norris (1967) does not report this species from the Lower Colorado Group in east-central Alberta; occurring also in the late Albian of Saskatchewan and Manitoba (R. L. Cox, pers. comm.).

Genus AEQUITRIRADITES (Delcourt & Sprumont) Cookson & Dettmann 1961

1955 *Aequitriradites* Delcourt & Sprumont, p. 44.

1961 *Selaginellidites* Krasnova in Samoilovich, *et al*., p. 38.

1961 *Aequitriradites* (Delcourt & Sprumont) Cookson & Dettmann, p. 42.

Type species: *Aequitriradites dubius* (Delcourt & Sprumont) Delcourt, Dettmann and Hughes 1963.

### *Aequitriradites spinulosus*

(Cookson & Dettmann) Cookson & Dettmann 1961 (902)

Plate 4, fig. 22

Selected syn.

1958 *Cirratriradites spinulosus* Cookson & Dettmann, p. 113; pl. 18, figs. 9-13 and pl. 19, figs. 1-2, 5-7 (*non* figs. 3-4).

1961 *Selaginellidites spinulosus* (Cookson & Dettmann) Krasnova in Samoilovich, *et al*., p. 41; pl. 11, figs. 2-3.

1961 *Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann, p. 427; pl. 52, figs. 7-12.

*Dimensions*: Equatorial diameters on 3 specimens: total diameter, 65-85μ; inner diameter, 39-59μ; zona 13-15μ wide.

*Distribution*: Lower Cretaceous of eastern Australia; Hauterivian to Danian in the U.S.S.R. (Bolkhovitina, 1959; Samoilovich, *et al*., 1961); Valanginian-Middle Albian of western Canada (Pocock, 1962; Singh, 1964). Rare specimens noted in samples from the upper Grand Rapids and Viking Formations and from the Paddy Member, thus extending the range in western Canada to late Albian.

Aequitriradites sp. A. (907)

Plate 4 , fig. 28

Description: Amb triangular; apices slightly acute; sides convex. Wall extended equatorially to form a thin scabrate zona about 1/3 radius of spore in width. Hilate, the hilum represented by a smooth distal polar area. Inner proximal ornament of minute grana or irregularly shaped vermiculate elements, the latter becoming more sparsely and somewhat radially arranged near the zona; the grana more concentrated in the proximal polar region. Distally, the inner region is ornamented with an anastomosing network of very low, narrow (1/2-1μ), sinuous, short (2-5μ long), rugulae, oriented in a radial manner and absent from a distal smooth region interpreted as the hilum position.
Dimensions: Equatorial diameter on 1 specimen; total diameter, 57μ; width of zona, 16μ.
Distribution: Present only in one sample of the upper Grand Rapids Formation, "Grosmont" section.

## Genus ROUSEISPORITES Pocock 1962

1962 Rouseisporites Pocock, p. 53.

1963 Rouseisporites Pocock; Dettmann, p. 96 (diagnosis restated)

Type species: Rouseisporites reticulatus Pocock 1962.

Rouseisporites reticulatus Pocock 1962 (903)

Plate 4 , fig. 27

1962 Rouseisporites reticulatus Pocock, p. 53; pl. 7, figs. 101-105.

1963 Rouseisporites reticulatus Pocock; Dettmann, p. 97; pl. 23, figs. 4-9; fig. 6d.

1964 Rouseisporites reticulatus Pocock; Singh, p. 90; pl. 11, figs. 16-17.

Dimensions: Equatorial diameter on 4 specimens, 56-60μ.

Distribution: Present in Barremian to Albian strata of western Canada (Singh, 1964; Pocock, 1962) and in Aptian-Albian strata of eastern Australia and New Guinea (Cookson and Dettmann, 1958). Noted only in samples from the upper Grand Rapids Formation in east-central Alberta in this thesis. The species appears confined to Aptian-Middle Albian strata in western Canada.

### Rouseisporites triangularis Pocock 1962 (904)

Plate 4, fig. 21

1962 Rouseisporites triangularis Pocock, p. 54; pl. 7, figs. 110-111.

1964 Rouseisporites triangularis Pocock; Singh, p. 91; pl. 11, fig. 19.

Dimensions: Equatorial diameter on 2 specimens, 48 and 49μ.

Comparison: Dettmann (1963, p. 97) notes that Rouseisporites triangularis is similar to R. simplex (Cookson & Dettmann) Dettmann 1963 but differs in having a more conspicious tetrad mark, longer distal ridges and a more robust outer layer which invaginates larger depressions in the equatorial regions.

Distribution: Aptian to Middle Albian of western Canada (Pocock, 1962; Singh, 1964) rare specimens found in this thesis from samples of the upper Grand Rapids Formation and the Harmon Member, Peace River Formation.

## Genus COOKSONITES (Pocock) Dettmann 1963

1962 *Cooksonites* Pocock, p. 54 (pars).

1963 *Cooksonites* (Pocock) Dettmann, p. 90.

1964 *Cooksonites* Pocock; Singh, p. 92 (pars).

Type species: *Cooksonites variabilis* Pocock 1962.

### *Cooksonites variabilis* Pocock 1962 (905)

Plate 4, fig. 20

Selected syn.

1962 *Cooksonites variabilis* Pocock, p. 54; pl. 7, figs. 112-117.

*Dimensions*: Equatorial diameter on 1 specimen, 67μ; cingulum variable, 8-14μ.

*Remarks*: Sections of this species by Dettmann (1963; pl. 21, fig. 11) show that the exine is one-layered and thickened equatorially to form a cingulum.

*Distribution*: Previously reported from Valanginian to Middle Albian strata of western Canada (Pocock, 1962; Singh, 1964); the Aptian-Albian "Speciosus" assemblage of eastern Australia (Dettmann, 1963); noted in this thesis in one sample from the uppermost Grand Rapids Formation, "Grosmont" section.

## SPORITES INCERTAE

### Genus Undetermined sp. A. (130)

Plate 4, figs. 24 and 30

Description: Amb subtriangular. Trilete; laesurae extend nearly to the equator and are slightly raised into low (1-2μ) membranous lips. Proximal surface smooth. The distal surface ornamented with isodiametric grana and verrucae as well as some elongate rugulae, grana present nearer the equatorial region grading into the larger sculpture elements.

Construction of spore apparently cavate, the inner layer laevigate and paralleling the amb of the outer layer. Ornament on the outer layer also zoned, the larger elements found only within the circumference of the inner layer.

Dimensions: Equatorial diameters on 1 specimen; outer layer, 43μ; inner layer, 31μ.

Remarks: The taxonomic position of this specimen is uncertain. To the writer's knowledge, no species have been described which correspond to this type of structure in Mesozoic strata. The miospore genus Duplexisporites Deák (in Playford and Dettmann, 1965) has similar structure but differs in other respects.

Distribution: One specimen recorded from the Lower Shaftesbury Formation, "Spirit River" section.

### Genus Undetermined sp. B. (753)

Plate 4, fig. 29

Description: Amb subcircular. Two layered construction or ?zonate. Trilete; laesurae ridge-like, narrow, extending to the spore periphery.

Inner layer nearly circular and smooth-walled, extending about 2/3 spore radius. Outer layer smooth proximally; distally bearing low grana or irregular vermiculate elements, closely packed and often anastomosing to enclose irregular lumina. Vermiculi 1-2μ wide and about 1μ high, and 2-4μ long.

Dimensions: Equatorial diameter on 3 specimens, 45-50μ; inner layer, 28-34μ.

Distribution: Present rarely in samples from the Viking Formation in the "Wabamun" section and the Lower Shaftesbury Formation in the "Spirit River" section.

Anteturma POLLENITES Potonié 1931

Turma SACCITES Erdtman 1947

Subturma MONOSACCITES (Chitaley) Potonié & Kremp 1954

Infraturma SACCIZONATI Bhardwaj 1957

## Genus CEREBROPOLLENITES Nilsson 1958

Type species: Cerebropollenites mesozoicus (Couper) Nilsson 1958.

### Cerebropollenites mesozoicus (Couper) Nilsson 1958 (10001)

Plate 4, figs. 31-32

Selected syn.

1958 Tsugaepollenites mesozoicus Couper, p. 155; pl. 30, figs. 8-10.

1958 Cerebropollenites mesozoicus (Couper) Nilsson, p. 72; pl. 6, figs. 10-12.

Dimensions: Equatorial diameter on 8 measured specimens, 31-66μ.

Distribution: Lower Jurassic to Lower Cretaceous of Europe (Couper, 1958; Nilsson, 1958); Middle Jurassic to Upper Cretaceous of western Canada (Pocock, 1962; Singh, 1964; Norris, 1967); present in samples from all strata investigated in this thesis.

## Subturma DISACCITES Cookson 1947

### Genus VITREISPORITES (Leschik) Jansonius 1962

Type species: Vitreisporites signatus Leschik 1955.

1955 Vitreisporites Leschik, p. 53.

1958 Caytonipollenites Couper, p. 149.

1962 Vitreisporites (Leschik) Jansonius, p. 55.

### Vitreisporites pallidus (Reissinger) Nilsson 1958 (10112)

Plate 4 , fig. 19

Selected syn.

1938 Pityosporites pallidus Reissinger, p. 14.

1950 Pityopollenites pallidus (Reissinger) Reissinger, p. 109; pl. 15, figs. 1-5.

1953 Caytonia oncodes Bolkhovitina, p. 72; pl. 11, fig. 1.

1957 Pityosporites pallidus Reissinger; Balme, p. 36; pl. 10, figs. 112-113.

1958 Caytonipollenites pallidus (Reissinger) Couper, p. 150; pl. 26, figs. 7-8.

1958 Vitreisporites pallidus (Reissinger) Nilsson, p. 78; pl. 7, figs. 12-14.

Dimensions: The following abbreviations will be used throughout this and following sections dealing with the dimensions of bisaccate pollen grains:

| | |
|---|---|
| Breadth of grain (BG) | Length of corpus (CL) |
| Breadth of corpus (CB) | Length of sacci (SL) |
| Breadth of sacci (SB) | Depth of corpus (CD) |
| Breadth of aposaccia (AB) | Depth of sacci (SD) |

The measurements are those of Couper (1958), Pocock (1962) and others. The number of specimens measured is indicated by a figure in brackets after the measurements.

BG: 22-39μ (15). CL: 12-25μ (15). SB: 7-13μ (15).

Remarks: *Vitreisporites pallidus* (Reissinger) Nilsson is distinguished from *V. signatus* Leschik by its larger size.

Distribution: Worldwide distribution in Mesozoic strata; noted in samples from all units investigated.

### Genus ALISPORITES Daugherty 1941 restr. Pot. & Kr. 1956

Selected syn.

1941 *Alisporites* Daugherty, p. 98.

1956 *Alisporites* Daugherty restr. Potonié & Kremp, p. 176.

1959 *Alisporites* (Daugherty) Rouse, p. 314.

Type species: *Alisporites opii* Daugherty 1941.

### *Alisporites grandis* (Cookson) Dettmann 1963 (10101)

Plate 5 , fig. 2

Selected syn.

1953 *Disaccites grandis* Cookson, p. 471; pl. 2, fig. 41.

1957 *Pityosporites grandis* (Cookson) Balme, p. 36; pl. 10, figs. 110-111.

1959 *Alisporites rotundus* Rouse, p. 316; pl. 1, figs. 15-16.

1961 Pseudopicea grandis Rovnina in Samoilovich, et al., p. 44; pl. 44, figs. 1-2.

1962 Alisporites australis de Jersey (pars), p. 8; pl. 7, fig. 14 and pl. 3, figs. 3-4.

1962 Alisporites sp. 1. de Jersey, p. 9; pl. 3, fig. 1.

1962 Alisporites sp. 2. de Jersey, p. 9; pl. 2, fig. 13.

1963 Alisporites grandis (Cookson) Dettmann, p. 102; pl. 25, figs. 1-4.

1964 Alisporites sp. 1. de Jersey & Patten, p. 9; pl. 6, fig. 7.

? 1964 Picea elliptica Panova in Pokrovskaya & Stel'mak, p. 180; pl. 12, figs. 6-7.

Dimensions: The following dimensions on 15 specimens -
BG: 85-150μ. SL: 56-98μ. CL: 56-98μ. Ratio BG/SL: 1.3 to 2.0.

Remarks: Pocock (1962) reports a size range for this species of 78-128μ (BG). Dettmann (1963) gives 78-136 and Singh (1964) quotes 75-120μ. One specimen noted in this study had a total breadth of 150μ and a length of 98μ, but was otherwise indistinguishable from other specimens assigned to Alisporites grandis.

Picea elliptica Panova in Pokrovskaya and Stel'mak (1964) appears to be very similar to Alisporites grandis (Cookson) Dettmann but cannot be satisfactorily compared from the drawing.

Distribution: Jurassic and Cretaceous of Australia (Balme, 1957; de Jersey, 1962; Dettmann, 1963); Lower Cretaceous of western Canada (Pocock, 1962; Singh, 1964; Norris, 1967); Lower Cretaceous of Russia (Samoilovich, et al., 1961); present in all units investigated except the Paddy Member.

## Alisporites robustus Nilsson 1958 (10102)

Plate 4, figs. 25-26

Selected syn.

1958 Alisporites robustus Nilsson, p. 82; pl. 8, figs. 2-3.

1959 Alisporites bisaccus Rouse, p. 316; pl. 1, figs. 13-14.

1959 Alisporites bilateralis Rouse, p. 316; pl. 1, figs. 10-11.

1962 Alisporites parvus de Jersey (pars), p. 9; pl. 4, fig.s 1-2 only.

1962 Alisporites thomasii (Couper) Pocock (pars), p. 62; pl. 9, fig. 143 only.

1964 Alisporites thomasii (Couper) Pocock; Singh (pars), p. 109; pl. 14, figs. 11-12.

non Pteruchipollenites thomasii Couper 1958, p. 150; pl. 26, figs. 10-12.

Description: Bilaterally symmetrical, bisaccate pollen grains. Outline ovoid and smooth. Corpus subcircular and indistinct with thin proximal cap. Sacci length equal or nearly equal to corpus length; sacci very slightly distally pendant, with infrareticulate ornament; distal sacci roots straight or nearly straight, enclosing a straight-sided aposaccia.

Dimensions:

BG: 50-84µ (37). CB: 27-44µ (12). CL: 29-61µ (37). SB: 19-34µ (23). SL: 29-61µ (37). Ration BG/SL: 1.2-1.4.

Remarks: The writer was unable to obtain the original type specimens of Rouse (1959) for the species, Alisporites bisaccus and A. bilateralis. However, one of the original type samples has been rediscovered and a portion macerated for comparative purposes. The specimens of the genus

*Alisporites* recovered from the sample (Sample As - 2:3 of Rouse, 1959 - Sample BW 164 of the writer) are poorly preserved. The writer was able to distinguish between the several forms distinguished by Rouse only on the basis of their dimensions. The writer thus concludes that no essential difference other than size can be used to distinguish *Alisporites bisaccus* and *Alisporites bilateralis*. Because *Alisporites robustus* Nilsson 1958 was published prior to the species of Rouse, that name must take precedence.

A problem also arises with *Alisporites minutus* Rouse 1959 which appears to differ from *Alisporites robustus* only in size range. As well, at its lower limits, *Alisporites minutus* is closely comparable in size and morphology with *Vitreisporites pallidus* (Reissinger) Nilsson.

It should also be pointed out that the lower size limit of *Alisporites grandis* (Cookson) Dettmann slightly overlaps that of *A. robustus*. In this thesis the writer has adopted several arbitrary size limits to define the end members of these species. These are:

*Vitreisporites pallidus* (Reissinger) Nilsson: 21-39μ.
*Alisporites minutus* Rouse: 40-49μ.
*Alisporites robustus* Nilsson: 50-84μ.
*Alisporites grandis* (Cookson) Dettmann: 85-150μ.

Although these size limits are arbitrarily chosen, the writer thinks that they define useful size categories of similar bisaccate grains. They also conform to the size ranges of a number of well-established species commonly reported in the literature. The writer thinks that some of the size limits of Rouse (1959) are too narrow to be of value in distinguishing broad size categories in these forms.

Distribution: Jurassic and Cretaceous of Australia (de Jersey, 1962; Dettmann, 1963); Jurassic and Cretaceous of western Canada (Rouse, 1959; Pocock, 1962; Singh, 1964; Norris, 1967); Cretaceous of Europe (Nilsson, 1958).

### *Alisporites minutus* Rouse 1959 (10103)

Plate 5 , fig. 1

1959 *Alisporites minutus* Rouse, p. 316; pl. 1, fig. 12.

Dimensions:

BG: 41-48µ (15). CB: 13-28µ (5). SB: 16-19µ (5). SL: 23-31µ (15).

Comparison: *Alisporites minutus* Rouse is distinguished only by its total breadth, being smaller than *A. robustus* Nilsson and larger than *Vitreisporites pallidus* (Reissinger) Nilsson.

Distribution: Upper Jurassic of southeastern British Columbia (Rouse, 1959); present in samples from the Joli Fou and Viking Formations, the Upper Shale Unit, the Harmon and Cadotte Members and the Lower Shaftesbury and Pelican Formations.

### *Alisporites microsaccus* (Couper) Pocock 1962 (10104)

Plate 5 , fig. 4

Selected syn.

1958 *Pteruchipollenites microsaccus* Couper, p. 151; pl. 26, figs. 13-14.

1962 *Alisporites microsaccus* (Couper) Pocock, p. 62; pl. 9, figs. 142-144.

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb subcircular, outline in polar view smooth. Corpus indistinct, generally longer than broad; proximal exine little thickened. Sacci only slightly inclined, their breadth equal or less than 2/5 their length; distal roots more or less straight; sacci microreticulate.

Dimensions:

BG: 52-67μ (4). CL: 53-80μ (4). SB: 21-28μ (2). SL: 53-80μ (4).

Comparison: *Alisporites microsaccus* (Couper) Pocock is distinguished by its corpus which is longer than broad and by its small sacci.

Distribution: Middle and Upper Jurassic of England (Couper, 1958); Valanginian to Upper Albian (Pocock, 1962; Singh, 1964; and this thesis) of western Canada; present rarely in samples from the Cadotte Member, the Pelican Formation and the Upper Shale Unit.

## Genus PARVISACCITES Couper 1958

Type species: *Parvisaccites radiatus* Couper 1958.

### *Parvisaccites radiatus* Couper 1958 (10105)

Plate 4 , fig. 33

1958 *Parvisaccites radiatus* Couper, p. 154; pl. 29, figs. 5-8 and pl. 30, figs. 1-2.

Distribution: Lower Cretaceous of England (Couper, 1958); Barremian-Albian of Maryland, U.S.A. (Brenner, 1963); Lower Cretaceous of western Canada (Pocock, 1962; Singh, 1964; Norris, 1967); present in samples from the Lower Colorado Group and from the Cadotte Member in the "Grouard" section.

### Parvisaccites amplus Brenner 1963 (10113)

Plate 5, fig. 12

1963 Parvisaccites amplus Brenner, p. 78; pl. 28, fig. 1 and pl. 29, fig. 1.

Dimensions: The following dimensions on 1 specimen -

BG: 126µ. CB: 98µ. CD: 83µ. SB: 62µ. SD: 70µ.

Distribution: Previously reported only from the Patapsco Formation (Albian) of Maryland, U.S.A. (Brenner, 1963); recorded here from one sample in the Upper Shale Unit, "Wabamun" section.

## Genus ABIETINEAEPOLLENITES Potonié 1951

Type species: Abietineaepollenites microalatus (Potonié) Potonié 1951.

### Abietineaepollenites aequisaccus sp. nov. (10106)

Plate 5, figs. 3 - 4

Holotype: BW 102/2 at 576 - 1057; breadth of grain, 64µ.

Description: Bilaterally symmetrical, bisaccate pollen grains. Outline more or less subelliptical. Corpus circular or subcircular; proximal corpus exine thickened and occasionally showing marginal folds at the corpus-sacci junctions; proximal exine 2-4µ thick. Sacci more or less distally pendant, their length equal or nearly equal to the corpus length; semi-circular to sub-elliptical in outline, extending relatively little past the corpus in polar view. Aposaccia nearly straight-sided or slightly convex; sacci ornament with an infra-reticulum, the muri about 1/2µ wide and the lumina polygonal and 2-3µ wide.

Dimensions:

BG: 42-74μ (20). CB: 29-45μ (20). CL: 31-45μ (20). SB: 20-34μ (20). SL: 29-47μ (20). Aposaccia width: 3-17μ (14).

Distribution: Present in samples from the Lower Colorado Group and the Peace River and Lower Shaftesbury Formations.

### *Abietineaepollenites auritus* sp. nov. (10107)

Plate 5, fig. 6

Holotype: BW 167/3 at 511 - 932; breadth of grain, 57μ.

Description: Bilaterally symmetrical, bisaccate pollen grains. Overall outline ovoid. Corpus subcircular or ovoid; length usually greater than breadth or nearly equal. Proximal cap with characteristic ornament of regularly arranged small grana; distal corpus exine punctate. Sacci length distinctly less than corpus length; sacci distally pendant, semi-circular in outline, with distal roots distinctly shorter than the corpus length outlining a relatively wide, straight-sided aposaccia; sacci infrareticulate, the lumina radially disposed, becoming smaller nearer the corpus.

Dimensions:

BG: 53-75μ (10). CB: 38-55μ (10). CL: 41-55μ (8). SB: 21-32μ (8). SL: 34-48μ (8).

Comparison: The small sacci and proximal granular cap distinguish *Abietineaepollenites auritus* sp. nov. from *A. aequisaccus* sp. nov.

Distribution: Present rarely in samples from the Joli Fou and Viking Formations and from the Cadotte Member-Joli Fou Formation in the "Grouard" section.

### Abietineaepollenites sp. A. (10120)

Plate 5, fig. 7

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb outline elliptical, outline more or less smooth. Corpus subcircular in polar view; proximally exine 2μ thick, thin distally. Sacci with proximal proximal roots; distal roots nearly straight outlining a relatively wide aposaccia; sacci longer than broad in polar outline, more than a semi-circle; infrareticulate ornament present on well preserved specimens; lumina 1-4μ wide and irregular in shape, muri narrow.

Dimensions: The following dimensions on 5 specimens -

BG: 70-99μ. CB: 42-59μ. CL: 34-58μ. SB: 29-44μ. SL: 35-52μ.

Width of aposaccia: 8-18μ.

Comparison: The irregular coarse lumina on the sacci and the overall dimensions of this form distinguish it from others described in this thesis.

Distribution: Found rarely in samples from the Joli Fou, Viking and Pelican Formations.

### Abietineaepollenites sp. B. (10121)

Plate 5, fig. 20

Description: Bilaterally symmetrical, bisaccate pollen grains. Outline in breadth axis ovoid. Corpus circular; smooth slightly thickened exine proximally. Sacci more or less semicircular in polar view and shorter than the corpus length; sacci apparently distally pendant; sacci walls punctate, smooth or microreticulate.

Dimensions: The following dimensions on 3 specimens -

GB: 74-116μ. CB: 53-84μ. CL: 53-85μ. SB: 32-66μ. SL: 49-77μ.

Comparison: This species is distinguished from other species assigned to Abietineaepollenites in this thesis by the large corpus, and the relatively short distal sacci roots.

### Genus PITYOSPORITES (Seward) Manum 1960

Type species: Pityosporites antarcticus (Seward) Manum 1960.

### Pityosporites constrictus Singh 1964 (10122)

Plate 5, fig. 8

1964 Pityosporites constrictus Singh, p. 122; pl. 16, fig. 8-9.

Remarks: Grains identical to this species, first recorded by Singh (1964) from the Mannville Group (Aptian to Middle Albian), were recorded from one sample in the "Grosmont" section of the uppermost Grand Rapids Formation. They are recorded here without comment.

Distribution: Mannville Group (Singh, 1964); not recorded in this thesis from the Lower Colorado Group or the Peace River-Lower Shaftesbury succession.

### Genus PINUSPOLLENITES Raatz 1937

Type species: Pinuspollenites labdacus (Potonié) Raatz 1937.

### Pinuspollenites sp. A. (10108)

Plate 5, figs. 11 and 15

Description: Bilaterally symmetrical, bisaccate pollen grains. Corpus with thick proximal exine, elongate in the breadth axis. Sacci with proximal proximal roots, distally pendant, and relatively large compared to the corpus, ovoid in lateral view; sculpture and structure of the sacci not preserved.

Dimensions:

GB: 44-76μ (9). CB: 28-50μ (9). CL: 24-29μ (4). CD: 15-27μ (4). SB: 21-43μ (6). SL: 22-31μ (6). SD: 18-31μ (4).

Remarks: Despite the imperfect preservation of the grains, this species is easily recognized and distinctive. The author thinks, however, that more material is necessary on which to formulate a new species.

Distribution: Present rarely in samples from the Lower Colorado Group, the Harmon and Cadotte Members of the Peace River Formation and the Pelican Formation.

### Genus PICEAEPOLLENITES Potonié 1931

Type species: *Piceaepollenites alatus* Potonié 1931.

### *Piceaepollenites*? sp. A. (10109)

Plate 5, fig. 19

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb elliptical, outline nearly smooth; elongate in the breadth axis. Corpus subcircular and often completely covered by the sacci in polar view. Sacci roughly semi-circular in polar view with straight distal roots which are very closely set; sacci infrapunctate, vermiculate or microreticulate, often completely enclosing the corpus except for the aposaccale region; sacci larger than the corpus and not strongly distally pendant.

*Dimensions:*

BG: 95-125μ (10). CB: 59-73μ (3). CL: 63-87μ (8). SB: 45-67μ (6). SL: 70-107μ (9). Width of aposaccia: 2-8μ.

*Comparison:* The large size, enclosure of the corpus by the sacci, and narrow aposaccia distinguish this species from other forms described in this thesis.

*Distribution:* Noted only in samples from the Harmon, Cadotte and Paddy Members and from the uppermost Grand Rapids Formation.

### Genus CEDRIPITES Wodehouse 1933

Type species: *Cedripites eocenicus* Wodehouse 1933.

### *Cedripites cretaceus* Pocock 1962 (10110)

Plate 5, fig. 13

Selected syn.

1962 *Cedripites cretaceus* Pocock, p. 63; pl. 9, figs. 145-146 and pl. 10, figs. 147-148.

*Dimensions:*

BG: 52-126μ (23). CB: 37-97μ (13). CD: 27-59μ (13). SB: 15-37μ (13). SD: 23-56μ (13).

*Comparison:* *Cedripites cretaceus* Pocock 1962 is characterized by equatorial proximal sacci roots, and sacci which are longer than, and often envelope, the corpus distally.

*Distribution:* Lower Cretaceous of Alberta (Pocock, 1962; Singh, 1964; Norris, 1967); present in all strata investigated in this thesis.

### Cedripites canadensis Pocock 1962 (10111)

Plate 5, fig. 9

Selected syn.

1962 Cedripites canadensis Pocock, p. 63; pl. 10, figs. 149-150.

Dimensions:

BG: 50-103μ (14). CB: 42-63μ (11). CD: 31-58μ (7). SB: 22-50μ (7). SD: 29-43μ (7).

Comparison: Cedripites canadensis Pocock 1962 is distinguished from the similar species, C. cretaceus Pocock 1962, by possession of distinctly proximal proximal sacci roots and distal sacci roots that are shorter than the corpus in length; the sacci never envelope the corpus as in C. cretaceus.

Distribution: Lower Cretaceous of Alberta (Pocock, 1962; Singh, 1964; Norris, 1967); present in all strata investigated in this thesis.

### Genus PHYLLOCLADIDITES Cookson ex Couper 1953

Type species: Phyllocladidites mawsoni Cookson 1947.

1947 Phyllocladidites Cookson, p. 132. nov. spt.

1953 Phyllocladidites Cookson ex Couper, p. 38.

1953 Dacrydiumites Cookson, p. 56.

### Phyllocladidites sp. A. (10151)

Plate 5, figs. 10 and 14

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb subcircular, outline smooth. Corpus subcircular; proximal exine 3-5μ thick and punctate. Sacci small with more or less straight distal roots extending about 2/3 corpus length; sacci length distinctly less than corpus length; sacci often not expanded or if expanded, folded and crumpled, proximal sacci roots distal to the equatorial plane.

Dimensions:

BG: 41-66μ (11). BC: 30-66μ (11). CL: 42-56μ (7). BS: 14-21μ (5). LS: 18-36μ (8). DS: 15-39μ (3).

Comparison: *Phyllocladidites* sp. A. bears some resemblance to *Phyllocladidites inchoatus* (Pierce) Norris 1967 but is larger overall and has much larger sacci which do not show any infrasculpture on the specimens available for examination.

Distribution: Present rarely in samples from the Joli Fou, Viking, Pelican and Lower Shaftesbury Formations and from the Cadotte and Paddy Members and the Upper Shale Unit.

### *Phyllocladidites* sp. B. (10152)

Plate 5, fig. 21

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb ovoid, outline slightly lobed when sacci expanded. Corpus ovoid, elongate in the breadth axis. Proximal cap rugulate, finely granulate or vermiculate, about 4-5μ thick; distal exine of corpus thin and punctate. Sacci subcircular, thickened at the sacci-corpus junctions, much smaller than the corpus; distal roots nearly straight, outlining a wide aposaccale region; proximal sacci roots distal to the equatorial plane.

Dimensions:

BG: 44-65μ (8). CB: 39-50μ (7). CL: 23-33μ (2). CD: 29-34μ (2). SB: 15-26μ (6). SL: 16-17μ (2). SD: 24-25μ (2).

Comparison: *Phyllocladidites* sp. B. is distinguished from *Phyllocladidites* sp. A. by its proximal ornament and thickened corpus-sacci junctions. *Phyllocladidites minimus* (Brenner) Norris 1967 is smaller and has different proximal ornament.

### Genus PODOCARPIDITES Cookson ex Couper 1953

Type species: *Podocarpidites ellipticus* Cookson 1947.

### *Podocarpidites* cf. *P. ellipticus* Cookson 1947 (10153)

Plate 5, fig. 18

Cf. 1947 *Podocarpidites ellipticus* Cookson, p. 131; pl. 13, fig. 6.

1962 *Podocarpidites* cf. *P. ellipticus* Cookson; Pocock, p. 65; pl. 10, figs. 153-156.

1964 *Podocarpidites* cf. *P. ellipticus* Cookson; Singh, p. 115; pl. 15, fig. 11.

1967 *Podocarpidites* cf. *P. ellipticus* Cookson; Norris, p. 102; pl. 15, figs. 6-7.

Dimensions:

BG: 57-74μ (4). CB: 32-42μ (5). CL: 34-41μ (5). SB: 29-32μ (4). SL: 39-49μ (5). Width of aposaccia: 4-14μ (3).

Remarks: *Podocarpidites ellipticus* Cookson is similar to the specimens described above but has a wider distal aposaccale region and distinctly reticulate sacci.

Distribution: Lower Cretaceous of Alberta (Norris, 1967); present rarely in samples from the Harmon, Cadotte and Paddy Members and the Joli Fou Formation in central and west-central Alberta investigated in this thesis.

### Podocarpidites canadensis Pocock 1962 (10160)

Plate 6, fig. 14

1962 Podocarpidites canadensis Pocock, p. 66; pl. 10, figs. 157-158.

1964 Podocarpidites canadensis Pocock; Singh, p. 118; pl. 16, figs. 1-3.

Dimensions: Following dimensions on 2 specimens -

BG: 84μ. BC: 31-42μ. CL: 29-48μ. SB: 32-35μ. SL: 49-57μ.

Distribution: Lower Cretaceous of western Canada (Pocock, 1962; Singh, 1964); present rarely in samples from the uppermost Grand Rapids and the Pelican Formations.

### Podocarpidites multesimus (Bolk.) Pocock 1962 (10161)

Plate 6, fig. 9

1956 Podocarpus multesima Bolkhovitina, p. 127; pl. 24, fig. 235.

1962 Podocarpidites multesimus (Bolkhovitina) Pocock, p. 67; pl. 10, figs. 161-162 and pl. 11, fig. 163.

non Podocarpidites multesimus (Bolkhovitina) Pocock; Singh, p. 116; pl. 15, figs. 12-13.

Dimensions: The following dimensions on 6 specimens -

BG: 52-75μ. CB: 28-35μ. CL: 20-35μ. SB: 27-41μ. SL: 28-49μ.

Width of aposaccia: 4-10μ.

*Remarks*: *Podocarpidites multesimus* (Bolk.) Pocock is characterized by a subcircular to sometimes rhomboidal corpus and sacci which curve relatively gently to the distal roots and have their breadth nearly equal to their length.

*Distribution*: Jurassic and Lower Cretaceous in Alberta (Pocock, 1962). Lower Jurassic of the Vilyui Basin (Bolkhovitina, 1956); present rarely in samples from the Lower Colorado Group and the Cadotte Member, Peace River Formation.

## *Podocarpidites biformis* Rouse 1957 (10162)

Plate 6, fig. 10

1957 *Podocarpidites biformis* Rouse, p. 367; pl. 2, fig. 13.

1959 *Podocarpidites biformis* Rouse; Rouse, p. 313; pl. 1, figs. 8-9.

1964 *Podocarpidites multesimus auct. non* (Bolk.) Pocock; Singh, p. 116; pl. 15, fig. 12 only.

*Description*: Bilaterally symmetrical, bisaccate pollen grains. Amb ellipsoid, distinctly diploxylonoid. Corpus subcircular or elongate in the length axis; proximal cap thickened, 2-4μ thick. Sacci diploxylonoid with straight distal roots curving abruptly inwards to the distal roots and bordering a relatively narrow aposaccia. Sacci broadly reniform in shape.

*Dimensions*: The following dimensions on 2 specimens -

BG: 81-92μ. CB: 31-34μ. CL: 35-37μ. SB: 35-39μ. SL: 50-57μ.

*Comparison*: *Podocarpidites multesimus* (Bolk.) Pocock is smaller, often has a corpus elongate in the breadth axis and somewhat rhomboidal and has sacci of markedly different outline. The specimen illustrated by Singh (1964; pl. 15, fig. 12) conforms more to *Podocarpidites biformis* Rouse than to *P. multesimus* (Bolk.) Pocock in the opinion of the writer.

Distribution: Jurassic and Lower Cretaceous of western Canada (Rouse, 1957; 1959; Pocock, 1962; Singh, 1964). Present rarely in samples from the Viking and Lower Shaftesbury Formations.

### *Podocarpidites* sp. A. (10155)

Plate 6 , fig. 18

Description: Bilaterally symmetrical, bisaccate pollen grains. Corpus longer than broad; proximal exine thickened and often markedly thickened at the junction of the corpus and the proximal sacci roots. Sacci length greater than corpus length; sacci semicircular in polar view; infrareticulate ornament where preserved. Aposaccia relatively narrow and straight-sided.

Dimensions:

BG: 57-78μ (10). CB: 19-34μ (10). CL: 28-53μ (10). SB: 22-40μ (10). SL: 36-62μ (10). Width of aposaccia: 2-6μ (6).

Comparison: *Podocarpus patula* Bolkhovitina 1956, p. 128; pl. 24, fig. 238, is similar but much larger in breadth (95-120μ).

Distribution: Rare in samples from the Viking Formation and Upper Shale Unit and from the Cadotte and Paddy Members and the Lower Shaftesbury Formation.

### *Podocarpidites* sp. B. (10154)

Plate 6 , fig. 4

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb ovoid, outline weakly diploxylonoid. Corpus subcircular to circular; proximal cap thin and scabrate. Sacci greater than a semicircle in polar view; distal roots equal corpus length and outline a straight sided, narrow aposaccia; sacci length greater than corpus length; outline of sacci near distal roots gently curving. Well preserved specimens show an infrareticulate ornament, the lumina 1-2μ wide, and polygonal, the muri narrow, about 1/2μ wide.

Dimensions: The following dimensions on 6 specimens - BG: 60-88μ. CB: 35-50μ. CL: 32-45μ. SB: 29-43μ. SL: 38-56μ. Width of aposaccia: 2-7μ.

Comparison: The large corpus in relation to the sacci and the long distal sacci roots distinguish this species from other similar forms described in this thesis.

Distribution: Rare in samples from the Upper Mannville Group, Cadotte Member, Viking Formation and Upper Shale Unit.

### Genus RUGUBIVESICULITES Pierce 1961

Type species: *Rugubivesiculites convolutus* Pierce 1961.

Restated Diagnosis: Bilaterally symmetrical, bisaccate pollen grains. Amb ellipsoid and elongate in the breadth axis. Corpus circular or subcircular in polar view, ovoid in equatorial view. Proximal cap bearing variably developed rugulate cavate ornament over the whole proximal surface or concentrated about a prominent marginal frill. Sacci with terminal proximal roots, slightly distally pendent, smooth or granulate but often with infrareticulate ornament.

Remarks: The original diagnosis of Pierce (1961, p. 39) is: "Two-winged pollen with rugulate design on cap". The writer has amplified this diagnosis but has not changed the intent of the genus as conceived by Pierce.

### Rugubivesiculites rugosus Pierce 1961 (10156)

Plate 6, fig. 2

1961 Rugubivesiculites rugosus Pierce, p. 40; pl. 2, figs. 59-60.

1967 Rugubivesiculites rugosus Pierce; Norris, p. 104; pl. 16, figs. 6-7.

Description: Bilaterally symmetrical, bisaccate pollen grains. Corpus subcircular, generally slightly longer than broad. Proximal cap formed of rugulate thickenings, convoluted or sinuous and rounded in outline, 3-6µ wide and 2-4µ high, densely spaced and present over the whole of the proximal corpus, merging with a distinct marginal frill at the junction of the proximal sacci roots and the corpus. Sacci longer than broad, generally deeper than broad or nearly equal in these dimensions, with terminal proximal roots and latero-distally pendant; smooth-walled and often folded, nearly equal in length to the corpus.

Dimensions:

BG: 66-103µ (8). CB: 33-70µ (7). CL: 39-63µ (7). CD: 42-45µ (3).
SB: 25-44µ (9). SL: 33-64µ (7). SD: 33-56µ (5).

Remarks: The following forms may be synonymous with Rugubivesiculites rugosus Pierce 1961 but are illustrated only and not further described: Bisaccate grain in pl. 1, fig. 54 (Tschudy and Veach, 1965) from the lower part of the Thermopolis Shale, late Albian of Montana, U.S.A.

Bisaccate forms in pl. 7, figs. 8-13 (Leopold and Pakiser, 1964) from the Upper Cretaceous of Alabama, U.S.A.

Distribution: ?Cenomanian of Minnesota, U.S.A. (Pierce, 1961); Viking Formation and Upper Shale Unit in south-central and east-central Alberta (Norris, 1967; this thesis); Joli Fou, Viking and Upper Shale Unit of central Alberta, Lower Shaftesbury Formation of west-central Alberta, as noted in samples investigated in this thesis. Doubtful occurrences from the Upper Albian of Montana and the Upper Cretaceous of Alabama (Tschudy and Veach, 1965; Leopold and Pakiser, 1964); see also Part I, Chapter V, this thesis.

### Rugubivesiculites cf. R. reductus Pierce 1961 (10157)

Plate 6, figs. 11-12

Cf. 1961 Rugubivesiculites reductus Pierce, p. 41; pl. 2, figs. 64-65.

1963 Rugubivesiculites reductus ?auct. non Pierce; Brenner, p. 83; pl. 33, figs. 1-2.

1967 Rugubivesiculites reductus ?auct. non Pierce; Norris, p. 103; pl. 16, figs. 3-5.

Description: Bilaterally symmetrical bisaccate pollen grains. Corpus subcircular and generally slightly broader than long. Proximal cap ornamented with cavate, rugulate thickenings, sinuous and rounded, highly contorted, 3-5μ wide and 2-4μ high; rugulae sparse in the proximal polar region but becoming densely arranged towards the strongly developed marginal frill, the junction of the proximal sacci roots and the corpus. On some specimens the rugulae are almost entirely absent except at the margin. Sacci longer than broad, distally pendant with more or less terminal proximal roots and distal roots outlining a convex aposaccia, where visible; sacci smooth or with faint infrareticulation and often highly folded, longer than the corpus.

Dimensions:

BG: 63-106μ (9). CB: 33-58μ (10). CL: 27-53μ (8). SB: 26-37μ (9). SL: 35-62μ (10).

Remarks: The specimens described above, like those described by Brenner (1963) and Norris (1967), have a strongly developed marginal frill, faint infrareticulation on the sacci and sacci length as long or longer than the corpus length. Rugubivesiculites reductus Pierce 1961, from the illustrations (pl. 2, figs. 64-65) and description, appears to have a more weakly developed marginal frill, smaller rugulae on the proximal cap and a more pronounced infrareticulate ornament on the sacci. It is difficult, however, to determine the exact nature of the specimens described by Pierce from the illustrations because of their small size. Hence, the writer thinks that a questionable synonymy only may be indicated without recourse to the re-investigation of the type material.

The following forms may be synyonymous but are incompletely described or unpublished and are listed below without further comment:

non Podocarpidites sp. cf. P. biformis Leopold and Pakiser 1964, pl. 4, figs. 14-16 from the Tuscaloosa Group of Alabama, U.S.A.

Rugubivesiculites reductus Pierce (as R. fluens Pierce 1961) Pannella, p. 96; from the Fall River Formation in the Denver Basin (Upper Albian).

(Thesis, University of Colorado, 1966).

Comparison: The species described as Rugubivesiculites cf. R. reductus Pierce 1961 is distinguished from Rugubivesiculites reductus Pierce 1961 by possession of a more strongly developed marginal frill and by absence or marked reduction of the rugulae on the proximal cap.

Distribution: Previously reported from the Upper Albian and Cenomanian of Maryland (Brenner, 1963) and the Viking Formation and Upper Shale Unit of east-central Alberta (Norris, 1967); noted in this thesis from the Viking Formation and Upper Shale Unit of south-central Alberta, the Lower Colorado Group of central Alberta and east-central Alberta and the Lower Shaftesbury of west-central Alberta.

### Rugubivesiculites sp. A. (10158)

Plate 5, fig. 17 and Plate 6, fig. 1

Description: Bilaterally symmetrical, bisaccate pollen grains. Amb ovoid and elongate in the breadth axis. Corpus subcircular, elongate in the breadth axis, bearing a proximal frill formed of small, cavate, sac-like pouches; proximal cap bears contorted cavate vermiculate elements, 1-3μ wide, which are rounded and may enclose small irregular lumina. Sacci length nearly equals corpus length, outline in polar view less than a semicircle; sacci thin-walled and apparently only slightly distally pendant, longer than broad.

Dimensions:

BG: 65-84μ (4). CL: 39-56μ (3). CB: 32-59μ (2). SB: 23-29μ (2). SL: 36-58μ (3).

Comparison: This species is distinguished from other species assigned to Rugubivesiculites by its vermiculate proximal elements which may enclose small lumina.

Distribution: Present rarely in samples from the ?uppermost Cadotte Member, Viking and Pelican Formations.

### Rugubivesiculites sp. B. (10159)

Plate 6, fig. 13

Description: Bilaterally symmetrical, bisaccate pollen grain. Corpus longer than deep in equatorial view. Proximal cap bears cavate rugulae, 3-5μ wide and about 3μ high which are sinuous and irregular in outline, but not interconnected in a convolute pattern. Most of the rugulae are discrete and run from a marginal frill along the breadth of the corpus, ending freely; a few are twisted and may intertwine or anastomose. Rugulae distributed more or less evenly over the proximal cap and not concentrated near the marginal frill. Sacci with slightly distally inserted proximal roots, distally pendant, depth nearly equal to breadth, microreticulate.

Dimensions: The following dimensions on 1 specimen -

BG: 78μ. CB: 56μ. CD: 31μ. SB: 35μ. SD: 31μ.

Comparison: The discrete rugulae distinguish this form from other species of Rugubivesiculites described in this thesis.

Distribution: Noted in one sample from the basal Joli Fou Formation, "Grouard" section, central Alberta.

### Turma ALETES Ibrahim 1933

### Subturma AZONALETES (Luber) Potonié & Kremp 1954

### Infraturma PSILONAPITI Erdtman 1947

Genus INAPERTUROPOLLENITES (Pflug ex Thomson & Pflug) Potonié 1958

Type species: Inaperturopollenites dubius (Potonié & Venitz) Thomson & Pflug 1953.

### Inaperturopollenites hiatus (Potonié) Thomson & Pflug 1953 (10201)

Plate 6 , fig. 5

Remarks: Stanley (1965, p. 273) presents an extensive synonymy for this form. It may be noted that this species has been attributed to Taxodium (Wodehouse 1933), Taxodiaceaepollenites (Kremp, 1949) and more recently to Thuja? (Stanley, 1965). The writer thinks that such a simple, inapertuate form, distinguished only by its gaping hiatus and scabrate or faintly granulose exine, is best retained in Inaperturopollenites.

Comparison: This species is distinguished from Inaperturopollenites dubius (Potonié & Venitz) Thomson & Pflug 1953 only by its gaping hiatus and granulose to scabrate ornament, and from species attributed to Leiosphaeridia Eisenack 1958 (Sphaeromorphitae, Acritarcha) by its thin, highly folded wall.

Distribution: Worldwide distribution in the Cretaceous and Tertiary. Present in all strata investigated in this thesis.

### Inaperturopollenites dubius

(Potonié & Venitz) Thomson and Pflug 1953 (10202)

Plate 6 , fig. 6

Dimensions: Maximum diameter on 35 measured specimens: 22-47μ.

Comparison: Inaperturopollenites dubius is distinguished from

Laricoidites magnus (Potonié) Potonié, Thomson & Thiergart by its smaller size (an arbitrary value of less than 50μ in maximum diameter) and from Inaperturopollenites hiatus by its laevigate exine and lack of a hiatus. Leiosphaeridia Eisenack 1958 is not so thin-walled and lacks the extensive folding of the exine.

Distribution: Worldwide distribution in the Jurassic to Tertiary; present in all strata investigated in this thesis.

### Genus LARICOIDITES Potonié, Thomson & Thiergart 1950

Type species: Larcoidites magnus (Potonié) Potonie, Thomson & Thiergart 1950.

1950 Laricoidites Potonié, Thomson & Thiergart, p. 48.

1951 Laricoipollenites Potonié, pl. 20, fig. 26.

### Laricoidites magnus (Potonié) Pot., Thoms. & Thierg. 1950 (10203)

Plate 6, fig. 17

Dimensions: Maximum diameter on 41 measured specimens, 53-90μ.

Comparison: Laricoidites magnus is larger than other laevigate inaperturate species described in this thesis. An arbitrary lower limit of 50μ has been chosen to separate this form from Inaperturopollenites dubius in view of the fact that Potonié (1958, p. 77) quotes size ranges of 50 to 100μ for this form.

Distribution: Present in all units of the Lower Colorado Group and in the Peace River-Lower Shaftesbury Formations, although not as ubiquitous as the species of Inaperturopollenites herein described; present in many strata of Cretaceous and Tertiary age in North America and Europe.

### Infraturma TUBERINI Pant 1954

### Genus SEQUOIAPOLLENITES Thiergart 1938

Type species: Sequoiapollenites polyformosus Thiergart 1938.

### Sequoiapollenites sp. A. (10210)

Plate 6 , fig. 15

Description: Amb subcircular. Exine thin and scabrate. A short, tapered, rounded ligula arises from one side of the grain.

Dimensions: Diameter on 1 specimens, 29µ.

Distribution: Present in one sample from the Upper Shale Unit, "Wabamun" section, near the top of the unit.

### Infraturma GRANULONAPITI Cookson 1947

### Genus ARAUCARIACITES Cookson ex Couper 1953

Type species: Araucariacites australis Cookson 1947.

1947 Araucariacites australis Cookson, p. 130; pl. 13, fig. 3.

### Araucariacites australis Cookson 1947 (10204)

Plate 6, fig. 26

Dimensions: Maximum diameter on 17 measured specimens, 52-96µ.

Comparison: This species is distinguished by its granular ornament from other inaperturate forms and from forms assigned to the Sphaeromorphitae (Acritarcha).

Distribution: Present rarely in various units of the Peace River Formation, Lower Shaftesbury Formation and Lower Colorado Group; worldwide distribution in the Jurassic to Tertiary.

## Turma PLICATES (Naumova) Potonié

### Subturma PRAECOLPATES Potonié & Kremp 1954

### Genus EUCOMMIIDITES (Erdtman) Hughes 1961

1948 *Eucommiidites* Erdtman, p. 267.

1953 *Protoquercus* Bolkhovitina, p. 93.

? 1957 *Trifossapollenites* Rouse, p. 372.

1958 *Eucommiidites* (Erdtman) Couper, p. 160.

1961 *Eucommiidites* (Erdtman) Hughes, p. 292.

Type species: *Eucommiidites troedssonii* Erdtman 1948.

### *Eucommiidites troedssonii* Erdtman 1948 (10301)

Plate 6, fig. 7

Selected syn.

1948 *Tricolpites* (*Eucommiidites*) *troedssonii* Erdtman, p. 267; Text-figs. 5-10; 13-15.

1958 *Eucommiidites troedssonii* Erdtman; Couper, p. 160; pl. 31, figs. 23-27.

1961 *Eucommiidites troedssonii* (Erdtman) Hughes, p. 292; pl. 37, figs. 1-16.

Dimensions: Length of 15 measured specimens, 22-34μ; length to width ratio, 1.3 to 1.5.

Comparison: *Eucommiidites troedssonii* is distinguished from other species assigned to this genus by its smooth exine and elongate shape. *Eucommiidites minor* Groot and Penny 1960 is generally smaller and nearly equidimensional. *Eucommiidites delcourti* Hughes 1961 is also smaller with one face being punctate.

Distribution: Wide distribution in the Jurassic and Cretaceous. In western Canada, present in the Mannville Group (Singh, 1964) and the Lower Colorado Group (Norris, 1967) in east-central Alberta; present rarely in all strata investigated in this thesis with the exception of the Lower Shaftesbury Formation of west-central Alberta.

### *Eucommiidites minor* Groot & Penny 1960 (10302)

Plate 6, fig. 16

1960 *Eucommiidites minor* Groot & Penny, p. 234; pl. 2, fig. 14.

1963 *Eucommiidites troedssonii* Erdtman (pars); Brenner, p. 85; pl. 34, figs. 10-12 and pl. 35, fig. 1.

1967 *Eucommiidites minor* Groot & Penny; Norris, p. 105; pl. 16, figs. 12-13.

Dimensions: Longest diameter 21-28μ on 15 specimens; shorter diameter 21-28μ on 15 specimens; ratio of two diameters, 1.0 to 1.1.

Remarks: Bolkhovitina (1953, p. 93; pl. 15, figs. 29-32) describes a form called *Protoquercus agdjakendensis* Bolkhovitina. From the drawings, there is little doubt that this species belongs in *Eucommiidites* (Erdtman) Hughes and it appears to be very similar in size and shape to *Eucommiidites minor* Groot & Penny 1960. The writer thinks, however, that on the basis of the information available, it is best to transfer this form to *Eucommiidites* and only point out the similarity to *E. minor* at this time. The new combination is thus proposed:

*Eucommiidites* (al. *Protoquercus*) *agdjakendensis* (Bolkhovitina 1953, p. 93; pl. 15, figs. 29-32) comb. nov.

The genus, Protoquercus Bolkhovitina 1953 has herein been placed in synonymy with Eucommiidites (Erdtman) Hughes 1961. Brenner (1963, p. 86) included Eucommiidites agdjakendensis (Bolk.) comb. nov. in synomymy with E. troedssonii Erdtman. The writer thinks, however, that it is more closely allied to E. minor and is not synonymous with E. troedssonii.

Comparison: Although size ranges of Eucommiidites minor and E. troedssonii overlap, as pointed out by Brenner (1963, p. 86), the former species is characterized by nearly equidimensional measurements along the major furrow axis and at right angles to it.

Distribution: Albian of Maryland, U.S.A. (Groot and Penny, 1960); Upper Jurassic to Aptian of England (Norris, 1967); present in samples from the Lower Colorado Group, the Harmon and Cadotte Members and the Pelican Formation.

### Subturma POLYPLICATES Erdtman 1948

### Genus EPHEDRIPITES Bolkhovitina 1953

Type species: Ephedripites mediolobatus Bolkhovitina 1953.

Remarks: The writer uses this generic name in the understanding that some doubt exists as to its validity under the ICBN (1959, Lanjouw, ed.) according to Singh (1964, p. 131).

### Ephedripites patapscoensis Brenner 1963 (10351)

Plate 5, fig. 22

1963 Ephedripites patapscoensis Brenner, p. 90; pl. 38, figs. 4-5.

Description: Amb ovoid; outline ribbed and slightly fusiform. Five distinct muri, ending at the apices and partially fusing with each other. Muri 3-5μ wide and 4-6μ high, with thinner exine in between forming the floor of the lumina; muri slightly twisted into a shallow spiral. A faint indication of a "knob-like" structure formed by the fusion of the muri is present at one apex of the specimen.

Dimensions: Length, 44μ; width, 25μ; on 1 specimen.

Distribution: Previously reported by Brenner (1963) from the Patapsco Formation (probably Upper Albian) of Maryland, U.S.A. Recorded herein from one sample of the upper part of the Joli Fou Formation, "Chigwell" section.

## Subturma MONOCOLPATES Iversen & Troels-Smith 1950

## Genus CLAVATIPOLLENITES Couper 1958

Type species: Clavatipollenites hughesii Couper 1958.

### Clavatipollenites minutus Brenner 1963 (10401)

Plate 6, fig. 19

1963 Clavatipollenites minutus Brenner, p. 95; pl. 41, figs. 8-9.

1967 Clavatipollenites minutus Brenner; Norris, p. 106; pl. 16, fig. 19.

Dimensions: The following dimensions on 12 specimens - polar axis, $12\frac{1}{2}$ - 17μ; equatorial axis, $8\frac{1}{2}$ - 14μ. Ratio of P/E: 1.28 to 1.67.

Comparison: *Clavatipollenites minutus* Brenner is smaller than *C. hughesi* Couper 1958.

Distribution: Barremian to Albian of Maryland, U.S.A. (Brenner, 1963); Joli Fou Formation, east-central Alberta (Norris, 1967); recorded herein from the Joli Fou, Viking, and Upper Shale Unit and from the Lower Shaftesbury Formation and the uppermost Cadotte Member, "Grouard" section.

### *Clavatipollenites hughesii* Couper 1958 (10402)

Plate 7, fig. 20

Selected syn.

1958 *Clavatipollenites hughesii* Couper, p. 159; pl. 31, figs. 19-22.

Dimensions: The following dimensions on 15 measured specimens - polar axis, 21-35μ; equatorial axis, 13-26μ. Ratio of P/E: 1.14 to 1.90.

Distribution: Barremian to Aptian of England (Couper, 1958); Barremian to Albian of Maryland, U.S.A. (Brenner, 1963); Norris (1967) reports this form from the Upper Shale Unit of east-central Alberta; recorded here from samples of the Lower Colorado Group in south-central Alberta, the Peace River Formation, the Lower Shaftesbury Formation, and the upper Grand Rapids Formation.

### cf. *Clavatipollenites* sp. A. (10403)

Plate 6, figs. 21-22

Description: Bilaterally symmetrical, monosulcate pollen grain. Sulcus extending the length of the grain and marked by a rift in the outer sexine layer. Sexine retipilate, the muri formed of enlarged pilate heads, 1μ in diameter, and supported by the pilate columns, 1-2μ high, which are closely spaced, $\frac{1}{2}$ - $1\frac{1}{2}$μ apart; the pila enclose polygonal or ovoid lumina, 1-3μ wide. Nexine smooth and longer than broad in extent, thin walled.

*Dimensions*: The following dimensions on 1 specimen - sexine length, 21μ; nexine length, 16μ; nexine width, 13μ.

## Genus LILIACIDITES Couper 1953

Type species: *Liliacidites kaitangataensis* Couper 1953.

### *Liliacidites* cf. *L. textus* Norris 1967 (10404)

Plate 6 , figs. 23-24

*Description*: Bilaterally symmetrical, monosulcate pollen grains. Sulcus extends nearly the length of the grain and is marked by a distal laevigate area, 2-3μ wide. Sexine reticulate, the muri formed of closely spaced pilate heads which also join narrow muri; the pilate columns support the reticulum and connect it to the smooth nexine layer; pila 1-$2\frac{1}{2}$μ high, spaced 1-2μ apart; pilate heads about $\frac{1}{2}$μ in diameter and joined by narrow muri, $\frac{1}{2}$μ wide, which enclose sinuous, sometimes polygonal or ovoid lumina, 1-5μ in width; lumina smaller near the sulcus. Nexine thin, $\frac{1}{2}$ - 1μ, and slightly longer than broad; sexine variably disposed, depending on the amount of mechanical displacement from the nexine due to compaction of the grain during fossilization. The total exine thickness, 2-$3\frac{1}{2}$μ.

*Dimensions*: The following dimensions on 4 specimens - sexine length, $19\frac{1}{2}$ - 25μ; nexine length, 17-21μ; nexine width, 13-18μ.

Comparison: This form is distinguished by the narrow muri, sinuous lumina and smaller pila from Liliacidites sp. A., subsequently described. Liliacidites textus Norris 1967, p. 106; pl. 16, figs. 21-25 and pl. 17, figs. 1-2, is similar to the form described herein but has a wider sulcus and smaller pila.

Liliacidites (al. Peromonolites) reticulatus (Brenner 1963, p. 94; pl. 41, figs. 1-2) comb. nov. has smaller lumina which are not sinuous.

Distribution: Rare in samples from the Pelican Formation, "Grosmont" section, and from the uppermost Cadotte Member and Joli Fou Formation, "Grouard" section in central and east-central Alberta respectively. Norris (1967) reports similar forms from the Upper Shale Unit of east-central Alberta.

### Liliacidites sp. A. (10405)

Plate 6, figs. 20 and 25

Description: Bilaterally symmetrical, monosulcate pollen grains. Sulcus extends nearly the length of the grain, marked by a rift in the sexine. Sexine reticulate, the reticulum supported at intervals by pila; the pilate heads in plan view appearing wider than the intervening muri. Pila 3-4μ high, spaced 1-4μ apart, typically 2-3μ apart, with heads about $1\text{-}1\frac{1}{2}$μ in diameter. Intervening muroid connections from 3/4-1μ wide and enclosing slightly elongate or nearly equidimensional, polygonal or ovoid lumina, 2-5μ wide. Nexine smooth, about 1-2μ thick and generally longer than broad. Sexine variably disposed about the nexine probably depending on the amount of mechanical displacement.

*Dimensions*: The following dimensions on 4 specimens - sexine length, 21-31μ; nexine length, 17-27μ; nexine width, 12-23μ.

*Comparison*: The pila are higher and more widely spaced and the lumina are often larger than in *Liliacidites textus* Norris 1967, *Liliacidites reticulatus* (Brenner 1963) comb. nov., and *Liliacidites* cf. *L. textus* Norris 1967, described in this thesis.

*Distribution*: Rare in samples from the Paddy Member, basal Joli Fou Formation, "Grouard" section, and the Upper Shale Unit, "Wabamun" section.

## Subturma INTORTES (Naumova) Potonié 1958

### Genus CYCADOPITES Wodehouse ex Wilson & Webster 1946

Type species: *Cycadopites follicularis* Wilson & Webster 1946.

*Remarks*: Many smooth walled species with a single exine layer have been described belonging to this genus. Apart from the length/breadth ratios, total length, and occasionally the construction of the distal sulcus, few taxonomic characters are available to separate these forms. The original species concepts are sound but may overlap at the extreme ranges of length or length/breadth ratio. A number of these species have been recorded from the Lower Colorado Group and the Peace River-Lower Shaftesbury Formations. The diagnoses presented for these species represent attempts to set reasonable, albeit arbitrary, limits on the overlapping concepts. The restricted diagnoses presented below are based on comparison of published descriptions for these species and as far as possible represent the practice of previous authors.

### *Cycadopites fragilis* Singh 1964 (10501)

Plate 7, fig. 24

1959 *Cycadopites follicularis* (*auct*. *non* Wilson & Webster) Rouse, p. 313; pl. 1, figs. 3-4.

1962 *Monosulcites minimus auct*. *non* Cookson; Pocock, p. 77; pl. 13, figs. 206-208.

1964 *Cycadopites fragilis* Singh, p. 103; pl. 14, fig. 2.

1967 *Cycadopites fragilis* Singh; Norris, p. 105; pl. 16, figs. 16-18.

*Restricted Diagnosis*: Sulcul process wide, up to half the width of the grain; lips about 6μ wide; sulcus opening narrow and nearly parallel, widening slightly at the apices. Outline of grain fusiform. Length range, 24-43μ; length/breadth ratio (L/B): 1.3 to 2.0.

*Dimensions*: Length on 18 specimens, 24-42μ; width on 16 specimens, 16-28μ; depth on 2 specimens, 11-13μ.

*Remarks*: The specimens figured by Rouse (1959, pl. 1, figs. 1-2) as *Cycadopites ovatus* (*nom*. *nud*.) probably belong to *Cycadopites fragilis* Singh. Rouse (1959, p. 313) figured a holotype specimen but failed to provide a diagnosis as necessitated by Article 38 of the ICBN (Lanjouw, ed., 1966).

*Comparison*: As defined above, *Cycadopites fragilis* Singh 1964, is generally smaller than *C. follicularis* and has wider lips.

*Distribution*: Jurassic and Cretaceous of western Canada (Pocock, 1962; Singh, 1964; Rouse, 1959; Norris, 1967); present in samples from the Lower Colorado Group in south-central Alberta, absent in the Joli Fou and Pelican Formations in the "Grosmont" section but present through the Peace River and Lower Shaftesbury Formations as well as the upper Grand Rapids Formation.

Cycadopites follicularis Wilson & Webster 1946 (10502)

Plate 7, fig. 26

Selected syn.

1946 Cycadopites follicularis Wilson & Webster, p. 274; fig. 7.

non Cycadopites follicularis (Wilson & Webster) Rouse 1959, p. 313; pl. 1, figs. 3-4.

Restricted Diagnosis: Sulcul process narrow, about 1/3 the width of the grain; sulcul edges 3μ wide; with some overlaping in the polar regions and steadily widen towards the apices. Apices rounded to slightly fusiform. Length range, 35-49μ; L/B ratio: 1.7 to 2.7.

Dimensions: Length on 8 specimens, 35-49μ; breadth of 8 specimens, 14-28μ. L/B ratio: 1.7 to 2.7.

Remarks: The specimens described by Wilson and Webster (1946) as Cycadopites follicularis were 39-42μ long and 18-21μ in breadth. The dimensions given here enlarge the size ranges.

Comparison: The narrow sulcus and greater L/B ratio distinguish this species from Cycadopites fragilis. C. follicularis Wilson & Webster is also smaller than C. carpentieri (Delcourt & Sprumont) Singh and generally has a smaller L/B ratio than that species.

Distribution: Previously described from the Fort Union Formation, Palaeocene, of Montana (Wilson and Webster, 1946); present rarely in samples from the upper Grand Rapids Formation and Lower Colorado Group in south-central Alberta, and from the Lower Shaftesbury Formation in west-central Alberta.

Cycadopites carpentieri (Delcourt & Sprumont) Singh 1964 (10503)

Plate 7, fig. 23

Selected syn.

1955 Monosulcites carpentieri Delcourt & Sprumont, p. 54; fig. 14.

1958 Monosulcites carpentieri Delcourt & Sprumont; Couper, p. 158; pl. 26, figs. 26-27.

1964 Cycadopites carpentieri (Delcourt & Sprumont) Singh, p. 104; pl. 14, fig. 3.

Restricted Diagnosis: Sulcus running the length of the grain; sides of sulcus narrow, straight, or overlapping in the polar region. Lips narrow. Sulcus widening at the apices; apices rounded to slightly flattened. Length range, 40-90μ; L/B ratio: 2.3 to 3.4.

Dimensions: Length on 8 specimens, 43-84μ; width on 6 specimens, 14-32μ; depth on 3 specimens, 38-41μ. L/B ratio: 2.3 to 3.4

Comparison: Cycadopites carpentieri (Delcourt & Sprumont) Singh is distinguished from C. follicularis by its generally larger size and its greater L/B ratio. Specimens with a length between 40-49μ but with a L/B ratio greater than 2.7 have been assigned to C. carpentieri; those with a length of 50μ or more and L/B ratio of 2.3 or more also have been assigned to this species. These admittedly arbitrary limits represent the attempt of the writer to provide some criteria for assignment of specimens falling within the region of overlap between these two species.

Distribution: Previously reported from the Lower Cretaceous of Belgium (Delcourt and Sprumont, 1955), from the Middle Jurassic to

Lower Cretaceous of England (Couper, 1958) and from parts of the Mannville Group in east-central Alberta (Singh, 1964); recorded here from samples of the Lower Colorado Group in south-central Alberta.

### *Cycadopites formosus* Singh 1964 (10504)

Plate 8, fig. 14

1964 *Cycadopites formosus* Singh, p. 105; pl. 14, figs. 4-5.

*Description*: Bilaterally symmetrical, monosulcate pollen grains. Outline in polar view ovoid; L/B ratio, 1.4 to 1.5. Exine thin, about 2µ thick, laevigate and unfolded. Sulcus running the entire length of the grain; edges of the furrow overlapping in the polar region but widening at the longitudinal ends; lips of the sulcus 6-12µ wide.

*Dimensions*: Length on 4 specimens, 66-78µ; breadth on 3 specimens, 48-56µ; depth on 1 specimen, 30µ.

*Comparison*: *Cycadopites formosus* is distinguished from the other species described in this thesis by the combination of large size, relatively small L/B ratio and the wide lips. Singh (1964) quotes a size range of length, 50-65µ, so that the specimens described above extend this range, the length range now being 50-78µ.

*Distribution*: Aptian to Middle Albian in the Mannville Group of east-central Alberta (Singh, 1964); rare in samples from the Harmon and Cadotte Members and the Upper Shale Unit, thereby extending the range to Upper Albian.

## Cycadopites sp. A. (10505)

Plate 8 , fig. 25

Description: Pollen grains, bilaterally symmetrical, monosulcate. Amb elongate, fusiform, but apices bluntly truncated. Wall thin and scabrate. Sulcus narrow, extending the length of the grain, widening at the apices, bordered by narrow lips of varying width which are nearly absent at the apices.

Dimensions: Length on 2 specimens, 29-38μ; width on 2 specimens, 12-18μ. L/B ratio: 2.1 to 2.4.

Distribution: Rare specimens recovered from the Harmon and Paddy Members, "Spirit River" section.

## Cycadopites sp. B. (10506)

Plate 8 , fig. 13

Description: Bilaterally symmetrical, monosulcate pollen grain. Sulcus narrow in the polar region but widening at the apices. Apices truncated, sides of the grain convex. Exine thin and densely ornamented with grana, about 1μ wide and 1μ high.

Dimensions: Length, breadth and L/B ratio on 1 specimen, 45μ, 25μ and 1.8.

Distribution: Recovered in one sample from the Lower Shaftesbury Formation, "Spirit River" section.

## Subturma RETECTINES (Malyavkina) Potonié 1958

## Genus MONOSULCITES Cookson ex Couper

Type species: Monosulcites minimus Cookson 1947.

## Monosulcites sp. A. (10507)

Plate 8, figs. 22-23

Description: Bilaterally symmetrical pollen grains, monosulcate. Amb ovoid, apices rounded. Sulcus narrow and extending about 4/5 total length. Exine thin and laevigate to scabrate. One specimen exhibits folds about the sulcus.

Dimensions: Length on 3 specimens, 21-31μ; breadth on 3 specimens, 14-18μ; L/B ratio, 1.5 to 1.7.

Comparison: The narrow sulcus and lack of lips distinguish this form from species assigned to Cycadopites Wodehouse 1933.

Distribution: Rare specimens recovered from the Paddy Member, "Spirit River" section, and the Viking Formation, "Chigwell" section.

## Monosulcites sp. B. (10508)

Plate 8 , fig. 19

Description: Bilaterally symmetrical pollen grains, monosulcate. Amb elongate, ends fusiform and more or less pointed. Wall thin, laevigate. Sulcus narrow, extending nearly the length of the grain, bordered by broad lips which taper at the apices.

Dimensions: Length on 2 specimens, 45-63μ; breadth on 2 specimens, 13-21μ. L/B ratio: 3.0 to 3.5

Comparison: Species assigned to Cycadopites Wodehouse 1933 have a sulcus which widens at the apices. Monosulcites sp. A. has rounded apices and no lips about the sulcus and is also smaller.

### Subturma TRIPTYCHES (Naumova) Potonié 1958

### Genus TRICOLPITES (Cookson ex Couper 1953) emend.

Type species: Tricolpites reticulatus Cookson 1947.

Discussion: Cookson (1947, p. 134) published a description of a new "sporomorph" called Tricolpites reticulata. Couper (1953, p. 61) regarded Tricolpites as a form genus and published a diagnosis, selecting Tricolpites reticulatus as the type species for the genus. Couper (1953, p. 61) diagnosed the exine sculpture as variable.

Thompson and Pflug (1953, p. 95) proposed a similar genus, Tricolpopollenites, diagnosing it as having a smooth, baculate, fossulate, echinate or other type of ornament. However, Potonié (1960, p. 93) notes that these authors choose the genotype of the genus Cornaceoipollenites Potonié 1951 to be the genotype of Tricolpopollenites thus making the latter genus a junior synonym of Potonié's (1951) genus.

Potonié (1960, p. 95) emended Tricolpites Cookson ex Couper to exclude all but finely reticulate species. Later Belsky, Boltenhagen and Potonié (1965, p. 75) further emended this genus to include both coarse and finely reticulate forms.

The subgenera included under Tricolpites Erdtman as contained in van der Hammen (1956a) are all illegitimate forms under Article 63 of the ICBN (Lanjouw, ed., 1966). Van der Hammen chose pollen grains of modern genera and species as holotypes for the type species of the subgenera and thus all of his subgeneric and species forms become nomenclaturally superfluous and cannot be reintroduced into the taxonomic literature unless conserved under Article 14 of the ICBN.

Pierce (1961) raised some of these subgenera to generic status and described new fossil species based on fossil material with suitable holotype specimens. However, as van der Hammen's names are superfluous and furthermore cannot be reintroduced, these generic categories must also be considered illegitimate. Pierce also referred to the recent type specimens of van der Hammen (1956a). With reference to tricolpate grains, the following names must be rejected:

Bacutricolpites van der Hammen ex Pierce 1961, p. 48. Type species: Bacutricolpites magnus van der Hammen 1956a, p. 90; holotype is grain of modern species Plumbago scandens L.

Psilatricolpites van der Hammen ex Pierce 1961, p. 49. Type species: Psilatricolpites incomptus van der Hammen, p. 88; holotype is grain of modern species Bartsia santalinaefolia (HBK) Benth.

Retitricolpites van der Hammen ex Pierce 1961, p. 50. Type species: Retitricolpites ornatus van der Hammen 1956a, p. 90; holotype is grain of modern species Neea macrophylla Poepp. & Endl.

Of the remaining genera proposed by Pierce (1961), the following appear to be valid:

Verrutricolpites Pierce 1961, p. 52.

Gemmatricolpites Pierce 1961, p. 49.

Foveotricolpites Pierce 1961, p. 49.

The genus Clavatricolpites Pierce (1961, p. 48) is herein rejected under Article 38 of the ICBN (Lanjouw, ed., 1966). Both of the species proposed by Pierce, including the type species, Clavatricolpites prolatus Pierce 1961, p. 48; pl. 3, fig. 93, are illustrated at insufficient magnification to show essential characters of the forms.

No details of the exine structure or sculpture can be discerned from the illustrations in question (Pierce 1961, pl. 3, figs. 93-94).

Thus, tricolpate forms with some form of reticulate sculpture can only be accommodated by the genus *Tricolpites* (Cookson ex Couper) Belsky, Boltenhagen and Potonié 1965. Smooth walled, tricolpate forms belong in the genus *Cornaceiopollenites* Potonié 1951. Striate tricolpate forms belong in the genus *Striatopollis* Krutzsch 1959 and verrucate, gemmate and foveolate tricolpate forms belong in the various genera proposed by Pierce (1961).

Among the reticulate tricolpate forms assigned to *Tricolpites* are those with a simple reticulum and other types with a retipilate structure, the pila (clavae) so closely spaced as to touch or even fuse, forming a microreticulate pattern in surface view. Forms in which the pila are very small, closely set and fusing for the most part approach a tegillate condition. Those with an open reticulum formed either of simple muri or pila spaced so as to enclose relatively distinct lumina are non-tegillate in structure. The type species of *Tricolpites*, *T. reticulatus* Cookson is reticulate and not retipilate, and thus the writer thinks that *Tricolpites* should be reserved for these forms and a new genus proposed for retipilate forms. These various changes are proposed in following sections. The genus, *Tricolpites* Cookson ex Couper is emended below.

*Emended Diagnosis*: Radiosymmetric, tricolpate pollen grains. Amb circular or fossaperturate; shape nearly spherical to prolate. Exine two layered; sexine reticulate and non-tegillate; nexine structureless or structured. Modification of reticulation often occurring in the polar regions or along the colpi margins. Muri of variable thickness; lumina ovoid, polygonal or irregular in shape, fine to coarse size. Colpi generally long and simple or relatively complex; no trace of ora.

Selected syn.

1953 Tricolpites Cookson ex Couper, p. 61 (pars).

1960 Tricolpites (Cookson ex Couper) Potonié, p. 95.

1965 Tricolpites (Cookson ex Couper) Belsky, Boltenhagen & Potonié, p. 75 (pars).

Remarks: Species possessing a reticulum which is arranged in more or less radial fashion are included here, but species having striate ridges which do not or only rarely enclose lumina are referred to Striatopollis Krutzsch 1959.

In addition to the species to be described below, the following new combinations are proposed. The writer stresses that this is not an exhaustive list and represents only the common forms relevant to this particular investigation. As Boltenhagen (1967, p. 344) remarked, the genus really requires a monographic study to sort out all of the taxonomic problems associated with it.

Tricolpites (al. Retitricolpites) sphaeroides (Pierce 1961, p. 50; pl. 3, fig. 103) comb. nov.

Tricolpites (al. Retitricolpites) oblatoides (Pierce 1961, p. 50; pl. 3, fig. 104) comb. nov.

Tricolpites (al. Retitricolpites) minutus (Pierce 1961, p. 52; pl. 3, figs. 109-110) comb. nov.

Tricolpites (al. Tricolpopollenites) virgeus (Groot, Penny & Groot 1961, p. 133; pl. 26, figs. 16-17) comb. nov.

Tricolpites (al. Retitricolpites) vermimurus (Brenner 1963, p. 92; pl. 39, figs. 2-3) comb. nov.

Tricolpites (al. Retitricolpites) vulgaris (Pierce 1961)
comb. nov. (10704)
Plate 7, figs. 1-3 and 15

1961 Retitricolpites vulgaris Pierce, p. 50; pl. 3, figs. 101-102.

1967 Retitricolpites vulgaris Pierce; Norris, p. 108; pl. 17, figs. 20-24.

Description: Radiosymmetric pollen grains, tricolpate. Spheroidal to sub-prolate in profile, amb circular. Sexine non-tegillate, reticulate to foveo-reticulate. Muri rounded, simple and $\frac{1}{2}$- $1\frac{1}{2}$μ wide; lumina polygonal to slightly elongate, $\frac{1}{2}$- 1μ in diameter. Nexine not distinguished. Colpi long and simple.

Dimensions: Polar diameter on 20 specimens, 16-32μ; equatorial diameter on 30 specimens, 10-31μ. P/E ratio 1.1 to 2.0.

Remarks: It is possible that the similar species, Tricolpites minutus (Pierce 1961) comb. nov. may be synonymous, but the writer feels that type material should be used to confirm this.

Distribution: Previously recorded from ?Cenomanian or younger strata by Pierce (1961) and from the Lower Colorado Group in east-central Alberta (Norris, 1967); present in samples investigated from the Lower Colorado Group in south-central Alberta, the Lower Shaftesbury Formation, the Cadotte and Paddy Members, Peace River Formation, and the uppermost Cadotte Member and basal Joli Fou Formation in the "Grouard" section.

## *Tricolpites* (al. *Retitricolpites*) *paraneus*

(Norris 1967) comb. nov. (10702)

Plate 7, figs. 4-5

1967 *Retitricolpites paraneus* Norris, p. 109; pl. 18, figs. 15-20.

*Description*: Radiosymmetric, tricolpate pollen grains. Colpi long and simple. Exine thin, non-tegillate, reticulate with the lumina arranged more or less in radial rows over the entire surface of the grain. Muri thin, simple, about 1/4μ wide and 1/2μ high; lumina about 1/4μ wide equidimensional or becoming slightly elongate to form the striato-reticulate pattern; reticulum may be slightly reduced on the apocolpia.

*Dimensions*: Polar diameter on 8 specimens, 17$\frac{1}{2}$μ-19$\frac{1}{2}$μ; equatorial diameter on 11 specimens, 8$\frac{1}{2}$μ-17μ. P/E ratio, 1.4 to 2.1.

*Distribution*: Present rarely in samples from the Joli Fou, Viking and Pelican Formations of south- and east-central Alberta, from the Joli Fou Formation, "Grouard" section, and from the Paddy Member and the Lower Shaftesbury Formation, "Spirit River" section in west-central Alberta; previously recorded from the Lower Colorado Group in east-central Alberta (Norris, 1967).

## *Tricolpites* (al. *Retitricolpites*) *prosimilis*

(Norris 1967) comb. nov. (10705)

Plate 7, figs. 6-7

1967 *Retitricolpites prosimilis* Norris, p. 108; pl. 18, figs. 5-14.

*Description*: Radiosymmetric, tricolpate pollen grains. Profile subprolate to perprolate. Amb oval. Colpi, long, slit-like, nearly reaching the poles. Exine basically non-tegillate, reticulate, the reticulum reduced on the apocolpia. Muri about 1/4μ wide and 1/4-1/2μ high; lumina equidimensional and polygonal, 1/2-1μ wide, reduced to 1/4μ wide on the apocolpia and then grading to a punctate pattern. A punctate tegillum may develop on the apocolpia and the exine is also thickened in this region on some specimens.

Dimensions: Polar diameter on 4 specimens, $12\frac{1}{2}$- 24μ; equatorial diameter on 4 specimens, 10-15μ; P/E ratio, 1.3 to 1.95.

Comparison: This species is distinguished from Tricolpites vulgaris (Pierce 1961) comb. nov. by its more regularly shaped lumina, the exine thickening and reduction to a punctate tegillum on the apocolpia.

Distribution: Recorded from the Lower Colorado Group of east-central Alberta (Norris, 1967); noted rarely in samples investigated in this thesis from the Paddy Member, the Lower Shaftesbury Formation and the basal Joli Fou Formation in the "Grouard" section.

## Tricolpites sp. A. (10709)

Plate 7, figs. 8-9

Description: Radiosymmetric, tricolpate pollen grain. Amb subcircular. Apocolpia somewhat flattened, but still slightly arced. Sexine non-tegillate, reticulate, the muri about 1/2-1μ high and 1μ wide; lumina polygonal to fossulate, 3/4-2μ in diameter. Colpi simple.

Dimensions: Equatorial diameter on 1 specimen, 27μ.

Comparison: This form is distinguished from other species assigned to Tricolpites (Cookson ex Couper) emend. by its thick muri and often fossulate lumina.

Distribution: Noted in one sample from the Pelican Formation, "Grosmont" section.

### Genus RETICULITRICOLPITES gen. nov.

Type species: Reticulitricolpites (al. Tricolpites) alveolatus (Couper 1953) comb. nov., herein designated.

Diagnosis: Radiosymmetric, tricolpate pollen grains. Amb circular or fossaperturate; profile nearly spheroidal to prolate. Colpi long and simple or variously modified, without any trace of ora. Exine two layered; sexine retipilate, the pila (clavae) or gemmae so closely spaced as to form a reticulum in surface view; and often fusing in part or whole to form a tegillate sexine with punctate or microreticulate openings in surface view. Nexine distinct or indistinct, with one layer or structured. Modification of wall layers may occur near the poles and on the apocolpia.

Description of type species: Radiosymmetric, tricolpate pollen grains. Colpi long, about 4/5 polar diameter. Profile sub-prolate to sub-spheroidal. Sexine retipilate, pila about 2-3μ high, the heads, 1μ wide, and closely spaced forming a reticulate pattern in surface view; enclosed lumina about 1/2-1μ wide and polygonal or ovoid; sexine tegillate. Nexine faintly visible, about 1/4-1/2μ thick and structureless. Polar diameter, 40-53μ; equatorial diameter, 29-44μ. The citation of the type species is: Reticulitricolpites (al. Tricolpites) alveolatus (Couper 1953, p. 62; pl. 8, figs. 114-115) comb. nov. The holotype is illustrated as pl. 8, fig. 115 (Couper, 1953) and as pl. 10, fig. 18 (Couper, 1960), and is Lower to Middle Miocene in age (Couper, 1960).

Remarks: The following is a list of some of the species which are considered by the writer to belong in *Reticulitricolpites* gen. nov. This list, as for *Tricolpites* (Cookson ex Couper) emend. is not intended to be an exhaustive one and does not include species described later in this section under *Reticulitricolpites*.

*Reticulitricolpites* (al. *Tricolpites*) *matauraensis* (Couper 1953, p. 62; pl. 8, figs. 118-119 and pl. 9, fig. 144) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *waimumuensis* (Couper 1953, p. 63; pl. 8, fig. 122) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *brevicolpus* (Couper 1960, p. 65; pl. 11, figs. 16-17) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *delicatulus* (Couper 1960, p. 65; pl. 10, figs. 23-24) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *fissilis* (Couper 1960, p. 65; pl. 11, fig. 9) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *geranioides* (Couper 1960, p. 66; pl. 11, figs. 5-8) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *pilatus* (Couper 1960, p. 66; pl. 11, figs. 18-19) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *variexinus* (Couper 1960, p. 66; pl. 11, figs. 20-21) comb. nov.

*Reticulitricolpites* (al. *Tricolpites*) *waiparaensis* (Couper 1960, p. 66; pl. 11, figs. 13-15) comb. nov.

*Reticulitricolpites* (al. *Tricolpopollenites*) *micromunus* (Groot and Penny 1960, p. 232; pl. 2, figs. 6-7) comb. nov.

The genus Fraxinoipollenites Potonié (1951, p. 277) may be a partial synonym if the reticulate pattern is developed from fused clavae or gemmae. Potonié (1960, p. 94) mentions also a granulate ornament as well as a reticulate ornament.

### Reticulitricolpites (al. Tricolpites) sagax
(Norris 1967) comb. nov. (10701)
Plate 7, figs. 10, 16 and 21

1967 Tricolpites sagax Norris, p. 107; pl. 17, figs. 12-19.

Description: Pollen grains radiosymmetric, tricolpate; amb circular to fossaperturate. Colpi simple, long. Apocolpia rounded in polar view. Sexine composed of very small, closely spaced pila; pila individually difficult to see, but sometimes visible on the edges of grains, and in any case, giving a ragged outline at the grain edge. In surface view the pila may fuse to form a tegillate microreticulum, the lumina about 1/2-1μ wide. Sexine about 1μ thick; nexine not distinguished.

Dimensions: Polar diameter on 16 specimens, 15-27μ; equatorial diameter on 30 specimens, 11-23$\frac{1}{2}$μ. Polar diameter/equatorial diameter ratio (afterwards written as P/E ratio): 1.1 to 1.5.

Comparison: This species is distinguished by its microreticulate sexine and closely spaced retipilate structure.

Distribution: Previously reported by Norris (1967) from the Lower Colorado Group of east-central Alberta. Recorded in this thesis from the Paddy Member and Lower Shaftesbury Formation, "Spirit River" section, from the uppermost Cadotte Member and basal Joli Fou Formation, "Grouard" section, and the Lower Colorado Group of south-central Alberta.

Reticulitricolpites (al. Retitricolpites) georgensis
(Brenner 1963) comb. nov. (10703)
Plate 7, figs. 12-14 and 19

1963 Retitricolpites georgensis Brenner, p. 91; pl. 38, figs. 6-7.

1967 Retitricolpites georgensis Brenner; Norris, p. 108; pl. 18, figs. 1-4.

Description: Radiosymmetric, tricolpate pollen grains. Sexine retipilate, with almost uniformly large lumina, reduced only at the poles and on the apocolpia. Exine non-tegillate; nexine indistinct. Shape prolate to sub-prolate. Colpi long, extending nearly to the poles. Muri formed of pila with fused heads, the muri about 1/4μ wide, the pila about 1μ high, the columns about 3/4-1μ apart. Lumina 1-$1\frac{1}{2}$μ in diameter, reduced to about 1/2μ near the poles and on the apocolpia.

Dimensions: Polar diameter on 4 specimens, 18-22μ; equatorial diameter on 6 specimens, 12-29μ; P/E ratio, 1.15 to 1.50.

Comparison: The specimens described above agree in most respects with those described by Brenner (1963) except that some smaller grains are also included. Tricolpites (al. Retitricolpites) sphaeroides (Pierce 1961, p. 50; pl. 3, fig. 103) comb. nov. is very similar but somewhat smaller. It is difficult to make a comparison from the brief diagnosis given by Pierce and from the small illustration provided.

Distribution: Previously described from the Albian of Maryland (Brenner, 1963) and from the upper Joli Fou, Viking and Upper Shale Unit in east-central Alberta (Norris, 1967); noted rarely in this thesis from samples of the Viking, Lower Shaftesbury Formations and from the Upper Shale Unit; and the uppermost Cadotte Member and basal Joli Fou Formation in the "Grouard" section.

### *Reticulitricolpites crassus* sp. nov. (10707)

Plate 7, figs. 11 and 17-18

Holotype: BW 177/1 at 353 - 930; polar diameter, 16.5μ; equatorial diameter, 12μ; P/E ratio: 1.4.

Description: Radiosymmetric, tricolpate pollen grains. Amb subcircular, profile subprolate. Colpi simple and extending about 4/5 polar diameter. Exine crassinexinous. Sexine retipilate; pila about 1/2μ high, with thin columns and rounded heads about 1/2μ in diameter; pila so closely spaced as to form a tectate sexine having a microreticulate surface pattern, the lumina 1/4-1μ wide. Nexine without visible structure and 1-2μ thick, typically about $1\text{-}1\frac{1}{2}\mu$ thick, thinning at the poles and at the colpi margins. In polar view, the colpi have a characteristically U-shaped or shallow V-shaped outline.

Comparison: This species is distinguished by its crassinexinous exine, retipilate sexine and characteristically shaped colpi.

Distribution: Recorded only from the upper Joli Fou and Pelican Formations in the "Grosmont" section, central Alberta.

### Reticulitricolpites sp. A. (10708)

Plate 7, figs. 22 and 25

Description: Radiosymmetric, tricolpate pollen grains. Amb circular. Colpi slightly gaping in polar view. Sexine retipilate; pila with thin columns about 1μ high and large heads, 1-1$\frac{1}{2}$μ in diameter and 1μ thick, the heads touching or fused to form a thick-walled reticulate pattern; lumina 1/2-2μ wide, smaller near the colpi margins, polygonal to somewhat irregular in shape. Nexine indistinct, about 1/2-1μ thick, structureless. Total exine thickness, 2$\frac{1}{2}$-3μ.

Dimensions: Polar diameter on 2 specimens, 18-24μ.

Comparison: The massive pila and thick-walled retipilate sexine are distinctive.

Distribution: Present rarely in samples from the uppermost Cadotte Member, "Grouard" section and the Pelican Formation in the "Grosmont" section.

### Genus CORNACEOIPOLLENITES Potonié 1951

1951 Cornaceoipollenites Potonié

1953 Tricolpopollenites Pflug & Thomson, p. 95.

Type species: Cornaceiopollenites parmularius (Potonié) Potonié 1951.

### Cornaceoipollenites (al. Tricolpopollenites) parvulus (Groot & Penny 1960) comb. nov. (10706)

Plate 6, fig. 8

1960 Tricolpopollenites parvulus Groot & Penny, p. 232; pl. 2, figs. 8-9.

1961 Tricolpopollenites parvulus Groot & Penny; Groot, Penny & Groot, p. 132; pl. 26, figs. 3-4.

1967 Psilatricolpites parvulus (Groot & Penny) Norris, p. 107; pl. 17, figs. 5-6.

Description: Radiosymmetric, tricolpate pollen grains. Profile subprolate. Colpi simple; exine may be folded about colpi margins; colpi extending nearly the polar diameter. Sexine laevigate, nexine not distinctly visible.

Dimensions: Polar diameter on 2 specimens, 13-16μ; equatorial diameter on 2 specimens, 9-11μ. P/E ratio: about 1.45.

Distribution: Cenomanian, Turonian and Senonian of the Atlantic coastal plain (Groot and Penny, 1960; Groot, Penny and Groot, 1961); Upper Shale Unit of east-central Alberta (Norris, 1967); rare specimens recovered from samples of the Lower Shaftesbury Formation, west-central Alberta, and the Upper Shale Unit in south-central Alberta.

## Cornaceoipollenites sp. A. (10710)

Plate 8, fig. 4

Description: Radiosymmetric, tricolpate pollen grains. Colpi simple but highly invaginated. Crassisexinous. Sexine thick, 2μ in the apocolpal regions thinning to 1/2μ on the colpi margins, laevigate. Nexine about 1/2μ thick and structureless.

Dimensions: Equatorial diameter on 1 specimen, 21μ.

Distribution: Recorded in one sample from the uppermost Cadotte Member, "Grouard" section.

## TRIPTYCHES INCERTAE

### Tricolpate Forma A. (10711)

Plate 8, fig. 5

Description: Radiosymmetric pollen grain. Tricolpate; the colpi running nearly the polar diameter of the grain, distinctly ending before the terminal pole. Colpi undifferentiated, widest at the equatorial regions. Exine smooth. Amb prolate.

Dimensions: Polar diameter on 1 specimen, 49μ; equatorial diameter on 1 specimen, 35μ. P/E ratio: 1.40.

Distribution: Recorded from one sample of the Lower Shaftesbury Formation, "Spirit River" section, near the top of the section.

### Tricolpate? Forma B. (10712)

Plate 8, fig. 6

Description: Amb prolate, outline smooth. Sexine smooth; nexine not distinct. Three colpi running the length of the grain and widening at the poles. Either the colpi are simply ruptured and the grain is tricolpate or the colpi join and the grain is syncolpate.

Dimensions: Polar diameter on 1 specimen, 50μ; equatorial diameter on 1 specimen, 36μ. P/E ratio: 1.43.

Remarks: The interpretation of this specimen is not clear, but the grain is described for its potential importance. Couper (1964) notes that syncolpate grains have not been found in strata younger than the Cenomanian.

Distribution: Noted in one sample from near the base of the Upper Shale Unit, "Chigwell" section, in south-central Alberta.

## Subturma PTYCHOTRIPORINES Potonié 1960

## Infraturma PROLATI Erdtman 1943

### Tricolporate? Forma A. (10713)

Plate 8 , figs. 1-3

Description: Radiosymmetric, ?tricolporate pollen grains. The colpi simple, extending 3/4 polar diameter, with the simple ora situated equatorially and on the colpi; ora approximately 1/6 colpi length. Sexine reticulate; muri narrow; lumina about 1μ in diameter, smaller near the poles and along the colpi margins; sexine about 1μ thick on the apocolpia, becoming thinner about the ora. Nexine not distinctly visible.

Dimensions: Polar diameter on 1 specimen, 13.5μ; equatorial diameter on 2 specimens, $8\frac{1}{2}-13\frac{1}{2}\mu$. P/E ratio: 1.60.

Remarks: The writer knows of no other report of tricolporate grains in strata as old as the Upper Albian. Brenner (1967) records the first tricolporate types from the Raritan Formation (Cenomanian) of New Jersey, U.S.A. While the specimens described here are probably tricolporate it is difficult to see the ora distinctly on all the colpi and the writer prefers to leave them as a questionable occurrence until more evidence is forthcoming.

Distribution: Present rarely in samples from the Pelican Formation, "Grosmont" section and the Upper Shale Unit in the "Wabumun" section.

## INCERTAE POLLEN TYPE

### Periporate? Forma A. (10714)

Plate 8, fig. 7 and Text-fig. 18f

Description: Amb circular. Wall about 1-$1\frac{1}{2}\mu$ thick and ornamented with small coni or spines. At least six and perhaps ?eight pores? or openings, roughly hexagonal or rounded in shape. No apparent differentiation of the exine about the openings.

Dimensions: Diameter on 1 specimen, 17.5μ.

Remarks: The interpretation of the morphology of this grain is in doubt. The openings strongly suggest pores but the arrangement of the openings and their shape suggest they may not be of this nature. The specimen is included for its morphological interest. Polyporate grains have not been recorded earlier than the Upper Cretaceous.

Distribution: Recorded from one sample of the Paddy Formation, "Peace River" section, early Upper Albian, west-central Alberta.

## Turma POROSES (Naumova) Potonié 1960

## Subturma MONOPORINES (Naumova) Potonié 1960

### Genus CIRCULINA Malyavkina ex Klaus 1960

Type species: *Circulina meyeriana* Klaus 1960

### *Circulina* cf. *C. parva* Brenner 1963 (10801)

Plate 8, fig. 24 and Text-fig. 18g

cf. 1963 *Circulina parva* Brenner, p. 84; pl. 34, figs. 2-3.

cf. 1967 *Circulina parva* Brenner; Norris, p. 110; pl. 18, figs. 25-26.

Description: Amb circular or subcircular. A circular furrow divides the proximal and distal hemispheres and may or may not be accompanied by faint equatorial ridges, which are discontinuous and few in number. Exine smooth or scabrate. Some specimens show a faint distal opening, a pore, and a proximal triradiate scar, never more than 1/3 spore radius in length.

Dimensions: Equatorial diameter on 11 specimens, 21-34μ.

Comparison: The specimens described above agree with those placed in Circulina parva Brenner 1963 except that they are generally larger. Brenner (1963, p. 84) gives a size range of 13-23μ for equatorial diameter.

Distribution: Rare in samples from the Lower Colorado Group in south-central Alberta, the Harmon Member and Lower Shaftesbury Formation in west-central Alberta and the basal Joli Fou Formation in the "Grouard" section. Similar specimens reported from the Upper Barremian to Albian of Maryland (Brenner, 1963) and the Upper Mannville Group and Lower Colorado Group in east-central Alberta (Norris, 1967).

## Genus CLASSOPOLLIS (Pflug) Couper 1958

Selected syn.

1953 Classopollis Pflug, p. 91.

1958 Classopollis (Pflug) Couper 1958, p. 156.

1961 Classopollis (Pflug) Pocock & Jansonius, p. 443.

1963 Monilapollis Chang

1965 Pagiophyllumpollenites Chang, p. 171.

Type species: Classopollis torosus (Reissinger) Balme 1957.

Remarks: Pocock and Jansonius (1961) and Chaloner (1962) present detailed discussions of this genus. The nomenclature followed in this thesis is that of Chaloner (1962). Chaloner and Pettit (1963) present ultra-thin sections of specimens of *Classopollis* which show the exine to be very complex, at least two layers present, the outer layer having a series of complex sub-layers. Light microscopy cannot resolve these layers and the exines of *Classopollis* appear two layered with the outer layer seemingly baculate. These sections indicate that the "punctate" interpretation of Pocock and Jansonius (1961) is incorrect.

### *Classopollis torosus* (Reissinger) Balme 1957 (10803)

Plate 8, fig. 8

Selected syn.

1950 *Pollenites torosus* Reissinger, p. 115; pl. 14, fig. 20.

1953 *Classopollis classoides* Pflug, p. 91; pl. 16, figs. 20-25 and figs. 29-37.

1957 *Classopollis torosus* (Reissinger) Balme, p. 37; pl. 11, figs. 114-119.

1961 *Classopollis classoides* (Pflug) Pocock & Jansonius, p. 443; pl. 1, figs. 1-9.

Chaloner (1962) presents a more detailed synonymy. See also Pocock and Jansonius (1961) for an extended discussion and synonymy.

Description: Amb circular or subcircular. No grains noted in profile. Proximal, faint, short, trilete scar present or absent. Round distal pore, present or absent. Sexine complex, appearing as a tegillate structure with internal bacula; the bacula about 1/2μ wide. Sexine 1-$2\frac{1}{2}$μ thick and underlain by a nexine layer about 1/2μ thick. Sexine thins about the proximal and distal openings; nexine may also reflect these openings. Equatorially, six to ten granular ridges, discontinuous, or formed of fused granules and more or less continuous, rise from the sexine. Just above these ridges, a narrow, uniform sexine thinning may run parallel to the thickened bands.

Dimensions: Equatorial diameter on 18 specimens, 22-38μ.

Distribution: Worldwide distribution in the Upper Triassic to Lower Cretaceous, probably last appearing in the Cenomanian (Couper, 1964); recorded in the Lower Colorado Group of east-central Alberta (Norris, 1967); noted in this investigation from samples of the Upper Mannville Group and Lower Colorado Group.

### Classopollis cf. Classopollis minor

Pocock & Jansonius 1961 (10806)

Plate 8 , fig. 9

cf. 1961 Classopollis minor Pocock & Jansonius, p. 444; pl. 1, figs. 21-25.

Description: Amb circular in polar view. No grains noted in profile. Sexine 1-3μ thick, bearing a proximal trilete scar and a distal circular pore. Equatorially the sexine is thickened and bears eight to ten parallel bands, each about 1μ thick. On the proximal surface, a similar set of six to eight bands is developed in a triangular pattern, approximately parallelling the trilete scar outline and truncated by the equatorial set. Distal sexine ?infrabaculate. Nexine indistinct, thin, structureless under light microscopy.

Dimensions: Equatorial diameter on 1 specimen, 27μ.

Remarks: Only one specimen was noted, and although this agrees closely with the description given for *Classopollis minor* Pocock & Jansonius 1961, the writer thinks that more specimens are needed to make a confident assignment to that species.

Distribution: Present in one sample from the Pelican Formation in the "Grosmont" section. Pocock and Jansonius (1961, p. 444) quote a range of Lower Jurassic to Eocene and note that it is most abundant in the Middle and Upper Jurassic of western Canada.

### *Classopollis* cf. *Classopollis pflugii* Pocock & Jansonius 1961 (10807)

Plate 8, fig. 10

cf. 1961 *Classopollis pflugii* Pocock & Jansonius, p. 445; pl. 1, figs. 16-20.

Description: Ovoid in profile, with an equatorially thickened banding. Sexine finely pitted or irregularly fossulate, apparently loosened from the nexine in many places or having a vacuolate contact with the nexine. Sexine thickened at the equator in a band about 13μ wide and variously dissected into eleven canaliculate ribs which fuse at one point, but are otherwise parallel to each other or in some places anastomosing. The sexine bulges out at the equator and is $3\frac{1}{2}$μ thick at this point, thinning to 1μ elsewhere. Nexine about $1\frac{1}{2}$μ thick and uniform. The ribs may be 1-2μ wide.

Dimensions: Polar diameter on 1 specimen, 45μ; equatorial diameter, 34μ.

Remarks: The single specimen recorded above agrees closely with the diagnosis of Pocock and Jansonius (1961, p. 445); the writer feels more specimens are required to make a definite assignment to that species.

Distribution: One specimen recorded from the Lower Shaftesbury Formation, "Spirit River" section. Pocock and Jansonius (1961) record this species only from the Lower Cretaceous of western Canada.

### Genus EXESIPOLLENITES Balme 1957

Type species: *Exesipollenites tumulus* Balme 1957.

### *Exesipollenites tumulus* Balme 1957 (10805)

Plate 8, fig. 26

Selected syn.

1957 *Exesipollenites tumulus* Balme, p. 39; pl. 11, figs. 123-125.

Dimensions: Equatorial diameter on 4 specimens, 29-35μ.

Distribution: Lower Jurassic of Western Australia, Lower Cretaceous of western Canada and Maryland and the Lower Colorado Group in east-central Alberta (Norris, 1967); recorded in samples investigated in this thesis from the Upper Mannville Group and Upper Shale Unit.

## MIOSPORES INCERTAE SEDIS

### Genus SCHIZOSPORIS Cookson & Dettmann 1959

Type species: *Schizosporis reticulatus* Cookson & Dettmann 1959.

### *Schizosporis reticulatus* Cookson & Dettmann 1959 (10902)

Plate 8, fig. 15

Selected syn.

1959 Schizosporis reticulatus Cookson & Dettmann, p. 213; pl. 1, figs. 1-4.

Distribution: Rare in the Pelican and Joli Fou Formations in central and south-central Alberta respectively; two specimens noted. Norris (1967) reports this form from the Viking Formation of east-central Alberta and records a range of Berriasian to Cenomanian for the species.

MICROPLANKTON

### Group ACRITARCHA Evitt 1963

### Subgroup DISPHAEROMORPHITAE Downie, et al. 1963

### Genus PTEROCYSTIDIOPSIS Deflandre 1935

Type species: Pterocystidiopsis stephaniana Deflandre 1935.

### Pterocystidiopsis sp. A. (20001)

Plate 8 , fig. 21

Description: Two layered construction. Inner and outer layers nearly spherical. Outer wall layer hyaline, wrinkled and 1/2-1μ thick. Inner wall layer smooth and thin.

Dimensions: Diameter on 5 specimens: outer layer, 49-60μ; inner layer, 38-53μ. Ratio of outer to inner diameter, 1.1 to 1.4.

Distribution: Present in samples from the Harmon member and the Lower Shaftesbury Formation, "Spirit River" section.

### Subgroup PLATYMORPHITAE Downie, et al. 1963

### Platymorph Forma A. (20102)

Plate 8, fig. 27

Description: Two layered structure. Central layer completely surrounded by an outer planar layer. Inner layer optically more dense; outer layer scabrate. Outline of both layers, circular. No radial thickenings or suggestions of a lamellar equatorial construction noted.

Dimensions: Diameter on 2 specimens: outer layer, 83-122μ; inner layer, 36-42μ;ratio of outer to inner diameter, 2.3 to 2.9.

*Remarks*: The simple construction of the vesicle and the few specimens available for study make further definite assignment of this form impossible.

*Distribution*: Rare specimens present in the Viking Formation, "Battle Lake" section, and the Lower Shaftesbury Formation, "Spirit River" section.

### Subgroup ACANTHOMORPHITAE Downie, *et al*. 1963

### Genus BALTISPHAERIDIUM (Eisenack) Downie & Sarjeant 1963

Type species: *Baltisphaeridium longispinosum* (Eisenack) Eisenack 1958.

### *Baltisphaeridium rallum* sp. nov. (20401)

Plate 9, figs. 1-2

*Holotype*: BW 106/2 at 307 - 989; maximum diameter, 34μ; spines 4-9μ.

*Description*: Vesicle outline subcircular to circular. Wall thin, rarely folded. Vesicle ornamented with evenly and relatively densely distributed processes. Processes parallel-sided, apices rounded and bases not expanded; columns thin, 1μ wide or less; processes spaced 2-4μ apart; length from 2-15μ, typically 3-9μ.

*Dimensions*: Maximum diameter on 25 specimens, 27-59μ.

*Comparison*: *Baltisphaeridium rallum* sp. nov. is distinguished from *B*. *debilispinum* Wall & Downie and *B*. cf. *B*. *debilispinum* Wall & Downie by its parallel-sided processes which lack expanded bases.

*Distribution*: Recorded in samples from the Lower Colorado Group in south-central and central Alberta and from the Lower Shaftesbury Formation in west-central Alberta.

## Baltisphaeridium planispinum sp. nov. (20402)

Plate 8, fig. 16

Holotype: BW 168/2 at 390 - 1064; maximum diameter, 20μ; spines 11-20μ.

Description: Vesicle globular; ovoid to subcircular. Processes simple, flattened and pointed, apparently hollow; typically 8 in number but from 7-12 noted; length 7-24μ. Wall thin, smooth, often hyaline.

Dimensions: Maximum diameter on 18 specimens, 14-31μ.

Remarks: Examination of specimens under phase contrast suggests that the wall may be two-layered, the outer layer forming the spines.

Comparison: The long flattened spines, few in number, distinguish this form from other acanthomorph acritarchs described in this thesis.

Distribution: Present in samples from the Joli Fou and Viking Formations, south-central Alberta; the Viking and Pelican Formations in the "Grosmont" section; the upper Cadotte Member and Joli Fou Formation in the "Grouard" section and the Lower Shaftesbury Formation, "Spirit River" section.

## Baltisphaeridium turbinatum sp. nov. (20403)

Plate 8, figs. 28-29

Holotype: BW 114/3 at 392 - 1132; maximum diameter 32μ; spines c. 7μ.

Description: Vesicle circular or subcircular; globular. Wall thin, smooth, often hyaline. Thin, hyaline, spiny processes with expanded bases arise from the vesicle wall, apparently hollow; length 3-18μ, density varying; number of spines typically about 20, but as high as 40; tips acute but with a few specimens showing slight apical expansion or weakly bifid tips.

Dimensions: Maximum diameter on 25 specimens, 20-40μ.

Remarks: Some specimens may show slightly bifid or pilate tips on a few processes but these are relatively rare.

Comparison: *Baltisphaeridium turbinatum* sp. nov. is distinguished from *B. debilispinum* Wall & Downie 1963 and similar species by its larger size and longer spines.

Distribution: Noted in samples from the Viking Formation and Upper Shale Unit in south-central Alberta; from the Cadotte Member and the Lower Shaftesbury Formation in west-central Alberta and from the basal Joli Fou Formation, "Grouard" section, and the Pelican Formation, "Grosmont" section.

### *Baltisphaeridium* cf. *B. debilispinum* Wall & Downie 1963 (20404)

Plate 8, figs. 17 and 20

cf. 1963 *Baltisphaeridium debilispinum* Wall & Downie, p. 777; pl. 112, figs. 1-2; text-fig. 3a,b.

Description: Vesicle circular to subcircular. Wall about 1μ thick and unfolded. Spinose processes arise from the wall from conical bases, about 1μ wide; processes 1-4μ long and apparently not communicating with the interior of the vesicle.

Dimensions: Maximum diameter on 8 specimens, 16-26μ.

Remarks: The specimens described above have somewhat shorter spines than *B. debilispinum* Wall & Downie 1963 but are otherwise closely comparable.

Distribution: Rarely noted in samples from the Viking Formation and Upper Shale Unit in south-central Alberta; and from the Harmon Member and Lower Shaftesbury Formation in west-central Alberta. Closely comparable forms have been described from the Lower Permian of Britain (Wall and Downie, 1963) and from the Lower Jurassic of Britain (Wall, 1965).

### Genus MICRHYSTRIDIUM (Deflandre) Downie & Sarjeant 1963

Types species: Micrhystridium inconspicuum (Deflandre) Deflandre 1937.

### Micrhystridium cf. M. piliferum Deflandre 1937 (20406)

Plate 8, figs. 11 and 18

cf. 1937 Micrhystridium piliferum Deflandre, p. 80; pl. 15, fig. 11.

Description: Vesicle outline circular or subcircular. Wall thin and apparently one layered, smooth, sometimes hyaline. Processes variable in number, evenly distributed, short, rodlike (setaceous), 1/2-2μ long. Occasional specimens bear processes up to 3μ long. Vesicle often splitting along the mid-line or gaping along a partial split.

Dimensions: Maximum diameter on 25 measured specimens, 7-17μ.

Remarks: The specimens described here are closely comparable to the species, Micrhystridium piliferum Deflandre 1937.

Distribution: Present in abundance in all units of the Lower Colorado Group and the Peace River and Lower Shaftesbury Formations; a closely comparable species has been recorded from the Upper Cretaceous of France (Deflandre, 1937).

## Micrhystridium sp. A. (20407)

Plate 9 , fig. 5

Description: Vesicle subcircular. Wall thin and hyline. Processes long, parallel-sided but tapering near the tips; few in number (7-8); 10-22μ long and length generally greater than the vesicle diameter.

Dimensions: Maximum diameter on 3 specimens, 11-15μ.

Distribution: Rare in samples from the Lower Shaftesbury Formation, "Spirit River" section.

## Micrhystridium sp. B. (20405)

Plate 9 , fig. 13

Description: Vesicle outline subcircular to circular. Wall thin and ornamented with evenly but widely distributed minute coni, 1/2-1μ long.

Dimensions: Maximum diameter on 10 specimens, 7-21μ.

Distribution: Present rarely in samples from the Lower Colorado Group in south-central Alberta, "Battle Lake" section, and in the Viking Formation, "Wabamun" section.

## Subgroup POLYGONOMORPHITAE Downie, et al. 1963

## Genus VERYHACHIUM (Deunff) Downie & Sarjeant 1963

Type species: Veryhachium trisulcum Deunff 1958.

## Veryhachium iniquum sp. nov. (20503)

Plate 9, figs. 8-9 and Text-figs. 19a-c

Holotype: BW 144/2 at 527 - 1061; vesicle diameter, 13μ; processes, 4-6μ; 8 in number.

Description: Vesicle triangular; sides convex or weakly convex. Two or more short processes of variable shape present at or near the apices; an occasional process present elsewhere on the vesicle; total number of fully developed processes not more than 8, sometimes one or more rodlike processes present bringing the total to 9. Developed processes have broad bases, tapering to acute tips; length of processes, 1-6μ.

Dimensions: Maximum vesicle diameter on 6 specimens, excluding processes, 8-13μ.

Comparison: *Veryhachium iniquum* sp. nov. is distinguished by possession of two or more processes situated at one or more apices of the triangular vesicle.

Distribution: Rare specimens noted in samples from near the top of the Lower Shaftesbury Formation, "Spirit River" section, and near the top of the Upper Shale Unit, "Wabamun" section. R. L. Cox (Geological Survey of Canada, Calgary) has noted similar specimens in the Uppermost Albian of Saskatchewan; the writer has kindly been allowed to examine these forms and considers them conspecific with the species described above.

### *Veryhachium reductum* (Deunff) de Jekhowsky forma *trispinoides* Jekhowsky 1961 (20502)

Plate 9 , fig. 16

Selected syn.

1961 *Veryhachium reductum* (Deunff) de Jekhowsky forma *trispinoides* de Jekhowsky, p. 210; pl. 2, figs. 32-37.

1965 *Veryhachium reductum* (Deunff) de Jekhowsky forma *trispinoides* de Jekhowsky; Wall, p. 160; pl. 4, fig. 10.

Description: Vesicle triangular; sides convex or nearly straight. Pointed, tapering processes 4-13μ long arise at each apex. Wall thin and smooth, often hyaline.

Dimensions: Maximum vesicle diameter on 8 measured specimens, 20-25μ.

Comparison: *Veryhachium reductum* forma *trispinoides* is distinguished from *V. reductum* forma *breve* by its longer tapering processes.

Distribution: Noted in samples from the Joli Fou Formation throughout south-central and central Alberta and from the Lower Shaftesbury Formation, "Spirit River" section.

### *Veryhachium reductum* (Deunff) de Jekhowsky forma *breve*
### de Jekhowsky 1961 (20510)

Plate 9 , fig. 10

1961 *Veryhachium reductum* (Deunff) de Jekhowsky forma *breve* de Jekhowsky, p. 212; pl. 2, figs. 38-44.

Description: Vesicle triangular, sides strongly convex; with short apical processes of variable length, generally tapered and blunt, occasionally acute; length 3-8μ.

Dimensions: Maximum vesicle diameter on 4 specimens, 12-25μ.

Distribution: Rare specimens noted in the Lower Shaftesbury Formation and in the Upper Shale Unit, "Wabamun" section; previously recorded by de Jekhowsky (1961) from the Permo-Triassic of Europe and Africa.

### Veryhachium cf. V. collectum Wall 1965 (20505)

Plate 8, fig. 12

cf. 1965 Veryhachium collectum Wall, p. 159; pl. 3, figs. 11-14 and pl. 8, fig. 6.

Description: Vesicle rectanguloid, or trapezoidal, occasionally more or less pentagonal. Processes arise at the four corners and one to three may arise from the central vesicle. Occasional specimens have two processes at one corner. Processes with broad bases, tapering to acute tips; closed, hollow; length 6-25μ.

Dimensions: Maximum diameter on 20 specimens, 14-31μ; number of processes, 4-8.

Remarks: Veryhachium cf. V. collectum Wall 1965 is closely comparable to V. collectum Wall except that the size of the vesicle is larger. Wall (1965, p. 159) quotes a size range of 11-16μ for his specimens, compared to 14-31μ for those described in this thesis.

Distribution: Present in samples investigated in this thesis from the Lower Colorado Group in south-central Alberta, the Lower Shaftesbury Formation in the "Spirit River" section and in various units of the Lower Colorado Group, central and east-central Alberta; a closely comparable species occurs in the British Lias (Lower Jurassic) described by Wall (1965).

### Veryhachium europaeum Stockmans & Williere 1960 (20504)

Plate 9, fig. 6

1960 Veryhachium europaeum Stockmans & Williere, p. 3; pl. 2, fig. 25.

1963 *Veryhachium europaeum* Stockmans & Williere; Wall & Downie, p. 782; pl. 114, figs. 4-6.

1965 *Veryhachium europaeum* Stockmans & Williere: Wall, p. 159; pl. 4, figs. 1-2.

*Description*: Vesicle triangular; sides convex to concave. Pointed tapering processes arise at each apex and one, rarely two, arise in the mid-points of the sides. Size of processes variable, length 6-15μ, number of processes 4 to 6.

*Dimensions*: Maximum vesicle diameter on 18 specimens, 18-38μ.

*Distribution*: A long-ranging form, previously recorded from the Devonian of Belgium (Stockman and Williere, 1960), the Permian of England (Wall and Downie, 1963) and the Lower Jurassic of England (Wall, 1965); recovered from samples of the Lower Colorado Group in south-central Alberta and from the Lower Shaftesbury Formation in west-central Alberta and the Joli Fou Formation in the "Grouard" and "Grosmont" sections.

## *Veryhachium* sp. A. (20501)

Plate 9, fig. 17

*Description*: Vesicle triangular; sides concave and apices extended; processes not distinctly delimited from the apices. Wall smooth.

*Dimensions*: Maximum diameter from apex to side on 3 specimens, 22-32μ.

*Comparison*: This species is distinguished from other similar forms by its concave sides and extended apices.

Distribution: Rare in samples from the Joli Fou Formation, "Battle Lake" section, south-central Alberta, and the Joli Fou Formation in the "Grosmont" section, east-central Alberta.

### Veryhachium sp. B. (20506)

Plate 9, fig. 3 and Text-fig. 19d

Description: Vesicle pentagonal to somewhat hexagonal with rounded contours, elongate in one axis. One apex bearing a spinose process with spines arising at other points over the surface and at opposite corners.

Dimensions: Noted rarely in samples from the Joli Fou Formation, "Grosmont" section and the Viking Formation, "Battle Lake" section.

### Veryhachium sp. C. (20507)

Plate 9 , fig. 7

Description: Vesicle polygonal and often defined almost entirely by the bases of the spines; small tapering spines with broad bases arise from the central vesicle; 4 to 7 in number, typically about 5; length, 7-22μ, generally greater on the average than the diameter of the vesicle.

Dimensions: Vesicle diameter on 11 measured specimens, 11-17μ.

Remarks: The central vesicle is polygonal in outline and thus does not belong in Micrhystridium Deflandre. The spines are generally separable from the vesicle and thus the species is not conformable with the genus Estiastra Eisenack 1959.

Distribution: Noted in samples from the Joli Fou Formation in south-central and central Alberta and from one sample of the Viking

Formation, south-central Alberta.

Veryhachium? sp. D. (20508)

Plate 9, fig. 4 and Text-fig. 19e

Description: Vesicle elongate, rectanguloid. Processes concentrated at both ends of the vesicle; with broad bases, tapering to acute tips; variable in shape; length 9-28μ; 6 to 9 in number.

Dimensions: Maximum diameter on 3 specimens, 25-31μ; minimum diameter, 15-25μ.

Remarks: The processes are concentrated near the ends of the vesicle, a feature not generally noted in species of this genus. One specimen also bears 9 processes. For these reasons, the species is only doubtfully referred to Veryhachium.

Distribution: Noted rarely in the Viking Formation, south-central Alberta.

## Subgroup PTEROMORPHITAE Downie, et al. 1963

## Genus PTEROSPERMOPSIS W. Wetzel 1952

Type species: Pterospermosis danica W. Wetzel 1952.

### Pterospermopsis australiensis Deflandre & Cookson 1955 (20703)

Plate 9, fig. 11

Selected syn.

1955 Pterospermopsis australiensis Deflandre & Cookson, p. 286; pl. 3, fig. 4; figs. 52-53.

Description: Circular or subcircular central body, equatorially enclosed by a thin lamellar structure which may bear thickened rods extending from the central body; thickenings may or may not reach the periphery. Lamella often folded or crumpled.

Dimensions: Equatorial diameter on 18 specimens, 21-49μ; inner body, 8-18μ.

Distribution: Lower Cretaceous of Australia (Deflandre and Cookson, 1955); early Paleocene of South Dakota (Stanley, 1965); present in samples from the Viking Formation and the Upper Shale Unit, south-central Alberta, the Lower Shaftesbury Formation, the uppermost Cadotte Member and basal Joli Fou Formation, "Grouard" section, and the Joli Fou and Pelican Formations, "Grosmont" section.

### Pterospermopsis sp. A. (20704)

Plate 9 , fig. 12

Description: Circular or subcircular central body; enclosed equatorially by a thin lamellar structure, which may or may not bear thickened rods extending from the central body and reaching the periphery. Lamella often folded or crumpled. Large form.

Dimensions: Equatorial diameter on 7 specimens, 50-105μ; diameter of central body, 18-56μ.

Remarks: Very little difference exists in structure between Pterospermopsis sp. A. and P. australiensis Deflandre & Cookson 1955. Specimens intermediate in size between the small and large forms exist, so that an arbitrary limit of 50μ has been chosen to separate the two forms. The significance of size range in forms of unknown affinity is difficult to assess and often requires an arbitrary decision on the part of the worker. The writer feels that as long as limits are clearly stated, later workers will not be misled by such divisions. The size ranges chosen here serve a useful purpose in providing an indication of populations of large and small sized forms of similar construction.

Distribution: Present rarely in the Lower Colorado Group of south-central Alberta and in the Harmon Member and Lower Shaftesbury Formation of west-central Alberta.

### Pterospermopsis sp. B. (20701)

Plate 9, figs. 21-22

Description: Circular or subcircular central body surrounded equatorially by a thin lamella. Junction of the lamella and central body marked by a thickened or folded region. Thin and indistinct rodlike thickenings may or may not be present, radiating from the central body in the lamella. Lamella often folded and wrinkled; inner body smooth.

Dimensions: Equatorial diameter on 10 specimens, 50-74μ; diameter of inner body, 34-63μ.

Remarks: Examination of specimens under phase contrast supports the interpretation of a lamellar structure rather than a disphaeromorph structure of two spherical layers.

Comparison: This species differs from other forms of Pterospermopsis described in this thesis by the lack of distinct thickenings and the thickened, folded junction of body and lamella, as well as the thin-walled central layer.

*Distribution*: Present rarely in the Viking Formation and Upper Shale Unit, south-central Alberta; the Harmon Member, "Spirit River" section and the Joli Fou Formation in the "Grouard" and "Grosmont" sections.

### *Pterospermopsis* sp. C. (20702)

Plate 9, fig. 19

*Description*: Circular inner body surrounded equatorially by a thin lamella. Lamella and inner body scabrate.

*Dimensions*: Equatorial diameter on 3 specimens, 60-88μ; inner diameter, 24-41μ.

*Remarks*: Examination of specimens by phase contrast supports an interpretation of a lamellar structure rather than a disphaeromorph structure as in Platymorph type A. (No. 20102).

*Comparison*: *Pterospermopsis eurypteris* Cookson & Eisenack 1958, p. 49; pl. 8, figs. 9 and 13, is similar but the authors of this species quote a size range of 95-123μ. The form occurs in the Neocomian-Aptian of western Australia.

*Distribution*: Rarely present in samples from the Viking Formation and Upper Shale Unit in south-central Alberta.

### *Pterospermopsis*? sp. D. (20705)

Plate 9, fig. 20

*Description*: Circular central body enclosed equatorially by a wrinkled, ?radially thickened lamella. Outline of lamella irregular and ruffled.

*Dimensions*: Equatorial diameter on 3 specimens, 126-207μ; diameter of inner body, 28-74μ.

Remarks: The exact interpretation of the structure of this form is uncertain as all specimens noted are somewhat corroded. The large size and lamellar structure, however, make this form easily recognizable.

Distribution: Noted only in one sample from the Upper Shale Unit, "Chigwell" section, south-central Alberta.

### Subgroup NETROMORPHITAE Downie, *et al*. 1963

### Genus LEIOFUSA Eisenack 1938

Type species: *Leiofusa fusiformis* (Eisenack) Eisenack 1938.

### *Leiofusa jurassica* Cookson & Eisenack 1958 (20751)

Plate 9, fig. 18

Selected syn.

1958 *Leiofusa jurassica* Cookson & Eisenack, p. 51; pl. 10, figs. 3-4.

Dimensions: Total length on 15 measured specimens, 29-63μ; width of 15 measured specimens, 7-19μ.

Remarks: One or more of the apical projections may be reduced and occasionally, one or two very small spines or rodlike projections may also develop on the test. The test is often split in the mid-line. This break may correspond to the presumed position of the pylome as suggested for a generalised leiofusid type by Combaz, *et al*. (1967, fig. 2).

Distribution: Geological range from Upper Carboniferous to Oligocene according to Combaz, *et al*. (1967, fig. 3); reported from the Lower Jurassic of Britain (Wall, 1965); recorded in samples from the Lower

Colorado Group, south-central Alberta, the Lower Shaftesbury Formation, west-central Alberta, and the Pelican Formation in the "Grosmont" section.

## Leiofusa cf. L. lidiae Gorka 1963 (20752)

Plate 9, fig. 26

cf. 1963 Leiofusa lidiae Gorka, p. 37; pl. 5, fig. 6.

Description: Outline fusiform. Elongate apical and antapical horns, tapering to bluntly rounded tips. Body fusiform. Wall thin and unsculptured; pylome partly developed.

Dimensions: The following dimensions on 1 specimen: total length, 392μ; length of horns, 140μ and 168μ; length of body, 84μ.

Remarks: This specimen agrees well with Leiofusa lidiae Gorka 1963, but the writer hesitates to indicate synonymy on the basis of one specimen.

Distribution: Present in one sample from the Lower Shaftesbury Formation in west-central Alberta. Gorka (1963) reports a closely comparable form from the Maestrichtian of Poland.

## Leiofusa sp. A. (20753)

Plate 9, fig. 23 and Text-fig. 19f

Description: Vesicle roughly fusiform, widest at the mid-line and tapering rapidly to pointed apices which are distally solid. Vesicle wall about 1μ thick, hyaline, sometimes folded or ruptured.

Dimensions: The following dimensions on 2 specimens: total length, 41-54μ; width at maximum, 21-26μ.

Comparison: The distally solid projections and thicker wall distinguish this form from *Leiofusa jurassica* Cookson & Eisenack.

Distribution: Present in the basal Joli Fou Formation, "Grosmont" section.

### cf. *Leiofusa* sp. B. (20754)

Plate 9 , fig. 15

Description: Vesicle elongated, more or less fusiform; terminated with tapering pointed spines at each apex. At, or near one apex, a lateral tapering spine also occurs. The essential fusiform symmetry is maintained.

Dimensions: Total length on 3 specimens, 39-45μ; vesicle length 25-27μ; spine length, 6-15μ.

Remarks: The specimens assigned to cf. *Leiofusa* sp. B. are similar to *Leiofusa* Eisenack 1938 except for the development of a small lateral spine. The species *Metaleiofusa arcuata* Wall 1965 is smaller and has essentially a non-fusiform symmetry.

Distribution: Present rarely in samples from the uppermost Cadotte Member, "Grouard" section and the Joli Fou Formation near the base in "Battle Lake" and "Wabamun" section, south-central Alberta; a single specimen of this form is also present in the basal Joli Fou Formation in East Fort Augustus No. 1 well at the 2424-2427' level (sample N61/1 of G. Norris), in east-central Alberta (Norris, 1967).

### Genus METALEIOFUSA Wall 1965

Type species: *Metaleiofusa arcuata* Wall 1965.

### Metaleiofusa sp. A. (20755)

Plate 10, fig. 2 and Text-fig. 19h

Description: Vesicle somewhat pyriform in outline with one apex prolonged into a tapering, pointed spine; the opposite pole slightly rounded with one or more processes at each corner. Number of spines from 3 to 5, variable in size and morphology, but all with tapering columns and acute tips.

Dimensions: The following measurements on 2 specimens: total length including the apical spine, 27-33μ; vesicle body, 18-25μ; other spines, 6-12μ.

Comparison: This form is somewhat similar to species of Metaleiofusa described by Wall (1965) but is larger than M. arcuata or M. diagonalis.

Distribution: Rare specimens noted in samples from the Joli Fou Formation, "Grosmont" section and the Lower Shaftesbury Formation, "Spirit River" section.

### ?Metaleiofusa sp. B. (20756)

Plate 10, fig. 3 & Text-fig. 19j

Description: Vesicle approximately fusiform with each apex prolonged into a tapering pointed spine. Three lateral spines arise from the central vesicle. Vesicle globular, not flattened.

Dimensions: Total length on 2 specimens, 43-46μ; maximum width on 2 specimens, 18-20μ.

Remarks: The form differs from Leiofusa Eisenack 1938 by having a number of spines besides the apical elongations and from Metaleiofusa Wall 1965 in having the spines at other than the apices. Veryhachium Deunff 1958 is polygonal and flattened, not inflated.

Text-figures 19a-j. Camera lucida drawings of selected microplankton specimens showing various structural features.

19a-c. *Veryhachium iniquum* sp. nov. (a) Holotype, X1000. (b) Complete specimen, BW190/1: 347 - 1047, X2000. (c) specimen showing additional small processes, BW152/3: 661 - 957, X2000.

19d. *Veryhachium* sp. B. Specimen with six processes, BW106/2: 497 - 1035, X550.

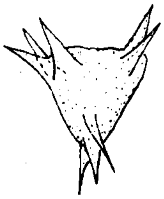
19e. *Veryhachium*? sp. D. Note concentration of processes near vesicle ends. BW131/1: 609 - 1080, X1000. Compare with Plate 9, fig. 4.

19f. *Leiofusa* sp. A. BW137/1: 193 - 982, X1800. Specimen illustrated also as Plate 9, fig. 23.

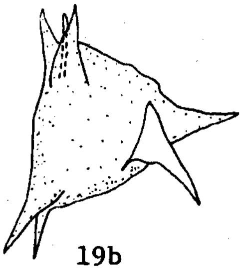
19g. Cf. *Leiofusa* sp. B. BW171/2: 530 - 1131. X550. Specimen figured also in Plate 9, fig. 15.

19h. *Metaleiofusa* sp. A. BW137/1: 375 - 1022, X1800. Same specimen illustrated in Plate 10, fig. 2.

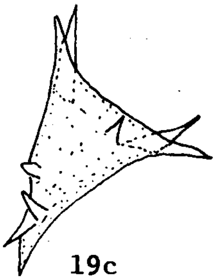
19j. ?*Metaleiofusa* sp. B. BW137/1: 265 - 1003, X1500. Specimen illustrated also in Plate 10, fig. 7.



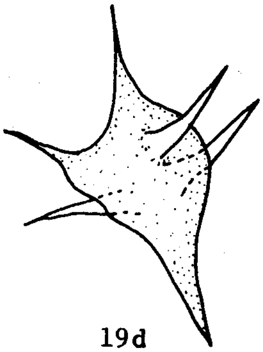
19a



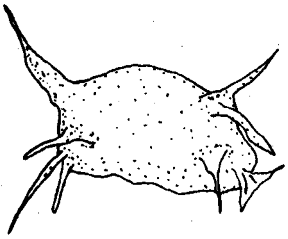
19b



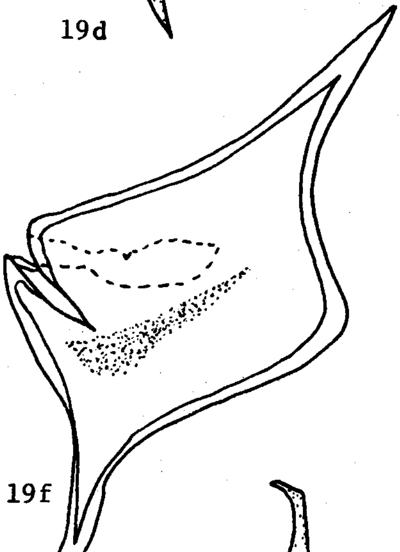
19c



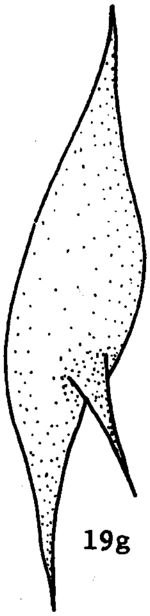
19d



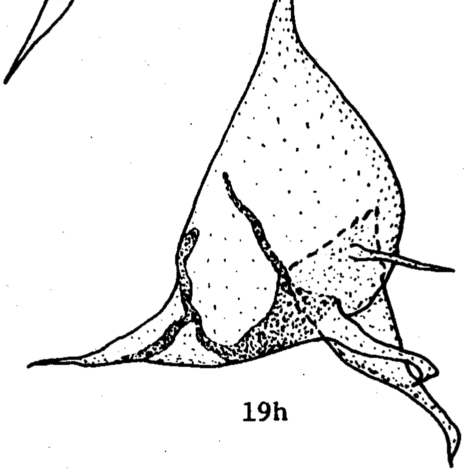
19e



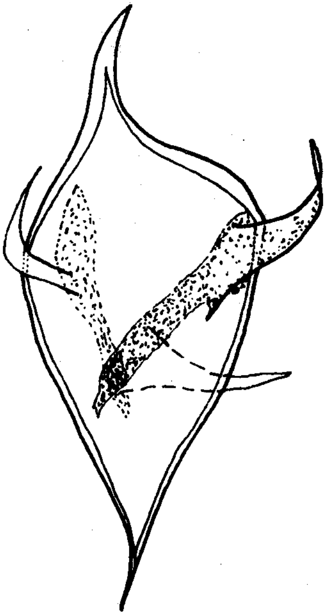
19f



19g



19h



19j

Text-figure 19

Distribution: Rare specimens noted in samples from the Joli Fou Formation in the "Grosmont" section.

### Subgroup SPHAEROMORPHITAE Downie, *et al.* 1963

### Genus LEIOSPHAERIDIA Eisenack 1958

Type species: *Leiosphaeridia baltica* Eisenack 1958.

Remarks: The species described below are not assigned formal names. The number of characters available for taxonomic division are few, including only the size and wall ornament or structure. Several species below are divided into two forms on the basis of an arbitrary size limit. The writer's views on this matter have been previously stated in the remarks concerning *Pterospermopsis* sp. A.

### *Leiosphaeridia* sp. A. (20801)

Plate 9, fig. 14

Description: Outline of vesicle circular or subcircular. Wall thin, rarely folded and laevigate or scabrate. A small split or circular pylome developed on some specimens. Diameter less than 50μ.

Dimensions: Maximum diameter on 37 measured specimens, 9-47μ.

Distribution: Noted in samples from all units investigated in this thesis.

### *Leiosphaeridia* sp. B. (20802)

Plate 10, fig. 7

Description: Outline circular or subcircular, to ovoid; wall thin and unfolded, laevigate or scabrate. Diameter 50μ or greater.

Dimensions: Maximum diameter on 10 specimens, 55-77μ.

Distribution: Present in samples from the Viking Formation and Upper Shale Unit, south-central Alberta, and the Paddy Member and Lower Shaftesbury Formation, west-central Alberta.

### *Leiosphaeridia* sp. C. (20803)

Plate 9 , fig. 27

Description: Vesicle circular or subcircular. Wall thin and hyaline and cross-crossed with numerous fine wrinkles or fine folds, but never with broad folds. Diameter less than 50μ.

Dimensions: Maximum diameter on 18 specimens, 29-49μ.

Distribution: Present in samples from the Lower Colorado Group, south-central Alberta and from the Lower Shaftesbury Formation in west-central Alberta.

### *Leiosphaeridia* sp. D. (20804)

Plate 10, fig. 8

Dimensions: Maximum diameter on 14 specimens, 52-81μ.

Comparison: This species is exactly similar to *Leiosphaeridia* sp. C. but has a diameter of 50μ or more.

Distribution: Present in samples from the Lower Colorado Group in south-central Alberta, the Paddy Member in west-central Alberta, and near the base of the Pelican Formation in the "Grosmont" section.

### *Leiosphaeridia* sp. E. (20805)

Plate 10, fig. 15

Description: Vesicle outline oval to subcircular; wall 1-3μ thick;

occasionally folded, the folds broad and few in number; laevigate to scabrate.

Dimensions: Maximum diameter on 25 measured specimens, 45-91μ.

Comparison: This form is distinguished from Araucariacites Cookson 1947 by its laevigate or scabrate ornament and from other species assigned to Leiosphaeridia in this thesis by its thick, broadly folded wall.

Distribution: Lower Colorado Group in south-central Alberta, Harmon and Paddy Members and the Lower Shaftesbury Formation in west-central Alberta, the basal Joli Fou Formation in the "Grouard" section, and the Pelican Formation in the "Grosmont" section.

### Leiosphaeridia sp. F. (20806)

Plate 9, fig. 24

Description: Vesicle thin-walled and elongate, outline rounded; wall scabrate or laevigate and folded to a verying degree. A small dark enclosed body often noted in the interior of the vesicle.

Dimensions: Maximum diameter on 11 specimens, 49-91μ.

Comparison: This species is distinguished from others assigned to Leiosphaeridia in this thesis by its elongate shape.

Distribution: Lower Colorado Group in south-central Alberta.

### Leiosphaeridia sp. G. (20807)

Plate 10, fig. 1

Description: Vesicle subcircular to nearly circular. Wall thick and unornamented, rarely folded. At one apex, a split, or ovoid pylome consistently developed.

Dimensions: The following measurements on 5 specimens; maximum diameter, 53-70μ; minimum diameter, 53-61μ.

Comparison: The thick, rarely folded wall and opening distinguish this form from others assigned to Leiosphaeridia in this thesis.

Distribution: Rare in samples from the upper Viking Formation and Upper Shale Unit in the "Battle Lake" section, south-central Alberta.

## ACRITARCHA SUBGROUP UNCERTAIN

### Genus PALAEOSTOMOCYSTIS Deflandre 1935

Type species: *Palaeostomocystis reticulata* Deflandre 1935.

### *Palaeostomocystis fragilis* Cookson & Eisenack 1962 (20901)

Plate 9, figs. 25 and 28

1962 *Palaeostomocystis fragilis* Cookson & Eisenack, p. 496; pl. 7, figs. 10-11.

1964 *Palaeostomocystis fragilis* Cookson & Eisenack; Cookson & Manum, p. 28; pl. 5, fig. 10.

Dimensions: Maximum diameter on 32 specimens, 60-140μ; width on 27 measured specimens, 25-77μ.

Remarks: One apex of a number of specimens examined was opened with the opening having a faintly irregular edge. This opening is interpreted as a pylome structure.

Distribution: Recorded in samples from the Viking, Pelican, and Lower Shaftesbury Formations and from the Upper Shale Unit; previously noted from the Upper Cretaceous of Australia (Cookson and Eisenack, 1962) and from the Upper Cretaceous of Graham Island and Ellef Ringnes Island, Canadian Arctic (Manum and Cookson, 1964).

### Genus CYCLOPSIELLA Drugg & Loeblich 1967

Type species: Cyclopsiella elliptica Drugg & Loeblich 1967.

### Cyclopsiella? sp. A. (20906)

Plate 10, fig. 9 & Text-figs. 20a-b

Description: Vesicle sac-like; outline ovoid or subcircular; vesicle wall thin, hyaline and folded. A more or less circular ?sub-apical or apical pylome, surrounded by a thickened rim at one apex; radial folds extend from the rim or are not present.

Dimensions: The following dimensions on 3 specimens; length, 56-70μ; width, 56-60μ; pylome diameter on 2 specimens, 18 and 29μ.

Comparison: Cyclopsiella? sp. A. most resembles Cyclopsiella vieta Drugg & Loeblich 1967, p. 192; pl. 3, figs. 7-9 and text-fig. 8, from the Oligocene of Mississippi, U.S.A. but differs in possessing a slightly different structure abount the pylome, in the absence of an apical plug and in the lack of the consistent equatorial fold exhibited by the illustrated specimens.

Distribution: Rare specimens recovered from the Cadotte Member, Peace River Formation and the Paddy Member, "Spirit River" section.

### Acritarch Forma A. (20903)

Plate 10, fig. 14

Description: Vesicle thin-walled with occasional folds, but without any consistent fold pattern; wall scabrate or smooth. Outline elongate with apices broadly rounded to somewhat flattened. Some specimens show an opening or breakage at one apex.

Dimensions: The following measurements on 5 specimens; length, 105-150μ; width, 49-80μ.

Comparison: This form differs in shape and does not possess the consistent longitudinal fold of *Paleostomocystis fragilis* Cookson & Eisenack 1962.

Distribution: Rare specimens noted in the Joli Fou Formation and Upper Shale Unit, south-central Alberta, the Lower Shaftesbury Formation in west-central Alberta and the Pelican Formation in the "Grosmont" section.

Division PYRROPHYTA Pascher

Class DINOPHYCEAE Pascher

Subclass DINIFEROPHYCIDAE Bergh

Order NORMODINALES Chatton

Family MICRODINIACEAE Eisenack 1964

Type genus: *Microdinium* Cookson & Eisenack 1960, p. 6.

Genus MICRODINIUM Cookson & Eisenack 1960

Type species: *Microdinium ornatum* Cookson & Eisenack 1960.

*Microdinium opacum* sp. nov. (21001)

Plate 10, figs. 5-6 and Text-figs. 20c-d

1961 Forma A Evitt, p. 390; pl. 1, fig. 14 and pl. 2, fig. 7.

Holotype: BW 134/1 at 555 - 940; length, 28μ; width, 25μ; dark area, 13μ in diameter. Tabulation: 1', 6", 6c, 6"', 1pv, 1"".

Description: Dinoflagellate cyst, pentagonal shape, corners rounded; epitract smaller than hypotract. Apical archaeopyle, formed by the loss of plate 1'; operculum polygonal in shape with attached sulcul tongue. Reflected tabulation determined as 1', 6", 6c, 6"', 1pv and 1""; plates outlined by low, simple ridges. Cyst bears a circular, darkened, ?thickened region at and just below the level of the cingulum, about half the cyst diameter in width. Cingulum provided with six plates, the plate outlines not always completely defined and not in line with more than one or two plates of the pre-cingular or post-cingular series. Sulcus somewhat flask-shaped with rounded to angular outline, extending onto the epitract to meet plate 1' and terminated antapically by plate 1"". Plates 6" and 1" and 6"' and 1"' often encroach making the sulcus narrow in this region. Cingulum nearly circular, with little or no displacement. Plate 1"' smaller than the other post-cingular plates; plate 6"' somewhat trapezoidal in shape. Plate 1"" is placed slightly asymmetrically with respect to the apical and antapical axis.

Dimensions: Length on 40 measured specimens, 19-36μ; width of darkened spot, 7-17μ; width of cyst on 12 measured specimens, 22-33μ.

Remarks: Most specimens are recovered from the matrix without an operculum or are preserved so that the shape of the operculum is difficult to determine. It is clear however, from several specimens that the operculum is formed of only 1 plate and that the apical series consists only of this one plate.

Distribution: Recorded in all units of the Lower Colorado Group throughout south-central and central Alberta and in the Peace River and Lower Shaftesbury Formations in west-central Alberta. Noted from the 2598-2607' level, Grand Rapids Formation, East Fort Augustus No. 1 well in east-central Alberta (sample kindly supplied by Dr. C. Singh, Research Council of Alberta). Vavdrova (1964) figures a similar form from the Lower Cretaceous of Czechoslovakia but it is difficult to make comparisons from her illustrations. The range of this form thus appears to be late Middle to Upper Albian judging from the available data.

### *Microdinium*? *cristatum* sp. nov. (21002)

Plate 10, figs. 10-13 and Text-fig. 20e

*Holotype*: BW 178/1 at 418 - 1123; length, 56μ; width, 66μ including sutures. Tabulation: 1', 6", 5-?6c, 6"', 1"".

*Description*: Dinoflagellate cyst with two layered construction, the outer layer forming crest-like sutures. Cyst outline ovoid to weakly rounded-pentagonal; epitract approximately equal to hypotract in length; antapex broadly rounded. Cingulum weakly helicoid; sulcus slightly curved and reaching onto the epitract, truncated by plates 1' and plates 6" and 1" in part; widening towards the antapex and ending at the antapical plate. Archaeopyle apical, the operculum not observed, but apparently formed of plate 1' and slightly expanded, including also the sutural crests and marginal portions of the adjacent pre-cingular plate series. Archaeopyle zig-zag in outline, reflecting the boundaries of the pre-cingular series. Outer layer of the cyst wall forms high, membranous sutural crests which outline a reflected tabulation of 1', 6", 5-?6c, 6"', and 1"". Both apical and antapical plates roughly polyhedral in shape, with the latter only about half as large as the former. Cingulum and sulcus also bordered by crests with the cingulum often having cingular septa enclosing 5 or 6? cingular plates. Crests up to 10μ high and smooth in outline or slightly crenulated, thin, often highly folded.

Dimensions: Length, including crests, on 9 specimens, 36-59μ; width, including cingular crests on 17 specimens, 32-56μ; 30 specimens recorded.

Remarks: The tabulation of this form corresponds most closely to *Microdinium* as does archaeopyle structure and apical plate number. *Meiourogonyaulax* Sarjeant 1966 has raised crest-like sutures but is defined as having ?4' plates by Sarjeant (1966, p. 145). The species described here otherwise closely resembles that genus. All previous species assigned to *Microdinium* possess very low ridges or sutures and for this and other reasons, discussed above, the species is only questionably assigned to that genus.

Distribution: Lower Colorado Group in south-central Alberta; Harmon Member and Lower Shaftesbury in west-central Alberta; uppermost Cadotte and Joli Fou Formation, "Grouard" section and the Joli Fou and Pelican Formations, "Grosmont" section.

### Family CANNINGIACEAE Sarjeant & Downie 1966

Type genus: *Canningia* Cookson & Eisenack 1960.

Remarks: Sarjeant and Downie characterized the family Canningiaceae as having an apical archaeopyle. They included the genus *Broomea* Cookson & Eisenack 1958. However, the holotype of the type species, *Broomea ramosa* Cookson & Eisenack, p. 41; pl. 6, fig. 7, exhibits a clearly defined intercalary archaeopyle with operculum formed of one intercalary plate. Hence *Broomea* cannot be included in this family.

### Genus DACTYLODINIUM gen. nov.

Type species: *Dactylodinium* (al. *Broomea*) *jaegeri* (Alberti) comb. nov., herein designated.

Diagnosis: Dinoflagellate cyst, elongate in the apical-antapical axis. More or less elongate apical horn and two equally or unequally developed antapical horns. Cyst outline rounded antapically between the horns and widest about the mid-line. Cingulum present or absent; sulcus indistinct or absent; epitract longer than hypotract. Wall thin and smooth or only finely ornamented. Archaeopyle apical or compound apical, the operculum consisting of the apical horn (and ?apical plates) and including or not including portions of other plate series on the epitract.

Description of type species: Dinoflagellate cyst; elongate in the apical-antapical axis. Elongate apical horn and two nearly equal antapical horns present. Cyst outline smooth, widest in the mid-line, tapering apically and rounded antapically between the antapical horns. Cyst wall thin and smooth or scabrate. Faint indications of a cingulum, the epitract being longer than the hypotract; no sulcus noted. Archaeopyle apical; operculum consisting of the apical horn and the ?apical plate system. The citation of the type species is as follows: Dactylodinium (al. Broomea) jaegeri (Alberti 1961, p. 26; pl. 5, figs. 1-7) comb. nov.

Remarks: At least nine species have been attributed to the genus Broomea Cookson & Eisenack. Most of these do not show the structure of the archaeopyle and the type of operculum and no further comment can be made until such information is available. The following species may have an intercalary archaeopyle as in the type: Broomea gochti Alberti 1961, p. 27; pl. 5, figs. 8-10. Eisenack (1964, p. 65) comments that at least one specimen of this form has a rectangular or perhaps round "Schlüpfloch" (archaeopyle) below the apex.

Broomea simplex Cookson & Eisenack 1958, p. 42; pl. 6, fig. 9.

The other species described so far, excepting those combined below in the new genus are referred to Broomea on the basis of their shape and construction of the cyst.

### Dactylodinium jaegeri (Alberti) comb. nov. (21101)

Plate 10, figs. 17-19 and Text-fig. 20f

Selected syn.

1961 Broomea jaegeri Alberti, p. 26; pl. 5, figs. 1-7.

? 1964 Broomea cf. jaegeri Alberti; Cookson & Hughes, p. 53; pl. 11, fig. 10.

Description: See the description of the type species.

Dimensions: Total length on 14 specimens, 105-199μ; width on 27 measured specimens, 22-42μ; length of the cyst body on 26 measured specimens, 46-112μ; length of shorter antapical horn, 4-21μ; length of longer antapical horn, 7-28μ.

Distribution: Recorded from the Hauterivian of Germany (Alberti, 1961); present in samples investigated in this thesis from all strata except the Paddy Member, Peace River Formation, "Spirit River" section. The range is thus extended to Upper Albian.

### Dactylodinium sp. A. (21102)

Plate 10, fig. 20

Description: Dinoflagellate cyst; elongate in the apical-antapical axis. Elongate apical horn and two relatively shorter, equally or

Text-figures 20a-f. Camera lucida drawings of selected microplankton specimens showing various structural features.

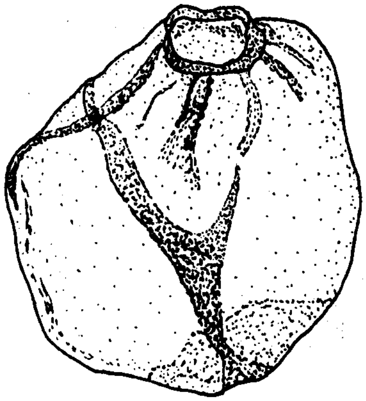
20a-b. Cyclopsiella? sp. A. (a) Specimen showing thickened lip about opening with accompanying radiating folds, BW156/1: 643 - 1065, X600. Illustrated also as Plate 10, fig. 9. (b) another specimen with radiating folds about the lip, BW160/1: 345 - 937, X800.

20c-d. Microdinium opacum sp. nov. (c) ventral view and (d) dorsal view by transparence of the holotype. Tabulation shown by solid lines, inferred tabulation by dotted lines. A portion of the operculum is present and the apical archaeopyle is developed, X1800. Illustrated also in Plate 10, figs. 5-6.

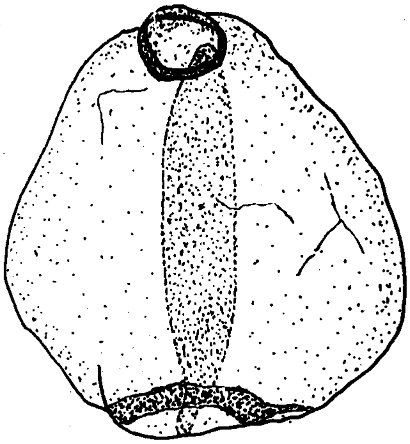
20e. Microdinium? cristatum sp. nov. Drawing of specimen in ventral focus; dorsal tabulation by transparence in solid lines, ventral tabulation in dotted lines and ventral plate numbers underlined; apical archaeopyle developed. BW75/2: 593 - 1103, X1700. Specimen illustrated also in Plate 10, figs. 10-11.

20f. Dactylodinium jaegeri (Alberti) comb. nov. Drawing of the specimen illustrated in Plate 10, figs. 17-18, X1250. A portion of the incipient operculum exploded to show the suture lines; other incipient suture lines dotted.

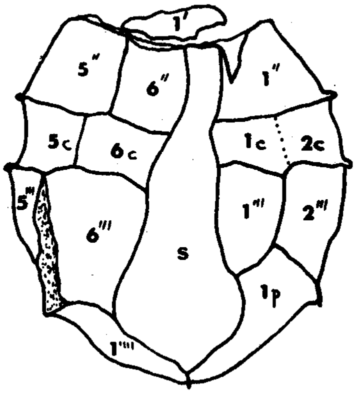
Text-figure 20



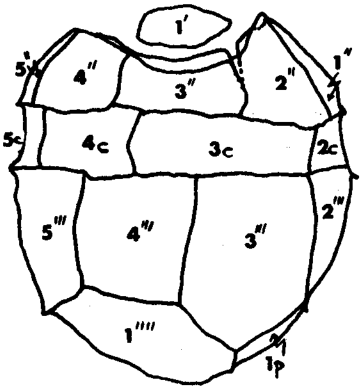
20a



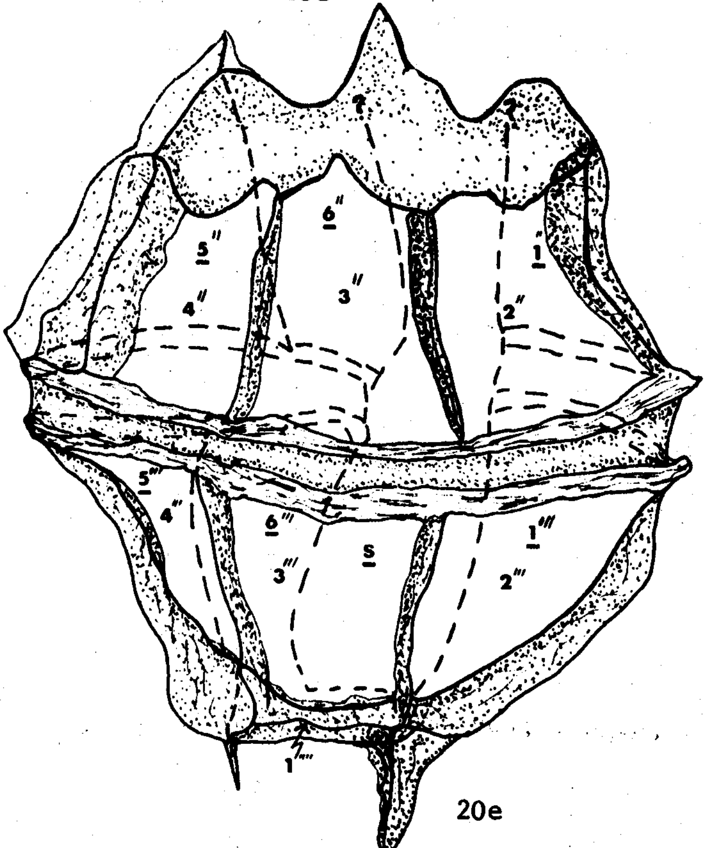
20b



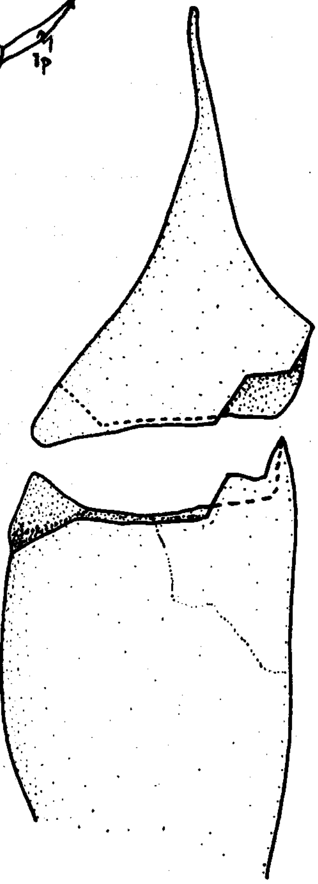
20c



20d



20e



20f

unequally developed antapical horns. Cyst outline smooth, widest at the mid-line, tapering apically and slightly flattened between the antapical horns. Wall thin and scabrate. Archaeopyle apical; operculum including the apical horn and probably the apical plate series. No indications of a cingulum or sulcus noted.

Dimensions: Total length on 1 specimen, 216μ; length of cyst body on 5 specimens, 63-78μ; width of body on 6 specimens, 22-37μ; antapical horns, 31-52μ and 34-88μ. Apical horn on 1 specimen, 103μ.

Comparison: *Dactylodinium* (al. ?*Broomea*) *longicornutum* (Alberti 1961, p. 27; pl. 5, figs. 18-21 and pl. 6, figs. 1-2) comb. nov. is very similar in construction and dimensions but possesses characteristic perforated horns. The specimens of this form illustrated by Alberti (1961, pl. 5, figs. 20-21) show an incipient development of an operculum identical to the type developed in *Dactylodinium* sp. A.

Distribution: Rare in samples from the Lower Colorado Group in south-central Alberta and from the Lower Shaftesbury Formation, west-central Alberta. Similar forms, as *Dactylodinium longicornutum* (Alberti) comb. nov. have been noted from the Hauterivian of Germany (Alberti, 1961) and the Speeton Clay, Upper Barremian of England (Sarjeant, 1966c).

## Genus CANNINGIA Cookson & Eisenack 1960

Type species: *Canningia reticulata* Cookson & Eisenack 1960.

### *Canningia crassa* sp. nov. (21104)

Plate 11, figs. 3 and 10 and Text-figs. 21a-b

Holotype: BW 123/1 at 570 - 964; length, 78μ; width, 61μ.

Description: Dinoflagellate cyst; outline in lateral view subcircular. Wall thick and often corroded to a reticulate or foveolate pseudosculpture; uncorroded specimens scabrate to granulose. Archaeopyle apical, with zig-zag margin indicating incipient reflected plating; operculum partially attached in some specimens, indicating the apex is prolonged into a slight prominence. Other indications of tabulation and cingulum or sulcus structure not noted.

Dimensions: Length on 24 measured specimens (2 complete), 45-84μ; width on 24 specimens, 59-101μ.

Comparison: *Canningia minor* Cookson & Hughes 1964, p. 43; pl. 8, figs. 1-3 and 5, is somewhat similar in size and aspect but appears to have a different archaeopyle structure and is thinner-walled and slightly longer than broad. *Canningia colliveri* Cookson & Eisenack 1960 has a different shape, an indented antapex and is granulate to sparsely spinulate.

Distribution: Specimens noted in various parts of the sections investigated throughout the Lower Colorado Group in south-central Alberta; in the Harmon and Paddy Members and Lower Shaftesbury Formation, west-central Alberta and in the Pelican Formation, "Grosmont" section.

### *Canningia* sp. A. (21103)

Plate 10, fig. 4

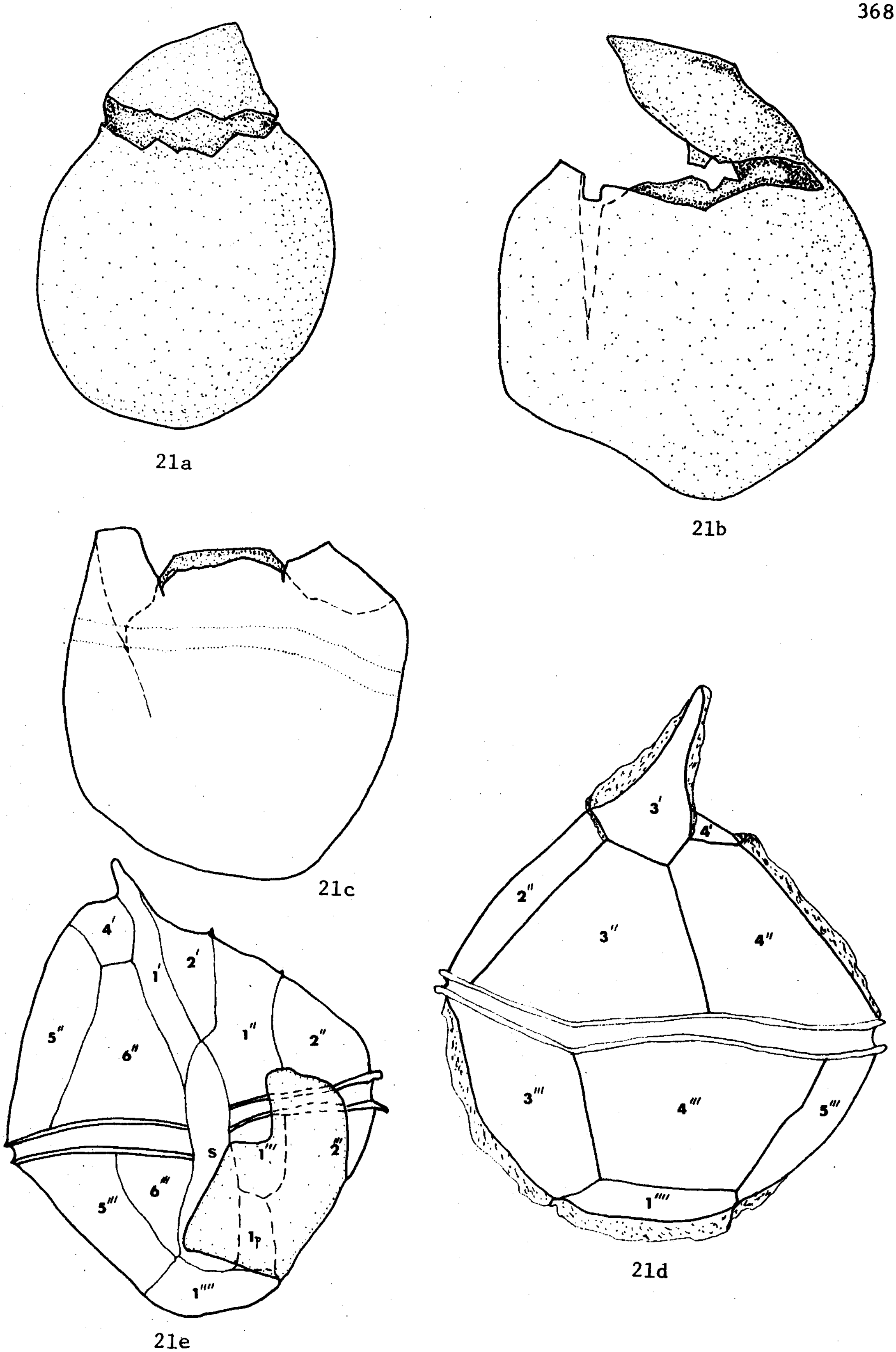
Description: Dinoflagellate cyst; outline pentagonal, corners rounded. Cyst widest at the mid-line where a faint cingulum trace is present, tapering to a slightly pointed apex and an antapex with

Text-figures 21a-e. Camera lucida drawings of selected microplankton specimens showing various structural features.

21a-b. *Canningia crassa* sp. nov. (a) Outline drawing of the holotype showing attached operculum, X1000; illustrated also in Plate 11, fig. 3. (b) another specimen with operculum still attached; BW124/1: 595 - 1058, X750; illustrated also in Plate 11, fig. 10.

21c. *Tenua* sp. A. Outline of specimen with apical archaeopyle and several accessory sutures visible; faint girdle trace dotted in: BW135/1: 658 - 1042, X800; illustrated also in Plate 10, fig. 23.

21d-e. *Gonyaulacysta globosa* sp. nov. (d) Dorsal tabulation pattern of the holotype; illustrated also in Plate 11, fig. 6. (e) Ventral tabulation pattern of specimen, BW106/2: 160 - 1122, X800; partly reconstructed postcingular series, derived from several other specimens; specimen illustrated also in Plate 14, fig. 1.



21a

21b

21c

21e

21d

Text-figure 21

two short antapical prominences, the antapex indented slightly between these. Cyst wall thin, scabrate. Apical archaeopyle noted on one specimen, margin zig-zag.

*Dimensions*: Total length on 2 specimens, 38-57μ; width on three specimens, 32-47μ.

*Distribution*: Rare specimens from the Viking Formation and Upper Shale Unit in south-central Alberta.

### *Canningia*? sp. B. (21105)

Plate 10, fig. 21

*Description*: Dinoflagellate cyst elongate in the apical-antapical axis. Wall 1-3μ thick and smooth or faintly wrinkled. Specimens similar in all aspects but showing an apical archaeopyle with a zig-zag margin and accessory suture markings are included in this form.

*Dimensions*: Length on 1 complete specimen, 137μ; length on 2 specimens with archaeopyles, 74-83μ. Width on 3 specimens, 102-112μ.

*Remarks*: The structure of this form is incompletely understood, there being only 3 specimens on which to base the description. The writer thus refers this form questionably to *Canningia* Cookson & Eisenack 1960, to which it bears some resemblance in having an apical archaeopyle and no trace of tabulation other than the incipient reflected plating indicated by the zig-zag margin of the archaeopyle.

## Family FROMEACEAE Sarjeant & Downie 1966

Type genus: *Fromea amphora* Cookson & Eisenack 1958.

## Genus FROMEA Cookson & Eisenack 1958

Type species: Fromea amphora Cookson & Eisenack 1958.

### Fromea amphora Cookson & Eisenack 1958 (21201)

Plate 10, fig. 16

Selected syn.

1958 Fromea amphora Cookson & Eisenack, p. 56; pl. 5, figs. 10-11.

1964 Fromea amphora Cookson & Eisenack 1958; Cookson & Hughes, p. 54; pl. 10, fig. 3.

Description: Outline ovoid and elongate in the apical-antapical axis. Wall 1-3μ thick and occasionally folded. Apical opening, archaeopyle, with a smooth margin, crescent-shaped in lateral, compressed view, variable in size. Occasional specimens show an archaeopyle with a more irregular margin and just a faint indication of zig-zag outline. Only a few specimens show any trace of a cingulum, generally in the form of a faint lineation or darkening of the wall in the mid-region of the cyst.

Dimensions: Total length on 30 measured specimens, with or without archaeopyle developed, 56-108μ; width on 30 specimens, 38-74μ.

Distribution: Recorded in samples from the Viking Formation and Upper Shale Unit, south-central Alberta; the Harmon and Cadotte Members and the Lower Shaftesbury Formation in west-central Alberta and the uppermost Cadotte Member and Joli Fou and Pelican Formations in central and east-central Alberta; previously reported from the Albian of South Australia (Cookson and Eisenack, 1958) and from the Upper Albian and lowermost Cenomanian of Britain (Cookson and Hughes, 1964); Cookson and Hughes (1964, p. 55) give the range of this form as Aptian to Cenomanian in South and Western Australia; Alberti (1961) reports this form from the Barremian of Germany; Sarjeant (1967) charts the geological range as Barremian to Lower Cenomanian.

## Fromea sp. A. (21202)

Plate 11, fig. 9

Description: Cyst elongate and ovoid. Apical opening, archaeopyle, with minutely ragged edge and on some specimens, a small notch perhaps corresponding to a sulcul notch. Wall smooth with no evidence of cingulum or sulcus; no reflected tabulation noted. Some specimens are relatively dark and others more translucent.

Dimensions: Total length on 9 measured specimens, 32-45µ; width on 8 measured specimens, 24-39µ.

Comparison: Fromea amphora Cookson & Eisenack 1958 is larger and has a somewhat differently constructed apical archaeopyle.

Distribution: Rare in the Joli Fou Formation and Upper Shale Unit in south-central Alberta, in the Lower Shaftesbury Formation, west-central Alberta, and in the uppermost Cadotte Member and basal Joli Fou Formation of the "Grouard" section.

## Genus TENUA Eisenack 1958

Type species: Tenua hystrix Eisenack 1958.

Remarks: Evitt (1961, p. 398) notes that the specimens used in the description of the type species possess an apical archaeopyle and may have the cingulum outlined by rows of spines.

## Tenua longispina sp. nov. (21206)

Plate 11, figs. 2 and 8

Holotype: BW 143/2 at 365 - 1070; length, 70µ; width, 70µ; spines, 4-10µ.

Description: Dinoflagellate cyst; outline in lateral view ovoid subcircular or circular. Wall 1-3µ thick and occasionally folded. Archaeopyle apical, a zig-zag margin suggesting the presence of incipient reflected plating; occasional specimens (including the holotype) with operculum still attached, showing the apex to be rounded and spiny. Cyst covered more or less evenly with tapering spines having pointed or slightly rounded apices, with occasional pilate processes present on some specimens. Spines outline no discernable tabulation, and only occasionally show the presence of a cingulum region, and less frequently a possible ventral sulcul region, by a less dense distribution of spines; length of spines 3-15µ, typically 5-10µ.

Dimensions: Length on 36 measured specimens (3 complete forms), 37-78µ.

Remarks: This species is based on specimens showing a zig-zag archaeopyle with only a few forms having the operculum still partially or wholly attached. Both types of specimens show the same morphology and those with operculum still attached show the same type of zig-zag breakage line; hence these specimens are considered to be representatives of the same species.

Distribution: Recorded in samples from the Lower Colorado Group in south-central Alberta, the Harmon Member and the Lower Shaftesbury

Formation in west-central Alberta, the "Grouard" section and the Pelican Formation, "Grosmont" section.

### Tenua sp. A. (21207)

Plate 10, fig. 23 and Text-fig. 21c

Description: Dinoflagellate cyst; outline in lateral view ovoid or subcircular. Wall 1-2μ thick and covered with discrete spines and coni, 2-4μ high; spines do not outline any reflected tabulation, but are absent in a narrow band in the mid-line indicating the presence of a reflected cingulum, and on some specimens outline a sinuous sulcul region on the posterior hypotract. Archaeopyle apical with a zig-zag margin indicating the presence of incipient reflected plating; sometimes a sulcul notch may be visible.

Dimensions: Length on 4 specimens with archaeopyle, 39-74μ; width on 4 specimens, 53-68μ.

Distribution: Rare specimens noted in the Cadotte Member and the Lower Shaftesbury Formation, west-central Alberta.

### Tenua? sp. B. (21208)

Plate 10, fig. 22 and Plate 11, fig. 7

Description: Dinoflagellate cyst; complete specimens ovoid or subcircular in outline. Reflected tabulation not evident. Archaeopyle apical with zig-zag margin indicating incipient reflected plating. Cyst wall covered with more or less densely packed spines, cones, and occasional clavate processes, 2-4μ high. Reflected cingulum and sulcus not observed. Occasional specimens show the operculum still attached in whole or part and the apex can be seen to be rounded. A faint helicoid cingulum observed on one specimen, outlined by spines.

Dimensions: Length on 9 specimens (with or without operculum), 45-70μ; width on 8 specimens, 40-64μ.

Comparison: Tenua? sp. B. is distinguished from Tenua sp. A. by its dense spine cover and lack of indication of a cingulum. Tenua longispinosa sp. nov. has longer spines.

Distribution: Present in the Viking Formation and Upper Shale Unit in south-central Alberta; rare in the Lower Shaftesbury Formation, west-central Alberta and in the Pelican Formation, "Grosmont" section.

### Tenua? sp. C. (21205)

Plate 11, fig. 1

Description: Dinoflagellate cyst; only incomplete specimens possessing what is interpreted as a zig-zag apical archaeopyle recovered. These specimens, circular or subcircular in outline in lateral view, and covered with a dense ornament of setae and occasional papillate elements, 1-$2\frac{1}{2}$μ high and about 1/2μ wide.

Dimensions: Length on 25 measured specimens with archaeopyle, 42-84μ.

Distribution: Present in the Lower Colorado Group of south-central Alberta; rare in the Lower Shaftesbury Formation, west-central Alberta and in the Pelican Formation, "Grosmont" section.

### Tenua? sp. D. (22952)

Plate 17, fig. 8

Description: Dinoflagellate cyst; outline circular or subcircular.

Wall thin, bearing simple tapering, and rarely bifurcate, thin processes, without expanded bases. Indistinct cingulum region outlined by smaller spinelike processes which enclose a smooth band near the mid-line. No other evidence of tabulation, although some adjacent processes may be joined by low, indistinct sutures. Apical archaeopyle noted on a few specimens; margin zig-zag.

Dimensions: Length on 10 specimens, 44-66μ; width on 6 measured specimens, 48-65μ; length of processes, 3-19μ; width at base of processes, 1/2-2μ. Total of 10 specimens recovered.

Comparison: *Cometodinium multispinosum* (Singh 1964) comb. nov. is more profusely spinose and does not have differentiation of the processes in the cingulum region. *Tenua longispina* sp. nov. has spinose processes which have thick bases and taper apically.

Distribution: Recovered only from the Joli Fou and Viking Formations in south-central Alberta ("Battle Lake" and "Chigwell" sections).

## Family GONYAULACYSTACEAE Sarjeant & Downie 1966

Type genus: *Gonyaulacysta* (Deflandre) Sarjeant 1966.

## Genus GONYAULACYSTA (Deflandre) Sarjeant 1966

Type species: *Gonyaulacysta jurassica* (Deflandre) Deflandre 1964.

### *Gonyaulacysta globosa* sp. nov. (21301)

Plate 11, figs. 4-6; Plate 14, fig. 1 and Text-figs. 21d-e

Holotype: BW 105/1 at 239 - 1017; length, 115μ; width, 90μ; apical horn, 18μ; tabulation: 4', 6", Oc, 6‴, 1p, 1⁗.

Description: Dinoflagellate cyst; globular to rounded-pentagonal outline. Cingulum, with faintly zig-zag outline, slightly helicoid; sulcus extending partially onto the epitract and meeting plate 1', widening slightly at the antapical end to meeting plate 1''''. Epitract and hypotract nearly equal in length. Distinct apical horn, variable in length and shape, often incompletely preserved. Reflected tabulation of 3-4?', ?1a, 6'', 0c, 6''', 1p, 1'''' demarcated by low, narrow sutures; occasional specimens have secondary ridges which are intratabular in position and parallel the plate boundaries. Ridges outlining the girdle are somewhat higher and more robust. Archaeopyle precingular; operculum formed of plate 3'', roughly trapezoidal in shape.

*Dimensions*: Length on 27 measured specimens, 74-115μ; width on 26 measured specimens, 64-92μ; apical horn length on 25 measured specimens, 10-31μ.

*Comparison*: *Gonyaulacysta globosa* sp. nov. is distinguished from other species of this genus by the combination of its shape and tabulation pattern. *Gonyaulacysta palla* Sarjeant 1966, p. 113; pl. 13, figs. 3-4; Text-fig. 24, is similar in shape and has an apical horn somewhat like some specimens of *G. globosa* sp. nov. but differs in plating, possessing 7''' plates and 6 cingular plates as well as in other details.

*Distribution*: Specimens noted from all units investigated except the Paddy Formation, west-central Alberta; known range is thus latest Middle and Upper Albian in western Canada.

## *Gonyaulacysta obesa* sp. nov. (21302)

Plate 12, figs. 1-2 and Text-figs. 22a-b

*Holotype*: BW 132/1 at 586 - 1060; length, 126μ; width, 94μ; apical horn, 32μ; tabulation: 3-?4', 6'', 0c, 6''', 1pv, 1''''.

*Description*: Dinoflagellate cyst; outline more or less pentagonal; epitract and hypotract approximately equal in length. Antapex rounded. Prominent, stout apical horn, often somewhat truncated. Cingulum helicoid, displaced about one cingulum width; sulcus slightly sinuous, extending onto the epitract, subtended by plate 1' apically and plate 1pv antapically. Reflected tabulation of 3-?4', 6'', 0c, 6''', 1pv, 1'''' marked by low sutures; most specimens exhibit a microreticulate intratabular sculpture, the muri narrow and the lumina rounded to polygonal. Archaeopyle precingular; the operculum formed of plate 3''.

*Dimensions*: Length on 12 measured specimens, 122-140μ; width on 11 measured specimens, 88-111μ; length of apical horn on 12 measured specimens, 21-35μ. Total of 18 specimens recovered.

*Comparison*: The combination of the shape, stout apical horn, intratabular microreticulation and plating pattern serve to distinguish this species from other forms described under *Gonyaulacysta*.

*Distribution*: Specimens recovered from all strata investigated except the Peace River Formation, "Spirit River" section, west-central Alberta, and the Joli Fou Formation in the "Grosmont" section. Known range is Upper Albian in western Canada.

## *Gonyaulacysta auctifica* sp. nov. (21303)

Plate 11, figs. 11-12 and Text-figs. 23a-b

*Holotype*: BW 106/2 at 620 - 1043; length, 125μ; width, 118μ; length of horn, 22μ; tabulation: 3', 2a, 6", 0c, at least 6-?9''', 1-?2p; ?pv, 1'''', ?4s.

*Description*: Dinoflagellate cyst; overall outline rounded - pentagonal; length of main cyst body approximately equal to the width; promiment apical horn. Wall 3-5μ thick, apparently two-layered, the outer layer forming the sutures and scabrate or laevigate. Helicoid tranverse cingulum, displaced about 1$\frac{1}{2}$ cingulum widths, bounded by raised sutures; sulcus somewhat sinuous or flask-shaped and apparently with up to 4 sulcul plates, approximately equally divided between the epitract and hypotract, truncated by plates 1' and antapically by 1'''' and ?1p. Tabulation complex, outlined by low, membranous, sinuous to often digitate sutures with sutures sometimes reflected by parallel intratabular crests. Epitractal tabulation: 3', 2a; 6"; hypotract complex, especially about the sulcus with at least: 0c, 6-?9''', 1p, ?4s, 1''''. Archaeopyle precingular, expanded; the operculum consists of plate 3" and the adjacent portion of the cingulum.

*Dimensions*: Length on 22 measured specimens, 112-147μ; width on 21 measured specimens, 77-118μ; apical horn on 20 measured specimens, 22-35μ. Total of 30 specimens recovered.

*Remarks*: The illustrations and figures of this species (pl. 11, figs. 11-12 and Text-fig. 23a - b) indicate the complexity of the hypotractal plating pattern and the difficulty of distinguishing true plates and reflected sutures which are intratabular. Thus as many as 9''' plates or as few as 6'''may be distinguished depending on the interpretation of the pattern. This situation obtains also in regard to the posterior plate series and the figures given are only estimates of the apparent pattern.

*Comparison*: *Gonyaulacysta auctifica* sp. nov. is distinguished by its combination of tabulation, archaeopyle type and shape. The small, nearly axially located plate 2a and the complex hypotractal plating are especially diagnostic. Other features of distinction include the two-layered wall with the thick inner layer (endophragm) and the long apical horn.

Other forms possessing an expanded precingular archaeopyle and having an operculum including plate 3" and the adjacent cingulum (*Palaeoperidinium castanea* Deflandre 1935 in Deflandre (1936); pl. 6, fig. 4, and the drawing by Lejeune-Carpentier (1946, p. 190; fig. 2) of the specimen figured by W. Wetzel 1933, p. 161; pl. 2, fig. 4 and called *Peridinium ventriosum* Wetzel) differ in construction of the cingulum and in tabulation.

*Distribution*: Lower Colorado Group in south-central Alberta; Joli Fou and Pelican Formations on the "Grosmont" section; "Grouard" section and Lower Shaftesbury Formation, west-central Alberta.

### *Gonyaulacysta villosa* sp. nov. (21304)

Plate 12, figs. 5-8 and Text-fig. 23c

*Holotype*: Imperial Oil Ltd. Slide 3471: 11-453/4 at 367 - 1087; length, 140μ; width, 105μ; length of apical horn, 35μ; tabulation: 5', ?2a, 6", ?c; ?7''', ?2p, 1''''.

*Description*: Dinoflagellate cyst; outline pentagonal and rounded to somewhat angular; prominent apical horn, tapering and slightly truncated at the tip. Cingulum helicoid, displaced about one cingulum width, with thick bordering ledges, and internally foveolate. Sulcus nearly straight and somewhat ovoid in shape, extending for about 1/3 its length onto the epitract; truncated by plate 1' and antapically by plate 1pv, from 3 to 4 sulcul plates, and in the medial sulcul trace, a further lobed depression; ledges bordering sulcus outline not so robust as those about the cingulum; internal divisions of sulcul plates low and narrow. Tabulation complex, outlined by strongly developed crest-like sutures, which may or may not be folded or flattened, up to 6μ high when expanded; tabulation variable, especially on the hypotract and approximately 4-6?', ?2a, 6", 0?c, 7-?9"', 1-2p, ?pv, 1"". Archaeopyle precingular, opening pentagonal to polygonal in shape; operculum formed of plate 3".

*Dimensions*: Total length on 25 measured specimens, 116-147μ; width on 24 measured specimens, 91-120μ; length of apical horn on 25 measured specimens, 18-42μ. Total of 36 specimens recorded.

*Remarks*: The hypotractal tabulation pattern is difficult to detemine with accuracy because of the presence of intratabular sutures and the variation in development of the various sutures in the specimens. It is possible that this species and also, perhaps, *Gonyaulacysta auctifica* sp. nov., may belong to the genus *Cribroperidinium* Neale & Sarjeant 1962. These species and the type species of that genus, *Cribroperidinium sepimentum* Neale & Sarjeant 1962, share certain common features including shape, well-developed sutural crests and complex hypotractal tabulation. However, C. sepimentum differs from these forms in its epitractal tabulation and in other features. The writer thinks it best at present to assign the newly described species to Gonyaulacysta (Deflandre) Sarjeant 1966.

Comparison: Gonyaulacysta villosa sp. nov. differs from G. auctifica sp. nov. in its epitractal tabulation, more well-developed sutural crests, and in other details of hypotractal tabulation and shape. Two other previously described species are somewhat similar to G. villosa sp. nov. and deserve some comment.

Gonyaulacysta (al. Gonyaulax) edwardsi (Cookson & Eisenack 1958, p. 32; pl. 3, figs. 5-6 and fig. 7) comb. nov. is similar in overall shape, general tabulation details and cingulum offset, but differs in cingulum structure and tabulation detail, especially in the apical and post-cingular series.

Gonyaulacysta orthoceras (Eisenack) Sarjeant 1966 is similar in overall outline, and general construction but is generally somewhat smaller in size and differs in detail of the tabulation, especially in the post-cingular series. Sarjeant (1966, p. 121) quotes a size range of 70-105μ compared with 116-147μ for G. villosa sp. nov.

It may be noted here that Sarjeant (1966) has already proposed the combination cited above as new. However, Tappan and Loeblich (1967) suggest that a number of these may be improperly made, and the writer proposes the above in case this should apply to that particular species.

Distribution: Recorded in various parts of the sections of the Lower Colorado Group investigated in south-central Alberta, in the Lower

Shaftesbury Formation, west-central Alberta, the Pelican Formation, "Grosmont" section, and the uppermost Cadotte Member, "Grouard" section.

Gonyaulacysta fragosa sp. nov. (21309)

Plate 12, figs. 3-4 and Text-figs. 22c-d

Holotype: Imperial Oil Ltd. Slide 5048: 10-349/2 at 334 - 1137; length, 97μ; width, 66μ, length of apical horn, 25μ; tabulation: 4', 6", Oc, 6"', 1p, 1"".

Description: Dinoflagellate cyst; outline pentagonal to somewhat rhomboidal, angular. Cyst wall thin and smooth. Cingulum nearly circular, marked by highly folded region in the mid-line and sometimes not well developed. Sulcus ill-defined but present on most specimens; slightly sinuous in shape, extending onto the epitract for about 1/3 or 1/4 of its length. Prominent apical horn, tapering. Low, folded sutures outline a relatively simple tabulation, not always well defined on all specimens; tabulation determined as: 4', 6", Oc, 6"', 1p, 1"". Archaeopyle precingular, trianguloid to trapezoid; operculum formed of plate 3".

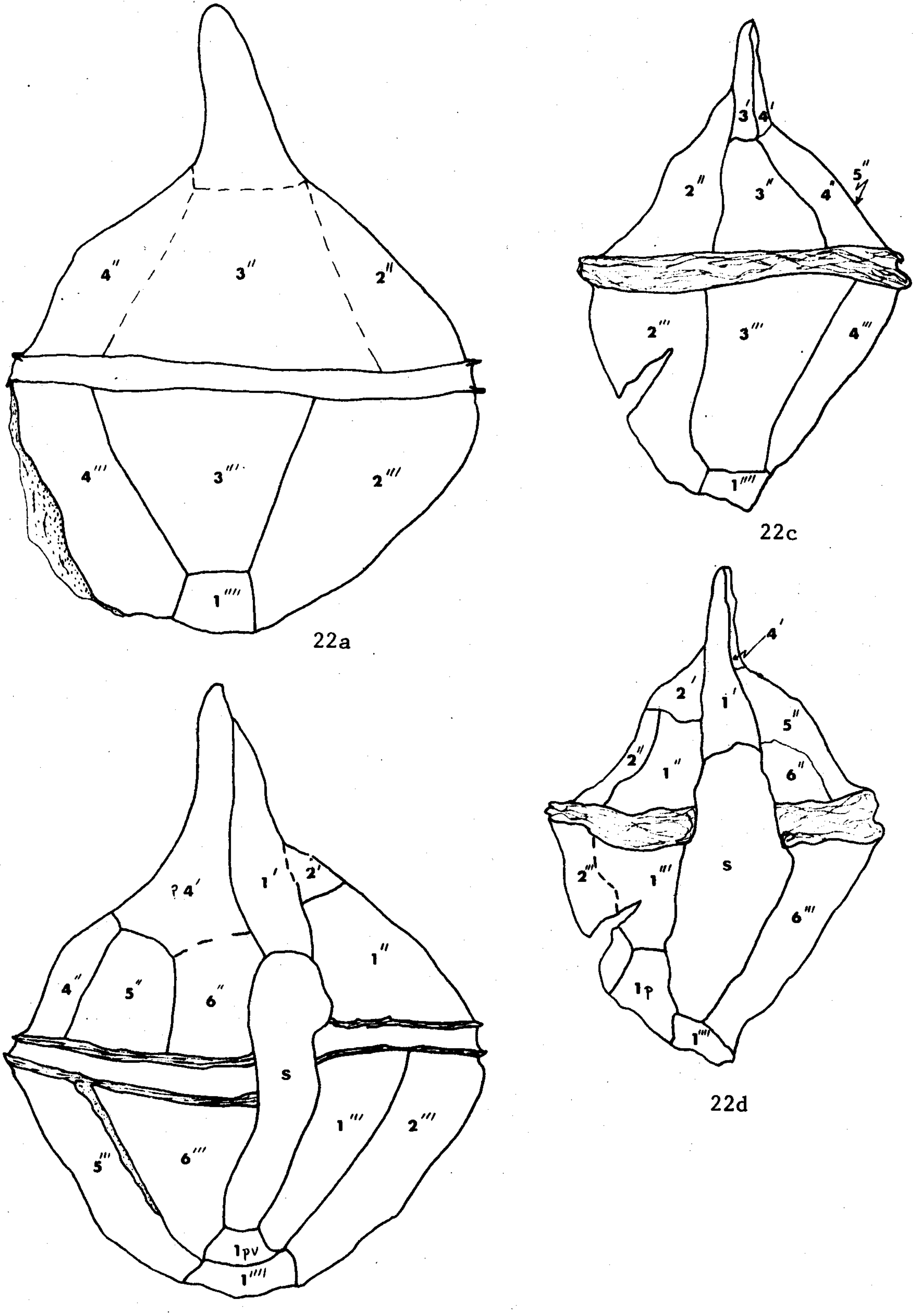
Dimensions: Total length on 13 measured complete specimens, 92-118μ; width on 17 measured specimens, 53-88μ; length of apical horn on 10 measured complete specimens, 11-32μ. Total of 24 specimens recorded.

Distribution: Specimens recorded from the Lower Colorado Group in various parts of the sections investigated in south-central Alberta, the Harmon Member and the Lower Shaftesbury Formation, west-central Alberta, the Pelican Formation in the "Grosmont" section, and the uppermost Cadotte Member in the "Grouard" section.

Text-figures 22a-d. Tabulation patterns for various species of *Gonyaulacysta* described from the Lower Colorado Group.

22a-b. *Gonyaulacysta obesa* sp. nov. Holotype. (a) dorsal pattern by transparence, in part. (b) ventral tabulation pattern. Both X800. Specimen illustrated also in Plate 12, fig. 2.

22c-d. *Gonyaulacysta fragosa* sp. nov. Holotype. (c) Dorsal tabulation pattern. (d) ventral tabulation by transparence. Both X800. Specimen illustrated also in Plate 13, figs. 3-4.



22a

22c

22d

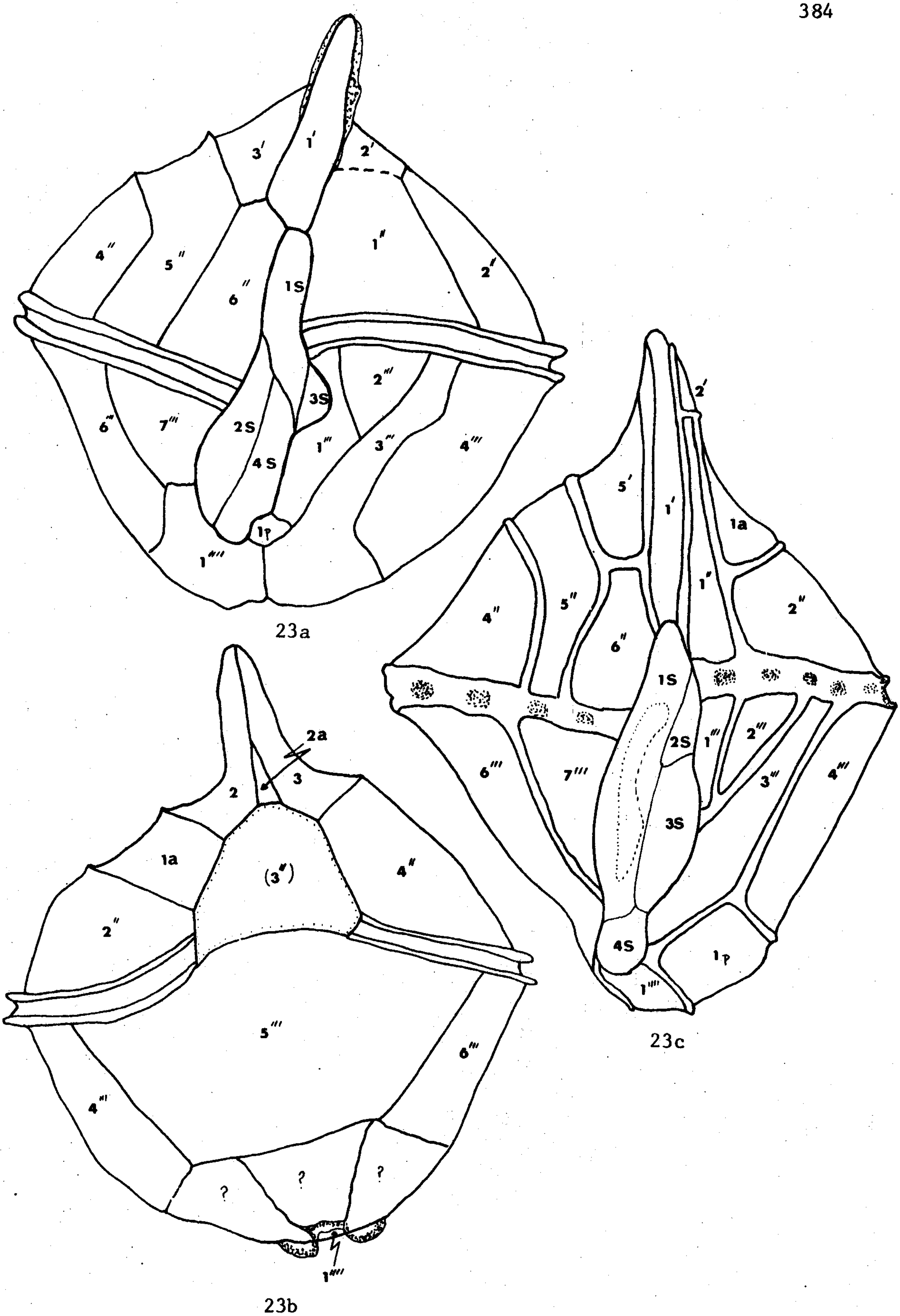
22b

Text-figure 22

Text-figures 23a–c. Tabulation patterns for various species of *Gonyaulacysta* described from the Lower Colorado Group. Numbering of pattern tentative.

23a-b. *Gonyaulacysta auctifica* sp. nov. Holotype. (a) Ventral tabulation pattern by transparence with image reversed to show the orientation of the girdle. (b) Dorsal tabulation pattern. Both X850. Specimen illustrated also in Plate 11, figs. 11-12.

23c. *Gonyaulacysta villosa* sp. nov. Distal tabulation pattern; BW105/2: 182 - 961, X750. Specimen illustrated also in Plate 12, fig. 7.



23a

23b

23c

Text-figure 23

### *Gonyaulacysta orthoceras* (Eisenack) Sarjeant 1966 (21305)

Plate 12, fig. 9

Selected syn.

1958 *Gonyaulax orthoceras* Eisenack, p. 388; pl. 21, figs. 3-11, pl. 24, fig. 1 and figs. 2-3.

1966 *Gonyaulacysta orthoceras* (Eisenack) Sarjeant, p. 121; pl. 14, figs. 5-6; Text-fig. 29.

*Dimensions*: The following dimensions for 2 specimens: length, 110-118μ; width, 91-97μ; length of apical horn, 29μ (both).

*Remarks*: Sarjeant (1966, p. 121-123) provides an emended diagnosis and description of this species, giving the tabulation scheme as: 4', 1a, 6", ?6c, 7''', 1p, 1''''. The specimens recorded from the Lower Colorado Group agree closely with this, there being some doubt about the posterior plates and the number of post-cingular plates. The specimens exhibit crests which are intratabular in position and parallel the plate boundaries. However, it is possible to confirm this tabulation: 4', 1a, 6", 0c, ?7''', 1p, 1''''; (?1pv, ?2p).

*Distribution*: Rare in samples from the Joli Fou and Viking Formations, south-central Alberta; previously recorded from the Valangian to Turonian (Eisenack, 1958; Gocht, 1959; Gorka, 1963; Sarjeant, 1966).

### *Gonyaulacysta* (al. *Palaeoperidinium*) *granulata*

(Singh 1964) comb. nov. (21310)

Plate 13, fig. 2

1964 *Palaeoperidinium granulatum* Singh, p. 135; pl. 18, figs. 2-3.

*Dimensions*: Length on 2 measured specimens, 80-119μ; width on

2 specimens, 84-112μ; length of apical horn, 7-14μ.

Remarks: This species resembles the genus Gonyaulacysta in shape has a precingular archaeopyle and bears a faint trace of tabulation, not clearly determinable, but referable to that genus.

Distribution: Singh (1964) reported the species from the Middle Albian of east-central Alberta; rare specimens are recorded here from the Joli Fou Formation of south-central Alberta, "Battle Lake" section; the range is thus extended to early Upper Albian.

### Gonyaulacysta sp. A. (21308)

Plate 13, fig. 1

Description: Dinoflagellate cyst; outline elongate in the apical axis. Cyst wall usually corroded on specimens observed, but where uncorroded, strongly punctate. Prominent apical horn, tapering and bearing a small "lid" or "plug-like" tip. Archaeopyle precingular; operculum formed from plate 3". Reflected tabulation outlined by low ridges and determined as 4-?6', ?1a, 6", Oc, 6"', ?1p, 1"". Cingulum relatively wide with broad bordering ledges and wide cross struts giving the cingulum course a foveolate aspect; sulcus present, extending partly onto the epitract. Epitract longer than the hypotract.

Dimensions: The following dimensions on 3 specimens; length, 134-147μ; length of apical horn, 25-30μ; cingulum about 11μ wide.

Remarks: This species bears some resemblance to Gonyaulacysta (al. Gonyaulax) apionis (Cookson & Eisenack 1958, p. 36; pl. 3, fig. 7 and figs. 3-4) comb. nov. in shape and structure of the apical horn and general outline, but differs in texture of wall, construction of the girdle and details of tabulation.

### Gonyaulacysta sp. B. (21307)

Plate 12, fig. 10

Description: Dinoflagellate cyst; outline rounded pentagonal with rounded antapex and distinct apical horn. Cingulum helicoid, robust, with thick bordering ledges and wide cross struts, leaving only large foveolate pits along the course. Sulcus sinuous and extending onto the epitract, subtended apically by a long, narrow plate 1' and antapically by plate 1''''. Crest-like sutures outline a reflected tabulation, determined in part as: 6', 1a, 6'', 0c, 6''', ?1p, 1''''. Precingular archaeopyle; operculum formed of plate 3'' and including the part of the reflected cingulum adjacent to plate 3''. Plates 1' and 2' elongate; plates 3' and 6' small.

Dimensions: The following dimensions on 2 specimens: length, 126-130μ; width, 95-112μ; length of apical horn, 18-35μ.

Comparison: The pronounced cingulum, expanded archaeopyle and tabulation make this form distinctive. Gonyaulacysta sp. B. differs from Gonyaulacysta auctifera sp. nov. in tabulation and cingulum structure and from G. villosa sp. nov. in tabulation and other features.

Distribution: Rarely present in the Joli Fou Formation and the Upper Shale Unit, "Battle Lake" section, south-central Alberta.

### Family PAREODINIACEAE (Gocht) Sarjeant & Downie 1966

Type genus: Pareodinia Deflandre 1947.

Remarks: Norris and Sarjeant (1965) emended the Family Pareodiniaceae Gocht 1957 to include forms with an apical, intercalary or precingular archaeopyle. Sarjeant and Downie (1966) further emended this family to exclude forms with apical archaeopyles and stated that they considered the Family Apteodiniaceae Eisenack 1961 to be a later synyonym for the Pareodiniaceae.

### Genus TRICHODINIUM Eisenack & Cookson 1960

Type species: Trichodinium pellitum Eisenack & Cookson 1960.

### Trichodinium sp. A. (21406)

Plate 13, fig. 3

Description: Dinoflagellate cyst; outline subcircular. Cingulum marked by a row of small spines, bordering a barren region; sulcus not marked. Cyst ornamented with small spines, 2-3μ high which do not outline any distinct reflected tabulation pattern. Archaeopyle precingular in position, trapezoidal in shape.

Dimensions: The following dimensions on 2 specimens: length, 45-55μ; width, 50-53μ respectively.

Comparison: The few specimens noted above most resemble Trichodinium intermedium Eisenack & Cookson 1960, p. 6; pl. 2, figs. 5-6, but differ in having a better defined cingulum and in lacking an apical prominence, as well as being smaller.

Distribution: Rare in the Upper Shale Unit, "Battle Lake" section, south-central Alberta.

## Genus PAREODINIA Deflandre 1947

Type species: Pareodinia ceratophora Deflandre 1947.

### Pareodinia? sp. A. (21407)

Plate 12, fig. 11

Description: Dinoflagellate cyst; outline elongate, widest in the mid-line with an apical horn. Antapex rounded or with a slight axial indentation but without antapical prominences or horns. Apical horn thin, tapering to a point. Wall scabrate and thin. No archaeopyle structure noted.

Dimensions: The following dimensions on 7 specimens; length, 36-84μ; width, 19-42μ; length of apical horn, 7-21μ.

Remarks: This species is doubtfully referred to Pareodinia because of the lack of an archaeopyle structure. The shape of the cyst is similar to other described species of that genus but is also reminescent of species assigned to Broomea Cookson & Eisenack 1958, particularly Broomea exigua Alberti 1961, p. 26; pl. 5, fig. 14 and B. pellifera Alberti 1961, p. 26; pl. 5, figs. 11-13. These species appear to differ in construction only in the possession of two very poorly defined antapical horns.

Distribution: Rare specimens noted from the Joli Fou Formation, south-central Alberta, the Paddy Member and Lower Shaftesbury Formations, west-central Alberta and the "Grouard" section.

## PROXIMATE CYSTS INCERTAE

Remarks: The forms included below are considered by the writer to correspond to the cyst group termed proximate by Downie and Sarjeant (1966b, p. 15), but are insufficiently understood to be placed with confidence in existing families.

### *Proximate Cyst* Forma A. (21702)

Plate 13, figs. 4 and 7 and Text-figs. 24a-b

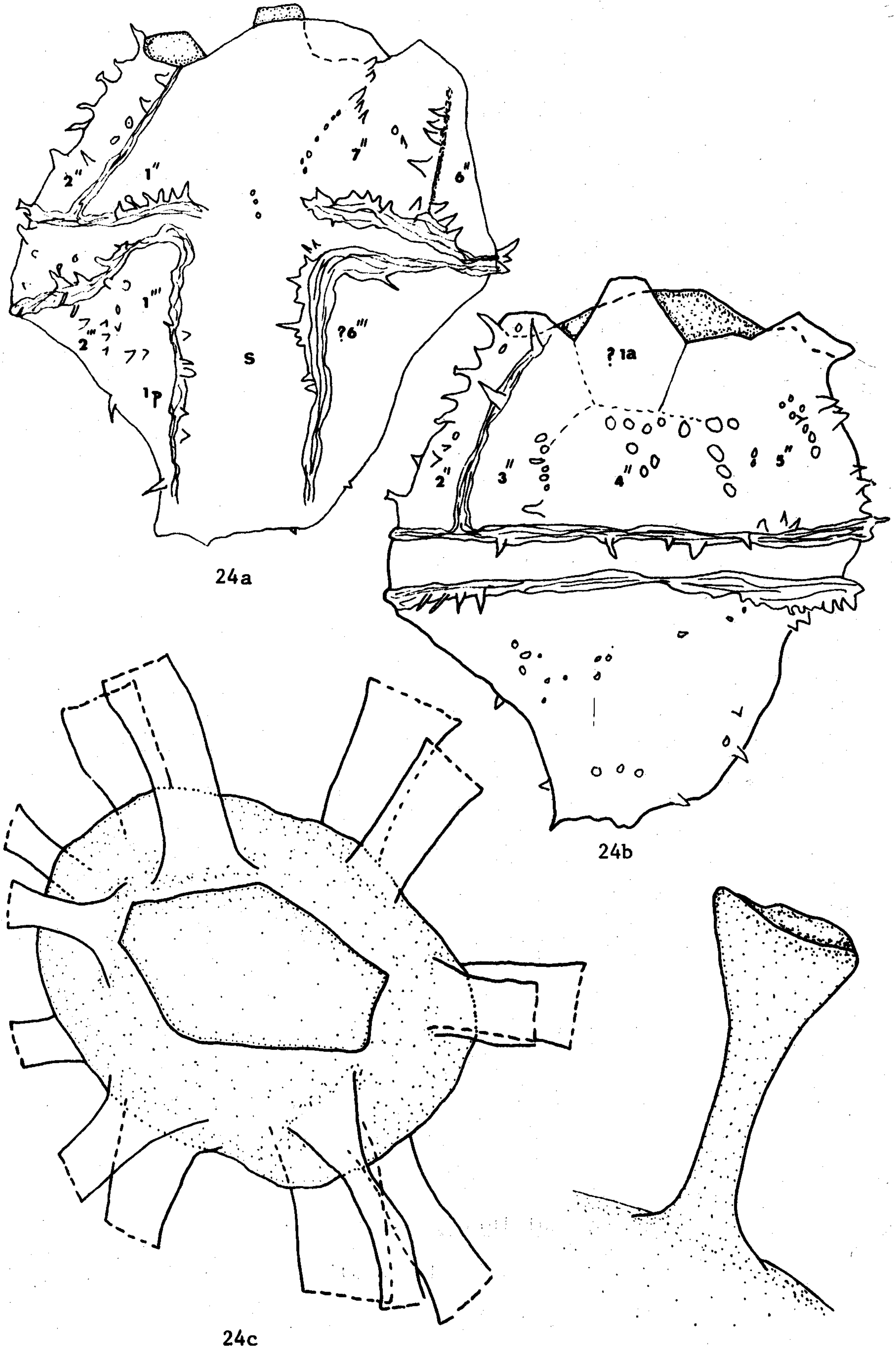
*Description*: Dinoflagellate cyst; outline pentagonal, width greatest at the cingulum; epitract longer than hypotract. Epitract tapering to a pointed or slightly rounded apex; hypotract tapering, often rapidly and then truncated antapically. Cyst appears ventrally flattened and dorsally somewhat convex in oblique orientation. Cingulum well-marked by spiny ridges or rows of spines, nearly circular; sulcus marked by spiny ridges, ridges or spine rows and relative straight, extending just onto the epitract, ending at the antapex.

Reflected tabulation imperfectly indicated by ?intratabular spines or rows of spines and occasionally sutural ridges on some specimens. Tabulation partly determined as ?4', ?1a, ?7", Oc, ?6''', ?1p, 1''''. The intercalary plate appears to be outlined on some specimens partly by spine rows at the base and partly by the shape of the archaeopyle, a polygonal portion of the margin (Text-fig. 24b) corresponding in position and shape to plate 1a. The archaeopyle is apical, the margin indicating the loss of at least four plates, but not including a postulated intercalary plate. Opercula found partially attached showed no detail of reflected tabulation, but indicate the shape of the apex and support the interpretation of an apical series of 4 plates.

Text-figures 24a-d. Camera lucida drawings of selected microplankton specimens showing various structural features.

24a-b. Proximate Cyst Forma A. (a) Ventral surface by transparence. (b) Dorsal surface showing position of spines and suggested tabulation pattern. Apical archaeopyle developed. Both X1800. BW103/1: 441 - 1011. Specimen illustrated also in Plate 13, figs. 4 and 7.

24c-d. Oligosphaeridium totum sp. nov. (c) Outline of holotype, apical view showing insertion of fourteen processes and outline of the apical archaeopyle. (d) Single process from the same specimen. Both X1700. Specimen illustrated also in Plate 13, figs. 6 and 10.



24a

24b

24c

24d

Text-figure 24

Dimensions: Total length, including specimens without opercula on 6 specimens, 52-74μ; width on 5 suitably oriented specimens, 35-49μ; ratio of epitract to hypotract length on 2 specimens, 1.7 to 2.0.

Remarks: The combination of the apical archaeopyle and spine rows or ridges reflecting tabulation and shape and construction of the cyst body exclude this species from the families Fromeaceae, Microdiniaceae and Canningiaceae. In some aspects, the form resembles members of the Deflandreaceae but lacks a capsule and has an apical instead of an intercalary archaeopyle.

Davey (in press) describes a new genus, to be named Epelidosphaeridium, possessing an apical archaeopyle, distinct cingulum and sulcus and numerous, short truncated spines (Davey, pers. comm.). The writer has not seen illustrations of forms assigned to this genus, but thinks that Proximate Cyst Forma A. may be included in that taxon.

Distribution: Rare specimens recovered from the Viking Formation and Upper Shale Units, south-central Alberta, from the Lower Shaftesbury Formation of west-central Alberta, and from the "Grouard" section, probably basal Joli Fou Formation.

### Genus PALAEOPERIDINIUM Deflandre ex Sarjeant 1967

Type species: Palaeoperidinium pyrophorum (Ehrenberg) Sarjeant 1967.

Remarks: Loeblich (1968) after discussing the procedure of Sarjeant (1967), concludes that the genus should be cited Palaeoperidinium Deflandre ex Sarjeant and not Palaeoperidinium (Deflandre) Sarjeant 1967. The writer concurs with Loeblich's views.

Palaeoperidinium cretaceum (Pocock 1962) emend. (21706)

Plate 12, figs. 12-13 and Plate 13, fig. 12

1962 Palaeoperidinium cretaceum Pocock, p. 80; pl. 14, figs. 219-221.

1964 Palaeoperidinium cretaceum Pocock; Singh, p. 134; pl. 18, fig. 1.

1964 Palaeoperidinium cf. cretaceum Pocock; Manum & Cookson, p. 20; pl. 3, figs. 11-12.

Emended Diagnosis: Dinoflagellate cyst; outline pentagonal or rounded-pentagonal; apex tapering to a rounded or slightly pointed apical promience; antapex with two antapical horns, equally or unequally developed. Epitract slightly longer or nearly equal in length to the hypotract; hypotract tapering slightly towards the antapex. Cyst wall thin, occasional specimens suggest a two-layered cyst wall; tabulation pattern not developed; many specimens showing persistent lineation patterns unrelatable to tabulation. Cingulum present, often indistinct, outlined by narrow folds or low ridges; sulcus not noted. Archaeopyle apparently apical, the operculum including the apical horn; specimens observed with a rupture at the cingulum are interpreted as having undergone mechanical breakage.

Dimensions: Length of cyst body on 42 measured specimens, 63-119μ; width of cyst on 42 measured specimens, 41-88μ; apical horn, 5-18μ; antapical horns, the shorter 3-17μ, the longer, 12-29μ. A total of 90 specimens recorded, many more observed.

Remarks: The writer has placed this genus in Palaeoperidinium in the full knowledge that it is not a species of this genus. However, the species does not belong in a genus to be proposed, called Astrocysta (Davey, in press), as suggested by Sarjeant (1967). That genus is defined (Davey, pers. comm.) as possessing an intercalary archaeopyle, while *Palaeoperidinium cretaceum* (Pocock 1962) emend. has an apical archaeopyle.

The exact position of this species is uncertain at present. The shape of this species approximates members of the genus *Deflandrea* Eisenack and the apical archaeopyle and general construction suggest an affinity with the Canningiaceae. The species is herein emended to include reference to the apical archaeopyle and other features of wall structure.

*Distribution*: Previously reported from the Valanginian to Middle Albian of western Canada (Singh, 1964; Pocock, 1962) and the Upper Cretaceous of the Canadian Arctic (Manum and Cookson, 1964); recorded here in abundance from all strata investigated in the Lower Colorado Group, Peace River and Lower Shaftesbury Formations.

### *Palaeoperidinium* sp. A. (21703)

Plate 13, fig. 5

*Description*: Dinoflagellate cyst; outline rounded-pentagonal. A short, tapered, apical horn and two unequally developed antapical horns. Cyst wall two-layered, the outer layer sometimes partially detached or loosened from the inner layer, and showing evidence of reflected tabulation; intertabular regions marked by a striated pattern and intratabular regions by a regular grid-like pattern. The tabulation scheme appears close to that of the modern genus, *Peridinium*, but cannot be determined in detail from the specimens available; pattern similar to: 3-4', 2-3a, 7", 5"', 2'"'. Cingulum circular, marked by low ridges and interrupted by a shallow longitudinal sulcus which expands onto the epitract. Archaeopyle formation not observed; some specimens ruptured near the cingulum but this is attributed to mechanical breakage during fossilization or during processing procedures.

Dimensions: The following dimensions on 6 specimens: length, 63-112μ; width, 57-101μ; antapical horns, 4-10μ and 7-15μ. Total of 8 specimens recorded.

Remarks: Most of the specimens have only part of the tabulation pattern preserved and are so flattened as to be viewable in only one plane. The specimens resemble the form described as Peridinium basilium Drugg 1967, p. 13; pl. 1, figs. 9-11 and pl. 9, fig. 1a-b in size and structure of the outer wall layer, but lacks an internal body and has unequally developed antapical horns.

Distribution: Rare specimens noted in the Lower Colorado Group, south-central Alberta, the Pelican Formation, "Grosmont" section, the uppermost Cadotte Member, "Grouard" section, and in the Lower Shaftesbury Formation, west-central Alberta.

## Family HYSTRICHOSPHAERIDIACEAE (Evitt) Sarjeant & Downie 1966

Type genus: Hystrichosphaeridium (Deflandre) Davey & Williams 1966.

## Genus LITOSPHAERIDIUM Davey & Williams 1966

Type species: Litosphaeridium (al. Hystrichosphaeridium) siphoniphorum (Cookson & Eisenack) Davey & Williams 1966.

## *Litosphaeridium*? sp. A. (22001)

Plate 13, fig. 14

**Description:** Dinoflagellate cyst; outline in longitudinal view subcircular and in apical view nearly circular. Apical archaeopyle, roughly hexagonal in outline. Tubular and occasionally subconical processes arise from the cyst wall, the columns faintly ribbed and the apices entire to slightly serrate; never more than 16 in number and interpreted to correspond to a reflected tabulation of 3', 6", 5"', 1p, 1"". The tabulation pattern is arrived at by assumption of an intratabular position for each column and by the placement of the processes in relation to the archaeopyle. Wall finely granulose or smooth; processes smooth between the ribs.

**Dimensions:** Length on 5 measured specimens, 22-29μ; width on 10 measured specimens, 18-31μ; processes 3-20μ long and 10 to 16 in number. A total of 24 specimens recorded.

**Remarks:** Most of the specimens recorded are not well-oriented for detailed study or are not well-preserved. They are, however, sufficiently preserved to be recognizable as belonging to a single entity.

**Comparison:** *Litosphaeridium siphoniphorum* (Cookson & Eisenack) Davey & Williams, p. 80 is somewhat similar but differs in possessing a distinctly six-sided archaeopyle opening, generally sub-conical processes and also a wider variety of non-tubular type processes.

**Distribution:** Recorded from the Lower Colorado Group in various portions of the sections investigated in south-central and central Alberta, from the "Grouard" section, and from the Lower Shaftesbury Formation, west-central Alberta.

## Genus OLIGOSPHAERIDIUM Davey & Williams 1966

Type species: Oligosphaeridium complex (White) Davey & Williams 1966.

### Oligosphaeridium totum sp. nov. (22006)

Plate 13, figs. 6, 10-11 and Text-figs. 24c-d

Holotype: BW 124/1 at 542 - 937; width (maximum), 42µ; processes 14 in number, 21-31µ long and 3-9µ wide basally; specimen with apical archaeopyle.

Description: Dinoflagellate cysts; outline in lateral view subcircular, and in apical view circular or subcircular. Wall thin, scabrate, two layered, the outer layer giving rise to biconcave, obconical or nearly tubular processes. Processes with buccinate, entire apices, occasionally with slightly serrate edges and scattered foveae; open apically, hollow and with bases expanding slightly at the junction of the processes and the cyst wall. Number of processes not more than 18; specimens exhibiting a polygonal apical archaeopyle which may be irregularly polygonal or approaching a hexagonal outline, often possess 14 processes, one process appearing smaller. The arrangement of processes on suitably oriented specimens appears to correspond to a reflected tabulation of ?4', 6", Oc, 5-6"', 1p, 1"", when the processes are assumed to be intratabular in position.

Dimensions: Length on 30 measurable specimens (with and without apical archaeopyle), 36-59µ; width on 21 measured specimens, 29-48µ; length of processes, 12-37µ; basal width of processes, 3-12µ. A total of 52 specimens recorded.

Remarks: The tabulation pattern suggested in the description of specimens is purely interpretive. Well preserved specimens with a clearly defined apical archaeopyle show arrangement of processes corresponding to a pattern of 6", Oc, 5-6"', 1p, 1"", a total of 14 processes. However, specimens with apparently no apical archaeopyle developed have not been found with more than 14 processes. Descriptions of other species placed in this genus (Davey and Williams, 1966) suggest that this form probably possesses 4 apical processes which are lost as part of the operculum during archaeopyle formation. Because many other specimens exhibit only 8 or 9 processes, it is suggested that many of the processes were lost as a result of mechanical breakage either during processing procedures or during fossillization. Such an interpretation is supported by the occasional occurrence of specimens bearing rounded breaks in the cyst wall which correspond in position to normal emplacement of processes.

*Comparison*: *Oligosphaeridium totum* sp. nov. is distinguished by its relatively large biconcave, buccinate, entire processes. *Oligosphaeridium* (al. *Hystrichosphaeridium*) *albertense* (Pocock 1962, p. 82; pl. 15, figs. 226-227) comb. nov. has irregular processes which are larger and the cyst body is also larger; the processes are serrate or aculeate at the apices.

*Distribution*: Specimens recovered from various portions of the Lower Colorado Group in south-central Alberta, from the Pelican Formation, "Grosmont" section, the "Grouard" section and from the Paddy Member and Lower Shaftesbury Formation in west-central Alberta.

Oligosphaeridium minor sp. nov. (22005)

Plate 13, fig. 9 and Text-figs. 25a-b

Holotype: BW 142/3 at 287 - 922; length, 28μ; width, 25μ; length of processes, 10-14μ; basal width of processes, 2-5μ; number of processes 18.

Description: Dinoflagellate cysts; outline in lateral view subcircular to ovoid, circular in apical view. Wall thin, scabrate, two-layered, the outer layer forming tubular processes with buccinate, entire apices; the processes hollow and open at the apices. On well-preserved, suitably oriented specimens, the processes, if assumed to be intratabular in position correspond to a reflected tabulation of 4', 6", 0c, 6"', 1p, 1"". The 1p process is smaller and can be used to orient the cyst. Archaeopyle apical, approximately hexagonal in outline; the operculum bearing the 4 processes of the apical series.

Dimensions: Length of cyst on 8 measured specimens, 26-38μ; width of cyst on 6 measured specimens, 17-31μ; length of processes on 12 specimens, 4-16μ; width of processes on 8 specimens, 1-11μ. Total of 17 specimens recovered.

Comparison: This species is distinguished by the small, buccinate processes with entire apices. The cyst body and processes are typically much smaller than those in Oligosphaeridium totum sp. nov.

Distribution: Lower Colorado Group in south-central Alberta; Joli Fou and Pelican Formations, "Grosmont" section; uppermost Cadotte Member, "Grouard" section; and the Paddy Member and Lower Shaftesbury Formation, west-central Alberta.

Text-figures 25a-f. Camera lucida drawings of various species from the Lower Colorado Group belonging to the Hystrichosphaeridiaceae. Partial reflected tabulations indicated are tentative.

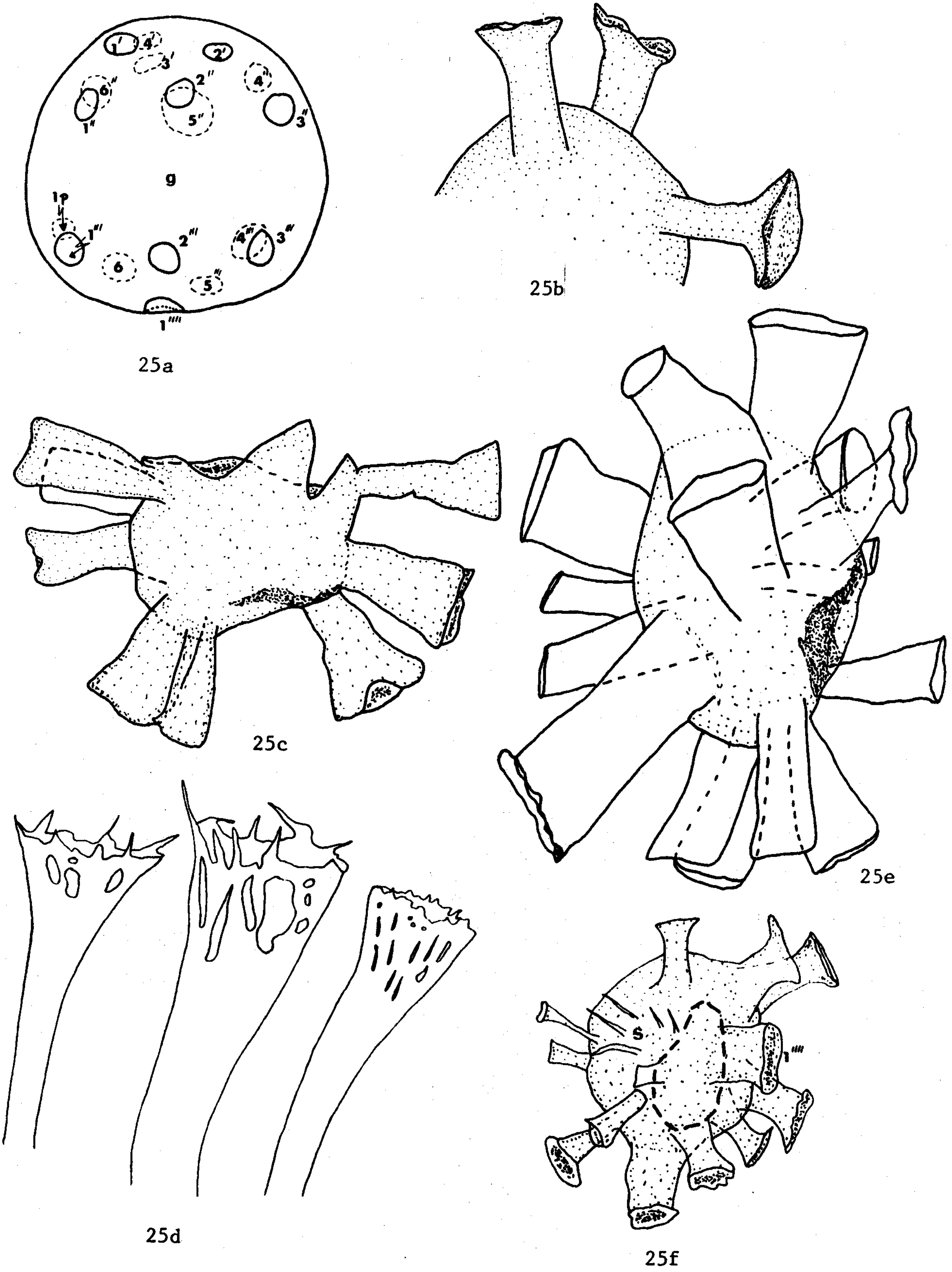
25a-b. *Oligosphaeridium* minor sp. nov. Holotype. (a) Outline diagram showing insertion of processes and suggested reflected tabulation pattern. (b) Several processes from the same specimen corresponding to the positions of 2', 3" and 4" in (a), X1600. Same specimen illustrated in Plate 13, fig. 9 with the three processes visible near the apical (right center) end.

25c. *Oligosphaeridium* sp. A. Note stout, somewhat tubular processes and development of an apical archaeopyle; BW124/2: 476 - 1122, X800. Same specimen illustrated also in Plate 14, fig. 4.

25d. *Oligosphaeridium* sp. B. Outline drawings of several of the processes of the specimen illustrated also as Plate 14, fig. 9; BW124/1: 437 - 1012, X3000.

25e. *Hystrichosphaeridium cylindratum* sp. nov. Holotype, X1400; illustrated also in Plate 14, fig. 5.

25f. *Hystrichosphaeridium* sp. A. Antapical orientation with 1"" process and sulcul processes in view; apical archaeopyle outline shown by dashed line; X800. Same specimen illustrated in Plate 15, fig. 6.



25a

25b

25c

25d

25e

25f

Text-figure 25

## *Oligosphaeridium complex*

(White) Davey & Williams 1966 (22008)

Plate 14, fig. 3

Selected syn.

1842 *Xanthidium tubiferum complex* White, p. 39; pl. 4, div. 3, fig. 11.

1940 *Hystrichosphaeridium elegentulum* Lejeune-Carpentier, p. 22; Text-figs. 11-12.

1946 *Hystrichosphaeridium complex* (White) Deflandre, p. 11.

1959 *Hystrichosphaeridium asterigerum* Gocht, p. 67; pl. 3, fig. 1 and pl. 7, figs. 1-4.

1966 *Oligosphaeridium complex* (White) Davey & Williams, p. 71; pl. 7, figs. 1-2; pl. 10, fig. 3 and Text-fig. 14.

*Dimensions*: Diameter of central body on 36 measured specimens, 32-66μ; length of processes, 7-52μ, typically 15-35μ. Number of specimens recorded, 50.

*Remarks*: Well preserved and suitably oriented specimens confirm the tabulation pattern suggested by Davey and Williams (1966, p. 71) of 4', 6", 5-6"', 1p, 1"". The apices of the processes are always flared with aculeate, sometimes bifid or bifurcating projections, occasionally somewhat spatulate projections, arising from the margin of the processes.

Gocht (1959, p. 67) describes a species named *Hystrichosphaeridium asterigerum* Gocht and notes that it bears similarity to *Oligosphaeridium* (al. *Hystrichosphaeridium*) *complex*. Gocht states (1959, pp. 67-68, in transl.): "*H. asterigerum* is distinguished from

H. complex by the form of the projections; the columns are thinner and they are not themselves flared into funnels. The distal processes at the tip are as a rule weakly basally widened and not united through spread-out membrane structures..." The writer, however, thinks that Gocht's illustrations show the forms to be gradational and that Gocht's form is essentially a variation of the basic pattern of Oligosphaeridium complex (White) Davey & Williams 1966. In this thesis, the two forms are considered synonymous.

Distribution: Widely distributed in strata of Neocomian to Lower Tertiary age (Gocht, 1959; Cookson and Eisenack, 1958; Davey and Williams, 1966, and many others); specimens recovered from all strata investigated in this thesis from the Lower Colorado Group, the Peace River and Lower Shaftesbury Formations.

### Oligosphaeridium (al. Hystrichosphaeridium) anthophorum
### (Cookson & Eisenack 1958) comb. nov. (22012)
### Plate 14, fig. 7

Selected syn.

1958 Hystrichosphaeridium anthophorum Cookson & Eisenack, p. 43; pl. 11, figs. 12-13 and figs. 16-18.

1961 Hystrichosphaeridium anthophorum Cookson & Eisenack; Alberti, p. 28; pl. 9, fig. 16.

Dimensions: Length of cyst body on 14 measured specimens, with and without archaeopyle, 37-66μ; width on 17 measured specimens, 41-62μ; length of processes, 15-44μ.

Remarks: If the processes are considered to be intratabular in position, the pattern can be interpreted as corresponding to a reflected tabulation of 4', 6", Oc, 6"', 1p, 1"". Complete specimens bear 18 processes while those with an apical archaeopyle bear no more than 14. A distinct sulcul notch is present on some specimens along the margin of the archaeopyle and corresponds in position to a smaller process interpreted as being the reflected 1p process.

The writer does not consider the combination proposed by Davey and Williams (1966, p. 77) to be valid under Article 33 (ICNB, Lanjouw, ed., 1966) and thus proposes the above combination.

*Comparison*: *Oligosphaeridium anthophorum* (Cookson & Eisenack 1958) comb. nov. is characterized by flaring fenestrate or foveate processes with entire margins. The closely related species, *Oligosphaeridium pulcherrimum* (Deflandre & Cookson) Davey & Williams 1966, also possesses fenestrate processes but without entire apices. ?*Oligosphaeridium* (al. *Hystrichosphaeridium*) *dictyophorum* (Cookson & Eisenack 1958, p. 44; pl. 11, fig. 14) comb. nov. appears to differ from these two species in having thin, solid-walled columns and wide-meshed, strongly expanded apices.

*Distribution*: The range of this species is Upper Jurassic to Albian (Cookson and Eisenack, 1958; Alberti, 1961; Sarjeant, 1967) and it occurs in the Jurassic and Aptian-Albian of West of Australia, and the Lower Cretaceous of Germany; recorded here from the Lower Colorado Group of south-central Alberta, central Alberta, and throughout the Peace River and Lower Shaftesbury Formations.

### *Oligosphaeridium* cf. *O. pulcherrimum*

(Deflandre & Cookson) Davey & Williams 1966 (22011)

Plate 14, fig. 2

Description: Dinoflagellate cyst; outline in lateral view circular or ovoid. Archaeopyle apical; operculum bears the 4 apical processes; margin of archaeopyle zig-zag. Process arrangement interpreted as intratabular and corresponding to a reflected tabulation of 4', 6", Oc, 5-6"', 1p, 1"". The processes have hollow, stout columns, are variable in shape and end in flared, partly fenestrate open apices which are dissected and drawn into pilate or fimbriate extensions; length, 13-42μ.

Dimensions: Width of cyst body on 3 specimens, 43-46μ.

Distribution: Rare specimens recorded from the Paddy Member, west-central Alberta, the Joli Fou Formation, "Grosmont" section, and the Upper Shale Unit, "Wabamun" section; previously recorded from the Neocomian to Eocene (Deflandre and Cookson, 1955; Valensi, 1955; Davey and Williams, 1966).

### *Oligosphaeridium* (al. *Hystrichosphaeridium*) *irregulare*

(Pocock 1962) comb. nov. (22029)

Plate 14, fig. 10

1962 *Hystrichosphaeridium irregulare* Pocock, p. 82; pl. 15, figs. 228-229.

1964 *Hystrichosphaeridium irregulare* Pocock; Singh, p. 139; pl. 19, figs. 1-4.

non Hystrichosphaeridium (al. Geodia) irregulare (Merrill 1895) Davey & Williams 1966, p. 70 (?invalid combination; see Art. 33, ICBN, Lanjouw, ed., 1966).

Description: Dinoflagellate cyst; outline in lateral view subcircular to ovoid. Cyst wall thin and smooth or scabrate. Archaeopyle apical, margin zig-zag; operculum bears 4 apical processes. If the processes are considered as intratabular in position, their arrangement suggests a basic reflected tabulation pattern of 4', 6", 0c, 6"', 1p, 1"", with some of the processes absent on some specimens. Processes highly variable in length and basal width, biconcave to tubular and hollow with flaring apices bearing long aculeate extensions or having highly dissected margins of variable shape.

Dimensions: Length of cyst body on 6 measured specimens, 40-66μ; width, 37-50μ. Length of processes, 14-30μ, basal width, 4-15μ; total of 10 specimens recovered.

Remarks: The original illustrations of Oligosphaeridium irregulare (Pocock) comb. nov. in Pocock (1962; pl. 15, figs. 228-229) are difficult to interpret and the description is not clearly stated. The assignment of the specimens described above to this species is made on the basis of Singh's (1964, p. 139) description and on comparison of the illustrations of Singh (1964) and those of Pocock (1962).

Distribution: Previously recorded from the Garbutt Formation, of basal Cretaceous age, Northwest Territories (Pocock, 1962) and the Lower and Middle Albian of east-central Alberta (Singh, 1964); rare specimens recorded here from the Joli Fou and Viking Formations of south-central Alberta and from the Joli Fou Formation, "Grosmont" section.

## *Oligosphaeridium* sp. A. (22003)

Plate 14, fig. 4 and Text-fig. 25c

**Description**: Dinoflagellate cyst; outline in lateral view ovoid or subcircular; circular to subcircular in apical view. Wall thin and scabrate, two layered; the outer layer gives rise to hollow processes with broad tubular columns and open apices which are little or not at all flared the edges entire or serrate. Some specimens exhibit an apical archaeopyle, roughly hexagonal in shape; the processes if considered intratabular in position can be shown on suitably oriented specimens to correspond to a reflected tabulation scheme of 4', 6", 0c, 5-6"', ?1p, 1"".

**Dimensions**: Length on 3 measured specimens, 39-42μ; width on 5 measured specimens, 32-50μ; length of processes, 18-35μ; basal width of processes, 6-11μ.

**Remarks**: Only a few of the total of 7 specimens recovered were properly oriented for length and width measurements. The species is distinguished by the broad, tubular processes with little flare at the apices. The tabulation pattern suggested is based on a composite study of all the specimens.

**Distribution**: Specimens recovered from the Upper Shale Unit in south-central Alberta and from the Lower Shaftesbury Formation in west-central Alberta.

### Oligosphaeridium sp. B. (22010)

Plate 14, fig. 9 and Text-fig. 25d

Description: Dinoflagellate cyst; outline in equatorial view ovoid; outline in apical view subcircular. Archaeopyle apical, margin zig-zag. Wall thin, scabrate, two layered, the outer layer forming processes interpreted as intratabular in position, their position corresponds to a reflected tabulation scheme of 4', 6", 0c, 5-6"', 1p, 1"". Processes with parallel or slightly tapering columns, occasionally obconical hollow, open apically; apices flaring, often buccinate with a greater or lesser degree of fenestration and occasional aculeate extensions. Processes rarely with a complete reticulate (fenestrate) network about the apex; fenestrations may sometimes persist down the columns.

Dimensions: Length on 6 measured specimens, 38-47μ; width on 8 specimens, 31-48μ; length of processes, 17-38μ. Total number of specimens recovered, 8.

Comparison: This species is distinguished from Oligosphaeridium anthophorum (Cookson & Eisenack) comb. nov. and other similar species by the slightly flared, sparsely fenestrate processes.

Distribution: Rare specimens recovered from the Upper Shale Unit, south-central Alberta and from the Lower Shaftesbury Formation, west-central Alberta.

### Oligosphaeridium? sp. C. (22009)

Plate 14, fig. 11

Description: Dinoflagellate cyst; outline in lateral view ovoid, subcircular or circular in apical view. Archaeopyle apical, margin zig-zag. Processes nearly parallel-sided, hollow, open apically, flaring slightly and well preserved forms with long fimbriate or aculeate extensions, sometimes tending to an orthogonal pattern. Tabulation scheme not proposed, although processes appear to correspond in position to the usual pattern for the genus; never more than 17 in number.

*Dimensions*: Length on 3 measured specimens, 48-52μ; width on 8 measured specimens, 32-63μ; length of processes, 15-44μ; width of processes, 3-7μ. Total of 11 specimens recovered.

*Remarks*: This species resembles others assigned to the genus *Oligosphaeridium* but the pattern of the processes cannot be determined and thus only a provisional referal is made.

*Comparison*: The long fimbriate extensions and broad tubular columns of the processes distinguish this form from *Oligosphaeridium complex* (White) Davey & Williams 1966.

*Distribution*: Rare specimens recovered from the Joli Fou Formation in south-central and central Alberta and from the Viking Formation in south-central Alberta.

### Genus HYSTRICHOSPHAERIDIUM (Deflandre) Davey & Williams 1966

*Type species*: *Hystrichosphaeridium tubiferum* (Ehrenberg) Davey & Williams 1966.

### *Hystrichosphaeridium cylindratum* sp. nov. (22015)

Plate 14, figs. 5-6 and Text-fig. 25e

*Holotype*: BW105/2 at 435 - 927; maximum diameter, 62μ; processes

22-30μ in length and 7-15μ in width; apical archaeopyle developed; 17 processes present.

Description: Dinoflagellate cyst; apical outline subcircular; lateral outline ovoid to subcircular. Wall thin and smooth or scabrate, often strongly folded; two layered. Processes interpreted as intratabular; arrangement corresponding to a tabulation scheme postulated as 4-?5', 6", 6c, 5-6"', 1p, 1"" with ? sulcul processes. Processes tubular and relatively wide, a few processes may approach a subconical outline; hollow; apices open, little or not at all flared and entire to serrate. No marked size difference occurs between processes of different series, although some specimens may have the cingular processes slightly reduced in size and the antapical process may be slightly larger on some specimens. Archaeopyle apical, margin zig-zag.

Dimensions: Length on 7 measured specimens, 46-74μ; width on 12 measured specimens, 41-63μ; length of processes, 10-35μ; basal width of processes, 3-24μ. Number of processes from 17 on specimens with archaeopyles up to 25 processes. Total of 23 specimens recorded.

Remarks: Most specimens encountered are not suitably oriented for precise determination of tabulation schemes or for accurate measurements. The tabulation scheme suggested is based on a composite study of a number of specimens.

Distribution: Specimens recovered from various parts of the sections investigated in the Lower Colorado Group, south-central Alberta; the Joli Fou Formation, "Grouard" section and the Lower Shaftesbury Formation, west-central Alberta.

## *Hystrichosphaeridium stellatum* Maier 1959 (22014)

Plate 13, fig. 8

Selected syn.

1959 *Hystrichosphaeridium stellatum* Maier, p. 320; pl. 33, figs. 3-4.

*Dimensions*: Length on 5 specimens, 42-56µ; width on 7 specimens, 34-54µ; length of processes, 10-33µ; basal width of processes, 3-13µ; number of processes 18 up to 25 on complete specimens.

*Remarks*: The processes, if assumed to be intratabular in position, reflect a tabulation scheme similar to : 4', 6'', 6c, 5-?6''', 1p, 1'''' and 1-3s. The antapical process is often slightly larger and set off from the rest of the processes. The sulcul processes are narrower than those of the other series and sometimes closed, or open, and of similar length.

*Distribution*: Previously recorded from Tertiary of Germany (Maier, 1959), the Albian-Cenomanian of Australia (Cookson and Eisenack, 1962), the Cambridge Greensand, ?basal Cenomanian, of England (Cookson and Hughes, 1964), the Upper Cretaceous of Graham Island, Canadian Arctic (Manum and Cookson, 1964) and the Danian of California, U.S.A. (Drugg, 1967); recorded from the Joli Fou and Viking Formations, south-central Alberta and the Lower Shaftesbury Formation of west-central Alberta.

## *Hystrichosphaeridium* sp. A. (22013)

Plate 15, fig. 6 and Text-fig. 25f

*Description*: Dinoflagellate cyst; circular in apical view; outline subcircular or circular in lateral view. Archaeopyle apical, outline polygonal. Wall thin and scabrate. Processes up to 25 in number; interpreted as intratabular in position and reflect a postulated tabulation scheme of 5', 6", 6c, 6"', 1p, 1"" and 1-5s. Processes, excepting sulcul ones, variable in shape from nearly tubular to strongly tapering or even biconcave-buccinate, hollow, apices open, entire or serrate and little flared unless buccinate; sulcul processes, one to five in number and thin, closed with simple or bifid apices. Processes sometimes slightly fibrous in construction.

Dimensions: Length on 2 measured specimens, 38-42μ; width on 3 measured specimens, 36-45μ; length of processes, 10-20, of the sulcul processes, 6-14μ; width of processes, 4-14μ, of the sulcul processes, 1-2μ. A total of 5 specimens recovered.

Distribution: Rare specimens recorded from the Lower Shaftesbury Formation, west-central Alberta and from the Upper Shale Unit, "Wabamun" section.

### Hystrichosphaeridium sp. B. (22016)

Plate 15, fig. 1 and Text-fig. 26a

Description: Dinoflagellate cyst; cyst body nearly circular in lateral view; subcircular or circular in apical view. Archaeopyle apical, polygonal outline. Wall thin and scabrate, two-layered; outer layer gives rise to relatively short, broad, tubular, hollow processes; apices open and entire or slightly serrate or undulating. One process very large and broad, interpreted as the 1"" process. Other processes interpreted as intratabular in position and reflecting a tabulation scheme of 4', 6", 6g, 5"', 1p, 1"" and ?1-3s. Some of the post-cingular processes larger than the pre-cingular ones but never approaching that of the 1'''' process; other processes vary in length and width but are approximately 1/3 to 1/2 the dimensions of the largest one.

*Dimensions*: Length on 4 specimens, 50-63μ; width on 5 specimens, 40-59μ; length of processes, 5-28μ; width of processes, 3-28μ; dimensions of the 1'''' process; length, 16-28μ, width, 18-28μ; number of processes from 20 to 24. Total number of specimens, 8.

*Remarks*: The large process is interpreted as the antapical process and has been used to orient specimens and provide the basis for postulation of a reflected tabulation scheme. Specimens with apical archaeopyles tend to confirm the interpretation of that process as being antapical in position.

*Distribution*: Upper Shale Unit in south-central Alberta and the Lower Shaftesbury Formation in west-central Alberta.

### *Hystrichosphaeridium* sp. C. (22018)

Plate 14, fig. 8

*Description*: Dinoflagellate cyst; outline subcircular in apical view, ovoid in lateral view. Archaeopyle apical, margin zig-zag. Wall thin and scabrate. Processes, 23-25 in number on complete specimens, interpreted as intratabular in position and reflecting a suggested tabulation scheme of ?4', 6", 6g, 5-?6''', 1p, 1''''. Columns of processes nearly tubular, occasionally tapered, with expanded, sometimes buccinate apices having aculeate extensions; processes open and hollow.

*Dimensions*: Length on 1 complete specimen, 65μ; width on 3 specimens, 50-63μ; length of processes, 21-40μ.

*Remarks*: The specimens assigned to this species are distinguished from *Oligosphaeridium complex* (White) Davey & Williams 1966 by the presence of processes attributable to a reflected cingular series and by the greater number of processes overall.

*Distribution*: Rare specimens recorded from the Upper Shale Unit in south-central Alberta, "Battle Lake" section and the Lower Shaftesbury Formation, west-central Alberta.

### *Hystrichosphaeridium*? sp. D. (22017)

Plate 14, fig. 12

*Description*: Dinoflagellate cyst; outline subcircular to ovoid. Wall thin and smooth. Processes tapering with narrow to relatively wide columns, hollow; apices open and flared with serrate or aculeate margins. One process, interpreted as being the antapical process, larger with a broad, little tapering column and a serrate to entire, little flaring, open apex. Reflected tabulation scheme not determined; number of processes visible 17 to 18.

*Dimensions*: The following dimensions on 2 specimens: length, 30-43μ; width, 27-37μ; length of processes 10-22μ; width of processes, 1-8μ.

*Remarks*: The assignment of this species, distinguished by the distinct 1"" process, to *Hystrichosphaeridium* is provisional. The number of processes suggest affinity with *Oligosphaeridium*, but the arrangement suggests a cingular series is present and some processes may be missing. These specimens illustrate the difficulty of placing poorly oriented or incomplete forms in certain genera of the Family Hystrichosphaeridiaceae, although the writer feels the schemes introduced by Davey and Williams (1966) are essentially sound.

Distribution: Rare specimens recorded from the Joli Fou and Viking Formations, south-central Alberta.

### Genus TANYOSPHAERIDIUM Davey & Williams 1966

Type species: *Tanyosphaeridium variecalamum* Davey & Williams 1966.

### *Tanyosphaeridium* sp. A. (22020)

Plate 14, fig. 13

Description: Dinoflagellate cyst; outline in lateral view elongate, contour smooth. Wall thin and scabrate. Apical archaeopyle with zig-zag margin. Processes arising from the cyst wall have more or less slightly tapered columns, hollow; apices slightly expanded, open and entire. The regular arrangement of the processes suggests that they may be intratabular and representing a reflected tabulation scheme. There is insufficient evidence, however, to support this in the specimens available for description.

Dimensions: Length on 8 specimens, 28-40μ; width on 7 measured specimens, 14-24μ; length of processes, 6-15μ. Number of processes up to 17.

Remarks: This species bears some similarity to the Cenomanian form, *Tanyosphaeridium variecalamum* Davey & Williams, p. 98; pl. 6, fig. 7 and Fig. 20, but differs in shape of the cyst and emplacement and number of processes.

Distribution: Rare specimens in the Joli Fou Formation and Upper

Shale Unit of south-central Alberta, the Joli Fou Formation in the "Grosmont" section and the Lower Shaftesbury Formation of west-central Alberta.

### Tanyosphaeridium sp. B. (22022)

Plate 15, fig. 13

Description: Dinoflagellate cyst; outline elongate in the apical-antapical axis; wall thin and scabrate. Processes hollow and tubular to buccinate; apices open, entire or serrate; numerous, approximately 30 to 40 on each specimen recovered. Emplacement of processes regular and suggesting a reflection of a tabulation scheme with 2 or more processes per plate; tabulation scheme not determined on specimens available for description. Archaeopyle apical.

Dimensions: Length on 4 specimens, 32-44μ; width on 4 specimens, 16-25μ; length of processes 6-22μ; total of 7 specimens recovered.

Comparison: This species differs from Tanyosphaeridium sp. A. in having a much larger number of processes and from other species attributed to this genus in the morphology of the processes.

Distribution: Rare specimens present in the Joli Fou Formation, "Battle Lake" and "Grosmont" sections and in the Viking Formation, "Battle Lake" section.

### Genus POLYSPHAERIDIUM Davey & Williams 1966

Type species: Polysphaeridium subtile Davey & Williams 1966.

Remarks: Davey and Williams (1966, p. 92) cite the type species of this genus as P. subtilum, but further down cite the correct spelling of "subtile". This spelling is also cited as the proper spelling in Loeblich and Loeblich (1968, p. 211).

### Polysphaeridium sp. A. (22023)

Plate 15, fig. 2

Description: Dinoflagellate cyst; outline subcircular. Wall thin. Numerous thin-columned processes arise from the cyst body; apices bifurcate or bifid and occasionally doubly bifurcate.

Dimensions: Length of cyst body on 7 specimens, 32-56μ; length of processes, 7-22μ; basal width of processes, 1-2μ; total of 7 specimens recorded.

Distribution: Rare specimens recovered from the Viking Formation and the Upper Shale Unit, south-central Alberta and from the Paddy Member and Lower Shaftesbury Formation, west-central Alberta.

## Genus DIPHYES (Cookson) Davey & Williams 1966

Type species: Diphyes colligerum (Deflandre & Cookson) Davey & Williams 1966.

### Diphyes sp. A. (22025)

Plate 15, fig. 9 and Text-fig. 26b

Description: Dinoflagellate cyst; outline circular; wall thin and scabrate. Numerous processes arise from the cyst wall, generally hollow and tubular to more or less buccinate with open apices, but also tapering and solid with pointed to bifid closed apices; one process larger than the rest, interpreted as an antapical process, broader and shorter, somewhat fenestrate, open distally and with fimbriate extensions.

Dimensions: The following dimensions on 1 specimen: length, 37μ; width, 34μ; processes 10-20μ long and 2-4μ wide; greater than 40 in number.

Distribution: A single specimen recorded from the basal Joli Fou Formation, "Battle Lake" section, south-central Alberta.

### Genus CORONIFERA Cookson & Eisenack 1958

Type species: *Coronifera oceanica* Cookson & Eisenack 1958.

### *Coronifera admixta* sp. nov. (22026)

Plate 15, fig. 7 and Text-figs. 26c-d

Holotype: BW105/2 at 592 - 1096; maximum diameter, 49μ; length of processes, 6-12μ.

Description: Dinoflagellate cyst; outline subcircular or circular; wall 1-2μ thick, often folded, scabrate or smooth. Processes densely spaced, consisting of long tapering spines, occasionally joined basally by low ridges; less commonly with bifid or bifurcate to doubly bifurcate processes and flattened membranous extensions; one or more bifid elements and generally one membranous process are present. Processes not providing evidence of a reflected tabulation pattern, although occasionally showing irregular groupings or patterns. Archaeopyle not clearly observed; several specimens with apical openings having zig-zag margins observed, but too poorly oriented for detailed study.

Dimensions: Maximum diameter on 15 specimens, 29-62μ; length of processes, 3-14μ. Total of 21 specimens recovered.

Comparison: *Coronifera admixta* sp. nov. differs from *C. oceanica* in not possessing a clearly defined apical spine and in having a membranous process and a more circular shape. This species is not to be confused with species assigned to *Diphyes* (Cookson) Davey &

Text-figure 26a-g. Camera lucida drawings of selected microplankton specimens showing various structural features.

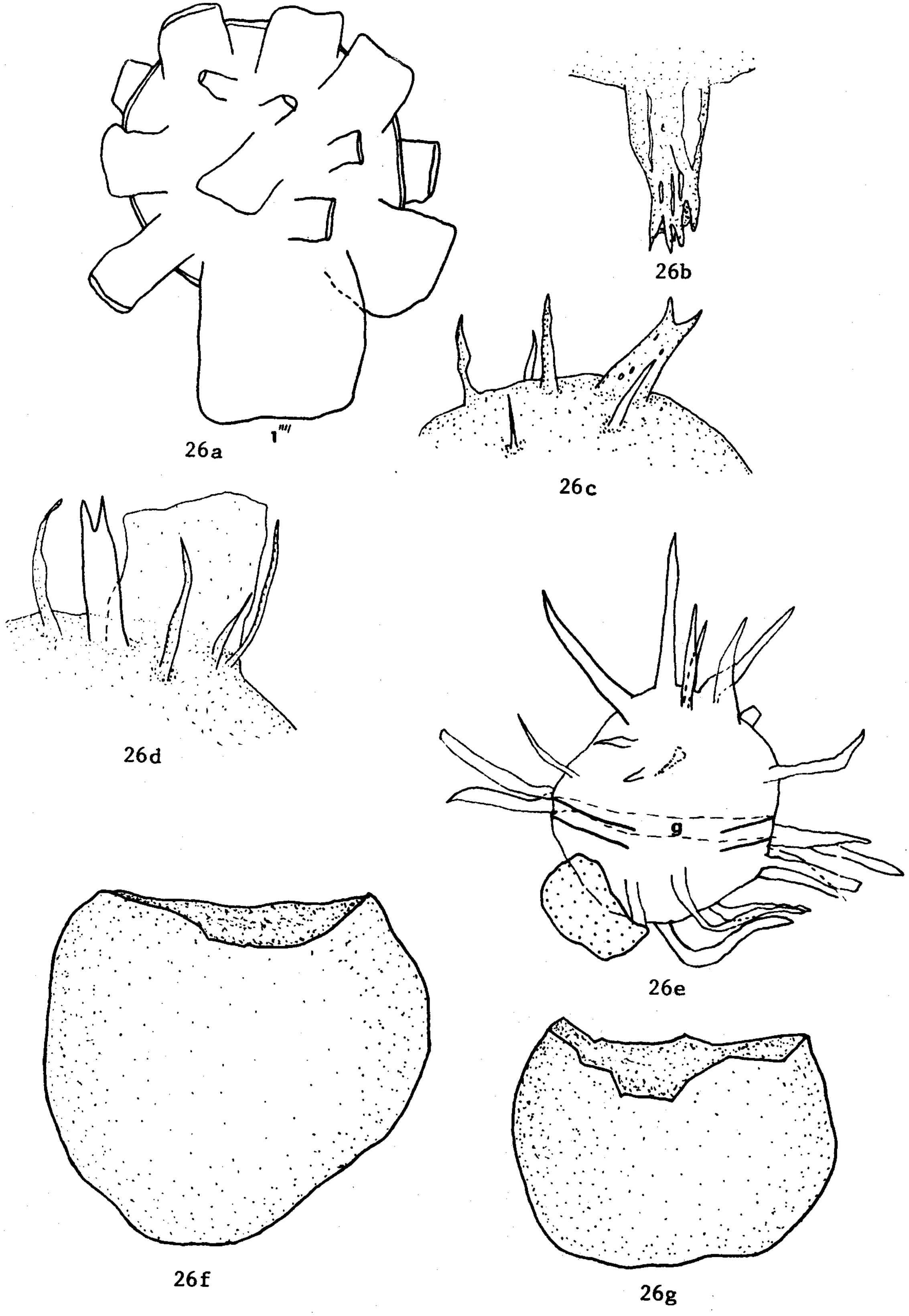
26a. *Hystrichosphaeridium* sp. B. Oblique antapical view of cyst showing insertion of some of the processes; large process interpreted as reflecting plate equivalent 1''''. X850. Same specimen illustrated as Plate 15, fig. 1. BW124/1: 310 - 1037.

26b. *Diphyes* sp. A. Drawing of the antapical process, X1700. Specimen illustrated also in Plate 15, fig. 9.

26c-d. *Coronifera admixta* sp. nov. (c) Holotype and (d) another specimen showing bifid, membranous and simple spinose processes; both X1700. Holotype illustrated also in Plate 15, fig. 7. Specimen in (d) from Imp. Oil Ltd. slide Imp 5048: 10-349/2: 391 - 1074.

26e. *Hystrichodinium* sp. A. Ventral surface showing insertion of processes and transverse girdle trace (g), X900. BW106/2: 543 - 1069. Specimen illustrated also in Plate 16, fig. 3.

26f-g. *Cometodinium multispinosum* (Singh) comb. nov. Outline drawings showing the shape of the cyst body and the archaeopyle opening, X2000. (f) BW179/1: 529 - 1029. (g) BW123/1: 416 - 1023; specimen illustrated also in Plate 16, fig. 8.



26a

26b

26c

26d

26e

26f

26g

Text-figure 26

Williams 1966. The membranous process is flattened and not cylindrical and is variable in position and not clearly antapical.

Distribution: Recorded from the Lower Colorado Group in south-central Alberta, the "Grouard" section, the Lower Shaftesbury Formation, west-central Alberta, and the Joli Fou and Pelican Formations, "Grosmont" section.

### Genus CALLAIOSPHAERIDIUM Davey & Williams 1966

1966 *Callaiosphaeridium* Davey & Williams, p. 103.

1967 *Hexasphaera* Clarke & Verdier, p. 42.

Type species: *Callaiosphaeridium asymmetricum* (Deflandre & Courteville) Davey & Williams 1966.

### *Callaiosphaeridium asymmetricum*

(Deflandre & Courteville) Davey & Williams 1966 (22027)

Plate 16, fig. 12

1939 *Hystrichosphaeridium asymmetricum* Deflandre & Courteville, p. 100; pl. 4, figs. 1-2.

1966 *Callaiosphaeridium asymmetricum* (Deflandre & Courteville) Davey & Williams, p. 104; pl. 8, figs. 9-10 and pl. 9, fig. 2.

1967 *Hexasphaera asymmetrica* (Deflandre & Courteville) Clarke & Verdier, p. 43; pl. 7, figs. 1-3; Text-fig. 17.

Dimensions: Measurements on 1 specimen: length, 46μ; width, 39μ; length of all process types, 10-23μ; total of 2 specimens recovered.

Remarks: Two specimens were recovered from samples investigated in this thesis. One is well-preserved and shows the large, tubular cingular series of processes and the circlets of pre-cingular and postcingular processes; the second is identifiable but poorly oriented for detailed study. The processes are arranged on the well preserved specimen so as to suggest a reflected tabulation pattern of 1-2?', 6", 6c, 5", 1p, ?1"", ?1s. Clarke and Verdier (1967, p. 42) misinterpret this form, characterising it as having a tabulation of 1', 1"" with 3 large plates, pre-cingular and post-cingular in position. The writer agrees with the interpretation of Davey and Williams (1966, p. 104).

*Distribution*: Previously recorded from the Hauterivian to Cenomanian of England (Davey and Williams, 1966; Clarke and Verdier, 1967) and from the Senonian of France (Deflandre and Courteville, 1939); rare specimens recovered in this investigation from the Joli Fou Formation, "Battle Lake" section and from the Pelican Formation, "Grosmont" section.

### Genus SYSTEMATOPHORA Klement 1960

1960 *Systematophora* Klement, p. 61.

1960 *Polystephanosphaera* Sarjeant, p. 140.

1961 *Hystrichosphaerina* Alberti, p. 38.

Type species: *Systematophora aerolata* Klement 1960.

### *Systematophora schindewolfi* (Alberti) Sarjeant 1966 (22028)

Plate 15, figs. 11 and 14

1961 *Hystrichosphaerina schindewolfi* Alberti, p. 38; pl. 10, figs. 1-3 and 6-7.

1966 *Systematophora schindewolfi* (Alberti) Sarjeant, p. 209; pl. 22, fig. 5.

*Dimensions*: Length on 9 measured specimens, 53-67μ; width on 7 measured specimens, 45-65μ; length of processes, 15-37μ. Total number of specimens recovered, 21.

*Remarks*: Complete specimens and those showing an apical archaeopyle with zig-zag margin and recognizable sulcul notch were recovered. The processes reflect a tabulation of 4', 6", 6c, 5''', 1-?2p, 1'''' on the specimens studied. Isolated opercula bearing four apical processes were also noted. Not all of the specimens were suitably oriented for measurement or study of the complete reflected tabulation and the scheme presented is a composite developed from the suite of specimens available for study. The processes are variable in morphology, ranging from those constructed of circular complexes of thin individual columns which anastomose and form a fenestrate network, united at the apex into an entire margin, and those nearly solid at the base, and becoming increasingly fenestrate towards the apices, ending again in an entire-margined rim. The processes attributed to the posterior intercalary series are somewhat smaller than the rest of the processes.

Contrary to the statement of Sarjeant (1966, p. 209) contained in the synonmy, the name *Systematophora schindewolfi* must be cited as *S. schindewolfi* (Alberti) Sarjeant 1966. The ICBN (Lanjouw, ed., 1966) does not recognize combination by implication (see Article 33, ICBN).

*Distribution*: Previously recorded from the Upper Barremian to Turonian of Germany (Alberti, 1961) and the Middle Barremian of England (Sarjeant, 1966); recovered in this thesis from samples of the Lower

Colorado Group, south-central Alberta; the Pelican Formation, "Grosmont" section, the uppermost Cadotte Member, "Grouard" section and the Lower Shaftesbury Formation in west-central Alberta.

Family HYSTRICHOSPHAERACEAE (Wetzel) Sarjeant & Downie 1966

Selected syn.

1936 Family Hystrichodiniaceae Deflandre 1936.

Type genus: Hystrichosphaera (Wetzel 1933) Davey & Williams 1966 (incorrectly cited as Hystrichosphaera Wetzel 1932 emend. Davey & Williams 1966 by Sarjeant & Downie 1966, p. 520).

Genus ACHOMOSPHAERA Evitt 1963

Type species: Achomosphaera ramulifera (Deflandre) Evitt 1963.

Remarks: The genus Achomosphaera was defined to exclude forms having sutures connecting the processes and outlining the reflected tabulation as in the genus Hystrichosphaera. Davey & Williams (1966, p. 46) state that one of the paratypes of the type material of Achomosphaera ramulifera (Deflandre) Evitt possessed faint lines on the cyst wall delimiting plate boundaries. These were not observed on the holotype. Such specimens are explicity excluded from the genus Achomosphaera Evitt 1963 and thus Achomosphaera ramulifera (Deflandre) Evitt sensu Davey & Williams 1966, p. 49 belongs in Hystrichosphaera and is not referable to A. ramulifera (Deflandre) Evitt 1963. The specimen figured as A. ramulifera (Deflandre) Evitt in Clarke and Verdier 1967, p. 40; pl. 8, fig. 1 appears to differ in the type of processes from the type species illustrated by Evitt (1963b, p. 161; Fig. 2).

### *Achomosphaera* sp. A. (22301)

Plate 15, figs. 3-4

*Description*: Dinoflagellate cyst; outline of cyst body in lateral view circular or subcircular. Wall thin, two layered; outer layer hyaline, sometimes folded. Processes arise from the outer wall; discrete, not joined by sutures or faint lines on the cyst wall; with thin, slightly tapering columns which trifurcate at the apex, each furcation then showing one or two orders of bifurcation; often a distinctive apical process, tapering and bifid, is present; processes sutural in position and outlining a reflected tabulation similar to the general type for the genus (?3', 5-?6', 6c, 5''', 1p, 1''''), but not determined in detail.

*Dimensions*: Length of cyst body on 4 specimens, 42-59μ; width on 2 measured specimens, 38-49μ; length of processes, 10-21μ; total of 4 specimens recovered.

*Remarks*: *Achomosphaera* sp. A. is somewhat similar to the type species, *A. ramulifera* in size and process type but assignment to that species is not warranted, in the opinion of the writer, on the basis of the material available.

*Distribution*: Rare specimens recovered from the Joli Fou and Viking Formations, south-central Alberta.

### *Achomosphaera* sp. B. (22302)

Plate 15, figs. 5 and 8

*Description*: Dinoflagellate cyst; cyst body elongate in the apical axis, oval in outline. Wall thin, smooth or scabrate; two-layered, the outer layer giving rise to discrete processes which appear sutural in position and outline a helicoid cingulum and slightly sinuous sulcus; processes with thin columns and bifucate with further orders of bifucation on the main dichotomies; tabulation pattern not determined. Precingular archaeopyle on one specimen.

*Dimensions*: The following dimensions on 2 recovered specimens: length of cyst body, 45μ (both); width of cyst body, 31-38μ; length of processes, 10-24μ; approximately 40 processes present on each example.

*Comparison*: *Achomosphaera* sp. B. differs from *Achomosphaera* sp. A. in having thinner processes and a sinuous sulcus and helicoid girdle.

*Distribution*: Rare specimens recovered from one sample of the Viking Formation, "Battle Lake" section.

### Genus HYSTRICHOSPHAERA (Wetzel) Davey & Williams 1966

Type species: *Hystrichosphaera ramosa* (Ehrenberg) Davey & Williams 1966.

### *Hystrichosphaera ramosa* (Ehrenberg) Davey & Williams 1966 (22303)

Plate 16, fig. 16

Selected syn.

1838 *Xanthidium ramosum* Ehrenberg; pl. 1, figs. 1-2 and 5.

1838 *Xanthidium furcatum* Ehrenberg; pl. 1, figs. 12 and 14.

1933 *Hystrichosphaera furcata* (Ehrenberg) Wetzel, p. 34; pl. 2, figs. 35a, 35b and pl. 5, figs. 1, 5, 9 and 15-16.

1933 *Hystrichosphaera ramosa* (Ehrenberg) Wetzel, p. 35; pl. 5, figs. 7-8, 10-12 and 18-19.

1966 *Hystrichosphaera ramosa* (Ehrenberg) Davey & Williams, p. 32.

*Dimensions*: Length on 18 measured specimens, 25-64μ; width on measured specimens, 26-52μ; length of processes, 5-21μ; total number of specimens recorded, 31.

*Remarks*: Most of the specimens recorded can be referred to the form *Hystrichosphaera ramosa* var. *ramosa* Davey & Williams 1966, p. 33. A few specimens closely resembled *H. ramosa* var. *gracilis* Davey & Williams 1966, p. 34 (long slender processes) and *H. ramosa* var. *granosa* Davey & Williams 1966, p. 35 (outer wall layer coarsely granular). These few specimens are otherwise similar to *H. ramosa ramosa* and all of them are included in this thesis simply as *H. ramosa* (Ehrenberg) Davey & Williams 1966.

*Distribution*: Previously described from the Middle Barremian to Eocene (many authors); recorded here from all strata investigated in the Lower Colorado Group and the Peace River and Lower Shaftesbury Formations.

## *Hystrichosphaera cingulata* (Wetzel) Deflandre 1954 (22308)

Plate 16, fig. 9

Selected syn.

1933 *Cymatiosphaera cingulata* Wetzel, p. 28; pl. 4, fig. 10.

1954 *Hystrichosphaera cingulata* (Wetzel) Deflandre, p. 258.

1966 *Hystrichosphaera cingulata* (Wetzel) Deflandre; Davey & Williams, p. 38; pl. 1, fig. 9.

*Dimensions*: Length of cyst body on 1 specimen, 43μ; width on 2 specimens, 31-36μ; length of processes, about 9μ.

Remarks: The sutures are prominent on this species and the gonal processes are very short, hardly projecting above the sutures. The apices of gonal processes are bifurcate. The reflected tabulation pattern is typical of the genus (3', 5", 6c, 5"', 1p, 1"").

Davey and Williams (1966, p. 38) report *Hystrichosphaera cingulata* (Wetzel) Deflandre and then subsequently propose a new variety, *H. cingulata* var. *reticulata* Davey & Williams 1966, p. 39 without citing a variety *H. cingulata cingulata*.

Distribution: Rare specimens recorded from the Viking Formation, "Battle Lake" section and the Pelican Formation, "Grosmont" section; previously recorded from the Cenomanian to Pleistocene (Davey and Williams, 1966, p. 39) and recorded here for the first time from Upper Albian strata.

### *Hystrichosphaera* cf. *Hystrichosphaera cornuta* Gerlach 1961 (22309)

Plate 15, fig. 10

Cf. 1961 *Hystrichosphaera cornuta* Gerlach, p. 180; pl. 27, figs. 10-12.

Dimensions: Length on 1 specimen, 52µ; processes 10-20µ in length; apical horn, 13µ long.

Remarks: Both gonal and sutural processes present, the latter few in number and thinner with bifucate tips; gonal processes have trifurcate tips which have one or two orders of bifurcation. The apical horn is slightly tapering and truncated.

Distribution: One specimen recorded from the Viking Formation, "Chigwell" section, south-central Alberta (Upper Albian); similar specimens recorded from the London Clay, Eocene (Davey and Williams, 1966) and the Middle Oligocene-Middle Miocene of Germany (Gerlach, 1961).

### *Hystrichosphaera* cf. *Hystrichosphaera buccina*
### Davey & Williams 1966 (22312)
### Plate 16, figs. 5 and 13

Cf. 1966 *Hystrichosphaera buccina* Davey & Williams, p. 42; pl. 4, fig. 1; Text-figs. 10-11.

*Dimensions*: Maximum length on 2 specimens, 45-52μ; length of inner layer (endophragm) on 2 specimens, 38-50μ; width of endophragm on 1 specimen, 39μ; length of processes, 7-15μ.

*Remarks*: The processes on the two specimens recorded in this thesis are tubular with slightly flared or buccinate apices which divide into spatulate secae. The reflected tabulation while not determined in detail appears to be close to that given for the species *H. buccina* Davey & Williams 1966 (3-4', 6", 6c, 5"', 1""). The specimens available for comparison are too few to make a definite assignment in the opinion of the writer and thus only a comparison is made. The specimens illustrated by Davey and Williams (1966, pl. 4, fig. 1 and Text-fig. 10) appear to have processes with more strongly developed apical spatulae than the specimens recovered here.

*Distribution*: Rare specimens recovered from the Harmon Member and the Lower Shaftesbury Formation, west-central Alberta. Somewhat similar forms reported from the Eocene of England (Davey and Williams, 1966).

## Genus HYSTRICHODINIUM (Deflandre) Sarjeant 1966

Type species: Hystrichodinium pulchrum Deflandre 1935.

### Hystrichodinium sp. A. (22313)

Plate 16, figs. 3 and 6 and Text-fig. 26e

Description: Dinoflagellate cyst; cyst body subcircular or ovoid-pentagonal in lateral view; wall thin and wrinkled. Cingulum slightly helicoid, marked by low ridges; position of sulcus indicated only by the ventral hiatus in the cingulum. Archaeopyle precingular, opening rounded-trapezoidal. Processes arising from cyst wall long and tapering, bases wide, apices pointed; position of processes not distinctly corresponding to any pattern suggesting reflected tabulation. Number of processes up to 32 on complete specimens.

Dimensions: Length of cyst body on 13 specimens, 32-66µ; width of cyst body on 10 measured specimens, 32-49µ; length of processes, 10-37µ; total number of specimens recovered, 18.

Remarks: Most specimens, while recognizable as belonging to this species on the basis of process type and shape and construction of the cyst body, are not well-preserved. The form resembles several previously described species of Hystrichodinium in a general way but differ in details of cyst size and process length. Hystrichodinium pulchrum Deflandre 1935, p. 229; pl. 5, fig. 1 and Text-figs. 9-11 is much larger; H. compactum Alberti 1961, p. 15; pl. 9, figs. 5-6 has much shorter processes.

Distribution: Recorded from the Joli Fou Formation and Upper Shale Unit in south-central Alberta, the Joli Fou Formation, "Grosmont" section, and the Harmon Member and Lower Shaftesbury Formation, west-central Alberta.

### Family AREOLIGERACEAE (Evitt) Sarjeant & Downie 1966

Type genus: *Areoligera* Lejeune-Carpentier 1938.

*Remarks*: Sarjeant and Downie (1966, p. 519) emended the family Areoligeraceae to exclude genera like *Canningia* and *Tenua*, which although possessing apical archaeopyles were smooth or ornamented with discrete sculpture elements.

### Genus CYCLONEPHELIUM (Deflandre & Cookson) Cookson & Eisenack 1962.

Type species: *Cyclonephelium compactum* Deflandre & Cookson 1955.

### *Cyclonephelium* cf. *Cyclonephelium compactum*
Deflandre & Cookson 1955 (22501)
Plate 15, fig. 12 and Plate 16, fig. 4

Cf. 1955 *Cyclonephelium compactum* Deflandre & Cookson, p. 285; pl. 2, figs. 11-13.

Cf. 1962 *Cyclonephelium compactum* Deflandre & Cookson; Cookson & Eisenack; pl. 5, fig. 1 (refigured holotype specimen)

*Description*: Dinoflagellate cyst; complete specimens with a slightly elongate outline in lateral view, an apical prominence and with or without a short, somewhat asymmetrically placed antapical prominence; antapex otherwise rounded. Archaeopyle apical with margin of opening zig-zag. Complexes of processes arranged in soleate pattern leaving a dorsal and ventral hypotractal region barren, and delimiting a cingulum and ventral sulcul region. Individual processes in the complexes consisting of thin columns which fork at their apices and often interconnect with adjacent processes, and which are joined basally by thin membranes to form soleate patterns. The processes are closed apically and appear to be present in an intertabular position; processes 7-28μ long. Tabulation pattern not determined in detail; study of the well preserved specimens suggests that at least ?4', 5-?6" and ?6"' plates are represented.

*Dimensions*: Length on 6 complete specimens, 96-126μ; length of 13 specimens (including those with apical archaeopyles), 84-126μ; width on 10 measured specimens, 81-98μ; total number of specimens recorded, 30.

*Remarks*: *Cyclonephelium* cf. *C*. *compactum* described herein closely resembles *C*. *compactum* Deflandre & Cookson 1955. However, the details of the distribution of processes cannot be accurately compared on the basis of published figures alone and the writer prefers to make only a provisional assignment of the specimens recovered to that species. *Cyclonephelium* cf. *C*. *compactum* is distinguished from other species of that genus by the type and arrangement of the processes.

*Distribution*: Recorded from various portions of the sections of the Lower Colorado Group investigated from south-central Alberta; from the uppermost Cadotte and basal Joli Fou, "Grouard" section, the Pelican Formation, "Grosmont" section and the Lower Shaftesbury Formation, west-central Alberta. Similar forms have been recorded from the Albian to ?Senonian of Australia (Deflandre and Cookson, 1955; Cookson and Eisenack, 1958). Sarjeant (1967, Table VII) gives a range of Aptian to Campanian.

## *Cyclonephelium* sp. A. (22506)

Plate 16, figs. 1-2

*Description*: Dinoflagellate cyst; cyst body outline rhomboidal or rounded-pentagonal. Apical horn stout and rounded; antapical prominence short, slightly asymmetrical in position and shape. Archaeopyle apical, the margin of the opening zig-zag. Processes relatively widely spaced, peripheral in position, leaving a wide smooth ventral region, circular in outline and a smaller proximal smooth area; processes thin and becoming strongly trabeculate, forming net-like complexes having an annular or soleate pattern; basal connecting sutures thin and occasionally web-like. Tabulation pattern not determinable on the specimens available for study.

*Dimensions*: Length on 4 specimens (with archaeopyles), 67-84µ; width on 4 measured specimens, 91-105µ; length of processes 10-24µ; total of 5 specimens recovered.

*Comparison*: *Cyclonephelium* sp. A. differs from *Cyclonephelium* cf. *C. compactum* Deflandre & Cookson 1955 is having more widely spaced processes which form an extensive trabeculate network. The only previously described species resembling *Cyclonephelium* sp. A. is *Cyclonephelium*? (al. *Hystrichosphaeridium*) *heteracanthum* (Deflandre & Cookson 1955, p. 276; pl. 2, figs. 5-6 and Figs. 40-41) comb. nov. The detailed structure of the processes in that species, however, is different to those of *Cyclonephelium* sp. A.

*Distribution*: Rare specimens recorded from the Pelican Formation, "Grosmont" section, and from the Upper Shale Unit, south-central Alberta, "Wabamun" section.

### Cyclonephelium sp. B. (22502)

Plate 19, figs. 1-2

Description: Dinoflagellate cyst; outline subcircular in lateral view. Apical regions on complete specimens without an apical prominence; antapex rounded. Wall 1-2μ thick and little folded. Processes arranged in annulate or soleate complexes, adjacent processes discrete or joined by low basal sutures or thin membranous sutures extending toward the apices of the processes, the latter type found mainly on the hypotract; individual processes are thin, apparently hollow, closed, the columns parallel-sided and having simple, bifid or bifurcate apices. Tabulation pattern suggested, especially by process arrangement on the hypotract, but not determinable; rows of process complexes may delimit a smooth cingular region and a ventral sulcul region. Archaeopyle apical with zig-zag margin, sometimes showing a sulcul notch.

Dimensions: Length on 3 specimens (with and without apical archaeopyle, 45-56μ; width on 3 specimens, 47-57μ; length of processes, 4-11μ; total of 3 specimens recovered.

Distribution: Rare specimens recovered from the Joli Fou Formation and Upper Shale Unit in south-central Alberta and the Lower Shaftesbury Formation, west-central Alberta.

### Cyclonephelium sp. C. (22504)

Plate 16, fig. 14

Description: Dinoflagellate cyst; complete specimens not observed. Archaeopyle apical with zig-zag margin; remaining portion of cyst roughly hemispherical. Processes clavate or pilate with short expanded bases, 2-8μ in total length, discretely but densely spaced, marginate in position.

Dimensions: Length on 2 specimens, 53-56μ; width on 2 specimens, 66-70μ respectively.

Comparison: This form is distinguished from other similar types by the expanded bases of the processes.

Distribution: Rare specimens recorded from the Viking Formation and Upper Shale Unit, south-central Alberta.

### *Cyclonephelium* sp. D. (22503)

Plate 16, fig. 11

Description: Dinoflagellate cyst; complete specimens not observed; remaining cyst more or less hemispherical in outline; antapical prominence may be faintly developed; when present, slightly asymmetrical in position, rounded, short and stout. Archaeopyle apical with margin zig-zag. Processes clavate to capillate, with some specimens bearing shorter, thicker processes, somewhat like bacula but bifid at the apices; bases of processes not expanded; length, 2-10μ. Position of processes peripheral; sparsely spaced or absent in the central dorsal and ventral hypotractal regions. Density of processes varies but all are discrete and not joined in fields or complexes.

Dimensions: Length on 11 measured specimens, 44-70μ; width on 13 measured specimens, 53-70μ.

Comparison: *Cyclonephelium* sp. D. is distinguished from other similar species, especially *Cyclonephelium* sp. C., by its simple clavate to capillate processes without expanded bases.

## CHORATE AND PROXIMO-CHORATE CYSTS INCERTAE

Remarks: Downie and Sarjeant (1966, p. 15) distinguish types of cysts termed "chorate" and "proximo-chorate" in which the cysts possess pronounced outgrowths or processes or relatively high crests, often with spines or other extensions. Typical of the former type is the genus, Hystrichosphaeridium and of the latter type, Hystrichosphaera. The following forms conform to these generalized types of cysts but are insufficiently understood to be placed in existing families with confidence.

### Genus COMETODINIUM Deflandre & Courteville 1939

Type species: Cometodinium obscurum Deflandre & Courteville 1939.

Remarks: Sarjeant and Downie (1966, p. 519) tentatively place this genus in the Family Exochosphaeridiaceae Downie & Sarjeant 1966 on the basis of a report by Davey (in litt.) that Cenomanian specimens recorded from England possess a pre-cingular archaeopyle. No published figures of these forms have been presented and taken together with evidence presented below, for those reasons the genus is classed incertae.

### Cometodinium (al. Baltisphaeridium) multispinosum

(Singh 1964) comb. nov. (22951)

Plate 16, figs. 7-8 and 10 and Text-figs. 25f-g

1964 Baltisphaeridium multispinosum Singh, p. 141; pl. 20, figs. 1-2.

1966 Cometodinium sp. Sarjeant, p. 212; pl. 22, fig. 6.

1967 Cometodinium obscurum auct. non Deflandre & Courteville; Clarke & Verdier, p. 35; pl. 10, fig. 3 and pl. 11, fig. 9.

Description: Dinoflagellate cyst; outline ovoid, elongate in the apical axis, or nearly circular. Orientation in the absence of archaeopyle formation uncertain. Cyst ornamented with numerous, closely spaced, parallel-sided, thin fimbriate processes having rounded apices; length, 3-16μ. Processes do not outline any discernible pattern or reflected tabulation and except for one specimen, do not indicate the position of a cingulum. Specimens having exactly similar morphology to that described, but possessing an apical archaeopyle with a zig-zag rupture line have been noted rarely.

Dimensions: Maximum diameter on 37 specimens, 24-59μ; minimum diameter on 29 measured specimens, 18-59μ. Total number of specimens recorded, 50.

Remarks: The specimens recorded as Cometodinium sp. Sarjeant 1966, p. 212 and Cometodinium (al. Baltisphaeridium) multispinosum (Singh 1964) comb. nov. are often much larger than the specimens described in this thesis. The morphology of all of these types, however, is similar and no distinction can be made on this basis. The writer thus thinks that these are in fact representatives of the same species. In view of the finding of exactly similar specimens with an apical archaeopyle, the writer is inclined to disagree with the suggestion that Cometodinium possesses a precingular archaeopyle as in Downie and Sarjeant (1966, p. 519). The evidence must be viewed as conflicting and perhaps several distinct types exist, having similar morphology but possessing different modes of archaeopyle formation.

Comparison: *Cometodinium obscurum* Deflandre & Courteville 1939, p. 99; pl. 2, fig. 1 has longer processes and possesses a distinct cingulum. The specimens illustrated by Clarke and Verdier (1967; pl. 10, fig. 3 and pl. 11, fig. 9) do not belong to that species and appear exactly similar to *C. multispinosum* (Singh) comb. nov.

Distribution: Previously reported from the Lower Barremian of England (Sarjeant, 1966), the Middle Albian of east-central Alberta, and the Cenomanian-Lower Turonian of the Isle of Wight (Clarke and Verdier, 1967); recorded herein from all strata of the Lower Colorado Group, Peace River and Lower Shaftesbury Formation and from the Upper Mannville Group, "Grosmont" section.

### Genus TOOLONGIA (Cookson & Eisenack 1960) emend.

Type species: *Toolongia medusoides* (Cookson & Eisenack 1960) emend.

Discussion: Sarjeant and Downie (1966, p. 520) proposed a new family (termed a "cyst-family") of fossil dinoflagellates called the Toolongiaceae and based on the genus, *Toolongia*, as type. Without offering an emended diagnosis of the genus, these authors have characterized the family as having a cingular or epitractal archaeopyle and relatively weakly developed sutures bordering the cingulum. The writer presents below further evidence which leads him to emend the genus and its type species and to reject the Sarjeant and Downie diagnosis of the Family Toolongiaceae. The writer further thinks that until further evidence, in addition to that presented below, becomes available on tabulation and archaeopyle structure, that the genus *Toolongia* should be classed as a dinoflagellate *incertae*.

Emended Diagnosis: Dinoflagellate cyst; outline in lateral view approximately pentagonal, with antapex flattened and the apex prolonged into a more or less prominent apical horn. Cyst wall two layered, the inner layer subspherical or spherical; outer layer forming the apical horn and produced into folded membranous sutures outlining reflected tabulation and at the cingulum, thin, wide ledges, which in compressed apical view give the cyst a characteristic "zonate" appearance and the somewhat oval outline. Position of the sulcus often marked by invaginations of the cingular ledges in apical view. Tabulation not completely determined, but probably close to this scheme: ?3', ?0a, 5-?6", ?0c, 5"', ?p, 1"".

Remarks: Cookson and Eisenack (1960, p. 14) in their diagnosis of the genus characterize the genus as "hemispherical". The material to be described below indicates that they are referring to specimens preserved in apical orientation and strongly compressed. They make no reference to an apical horn, but this is often mechanically broken off, either due to compression in the sediment or perhaps processing procedures. They refer also to "radiating ledges, some of which join and form distinct fields" (ibid., p. 14). In the material described below the ridges can be seen to correspond to a reflected tabulation pattern. The wall, however, is so thin and highly folded that often the sutures cannot be traced over their complete course. The compressed apical orientation of these forms further complicates their interpretation.

Oodnadattia Eisenack & Cookson 1960, p. 6 is similar to

Toolongia (Cookson & Eisenack 1960) emend. in the construction of the cingulum, the apical horn and antapical plate. It appears to differ in the tabulation pattern, the intermediate plates a"-d" and 4-5 intermediate post-cingular plates not being present on the type species and a new species proposed below. Dinopterygium Deflandre 1935, p. 181 also shows wide, thin ledges bordering the cingulum but appears to have much more robust sutures and a different construction about the apex.

Toolongia medusoides (Cookson & Eisenack 1960) emend.

1960 Toolongia medusoides Cookson & Eisenack, p. 14; pl. 3, figs. 11-12.

Holotype: National Museum of Victoria no. P17816; illustrated in Cookson and Eisenack (1960; pl. 3, fig. 11); breadth, 100μ.

Diagnosis, herein emended: Dinoflagellate cyst; outline in apical view ovoid or subcircular; ?pentagonal in lateral view. ?Apical horn; antapex flattened. Cyst wall two-layered; the inner layer forming the cyst body and the outer layer produced into sutures outlining reflected tabulation and forming thin, membranous, wide borders about the cingulum; long tapering spines arise from the sutures; their position with respect to tabulation not determined. Epitractal cingulum border wider than the hypotractal cingulum border. Tabulation not determinable from the illustrations.

Remarks: The emendation is based on a re-interpretation of the data and illustrations of Cookson and Eisenack (1960) and supported by specimens of a closely comparable species described in this thesis.

## Toolongia alata sp. nov. (22961)

Plate 17, figs. 1-6 and Text-figs. 27a-b

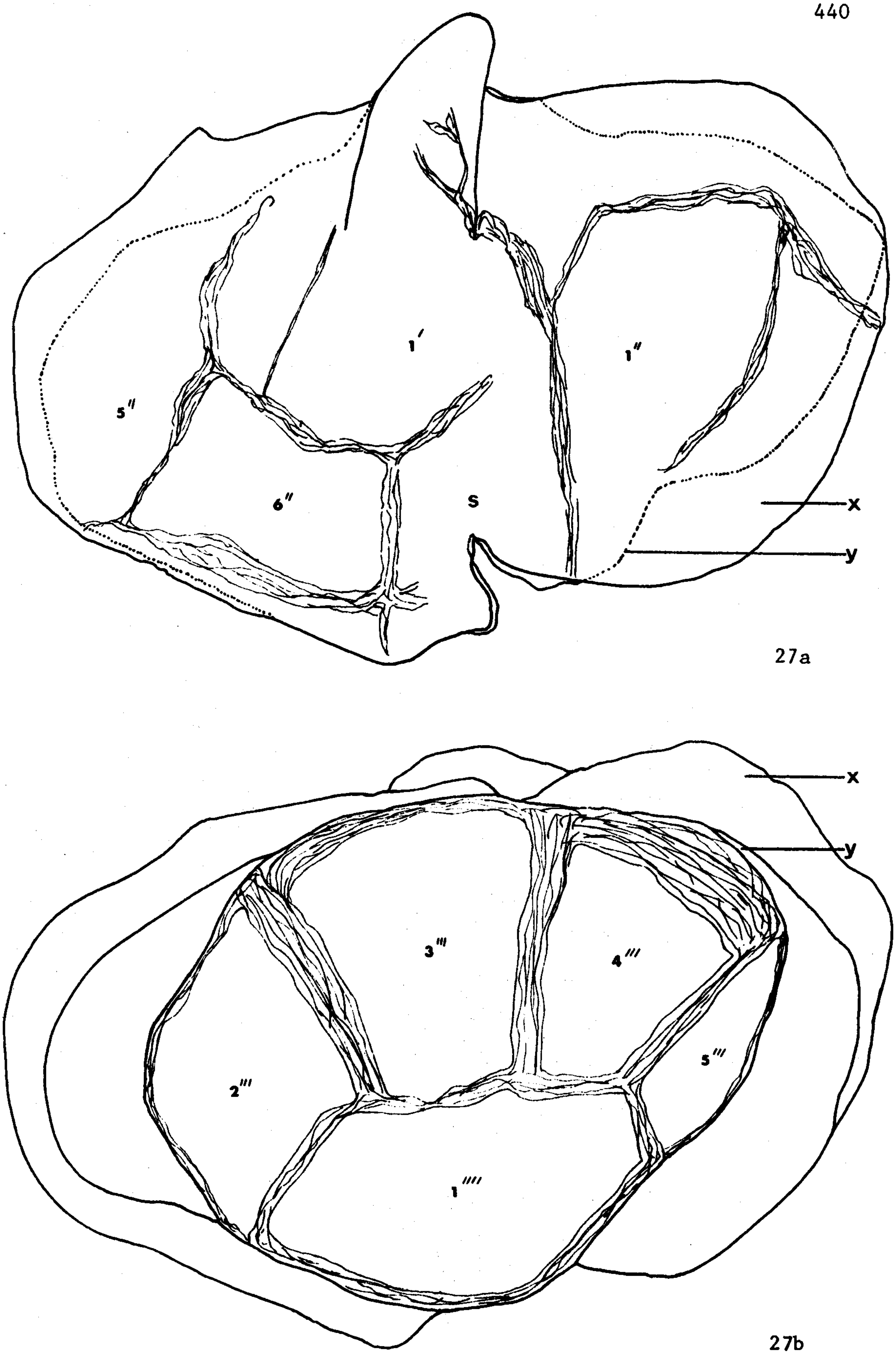
Holotype: BW 179/1 at 487 - 1007; diameter including cingulum ledges, 84μ; diameter on inner cyst, 42μ; tabulation: ?n', ?a, 5-?6', ?c, 5-?6''', ?p, 1''''

Description: Dinoflagellate cyst; outline in polar view subcircular to somewhat ovoid. Wall smooth and thin; two layered; inner layer forms the cyst body; the outer layer produced into low, highly folded crests (sutures) and wide, thin, membranous ledges bordering the cingulum. Long, stout apical horn, the tip rounded; antapex slightly flattened; outline in lateral view somewhat elongate and roughly pentagonal. Tabulation not readily determinable but probably somewhat similar to this scheme: 3-?4', ?a, 5-?6'', ?0c, 5-?6''', ?p, 1'''', the antapical plate is roughly polygonal and large. Sutures low and not bearing any projections or processes.

Dimensions: Equatorial width, including the cingular ledges, on 11 measured specimens, 72-90μ; width of cyst body on 9 measured specimens, 42-59μ; total number of 18 specimens recovered.

Remarks: On many specimens, a rounded notch in the cingular ledges marks the position of the sulcus. However, the sulcul course was not observed or was only indistinctly visible on the specimens available for study. Most of the specimens are preserved in apical orientation and flattened so that it is difficult to make out the complete tabulation, especially of the apical plate series. Many specimens have the apical horn missing but no specimens exhibited recognizable archaeopyle structure. The apical horn appears to have

Text-figure 27a-b. Toolongia alata sp. nov. Holotype specimen. (a) Apical focus showing the apical horn, part of the epitractal tabulation with numbering tentative and sulcus with sulcul indentation in cingulum ledges; apical cingulum ledge (y) overhangs antapical ledge (y). (b) Antapical view by transparence showing part of the distal tabulation and the antapical plate. Both X1800. Specimen illustrated also in Plate 17, figs. 3-6.



27a

27b

Text-figure 27

been lost by mechanical damage.

*Comparison*: *Toolongia alata* sp. nov. is distinguished from *T. medusoides* (Cookson & Eisenack 1960) emend. by the absence of long tapering spinose processes arising from the sutures and its somewhat smaller size range.

*Distribution*: Specimens recorded from the Joli Fou, Viking and Pelican Formations and the "Grouard" section.

### Proximo-chorate Cyst Forma A. (22311)

Plate 17, fig. 18

*Description*: Dinoflagellate cyst; wall two layered. Inner layer forms the main cyst body, elongate in the apical axis, outline ovoid. Outer layer produced into high crests outlining reflected tabulation, cingulum and sulcus. The crests generally without processes, or with a few simple thin processes, open and having slightly flared apices, except the cingular ledges which bear stout gonal processes; these processes, hollow, open apically, tubular with entire or slightly serrate margins, occasionally with clathrate extensions; one pair for each of the six cingular plates. Apical and antapical sutures generally slightly higher. Tabulation appears to be : 3', 6", 6c, 5"', 1p, 1"". Archaeopyle present on one specimen, apparently precingular in position and somewhat trapezoidal in outline. A few specimens show asymmetrical development of precingular crests.

*Dimensions*: The following dimensions on 5 specimens: total length including crests, 46-70μ; length of inner cyst wall, 42-50μ; width of inner cyst wall, 32-45μ; length of processes, 4-15μ.

Remarks: The tabulation and archaeopyle structure are similar to members of the Family Hystrichosphaeraceae, but the species differs from this family in its lack of gonal processes except at the equator. Hence the writer prefers to place it in an *incertae* position in view of the small number of specimens available for study and the uniqueness of the morphology.

Distribution: Specimens recovered only from the Lower Shaftesbury Formation, west-central Alberta.

### Proximo-chorate Cyst Forma B. (21003)

Plate 17, fig. 11 and Text-fig. 28a

Description: Dinoflagellate cyst; wall two layered; inner layer forms the main cyst body, ovoid in outline, elongate in the apical axis; outer layer produced to form high crests, 6-15 high, extending markedly at the apex and antapex; the crests outline a reflected tabulation postulated as ?1', 6", ?6c, 5"', 1"" and are simple, without processes; cingular ledges reduced to absent, the tabulation marked by short, truncated processes, closed and sometimes reduced to absent. Cingulum helicoid; sulcus extending partly onto the epitract, slightly sinuous in outline and truncated by the apical and antapical plates (1' and 1""). Several specimens possess apical archaeopyles, the operculum formed of plate 1' with portions of the precingular plate sutures also included.

Dimensions: Total length on 10 specimens, including the crests, 53-80μ; length of inner cyst layer on 10 specimens, 38-55μ; width of inner cyst layer on 11 specimens, 28-45μ. Total of 11 specimens recovered.

Remarks: The presence of only one apical plate is confirmed by apical orientations of several specimens. The margin of the archaeopyle is irregular but shows no well-defined accessory sutures on the specimens available.

Comparison: Though somewhat similar in construction this species differs from Proximo-chorate Forma A. by possession of an apical archaeopyle and reduced gonal processes on the cingulum ledges.

Distribution: Rare specimens present in various portions of sections investigated in the Lower Colorado Group, south-central Alberta, in the uppermost Cadotte Member, "Grouard" section, and in the Harmon Member and Lower Shaftesbury Formation, west-central Alberta.

### Family MEMBRANILARNACIACEAE Sarjeant & Downie 1966

Type genus: *Membranilarnacia* Eisenack 1963.

### Genus CHLAMYDOPHORELLA Cookson & Eisenack 1958

Syn.

1961 *Gardodinium* Alberti, p. 18.

Type species: *Chlamydophorella nyei* Cookson & Eisenack 1958.

Discussion: Descriptions of the type species of *Chlamydophorella* Cookson & Eisenack 1958 (*C. nyei* Cookson & Eisenack 1958, p. 56; pl. 11, figs. 1-3) and of *Gardodinium* Alberti 1961 (*G. eisenacki* Alberti 1961, p. 18; pl. 3, figs. 8-13) indicate that they are similarly constructed and belong to the same generic concept. Both species have an internal capsule, from which arise bifurcate or bifid processes supporting an outer membranous layer, the outer layer being produced into an apical horn. The writer thus thinks that *Gardodinium* is a junior synonym of *Chlamydophorella* and proposed the following new combinations:

*Chlamydophorella* (al. *Scriniodinium*) *trabeculosa* (Gocht 1959, p. 62; pl. 4, fig. 5 and pl. 8, fig. 2) comb. nov.

*Chlamydophorella* (al. *Scriniodinium*) cf. *trabeculosa* (Gocht; in Alberti 1961, p. 18; pl. 3, fig. 7) comb. nov.

*Chlamydophorella* (al. *Gardodinium*) *eisenacki* (Alberti 1961, p. 18; pl. 3, figs. 8-13) comb. nov.

*Chlamydophorella* (al. *Gardodinium*) *albertii* (Neale & Sarjeant, 1962, p. 445; pl. 19, fig. 8; Text-fig. 4) comb. nov. (Wrongly cited in the text and plate legends as pl. 19, fig. 6).

*Remarks*: Cookson and Eisenack (1958, p. 57) refer to a specimen, *Chlamydophorella* sp. and comment that it appears to have developed "a large opening or pylome as the result of the breaking away of the apical region". They further suggest that is is "probable" that *Chlamydophorella nyei* also opened in a similar manner, that is by an apical archaeopyle. Specimens to be described below confirm this view.

### *Chlamydophorella nyei* Cookson & Eisenack 1958 (23101)

Plate 16, figs. 19-20

1958 *Chlamydophorella nyei* Cookson & Eisenack, p. 56; pl. 11, figs. 1-3.

*Dimensions*: Total length of outer layer on 6 complete specimens, 56-70μ; length of inner body on 16 specimens, 32-49μ; width of outer layer on 15 specimens, 36-49μ; length of processes, 3-10μ; total of 22 specimens recorded, many more seen.

Remarks: Several suitably oriented specimens confirm the suggestion of Cookson and Eisenack (1958, p. 57) that this species possesses an apical archaeopyle. The operculum consists of the apical horn and a portion of the apical outer cyst layer and part of the apical portion of the inner layer. The detailed construction of the operculum is not known as no detached or partially attached opercula have been seen.

The apex of the inner layer rarely or only slightly extends up into the apical horn. The supporting bifid processes do not extend into the apical horn and are often absent or reduced in density in a central region interpreted as indicating a reflected sulcul region.

Comparison: The specimens recorded above as *Chlamydophorella nyei* Cookson & Eisenack 1958 are slightly larger in size range than the specimens reported by those authors. *Chlamydophorella* (al. *Gardodinium*) *eisenacki* (Alberti 1961) comb. nov. is also similar but larger in size and appears to have a more polygonal outline, despite Alberti's (1961, p. 18) diagnosis which states the outline to be "nearly oval" (transl.).

Distribution: Previously recorded from the Aptian-Lower Turonian of West Australia (Cookson & Eisenack, 1958) and the Cenomanian of England (Cookson & Hughes, 1964); recorded here from all strata investigated in the Lower Colorado Group, Peace River and Lower Shaftesbury Formations.

### *Chlamydophorella* sp. A. (23102)

Plate 16, figs. 17-18

Description: Dinoflagellate cyst; two layered construction. Outline of the outer layer nearly circular except for a short, rounded apical prominence. Inner layer circular or subcircular and showing little or no apical extension. Inner layer bears bifid to bifurcate processes which support the outer cyst and the apical extension. Processes generally discrete but sometimes arranged in arcuate complexes and joined basally by low sutures. Archaeopyle apical; operculum including both cyst layers, the remaining cyst being hemispherical in shape with a zig-zag margin. Detached or partially detached opercula not noted.

Dimensions: Total length on 5 specimens, 45-50μ; length of inner cyst layer, 35-39μ; width of outer layer, 36-49μ; total of 6 specimens recovered.

Comparison: This species differs from other similar forms in having a nearly spherical outline and in having processes on the apical portion of the inner cyst wall.

Distribution: Rare specimens recorded from the Upper Shale Unit, "Battle Lake" section, the Lower Shaftesbury Formation, west-central Alberta and the uppermost Cadotte Member, "Grouard" section.

### Family NETRELYTRACEAE Sarjeant & Downie 1966

Type genus: Netrelytron (Sarjeant) Sarjeant 1966.

### Genus KALYPTEA Cookson & Eisenack 1960

Type species: Kalyptea diceras Cookson & Eisenack 1960.

### Kalyptea monoceras Cookson & Eisenack 1960 (23201)

Plate 16, fig. 21

1960 Kalyptea monoceras Cookson & Eisenack, p. 257; pl. 39, figs. 2-3.

Description: Dinoflagellate cyst; two layered construction, the inner layer elongate in the apical axis and with a small, tapering apical horn and rounded antapex; wall 2μ thick; outer layer formed of a mucillaginous envelope which has mineral particles and other fine debris adhering to it and which surrounds the entire inner layer.
Dimensions: The following dimensions on 3 specimens: Total length of outer layer, 58-76μ; length of inner cyst, 44-53μ; width of inner cyst, 32-43μ; apical horn, 6-12μ long.
Distribution: Rare specimens recovered from samples of the Viking Formation and Upper Shale Unit, "Chigwell" section.

### Kalyptea? sp. A. (23202)

Plate 17, fig. 7

Description: Dinoflagellate cyst; overall outline ovoid to subcircular. Two layered construction; inner layer circular or subcircular, lacking any apical or antapical prominence and enclosed by an outer diaphanous veil, apparently mucillaginous and coated with extraneous debris. Relatively small inner cyst layer.
Dimensions: Total length of outer layer on 10 specimens, 43-91μ; length of inner cyst, 31-50μ; width of inner cyst, 25-45μ; total number of specimens recorded, 10.
Remarks: The species is not referred with certainty to the genus Kalyptea because the inner body lacks an apical horn. Specimens apparently similar to this form, but not figured or described formally, have been recorded by Cookson and Hughes (1964) from the Cenomanian of England.

Distribution: Specimens recorded from the Viking Formation and Upper Shale Unit in south-central Alberta, the Cadotte and Paddy Members and the Lower Shaftesbury Formation, west-central Alberta, and the Joli Fou and Pelican Formations, "Grosmont" section.

### Kalyptea? sp. B. (23203)

Plate 17, fig. 9

Description: Dinoflagellate cyst; two layered construction, ovoid in outline, the inner layer subcircular to ovoid and completely surrounded by an outer diaphanous veil, probably mucillaginous, with adhering mineral and organic debris. Inner cyst layer relatively large.

Dimensions: Total length on 8 specimens, 81-101μ; length of inner cyst layer on 7 specimens, 59-88μ; width of inner cyst on 8 specimens, 42-62μ; total number of specimens recorded, 9.

Comparison: The inner cyst layer is larger and generally wider than that of Kalyptea? sp. A.; the overall size is also generally larger.

Distribution: Rare specimens recovered from the Lower Colorado Group, various portions of the sections investigated, in south-central Alberta, and from the Harmon Member and the Lower Shaftesbury Formation, west-central Alberta.

## Family HEXAGONIFERACEAE Sarjeant & Downie 1966

Type genus: Hexagonifera (Cookson & Eisenack) Cookson & Eisenack 1962.

Genus HEXAGONIFERA (Cookson & Eisenack) Cookson & Eisenack 1962

Type species: Hexagonifera glabra Cookson & Eisenack 1961.

### Hexagonifera? sp. A. (23252)

Plate 17, fig. 20; Plate 18, fig. 6 and Text-fig. 28b

Description: Dinoflagellate cyst; cavate; outline of cyst in lateral view ovoid (no complete specimens found). Outer layer thin and membranous, showing faint indications of a cingulum and tabulation, the latter incomplete and not determinable. Archaeopyle apical with zig-zag margin, accessory sutures and sulcul notch often well-developed; operculum not noted but probably composed of the apical plate series. Capsule nearly fills the outer cyst cavity, the capsule wall thin and smooth, the apical opening reflecting the accessory sutures and sulcul notch where developed.

Dimensions: Total length on 10 measured specimens, 39-53μ; total width on 10 measured specimens, 45-56μ; total of 20 specimens recovered.

Remarks: Not all specimens show the sutures and notch clearly and as well no complete specimens have been recorded. For these reasons, the form is only questionably referred to Hexagonifera.

Distribution: Recorded from the Upper Shale Unit, south-central Alberta, from the Lower Shaftesbury Formation, west-central Alberta, and from the top of the Pelican Formation, "Grosmont" section.

Family DEFLANDREACEAE (Eisenack) Sarjeant & Downie 1966

Type genus: Deflandrea (Eisenack) Williams & Downie 1966.

## Genus DEFLANDREA (Eisenack) Williams & Downie 1966

Type species: Deflandrea phosphoritica Eisenack 1938.

### Deflandrea dignitosa sp. nov. (23301)

Plate 17, figs. 15-16 and Text-fig. 28c

Holotype: Imp. 3471: 11-453/4 at 411 - 1090; total length, 79μ; capsule length, 56μ; width, 49μ; intercalary archaeopyle present.

Description: Dinoflagellate cyst; cavate; outer layer elongate with a more or less pointed apex, generally differentiated into a distinct apical prominence, and an antapex, generally developed into one or two small, anatapical prominences. Inner layer, the capsule, ovoid to subcircular, more rarely elongate. Cingulum marked by rows of small granules on the outer cyst wall or absent, circular; sulcus occasionally visible, indistinct, not extending onto the epitract; no indications of tabulation. Epitract and hypotract nearly equal in length; width greatest at the mid-line, tapering to the antapex which is flattened between the antapical prominences. A polygonal intercalary archaeopyle developed on many specimens, large, the outline suggesting that the operculum is formed of one or more intercalary plates. Both wall layers smooth or scabrate and unfolded.

Dimensions: Total length on 34 measured specimens, 56-98μ; length of capsule on 34 measured specimens, 36-71μ; width on 34 measured specimens, 38-62μ; total of 48 specimens recorded.

Remarks: The cingulum and sulcus are often marked by rows of granules or fine lines on the outer cyst wall. No distinct pattern of tabulation has been observed. Undescribed specimens similar to this form but having a small intercalary archaeopyle and serrated cingulum and sulcus ledges as well as ?intratabular granules or coni are not considered to belong to this species. It may be that some of these finely tabulated forms are well-preserved examples of Deflandrea dignitosa sp. nov. The writer feels, however, that more specimens are needed to clarify their position in relation to this species and their morphology; hence the writer does not choose to describe them at this time.

Comparison: Deflandrea dignitosa sp. nov. is characterized by its shape and archaeopyle shape from similar species such as Deflandrea cincta Cookson & Eisenack 1958, p. 26; pl. 4, figs. 1-3.

Distribution: Recorded from the Viking Formation and Upper Shale Unit in south-central Alberta; the Pelican Formation in central Alberta; and the Lower Shaftesbury Formation in west-central Alberta.

### Genus SPINIDINIUM Cookson & Eisenack 1960

Type species: Spinidinium styloniferum Cookson & Eisenack 1960.

Remarks: It is clear from the description of the type species, S. styloniferum Cookson & Eisenack 1960, p. 489; pl. 1, figs. 1-5, that the form has two wall layers, a polygonal intercalary archaeopyle formed by the loss of an intercalary plate equivalent, and has short cones and spines which, in some illustrations of the species, appear to outline a reflected tabulation of ?4', 1a-?3a, 5-?7", 0c, 5-?6"', 1"". The spines appear to be intertabular but intratabular spines are also present. The wall layers may be distinct or so closely appressed as to appear unseparated. In view of these characters, the writer feels this genus should be assigned to the Family Deflandreaceae and not to the Family Pareodiniaceae (Gocht) Sarjeant & Downie 1966 as Sarjeant and Downie (1966, p. 516) have done.

### Spinidinium vestitum sp. nov. (23310)

Plate 17, figs. 12-14; Plate 18, fig. 1 and Text-figs. 28d and 29a-b

Holotype: BW 117/1 at 381 - 1027; Total length, 73μ; width, 55μ.

Description: Dinoflagellate cyst; two layered construction, the inner and outer layers closely appressed; inner layer often visible at the edge or rendered visible by folding or breakage of one or more layers. Cyst outline pentagonal or pentagonal-elongate, the epitract longer than the hypotract. Apex tapering but truncated, often crowned with a ring of four or five small spines; antapex flattened and slightly invaginated, the left-hand side (in ventral view) sometimes prolonged into an antapical prominence ended by a small spine, giving the antapex an oblique outline. Cingulum also present, nearly circular, outlined by raised ridges which may be simple, or toothed, or by rows of small spines and cones; prominent sulcus always present, extending onto the epitract, terminated by spine rows and occasionally by a sutural ridge indicating apical plate equivalent 1'; sulcus extends to the antapex, widening slightly or nearly straight, outlined by raised simple or spinose ridges and terminated by the antapical plate equivalent. Spines and cones present, 1-4μ high, sometimes distinctly outlining reflected tabulation and always scattered sparsely and randomly over the outer cyst wall.

Most specimens available for study with archaeopyle structure possess an intercalary archaeopyle, somewhat hexagonal in shape. Many specimens, however, including the holotype show a complicated opening in the intercalary position suggesting either mechanical breakage or the possibility of an intercalary archaeopyle formed of more than one plate equivalent. The holotype exhibits a complex archaeopyle, the outer layer possessing the enlarged archaeopyle and the inner layer exhibiting a clearly hexagonal archaeopyle as well. In other specimens, parts of the operculum are present between the two wall layers. Some specimens, either through mechanical breakage, or through regular breakdown along accessory sutures, exhibit breaks corresponding in position to the outlines of a postulated plate equivalent, 4", and sometimes the sutures between postulated plates 2-4" are ruptured.

Tabulation is not well shown on any one specimen. It appears that the following scheme, based on observation of the archaeopyle structure and breakdown of sutures, as well as on spine rows and sutural ridges, may be a reasonable approximation: 4', 1-?3a, ?7", Oc, 5-?6"', ?1p, ?1"". Plate 4' is outlined by a circlet of apical spines and crowns the apex. Plates 1" and 2" are often visible through outlining by spine rows or sutural ridges. Plates 3-4" may be marked by spines or by breakdown of sutures; plates 5-7" are marked by spine rows or sutures. The position of the archaeopyle, the general symmetry of the cyst and the position of other plates suggest that the intercalary plate or plates lie astride the apical-antapical axis, abutting on plates 3-5" and on plates 2-3'. Postcingular tabulation is more difficult to determine and is based on spine rows and sutures and the outline of the sulcus. It cannot be determined with certainty whether the antapical series consists of one or two plate equivalents, but there appears, from considerations of symmetry to be only one. A small posterior plate equivalent is often distinctly visible and outlined by spine rows but is not always present.

Dimensions: Total length on 51 measured specimens, 52-92μ; width on 47 measured specimens, 31-58μ; a total of 65 specimens recorded.

Remarks: The specimens included in the species, *Spinidinium vestitum* sp. nov. exhibit a variable morphology, but all are characterized by the combination of intercalary archaeopyle development, a circular cingulum and well-defined sulcus outlined by spiny sutures or simple ridges, a two layered wall and characteristic tabulation, which may be variably developed.

Comparison: *Spinidinium styloniferum* Cookson & Eisenack 1960 differs in its construction of the wall layers, spine pattern and apex, and possession of a helicoid cingulum. *S. densispinatum* Stanley 1965, p. 226; pl. 21, figs. 1-5 and *S. microceratum* Stanley 1965, p. 227; pl. 22, figs. 5-6, differ in their shape, slightly helicoid cingulum, and their profusion of intratabular spines, among other characteristics.

Distribution: Recorded from various portions of sections of the Lower Colorado Group in south-central Alberta and from the Joli Fou and Pelican Formations, "Grosmont" section; from the "Grouard" section and the Lower Shaftesbury Formation, west-central Alberta.

## Spinidinium sp. A. (23311)

Plate 18, fig. 13

Description: Dinoflagellate cyst; probably two layered, inner layer not visible; outer layer forms spines and sutures (as confirmed under phase contrast). Elongate pentagonal shape with the epitract longer than the hypotract; dorsally convex and ventrally somewhat flattened. Distinct circular cingulum and sulcus; both marked by low ridges bearing spines or by spine rows. Apex slightly tapered, without an apical horn but with apical spines; antapex flattened or invaginated slightly and formed of plate equivalent 1'''', hypotract tapering slightly. Tabulation not determined in detail, outlined in part by low spiny sutures or rows of spines. Spines distinctive, rod-like or knobbed, somewhat bipartite, numerous, present both intratabularly and intertabularly. Intercalary archaeopyle present on several specimens.

Dimensions: The following dimensions on 6 specimens: total length, 76-98μ; width, 42-53μ; spines 3-5μ.

Comparison: This species is characterized by the distinctive spines formed by the outer layer from all other species previously described under the genus Spinidinium.

Distribution: Rare specimens recovered from the Harmon Member, "Spirit River" section, the Upper Shale Unit, "Battle Lake" section; recovered in moderate numbers from the lower part of the Upper Shale Unit, "Chigwell" section.

## *Spinidinium* sp. B. (23312)

Plate 18, fig. 9 and Text-fig. 30a

Description: Dinoflagellate cyst; two layered wall, the outer layer forming spines and sutural ridges. Outline rounded-pentagonal; epitract longer than hypotract. Cingulum helicoid, displaced about one cingulum width; sulcus extends well onto the epitract, for at least half the total sulcul length; both cingulum and sulcus outlined by distinct spiny ridges. The sulcus subtended apically by a row of spines marking the base of plate equivalent 1' and antapically by plate equivalent 1"". The cyst tapers slightly at the apex which is rounded and crowned with a ring of apical spines marking the outline of plate equivalent 4'; the antapex is flattened or slightly oblique where one corner extends slightly. Tabulation not completely determinable but appears to be 4', 1a-?3a, 6-?7", 0c, 5?"', ?1p, 1""; outlined in part by sutural ridges and in part by spiny ridges or spine rows; spines simple and about 1-3μ high. Archaeopyle structure difficult to determine clearly; probably intercalary with either mechanical breakage or accessory sutures or both combining to form an irregular opening in the intercalary region.

Dimensions: One specimen noted in suitable orientation: length, 80μ; width, 34μ; dimensions of 3 specimens, tilted obliquely: length, 49-57μ; width, 36-42μ.

Comparison: This species, while similar in many respects to *Spinidinium vestitum* sp. nov., is separated on the basis of its possession of a helicoid cingulum.

Distribution: Rare specimens recorded from the Viking Formation, "Chigwell" section and from the Lower Shaftesbury Formation, west-central Alberta.

### Spinidinium? sp. C. (23313)

Plate 17, fig. 10 and Text-fig. 30b

Description: Dinoflagellate cyst; cavate; elongate-pentagonal outer layer with tapering apex and slightly flattened antapex; inner layer nearly circular, situated approximately about the mid-line, leaving apical and antapical cavities. Cingulum helicoid, displaced about half a cingulum width; sulcus well marked, extending well onto the epitract and subtended apically by a spine row marking the base of plate equivalent 1', and antapically by the antapical plate equivalent, 1"". Spiny ridges or spine rows mark the course of the cingulum and sulcus and indicate reflected tabulation. Well preserved specimens show that the spines are intratabular, parallelling the outline of the reflected plate equivalent and present just inside the suture separating the fields. Tabulation not determined in detail but similar to the general type outlined for the genus Spinidinium Cookson & Eisenack. Archaeopyle developed on one specimen, intercalary in position; operculum still partly attached and similar in shape to plate ?1a or ?2a.

Dimensions: The following dimensions on 2 specimens: length, 61-70μ; width, 39-40μ; capsule length, 29-35μ; capsule width, 33-39μ. Total of 3 specimens recovered.

Distribution: Rare specimens recovered from the "Grouard" section and from the Lower Shaftesbury Formation, "Spirit River" section.

## Genus DINGODINIUM Cookson & Eisenack 1958

Type species: Dingodinium jurassicum Cookson & Eisenack 1958.

### Dingodinium cerviculum Cookson & Eisenack 1958 (23302)

Plate 17, fig. 19

Selected syn.

1958 Dingodinium cerviculum Cookson & Eisenack, p. 40; pl. 1, figs. 12-14.

Dimensions: Total length on 22 measured specimens, 52-80μ; total width on 19 specimens, 34-53μ; length of the capsule, 21-45μ; width of capsule, 34-48μ; total number of specimens recorded, 32.

Remarks: The broad, little tapering, truncated apical horn is well developed on the specimens discussed herein. Occasionally the horn appears to be open apically, but this is interpreted as probable mechanical breakage. Occasional specimens display a rectanguloid opening in the cyst wall layers corresponding in position to an intercalary archaeopyle. The inner capsule bears small grana, 1/2-1μ in diameter and height.

Comparison: This species is distinguished from Dingodinium jurassicum Cookson & Eisenack 1958 by the presence of a stout apical horn, and from D. europaeum Eisenack 1958 by the granulate capsule wall.

Distribution: Previously recorded from the Lower Cretaceous of Australia (Cookson & Eisenack, 1958) and from the Hauterivian to Turonian of Germany (Alberti, 1961). Concerning the latter occurrence, Alberti (1961, p. 17) remarks that the Turonian examples may be "umgelagent", which the writer translates as "reworked" or "recycled". Sarjeant (1967, Table X) gives a range of Hauterivian

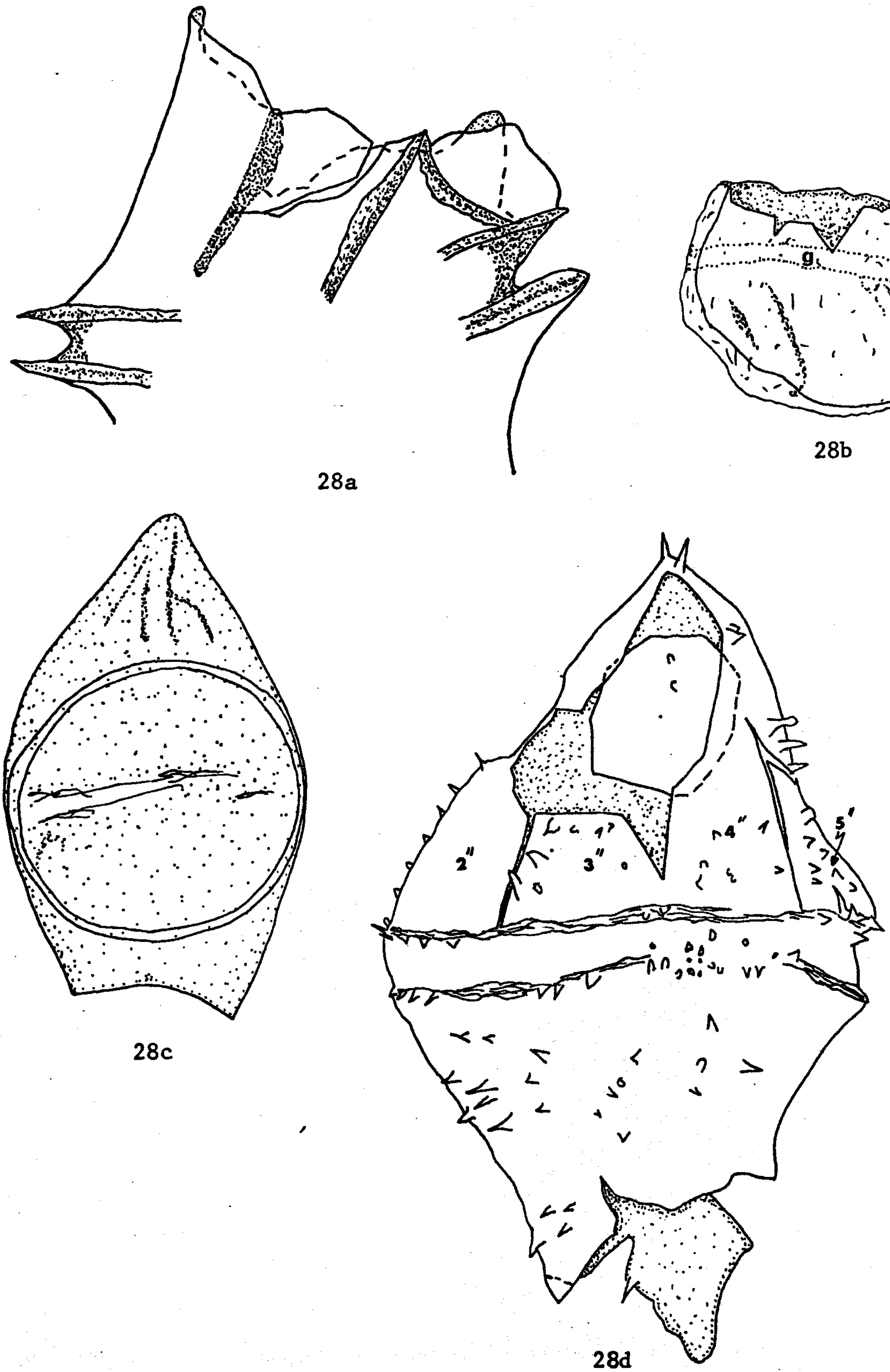
Text-figure 28a-d. Camera lucida drawings of selected microplankton specimens showing various structural features.

28a. Proximo-chorate Cyst Forma A. Apical portion of specimen illustrated in Plate 17, fig. 11 showing outline of the apical opening (archaeopyle?); X2000. BW105/2: 277 - 937.

28b. *Hexagonifera?* sp. A. Specimen in ventral view showing zig-zag outline of apical archaeopyle, outer thin layer, and transverse girdle trace (g), dotted, on dorsal surface. X800. Same specimen illustrated as Plate 17, fig. 20.

28c. *Deflandrea dignitosa* sp. nov. Specimen showing capsule and faint indication of transverse girdle structure; X900. BW148/1: 605 - 1091.

28d. *Spinidinium vestitum* sp. nov. Dorsal surface of specimen showing a portion of the tabulation pattern, transverse girdle and intercalary opening and rupture. An intercalary plate remains in the archaeopyle opening; BW191/1: 343 - 1035. X1650. Specimen illustrated also as Plate 18, fig. 1.



28a

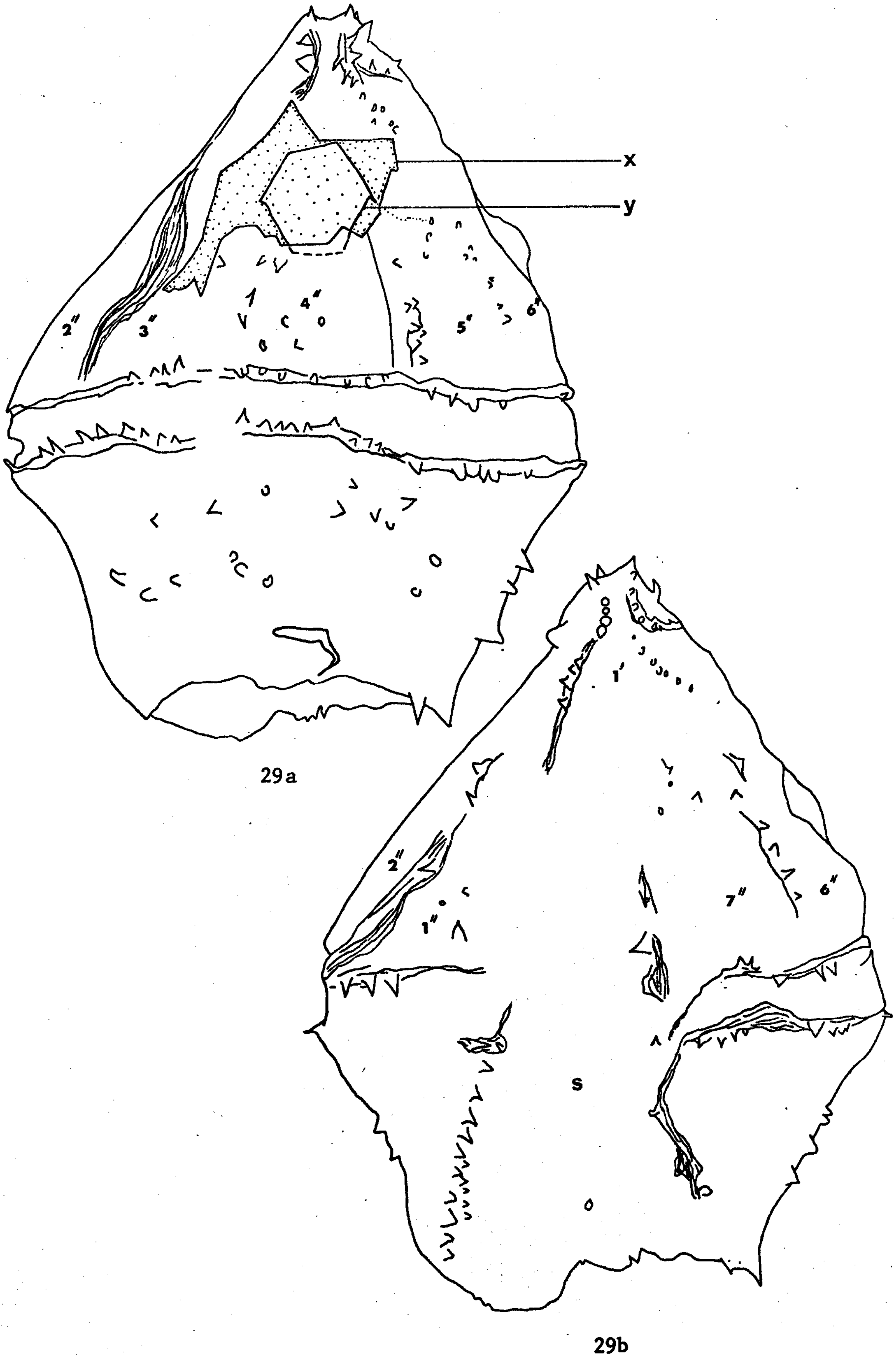
28b

28c

28d

Text-figure 28

Text-figure 29a-b. *Spinidinium vestitum* sp. nov. Holotype specimen. (a) Dorsal surface showing spine rows, suggested partial tabulation pattern, and archaeopyle structure of the outer (x) and inner layer (y). (b) Ventral surface by transparence showing sulcus (s) and partial tabulation pattern. Both X1650. Specimen illustrated also in Plate 17, figs. 12-14.



29a

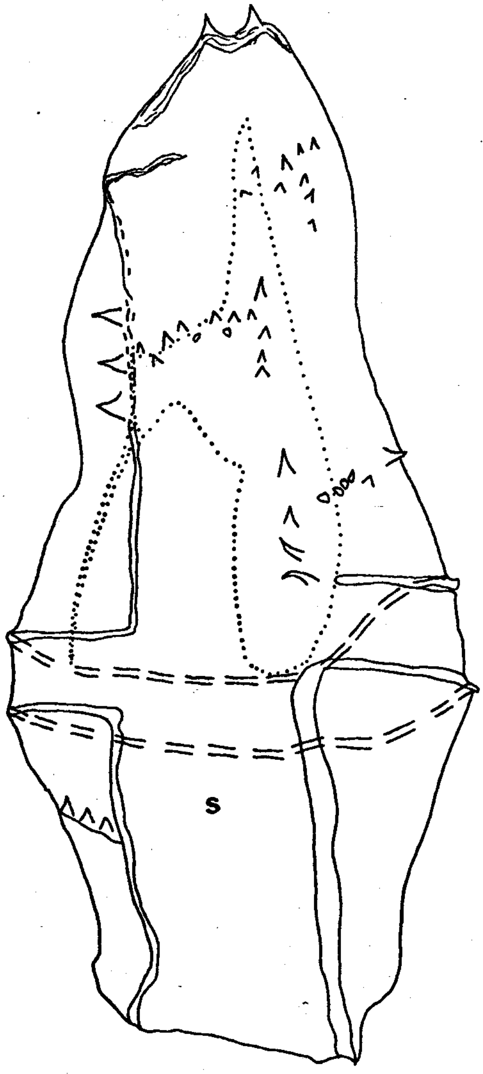
29b

Text-figure 29

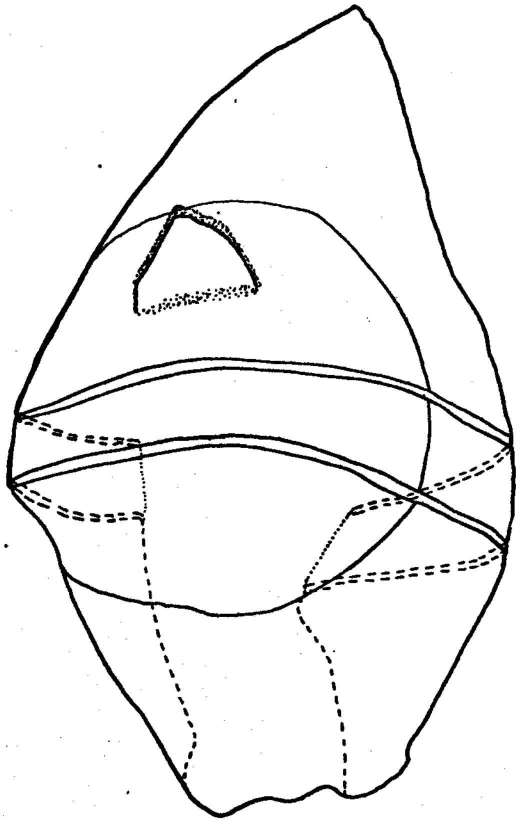
Text-figure 30a-b. Camera lucida drawings of specimens of the genus Spinidinium described from the Lower Colorado Group.

30a. Spinidinium sp. B. Outline drawing of the ventral surface, with some detail of dorsal surface by transparence. Note helicoid transverse girdle, sulcus (s) and dorsal split in cyst wall (dotted). X1700. Same specimen illustrated also as Plate 18, fig. 9. BW146/1: 422 - 1114.

30b. Spinidinium sp. C. Outline drawing showing helicoid transverse girdle, capsule and partially detached operculum, dorsal view. Ventral sulcus and transverse girdle pattern by transparence. X1750. BW144/3: 557 - 946. Specimen illustrated also in Plate 17, fig. 10.



30a



30b

Text-figure 30

to mid-Cenomanian. Specimens recovered in this thesis from the Lower Colorado Group, south-central Alberta; the Pelican Formation, "Grosmont" section, the basal Joli Fou Formation, "Grouard" section and the Harmon Member and Lower Shaftesbury Formation, west-central Alberta.

Family PSEUDOCERATIACEAE (Eisenack) Sarjeant & Downie 1966

Type genus: Pseudoceratium Gocht 1957.

Remarks: Vozzhennikova (1965) proposes three separate families to accommodate the genera grouped by Sarjeant & Downie (1966, p. 523) into the one family cited above. The writer thinks, in agreement with the views of Sarjeant & Downie that such a subdivision exceeds the present understanding of these forms. Further, Vozzhennikova (1965, p. 111; in transl.) includes the genus Broomea Cookson & Eisenack, which has an intercalary archaeopyle rather than an apical archaeopyle, and she also exludes the genera, Odontochitina Deflandre and Aptea Eisenack among others despite their possession of an apical archaeopyle and a shape similar to the type genus. In view of Evitt's (1961; 1967) contributions towards the understanding of the importance of the archaeopyle in dinoflagellate cyst taxonomy, the writer cannot accept these exclusions.

Genus APTEA Eisenack 1958

Type species: Aptea polymorpha Eisenack 1958.

Aptea cf. Aptea polymorpha Eisenack 1958 (23501)

Plate 18, figs. 2-4 and 7

Selected syn.

Cf. 1958 *Aptea polymorpha* Eisenack, p. 394; pl. 22, figs. 5-12.
? 1962 *Pseudoceratium pelliferum auct. non* Gocht 1957; Pocock, p. 79; pl. 14, figs. 215-218.
? 1964 *Pseudoceratium pelliferum auct. non* Gocht 1957; Singh, p. 144; pl. 20, figs. 5-6.

*Description*: Dinoflagellate cyst; ?cavate; outline elongate in the apical axis, with a short, tapering, apical horn; the cyst widest at the mid-line, tapering towards the antapex, symmetry broken by a short, rounded lateral horn; the antapex nearly rounded or with a short, rounded, asymmetrical antapical prominence. Cyst wall two-layered; the outer layer membranous and rarely preserved in the specimens available for study; the inner body supplied with a low, sometimes imperfect reticulum which supports the outer membranous layer in the one complete specimen. Reticulum sometimes reduced to absent in a ventral, hypotractal region interpreted as a sulcul region. Archaeopyle apical, with well-defined zig-zag rupture line; the operculum sometimes still attached and comprising the apical horn and part of the apical epitract; the margin outline suggests 4 to ?5 apical reflected plates. No other evidence for tabulation noted. The complete specimen shows a slightly helicoid cingulum marked by faint ridges on the membranous layer but no tabulation pattern.

*Dimensions*: Length on 1 complete specimen, 108μ; width on 1 complete specimen, 84μ; apical horn, 24μ. Length of inner body on 15 measured specimens (without archaeopyle), 73-103μ; width of inner body on 21 measured specimens, 53-83μ; length of apical prominence on the inner body on 12 measured specimens, 8-24μ. Total number of specimens recorded, 34.

*Remarks*: *Aptea* cf. *Aptea polymorpha* Eisenack 1958 compares closely in size and shape with *A. polymorpha* Eisenack 1957 and as well in archaeopyle and operculum structure. The single complete specimen is undoubtedly *A. polymorpha* but the others described above lack the outer membranous layer and are not always well preserved. The writer prefers to indicate the close resemblance of the whole population of specimens rather than referring only the one form to Eisenack's species.

*Comparison*: *Pseudoceratium pelliferum auct. non* Gocht 1957 in Pocock 1962, p. 79; pl. 14, figs. 215-218 (especially fig. 215) appear to be poorly preserved examples of *A. polymorpha* Eisenack, lacking the membranous outer layer. *Pseudoceratium pelliferum auct. non* Gocht 1957 in Singh 1964, p. 144; pl. 20, figs. 5-6, also appears to be *A. polymorpha* Eisenack.

*Pseudoceratium pelliferum* Gocht 1957, p. 166; pl. 18, figs. 1-2 is easily distinguished from *Aptea polymorpha* Eisenack 1958 by its spinose ornament with spines tips often anastomosing and by its much larger size (length, 120-160μ; width, 50-70μ). No specimens belonging to *Pseudoceratium pelliferum* Gocht have been observed in any samples from the Mannville Group and younger strata in western Canada available to the author.

*Distribution*: Specimens recovered from all strata investigated with the exception of the Joli Fou Formation, "Grosmont" section and the Cadotte and Paddy Members, "Spirit River" section, west-central Alberta; closely comparable specimens are described by Eisenack (1958) from the Aptian of Germany and from the Valanginian to Middle Albian of western Canada (Pocock, 1962; Singh, 1964).

## Genus PSEUDOCERATIUM Gocht 1957

Type species: Pseudoceratium pelliferum Gocht 1957.

### Pseudoceratium expolitum sp. nov. (23502)

Plate 18, figs. 5 and 11

Holotype: BW 117/1 at 417 - 948; total length, 158µ; maximum width, 66µ; apical horn, 42µ; lateral horn, 28µ; antapical horn, 58µ.

Description: Dinoflagellate cyst; cavate?; cyst body essentially elongate-ovoid, somewhat asymmetrically developed, bearing one elongate, tapering apical horn, one lateral horn, which distorts the symmetry of the outline to a varying extent, and one asymmetrically placed, tapering antapical horn, the apex rounded (truncated) to acute. The cyst body has rounded contours and bulges slightly opposite the position of the lateral horn, about mid-way down the hypotract. Archaeopyle apical, the margin zig-zag; the operculum includes the apical horn and part of the epitract. No evidence of cingulum or sulcus structure or tabulation noted on the specimens available for study. Wall appears thick and is smooth or occasionally scabrate to microreticulate, the latter probably due to corrosion. The ventral portion of the cyst body appears flattened, the dorsal side, slightly convex. A few specimens retain the essentially asymmetrical construction but have the horns reduced in size.

Dimensions: Total length on 21 specimens, 102-169µ; maximum width on 24 specimens, 45-102µ; lengths of horns: apical, 15-52µ; lateral, 10-32µ; antapical, 7-58µ.

Comparison: Several species similar to Pseudoceratium expolitum sp. nov. have been figured and described by Gocht (1957). *P. ?nudum* Gocht 1957, p. 168; pl. 18, figs. 3-4 and 6 shows some similarity in construction and size but it is difficult to make a clear comparison from the illustrations. Gocht gives a size range for this species of 190-228µ and a range in width of 45-75µ. It thus appears to differ from *P. expolitum* sp. nov. by being much larger in total length. A second form described by Gocht as *Pseudoceratium*? sp. Gocht 1957, p. 169; pl. 18, fig. 5 also appears similar but appears to possess an internal body, not evident in the specimens of *P. expolitum* sp. nov. It is entirely possible that *P. expolitum* is two layered, with a definite capsule, but this has not been observed. Gocht's (1957) species is also larger than *P. expolitum* sp. nov. Thus it seems best at present to propose a new species for the specimens described above and to note the similarity of the species described by Gocht (1957).

*Distribution*: Recorded from the Joli Fou and Viking Formations and from the Upper Shale Unit, south-central Alberta; present in the "Grouard" section, and in the Harmon and Cadotte Members and the Lower Shaftesbury Formation in west-central Alberta; absent from samples of the Joli Fou and Pelican Formations in the "Grosmont" section.

### Genus ODONTOCHITINA Deflandre 1935

Type species: *Odontochitina operculata* (Wetzel) Deflandre 1946.

### *Odontochitina operculata* (Wetzel) Deflandre 1946 (23503)

Plate 18, figs. 8 and 10

Selected syn.

1933 *Ceratium* (*Euceratium*) *operculatum* Wetzel, p. 170; pl. 11, figs. 21-22.

1935 *Odontochitina silicorum* Deflandre, p. 234; pl. 9, figs. 8-10.

1946 *Odontochitina operculata* (Wetzel) Deflandre, cards 1016-1019.

1961 *Odontochitina* sp. A. Alberti, p. 31; pl. 6, figs. 3-5.

1962 *Odontochitina silicorum* Deflandre; Pocock, p. 78; pl. 14, figs. 211-212.

1962 *Odontochitina athabaskensis* Pocock, p. 78; pl. 14, figs. 209-210.

*Dimensions*: Few complete specimens; one observed at 237µ in total length and a second nearly complete (apical horn broken) at 390µ plus; maximum width of the cyst, 35-77µ on 18 measured specimens; the shorter antapical horn from 59-118µ long, the longer from 81-177µ. Total number of specimens recorded, 28.

*Remarks*: Well preserved specimens available for study show a two layer construction of the cyst, the inner body closely appressed to the outer layer except at the apex and antapex and not extending into the apical horn. The apical and two antapical horns are formed by the outer cyst wall layer. Apical archaeopyles with zig-zag rupture margins and well-defined sulcul notches were observed on many specimens; detached operculum formed of the apical horn and part of the apical epitract were common in many samples investigated.

*Distribution*: Specimens recorded from all units of the Lower Colorado Group, Peace River Formation and Lower Shaftesbury Formation; present in the Lower Cretaceous of western Canada (Pocock, 1962; Singh, 1964); numerous workers report this species in strata ranging in age from Hauterivian to Campanian in Europe, England, Australia and other regions.

## DINOPHYCEAE INCERTAE

### Dinophyceae? Incertae Forma A. (23901)

Plate 18, fig. 12

Description: Dinoflagellate cyst?; outline rhomboid, contours rounded; elongate in the ?apical axis. Cyst wall thin and scabrate. A consistently folded region at the mid-line is taken as marking the position of a cingulum. A second consistent pattern of folding is developed in the long axis, often asymmetrically. The orientation of the cyst? body is uncertain.

Dimensions: The following dimensions on 8 recovered specimens: length, 41-96µ; width, 27-64µ.

Remarks: The systematic position of this form is uncertain in the absence of other characters which would point to dinoflagellate affinity.

Distribution: Specimens recorded from the Joli Fou Formation in the "Battle Lake" and "Chigwell" sections; and from the Joli Fou and Pelican Formations, "Grosmont" section.

# BIBLIOGRAPHY

Ager, D. V. 1963. *Principles of Palaeoecology*. McGraw-Hill Book Co., Toronto, Ontario.

Alberta Society of Petroleum Geologists. 1960. *Lexicon of Geologic names in the Western Canada Sedimentary Basin and Arctic Archipelago*. *Alberta Soc. Petrol. Geol.*, Calgary.

Alberta Study Group. 1954. Lower Cretaceous of the Peace River Region. In: L. M. Clark, ed. Western Canada Sedimentary Basin - a symposium. *Amer. Assoc. Petrol. Geol.*, Ralph Leslie Rutherford Memorial Volume: 268-278.

Alberti, G. 1961. Zur Kenntnis mesozoischer und alttertiär Dinoflagellaten und Hystrichosphaerideen von Nord- und Mitteldeutschland sowie einigen andern europäischen Gebieten. *Palaeontographica*, 116A: 1-58, pls. 1-12; table.

Archangelsky, S. and Gamerro, J. C. 1967. Spore and pollen types of the Lower Cretaceous in Patagonia (Argentina). *Rev. Palaeobotan. Palynol.*, 1: 211-217; 2 pls.

Armstrong, T. A. 1953. New exploration tool. *Oil and Gas Jour.*, 51: 64-65.

Badgley, P. C. 1952. Notes on the subsurface stratigraphy and oil and gas geology of the Lower Cretaceous series in Central Alberta. *Geol. Survey Canada Paper* 52-11.

Balme, B. E. 1957. Spores and pollen grains from the Mesozoic of Western Australia. *Austr. C. S. I. R. O. Coal. Res. Sect. Tech. Comm.* 25. 11 pls.

Barkley, F. A. 1934. The statistical theory of pollen analysis. *Ecology* 15: 283-289.

Belsky, C. Y. and Boltenhagen, E. 1963. Sporomorphes de position taxonomique incertaine du Crétacé supérieur du Gabon. *Grana Palynol.*, 4(2): 262-270.

——————— Boltenhagen, E. and Potonié, R. 1965. Sporae dispersae des Oberon Kreide von Gaun, Äquatorische Afrika. *Palaontol. Z.* 39(1/2): 72-85; 1 pl.

Bolkhovitina, N. A. 1950. Lower Cretaceous sporo-pollen complexes of the Chulymo-Enissey Basin of the South Urals and Kazakstan. *Trans. Conf. Sporo-pollen analysis*, 1948: 125-136. Ed. Moscow Univ.

Bolkhovitina, N. A. 1951. Complexes sporo-polliques des depots de l'Aptien et l'Albien de la partie centrale de la plat-forme russe. *Bull. Soc. Natural de Moscow, Sect. Geol.* 26(5): [illegible]-44.

—————— 1953. Spore-pollen characteristics of Cretaceous deposits of central regions of the USSR. (In Russian - French translation in GSC) *Trans. Inst. Geol. Sci., Acad. Sci. USSR*, 145, *Geol. Ser.* 61. 184 pp.

—————— 1959. Spore-pollen complexes of the Mesozoic deposits of the Vilui depression and their stratigraphic significance. (Russian). *Acad. Nauk SSSR, Trudy Geol. Inst.*, No. 24.

—————— 1961. Fossil and recent spores in the Schizaeaceae. (Russian) *Acad. Nauk. SSSR, Trudy Geol. Inst.* 40: 1-176; 51 pls.

—————— 1962. History of Schizaeaceae family in the geological past on the basis of spore studies. (Russian, English summ.) *First Intern. Conf. Palin. Tucson Rep. Sov. Palin. Akad. Nauk SSSR, Geol. Inst.*: 38-43.

—————— 1966. The fossil spores of the ferns of the family Gleicheniaceae (taxonomy and distribution). In: *The Importance of Palynological Analysis for the Stratigraphic and Palaeofloristic Investigations*. Nauka, Moscow, 1966: pp. 65-75.

Boltenhagen, E. 1967. Spores et pollen du Crétacé supérieur du Gabon. (en Français). *Pollen et Spores* 9(2): 335-355; 5 pls.

Bonamo, P. M. and Banks, H. P. 1966. *Calamophyton* in the middle Devonian of New York State. *Am. J. Bot.*, 53(8): 778-791, figs, 1-30.

Bowerbank, J. S. 1841. On the siliceous bodies of the Chalk, Greensands and Oolite. *Geol. Soc. London, Proc.*, 3: 278-81.

Brenner, G. J. 1963. The spores and pollen of the Potomac Group of Maryland. *Dept. Geol., Mineral & Water Resour., State of Maryland, Bull.* 27. 215 pp.; 43 pl.

—————— 1967. Early angiosperm pollen differentiation in the Albian to Cenomanian deposits of Delaware (USA) *Rev. Palaeobot. Palynol.*, 1: 219-227, 3 pls.

Brideaux, W. W. 1965. Upper Devonian plant microfossils from Eastern and Arctic Canada: their taxonomy and palaeoecological significance. *Thesis*. McMaster University, Hamilton, Ontario, Canada. 163pp.; 8 pls.

Brookes, D. and Thomas, K. W. 1967. The distribution of pollen grains on microscope slides. Part I. The non-randomness of the distribution. *Pollen et Spores*, 9(3): 621-629; 1 text-fig.; 5 tables.

Brown, C. A. 1960. *Palynological Techniques*. Louisiana State University, Baton Rouge, La. 188 pp.

Brown, C. W. and Pierce, R. L. 1962. Palynologic correlations in Cretaceous Eagle Ford Group. Northeast Texas. *Bull. Amer. Assoc. Petrol. Geol.* 46(12): 2133-2147.

Brush, G. S. and Barghoorn, E. S. 1964. The natural relationships of some Carboniferous microspores. *J. Paleontol.* 38(2): 325-330.

Bursa, A. S. 1962. Some morphogenetic factors in taxonomy of dinoflagellates. *Grana Palynol.*, 3(3): 54-66; 68 text-figs.

__________ 1964. *Discoasteromonas calciferus* n. sp., an arctic relict secreting Discoaster Tak Sin Hok 1927. *Grana Palynol.*, 6(1): 147-165; 4 pls; 22 text-figs.

Chaloner, W. G., 1959. Devonian megaspores from the Canadian Arctic. *Palaeontology*, 1; pt. 4: 321-332.

__________ 1962. Rhaeto-Liassic plants from the Henfield Borehole *Bull. Geol. Survey Gt. Brit.*, 19: 16-28; pl. 2; figs. 1-4.

Chatton, É. and Deflandre, G. 1952. Classe des Dinoflagellés ou Péridiniens. In: Grassé, P.-P., *Traité de Zoologie*, 1: 309-406; 94 figs.

Churchill, D. M. and Sarjeant, W. A. S. 1963. Freshwater microplankton from Flandrian (Holocene) peats of south western Australia. *Grana Palynol.* 3(3): 29-53; 2 pls.

Clarke, R. F. A. and Verdier, J. P. 1967. An investigation of microplankton assemblages from the Chalk of the Isle of Wight, England. *Verhandel. Koninkl. Ned. Akad. Wertenschap, Afdel. Natuurk, Eerste Reeks*, 24(3): 1-96; 17 pls.

✓Cobban, W. A. and Reeside, J. B. Jr. 1952. Correlation of the Cretaceous formations of the Western Interior of the United States. *Geol. Soc. Amer. Bull.* 63(10): 1011-1043.

Cole, L. C. 1949. The measurement of interspecific association. *Ecology*, 30: 411-424.

Combaz, A. Lange, F. W. and Pansart, J. 1967. Les "Leiofusidae" Eisenack, 1938. *Rev. Palaeobotan. Palynol.*, 1: 291-307.

Cookson, I. C. 1947. Plant microfossils from the Lignites of the Kerguelen Archipelago. *B. A. N. Z. Antarctic Res. Expedit.* 1929-31, Rept. Ser. A,: 127-142; pls. 13-17.

__________ and Eisenack, A. 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proc. Roy. Soc. Vict.*, 70(1): 19-79; 12 pls.

____________________ 1960. Microplankton from Australian Cretaceous sediments. *Micropaleontology*, 6(1): 1-18; pls. 1-3.

____________________ 1962. Additional microplankton from Australian Cretaceous sediments. *Microplaeontology*, 8(4): 485-507. pls. 1-7.

__________ and Hughes, N. F., 1964. Microplankton from the Cambridge Greensand (Mid-Cretaceous). *Palaeontology*, 7, pt. 1: 37-59.

Couper, R. A. 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *N. Z. Geol. Survey Palaeontol.* Bull. 22.

__________ 1958. British Mesozoic microspores and pollen grains. *Palaeontographica*, 103B: 75-179; pls. 15-31.

__________ 1960. New Zealand Mesozoic and Cainozoic plant microfossils. *N. Z. Geol. Survey Palaeontol. Bull.* 32; 12 pls.

__________ 1964. Spore-pollen correlation of the Cretaceous rocks of the Northern and Southern Hemispheres. *Palynology in Oil Exploration*, *S. E. P. M. Spec. Publ.* No. 11: 131-142.

Courteville, H. 1937. La glycerin gélatinée au micrographie (préparation et méthod de montage). *Bull. Soc. Francais Microsc.*, 6(2): 58-64.

Dougherty, L. H. 1941. The Upper Triassic flora of Arizona. *Carnegie Inst. Wash. Publ.* 526: 1-108;34 pls.

Davey, R. J. *In press*. Microplankton from the Lower Chalk (Cenomanian). *Bull. Brit. Mus. (Natural Hist.) Geol.*

__________ *et al.*, 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. Brit. Mus. (Natural Hist.) Geol.*, *Supp.* 3. 248 pp.; 25 pls.

__________ and Williams, G. L. 1966. The genera *Hystrichosphaera* and *Achomosphaera*. *In*: Davey *et al.*, 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. Brit. Mus. (Natural Hist.) Geol.*, *Supp.* 3: 28-52.

Davey, R. J. and Williams, G. L. 1966. The genus Hystrichosphaeridium and its allies. In: Davey, et al., 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. Bull. Brit. Mus. Natural Hist. Geol., Supp. 3: 53-106.

Davis, P. N. 1963. Palynology and stratigraphy of the Lower Cretaceous rocks of Northern Wyoming. Thesis. University of Oklahoma, Norman, Okla. 238pp; 14 pls.

Deák, M. H. 1962. Deux nouveau genres de spores de la série d'argiles et de marnes aptiennes. Bull. Hungarian Geol. Soc., 92(2): 233-235.

Deflandre, G. 1934. Sur les microfossiles d'origine planctonique conservés a l'état de matière organique dans les silex de la craie. Acad. Sci. Paris, C. R., 199: 966-968; text-figs.1-11.

____________ 1935. Considérations biologiques sur les microorganisms d'origine planctonique conservés dans les silex de la craie. Bull. Biol. Fr. Belg., 69: 213-244; pls. 5-9; text-figs. 1-11.

____________ 1936. Microfossiles des silex crétacés. 1. Generalités. Flagellés. Ann. Paléont., 25: 151-191; pls. 11-20.

____________ 1937. Microfossiles des silex crétacés II. Flagellés incertae sedis. Hystrichosphaeridées. Sarcodines. Organismes divers. Ann. Paléont., 26: 51-103; pls. 8-18.

____________ 1947. Le problème des Hystrichosphères. Inst. Oceanogr. Monaco, Bull. 918: 1-23.

____________ 1964. Remarques sur la classification des Dinoflagellées fossiles, a propos d'Evittodinium, nouveau genre crétacé de la famille Deflandreaceae. C. R. Acad. Sci., 258: 5027-5030; Figs. 1-9.

____________ and Cookson, I. C. 1955. Fossil microplankton from Australian late Mesozoic and Tertiary sediments. J. Mar. Freshw. Res. 6(2): 242-313; 9 pls.

Delcourt, A. F. and Sprumont, G. 1955. Les spores et les grains de pollen du Wealdien du Hainaut. Mém. Soc. Belge Géol. n. s. No. 5. 73 pp. 6 pl.

Dettmann, M. E. 1959. Upper Mesozoic microfloras in well cores from Woodside and Hedley, Victoria. Proc. Roy. Soc. Victoria. 71(2): 99-105.

____________ 1963. Upper Mesozoic microfloras of South-eastern Australia. Proc. Roy. Soc. Victoria, 77(pt. I). 148 pp.

Döring, H. 1964. Neue Sporengattungen und-arten aus dem Jura/ Kreide-Grenzbereich Norddeutschlande. *Monats. Deutsch. Acad. Wissen Berlin*, 6(1): 37-45; 2 pls.

__________ 1965. Die sporenpaläontologische Gliederung des Wealden in Westmecklenburg (Struktur Werle). *Geologie*, Jg. 14, Beih. 47: 1-118; 23 pl.

Dowling, D. B. Slipper, S. E. and McLearn, F. H. 1919. Investigations in the gas and oil fields of Alberta, Saskatchewan and Manitoba. *Geol. Survey Canada. Mem.* 116.

Downie, C. Evitt, W. R. and Sarjeant, W. A. S. 1963. Dinoflagellates, hystrichospheres and the classification of the acritarchs. *Stanf. Univ. Pub. Geol. Sci.*, 7(3): 3-16.

__________ and Sarjeant, W. A. S. 1963. On the interpretation and status of some hystrichosphere genera. *Palaeontology*, 6, pt. 1: 83-96.

__________ 1964. Bibliography and index of fossil dinoflagellates and acritarchs. *Geol. Soc. Amer. Memoir* 94.

__________ 1966. The morphology, terminology and classification of fossil dinoflagellate cysts. *In*: Davey, *et al*. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. Brit. Mus.* (*Natural Hist.*) *Geol.*, *Supp.* 3: 10-18.

__________ Williams, G. L. and Sarjeant, W. A. S. 1961. Classification of fossil microplankton. *Nature*. 192(4801): 471.

Drugg, W. S. 1967. Palynology of the Upper Moreno Formation (Late Cretaceous-Palaeocene), Escarpado Canyon, California. *Palaeontographica*, 120B: 1-71. pls. 1-9.

__________ and Loeblich, A. R., Jr. 1967. Some Eocene and Oligocene phytoplankton from the Gulf Coast, U.S.A. *Tulane Stud. Geol.*, 5(4): 181-194; 3 pls.

Ehrenburg, C. G. 1838. Über das Massenverhältnis der jetzt labenden Kiesellinfusorien und über ein neues Infusorien - Conglomerat als Polierschiefer von Jastraba in Ungarn. *Akad. Wiss. Berlin, Abh.* (1836), 1: 109-135; 1 pl.

__________ 1843. Über einige Jura-Infusorien Arten des Corallrags bei Krakau. *Akad. Wiss. Berlin, Mber.*: 61-63.

Eisenack, A. 1938. Hystrichosphaerideen und verwandte Formen in baltischen Silur. *Z. Geschiebeforsch.* 14: 1-30; 4 pls.

__________ 1954. Hystrichosphaerideen, Sporen oder Plankton? *Palaont. Z.*, 28: 9.

Eisenack, A., 1958. *Tasmanites* Newton 1875 und *Leiosphaeridia*, n. g. als Gattungen der Hystrichosphaerida. *Palaeontographica*, 110A: 1-19.

__________ 1961. Einige Erörterungen über fossile Dinoflagellaten nebst Übersicht über die zur Zeit bekannten Gattungen. *Neu. Jb. Geol. Paläont., Abh.*, 112(3); 281-324; 5 pls.

__________ 1962. Einige Bemerkungen zu neuer Arbeiten über Hystrichosphären. *Neu. Jb. Geol. Palaeont., Mh.* 2: 92-101.

__________ 1963. Hystrichosphären. (German, with English summ.) *Biol. Rev.*, 38: 107-139; text-figs. 1-4.

__________ 1964. Erörterungen über einige Gattungen fossiler Dinoflagellaten und über die Einordnung der Gattungen in das System. *Neues Jb. Geol. Palaeont., Monat.*, 1964(6): 321-336.

__________ 1964. *Katalog der fossilen Dinoflagellaten, Hystrichospharen und verwandten Mikrofossilien. Band I. Dinoflagellaten.* E. Schweizerbert'sche Verlagsbuchhandlung (Nagele und Obermiller). Stuttgart, West Germany.

__________ 1967. *Katalog der Fossilen Dinoflagellaten, Hystrichospharen und verwandten Mikrofossilien. Band I. Dinoflagellaten. 1. Ergänzungslieferung.* E. Schweizerbart'sche Verlagsbuchandlung (Nagele und Obermiller). Stuttgart, West Germany.

Erdtman, G. 1947. Suggestions for the classification of fossil and recent pollen grains and spores. *Svensk. Bot. Tidskr.*, 41(1): 104-114.

__________ 1952. *Pollen Morphology and Plant Taxonomy: Angiosperms*. Chronica Botanica, Waltham, Mass.

__________ 1960. The acetolysis method. A revised description. *Svensk. Bot. Tidskr.*, 54(4): 561-564.

Evitt, W. R. 1961. Observations on the morphology of fossil dinoflagellates. *Micropaleontology*, 7(4): 385-400; 9 pls.

__________ 1963a. A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs, I. *Proc. Nat. Acad. Sci.*, 49: 158-164.

__________ 1963b. A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs, II. *Proc. Nat. Acad. Sci.*, 49: 298-302.

Evitt, W. R. 1967. Dinoflagellate studies. II. The Archaeopyle. *Stanf. Univ. Pub. Geol. Sci.*, 10(3); 1-83; 11 pls.

——————— and Davidson, S. E. 1964. Dinoflagellate studies. I. Dinoflagellate cysts and thecae. *Stanf. Univ. Pub.*, *Geol. Sci.* 10(1): 1-12.

Faegri, K. and Iverson, J., 1950. *Text-Book of Modern Pollen Analysis.* E. Munksgaard, Copenhagen.

Fager, E. W. 1957. Determination and analysis of recurrent groups. *Ecology*, 38(4): 586-595.

Forsman, J. P. and Hunt, J. M. 1959. Insoluble organic matter (kerogen) in sedimentary rock. *Geochim. Cosmochim. Acta.* 15: 170-182.

Fritsch, F. E. 1956. *The Structure and Reproduction of the Algae.* Cambridge, Volume 1.

Funkhouser, J. W. and Evitt, W. R. 1959. Preparation techniques for acid-insoluable microfossils. *Micropalaeontology*, 5(3); 369-375.

Gerlach, E. 1961. Mikrofossilien aus dem Oligozän und Miozän Nordwestdeutschlands, unter besonderer Berucksichtigung der Hystrichosphaerideen und Dinoflagellaten. *Neu. Jb. Geol. Paläont.*, *Abh.* 112, pt. 2: 143-228; pls. 25-29.

Glaister, R. P. 1959. Lower Cretaceous of southern Alberta and adjoining areas. *Bull. Amer. Assoc. Petrol. Geol.*, 43(3), pt. 1: 590-640.

Gleddie, J. 1954. Upper Cretaceous in western Peace River Plains, Alberta. *In*: Clark, L. M., ed. Western Canada Sedimentary Basin - a symposium: *Am. Assoc. Petrol. Geol.*, Ralph Leslie Rutherford Memorial Volume: 486-509.

Gocht, H. 1957. Mikroplankton aus dem nordwestdeutschen Neokom. I. *Paläont. Z.*, 31(3/4): 163-185; pls. 18-20.

——————— 1959. Mikroplankton aus dem nordwestdeutschen Neokom. II. Paläont. Z., 33(1/2): 50-89; pls. 3-8.

Gorka, H. 1963. Coccolithophoridés, dinoflagellés, hystrichosphaeridés et microfossiles incertae sedis du Crétacé supérieur de Pologne. *Acta Palaeont. Polon.*, 8(1); 3-90; pls. 1-11.

Groot, J. J. and Groot, C. R. 1962. Plant microfossils from Aptian, Albian and Cenomanian deposits of Portugal. *Communic. Servicos Geologicos de Portugal.*, 46: 133-171; 10 pl.

Groot, J. J. and Penny, J. S. 1960. Plant microfossils and age of non-marine Cretaceous sediments of Maryland and Delaware. *Microplaeontology*, 6(2): 225-236.

——————— and Groot, C. R. 1961. Plant microfossils and age of the Raritan, Tuscaloosa and Magothy formations of the Eastern United States. *Palaeontographica*, *Abt*. B, 108: 121-140. 3 pl.

Pennsyl.

Guennel, G. K., 1958. Miospore analysis of the Pottsville Coals of Indiana. *Ind*. *Dept*. *Conserv*., *Geol*. *Surv*. *Bull*., 13: 1-101.

Hacquebard, P. A. 1957. Plant spores in coal from the Horton Group (Mississippian) of Nova Scotia. *Microplaeontology*, 3(4): 301-324.

——————— and Barss, M. S. 1957. A Caroniferous spore assemblage, in coal from the South Nahanni River area, Northwest Territories. *Geol*. *Survey* *of* *Canada* *Bull*. 40. 63 pp.; 6 pls.

Hammen, T. Van der. 1956a. A palynological systematic nomenclature. *Bol*. *geol*., 4: 63-101; 12 pls.

——————— 1956b. Description of some genera and species of fossil pollen and spores. *Bol*. *geol*., 4: 111-117; 2 pls.

Harris, W. F. 1955. A manual of the spores of New Zealand Pteridophyta. *N*. *Z*. *Dept*. *Sci*. *Indust*. *Res*. *Bull*. 116. 186 pp.

Hedlund, R. W. 1966. Palynology of the Red Branch Member of the Woodbine Formation (Cenomanian), Bryan County, Oklahoma. *Okla*. *Geol*. *Surv*. *Bull*. 112. 69 pp.; 10 pls.

——————— 1967. Taxonomic reevaluation of spore taxa from the Cenomanian of Oklahoma. *Pollen* *et* *Spores*. 9(3): 579-582.

Hoffman, E. 1948. Das Flyschproblem im Lichte der Pollenanalyse. *Phyton*., 1: 80-101.

——————— 1950. Pollenkorner im Oberkreideflysch von Muntigl bei Salzburg. *In*: Pre-Quaternary pollen grains and spores. *Proc*. *7th* *Internat*. *Botan*. *Congr*., *Stockholm*: 886-887.

Hoffmeister, W. S. 1954. Microfossil prospecting for petroleum. *U*. *S*. *Patent* *No*. *2,686,108*.

Hughes, N. F. 1955. Wealden plant microfossils. *Geol*. *Mag*., 92(3): 201-217.

——————— 1958. Palaeontological evidence for the age of the English Wealden. *Geol*. *Mag*., 95(1): 41-49.

Hughes, N. F. 1961. Further interpretation of *Eucommiidites* Erdtman 1948 *Palaeontology*, 4(2): 292-299. 2 pls.

——————— and Moody-Stuart, J. C. 1966. Descriptions of schizaeaceous spores taken from early Cretaceous macrofossils. *Palaeontology*, 9: 274-289, pls. 43-47.

——————————————— 1967. Palynological facies and correlation in the English Wealden. *Rev. Palaeobotan. Palynol.*, 1: 259-268.

——————— and Playford, G. 1961. Palynological reconnaissance of the Lower Carboniferous of Spitsbergen. *Micropalaeontology*, 7(1): 27-44.

Hume, G. S. 1930. The Highwood-Jumping Pound anticline, with notes on Turner Valley, new Black Diamond and Priddis Valley structures, Alberta. *Geol. Survey Canada Summ. Rept.* 1929, pt. B: 1-24.

Hyde, H. A. and Williams, D. A. 1945. (Palynology). *Nature*, 155: 265.

Hyman, L. H. 1940. *The Invertebrata. I. Protozoa*. McGraw-Hill Book Co., New York, USA.

Ibrahim, A. C. 1933. Sporenformen des Aegirhorizonts des Ruhr-Reviers. *Dissertation, Technischen Hochschule zu Berlin*. Konrad Triltsch (privately published), Würzburg. 48 pp.

Jansonius, J. 1962. Palynology of Permian and Triassic sedmiments, Peace River area, Canada. *Palaeontographica*, 110B: 35-98.

Jekhowsky, B. de. 1961. Sur quelques hystrichospheres permo-triasiques d'Europe et d'Afrique. *Rev. Microplaeont.*, 3(4): 207-212; 2 pls.

Jeletzky, J. A. 1956. Paleontology, basis of practical geochronology. *Am. Assoc. Petrol. Geol.*, 40: 679-706.

✓ ——————— 1968. Microfossil zones of the marine Cretaceous of the western interior of Canada and their correlation with the zones and stages of Europe and the western interior of the United States. *Geol. Survey Canada, Paper* 67-72.

Jersey, N. J. de. 1962. Triassic spores and pollen grains from the Ipswich coalfield. *Geol. Survey Queensld. Publ.* 307. 8 pp.; 6 pls.

Just, T. 1951. Mesozoic plant microfossils and their geologic significance. *J. Palaeont.*, 25: 729-735.

Khlonova, A. F. 1961. Spores and pollen of the Upper half of the Upper Cretaceous of the eastern part of the west Siberian lowland. (Russian). Acad. Nauk SSSR, Sib. otd., Trudy Inst. Geol. Geofiz., 7: 3-138; 16 pls.

King, C. 1876. U. S. Geological Exploration of the 40th Parallel., Atlas Map No. 1.

——— 1878. U. S. Geological Exploration of the 40th Parallel. Volume 1.

Kircheimer, F. 1932. On pollen from the Upper Cretaceous Dysodil of Banke, Namaqualand (South Africa), Trans. Roy. Soc. South Africa, 21: 41-50.

Klaus, W. 1960. Sporen der karnischen Stufe der ostalpinen Trias. Jb. Geologischen Bundesanstalt, 5: 107-183.

Knox, E. M. 1938. The spores of Pteridophyta, with observations on microspores in coals of Carboniferous age. Trans. Proc. Botan. Soc. Edinburgh, 32: 438-466.

Kosanke, R. M. 1967. "Miospores in the coal seams of the Carboniferous of Great Britain" - A review. J. Paleont., 42(1): 247-248.

Kremp, G. O. W. 1949. Pollenanalytische Untersuchung des miozänen Braunkohlenlagers von Konin an der Warthe. Paleontographica, 90B: 53-93.

——— 1965. Morphologic Encyclopedia of Palynology. University of Arizona Press, Tucson, Ariz.

Krutzsch, W. 1959. Einige neue Formgattungen und -arten von Sporen und Pollen aus der mitteleuropaischen Oberkreide und dem Tertiar. Palaeontographica, 105B: 125-157.

Kulp, J. R. 1961. Geologic time scale. Science, 133: 1105-1114.

Kuyl, O. S. Muller, J. and Waterbolk, H. T. 1955. The application of palynology to Oil Geology, with special reference to Western Venezuela. Geol. Mijnbouw, 17: 49-75; 8 pls.

Lanjouw, J., ed. 1961. International Code of Botanical Nomenclature. Kemink en Zoon N. V., Utrecht.

——— 1966. International Code of Botanical Nomenclature. Kemink en Zoon N. V., Utrecht.

Lejeune-Carpentier, M. 1937. L'étude microscopique des silex (4ième Note). Une interessante preparation d'Ehrenberg. Ann. Soc. Géol. Belg., 61(2/3): 59-71; 2 pls.

Lejeune-Carpenter, M. 1946. L'étude microscopique des silex (12ième Note). Espèces nouvelles ou douteuses de *Gonyaulax*. *Ann. Soc. Géol. Belg.*, 69(4): 187-197 Text-figs. 1-5.

Leopold, E. B. and Pakiser, H. M. 1964. Studies of pre-Selma Cretaceous core samples from the outcrop area in Western Alabama. E. A preliminary report on the pollen and spores of the pre-Selma Upper Cretaceous strata of Western Alabama. *U. S. Geol. Survey, Bull.* 1160E: 71-95; pls. 3-9.

Loeblich, A. R., Jr. 1968. "Katalog der Fossilen Dinoflagellaten...etc. 1. Erganzunglieferung". by A. Eisenack, 1967. A Review. *J. Paleont.*, 42(2): 607-608.

____________________ and Loeblich, A. R. III. 1968. Index to the genera, subgenera, and sections of the Pyrrhophyta, II. *J. Paleont.*, 42(1): 210-213.

Maier, D. 1959. Planktonuntersuchungen in teriären und quatären marinen Sedimenten. *Neu. Jb. Geol. Paläont., Abh.* 107(3): 278-340; 7 pls.

Malyavkina, V. S. 1949. Identification of spores and pollen (Jurassic and Cretaceous). (Russian). *Trudy VNIGRI*, n. s. No. 33.

Manum, S. 1962. Studies in the Tertiary flora of Spitsbergen, with notes on tertiary floras of Ellesmere Island, Greenland and Iceland. *Norsk Polarinst. Skrift.*, 125. 127 pp.; 21 pls.

Manum, S. and 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. *Norske Vidensk, Acad. Oslo. I. Mat.-Naturv. Klasse, Ny. Serie*, No. 17: 36p.; 7 pls.

McConnell, R. G. 1893. Report on a portion of the district of Athabaska, comprising the country between Peace River and Athabaska River north of Lesser Slave Lake, Canada. *Geol. Survey Canada, Ann. Rept*, 5, pt. D.

McLearn, F. H. 1944. Revision of the Lower Cretaceous of the western interior of Canada. *Canada Geol. Survey Paper* 44-17.

Mellon, G. B. and Wall, J. H. 1963. Correlation of the Blairmore Group and equivalent strata. *Bull. Can. Soc. Petrol. Geol.*, 11(4): 396-409.

Merrill, J. A. 1895. Fossil sponges of the flint nodules in the Lower Cretaceous of Texas. *Bull. Mus. Comp. Zool. Harv. (Geol. Ser. III)*, 28(1): 1-26; 1 pl.

Mills, F. C. 1955. *Statistical Methods*. 3rd ed. Henry Holt & Co., New York, N. Y.

Miner, E. L. 1932. Megaspores ascribed to *Selaginellites* from the Upper Cretaceous coals of Western Greenland. *J. Wash. Acad. Sci.*, 27: 497-506.

——— 1935. Paleobotanical examinations of Cretaceous and Tertiary coals. *Amer. Midl. Nat.*, 16(4): 585-621.

Muller, J. 1959. Palynology of recent Orinoco delta and shelf sediments. *Microplaeontology*, 5(1): 1-32.

——— 1968. Palynology of the Pedawan and Plateau Sandstone Formations (Cretaceous - Eocene) in Sarawak, Malaysia. *Micropaleontology*, 14(1): 1-37; 5 pls.

Naumova, S. N. 1939. Spores and pollen of the coals of the U. S. S. R. *17th Intern. Geol. Congr., Absts. Papers, U. S. S. R.* Chief Editorial Office, Mining-fuel and Geol.-Prospecting literature: 60-61.

——— 1953. Sporo-pollen complexes of the Upper Devonian of the Russian Platform and their stratigraphic significance. (Russian). *Trudy Inst. Geol. Nauk AN SSSR*, 143 (*Geol. Ser.* 60): 204 pp.

Nauss, A. W. 1945. Cretaceous stratigraphy of Vermillion area, Alberta, Canada. *Bull. Am. Assoc. Petrol. Geol.* 29(11): 1605-1629.

Neale, J. W. and Sarjeant, W. A. S. 1962. Microplankton from the Speeton Clay of Yorkshire. *Geol. Mag.*, 99(5): 439-458; 2 pls.

Newell, N. D. 1962. Paleontological gaps and geochronology. *J. Paleont.*, 36: 592-610.

Nilsson, T. 1958. Über das Vorkommen eines mesozoischen Sapropelgesteins in Schonen. *Lunds Univ. Arsskr., N. F., Avd.* 2, 54:111 pp.; 8 pls.

Norem, W. L. 1953. Separation of spores and pollen from siliceous rocks. *J. Paleont.*, 27: 881-888.

Norris, G. 1965. Archeopyle structures in Upper Jurassic dinoflagellates from southern England. *N. Z. J. Geol. Geophys.*, 8(5): 792-806.

——— 1967. Spores and pollen from the Lower Colorado Group (Albian-?Cenomanian) of Central Alberta. *Palaeontographica*, 120B: 73-115; pls. 10-18.

——— and Sarjeant, W. A. S. 1965. A descriptive index of genera of fossil Dinophyceae and Acritarcha. *N. Z. Geol. Survey Paleont. Bull.* 40-72 pp.

Norris, R. E. 1966. Unarmoured marine dinflagellates. *Endeavor*, 25(96): 124-128; 19 figs.

Obonitskaya, E. K. 1966. On the systematics and development of spores of the genus *Taurocusporites* Stover in Cretaceous deposits of Central Kizilkum and Southern Priaralie. (Russian, English summ.) *In*: The Importance of Palynological Analysis for the Stratigraphic and Paleofloristic Investigations. Nauca. Moscow, USSR. 1966: 97-103; 1 pl.

✓ Pannella, G. 1966. Palynology of the Dakota Group and Graneros shale of the Denver Basin. *Thesis*, University of Colorado. 1966. 173 pp.; 39 pls.

Pant, D. D. 1954. Suggestions for the classification of fossil spores and pollen. *Bot. Rev.*, 20: 33-53.

Pettijohn, F. J. 1949. *Sedimentary Rocks*. Harper & Brothers, New York, N. Y., USA.

Pierce, R. L. 1961. Lower Upper Cretaceous plant microfossils from Minnesota. *Univ. Minn., Minn. Geol. Survey Bull.*, 42: 1-86. 3 pls.

Playford, G., 1962. Lower Carboniferous spores of Spitsbergen. I. *Palaeontology*, 5, pt. 3: 550-618; 10 pls.

____________ 1963a. Lower Carboniferous spores of Spitsbergen. II *Palaeontology*, 5, pt. 4: 619-678; 8 pls.

____________ 1963b. Miospores from the Mississippian Horton Group, Eastern Canada. *Geol. Survey Canada Bull.* 107: 1-47; 11 pls.

____________ and Dettmann, M. E. 1965. Rhaeto-Liassic plant microfossils from the Leigh Creek coal measures, South Australia. *Senck. leth.*, 46(2/3): 127-181; 6 pl.

Pocock, S. A. J. 1962. Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canadian plains. *Palaeontographica*, 111B: 1-95; 15 pls.

______________ 1964. Pollen and spores of the Chlamydospermidae and Schizaeaceae from Upper Manville strata of the Saskatoon, area of Saskatchewan. *Grana Palynol.*, 5(2): 129-209.

______________ and Jansonius, J. 1961. The pollen genus *Classopollis* Pflug. *Micropaleontology*, 7(4): 439-449; 1 pl.

Potonie, R. 1931. Pollenformen aus Tertiären Braunkohlen. *Jb. Preuss. Geol. Landesanstalt*, 52: 1-7.

Potonié, R. 1951. Revision stratigraphisch wichter sporomorphen des mitteleuropäischen Tertiars. *Palaeontographica*, 91B: 131-151.

__________ 1956. Synopsis der Gattungen der Sporae dispersae. I. Teil: Sporites. *Beih*. *Geol*. Jb., 23. 103 pp.

__________ 1958. Synopsis der Gattungen der Sporae dispersae II. Teil: Sporites (Nachträge), Saccites, Aletes, Praecolpates, Polyplicates, Monocolpates. *Beih*. *Geol*. *Jb*., 31. 114 pp.

__________ 1960. Synopsis der Gattungen der Sporae dispersae III. Teil: Nachträge Sporites, Fortsetzung Pollenites mit Generalregister zu Teil I-III. *Beih*. *Geol*. *Jb*., 39. 189 pp.

__________ 1962. Synopsis der Sporae *in* *situ*. *Beih*. *Geol*. *Jb*., 52. 204 pp.

__________ 1966. Synopsis der Gattungen der Sporae dispersae. IV. Teil: Nachträge zu allen Gruppen (Turmae). *Beih*. *Geol*. Jb., 72. 244 pp.

__________ and Kremp, G. O. W. 1954. Die Gattungen der Paläozoischen Sporae dispersae und ihre Stratigraphie. *Geol*. *Jb*., 69: 111-194.

____________________ 1955. Die Sporae disperae des Ruhrkarbons. Teil I. *Palaeontographica*, 97B: 1-136.

____________________ 1956a. Die Sporae disperae des Ruhrkarbons. Teil II. *Palaeontographica*, 99B: 86-191.

____________________ 1956b. Die Sporae dispersae des Ruhrkarbons. Teil III. Palaeontographica, 100B: 76-121.

__________ Thomson, P. W. and Thiergart, F. 1951. Zur Nomenklatur und Klassification der neogenen Sporomorphae (Pollen und Sporen). *Geol*. *Jb*., 65: 35-69.

Radforth, N. W. and Rouse, G. E. 1954. The classification of recently discovered Cretaceous plant microfossils of potential importance to the stratigraphy of Western Canada coals. *Can*. *J*. *Bot*., 32: 187-201.

Raistrick, A. and Simpson, J. 1933. The microspores of some Northumberland coals, and their use in the correlation of coal seams. *Trans*. *Instn*. *Min*. *Engrs*. *Lond*., 85: 225-235 and 86: 55.

Reade, J. B. 1839. On some new organic remains in the Flink of Chalk. *Ann*. *Nat*. *Hist*., 2: 191-198; 2 pls.

Ross, Nils-Erik 1949. On a Cretaceous pollen- and spore-bearing clay of Scania: a preliminary report. *Bull. Geol. Inst. Uppsala*, 34: 25-43.

Rossignol, M. 1963. Aperçus sur le developpement des Hystrichosphères. *Bull. Mus. Nat. Hist. Natur.*, 35(2): 207-212.

Rouse, G. E. 1956. The disclosure and palaeobotanical evaluation of plant microfossils from selected Cretaceous coal-bearing strata of Canada. *Thesis*, McMaster University, Hamilton, Ontario, Canada. 304 pp.; 14 pls.

____________ 1957. The application of a new nomenclatural approach to Upper Cretaceous plant microfossils from Western Canada. *Can. J. Bot.*, 35: 349-375.

____________ 1959. Plant Microfossils from Kootenay coal-measures strata of British Columbia. *Micropaleontology*, 5(3): 303-324.

Rudkin, R. A. 1964. Lower Cretaceous. *In*: McCrossan, R. G. and Glaister, R. P., ed. *Geological History of Western Canada*. Alberta Society of Petroleum Geologists: 156-168.

Samoilovich, S. R., *et al*. 1961. Pollens et spores de la Siberie Occidentale, Jurassique-Paleocene. *Trudy VNIGRI*, No. 177. (Russian, in French transl.).

Sarjeant, W. A. S. 1966. Dinoflagellate cysts with *Gonyaulax*-type tabulation. *In*: Davey *et al*., 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts, *Bull. Brit. Mus. (Natural Hist.) Geol., Supp.* 3: 107-156.

__________________ 1966. Further dinoflagellate cysts from the Speeton Clay (Lower Cretaceous). *In*: Davey, *et al*., 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. Brit. Mus. (Natural Hist.) Geol., Supp.* 3: 199-214.

__________________ 1967. The genus *Palaeoperidinium* Deflandre (Dinophyceae). *Grana Palynol.*, 7(1): 241-258; figs. 1-6.

__________________ 1967. The stratigraphical distribution of fossil dinoflagellates. *Rev. Palaeobotan. Palynol.*, 1: 323-343.

__________________ and Downie, C. 1966. The classification of dinoflagellate cysts above generic level. *Grana Palynol.*, 6(3): 503-527.

Sarmiento, R., 1957. Microfossil zonation of the Mancos Group. *Bull. Am. Assoc. Petrol. Geolog.*, 41: 1683-1693.

Schemel, M. P. 1950. Cretaceous plant microfossils from Iowa. *Am. J. Bot.*, 37(9): 750-754.

Schopf, J. M. 1938. Spores from the Herrin (No. 6) Coal Bed in Illinois. *Ill. Geol. Survey Rept. Invest.* 50.

____________, Wilson, L. R. and Bentall, R. 1944. An annotated synopsis of Palaeozoic fossil spores and the definition of generic groups. *Ill. St. Geol. Survey, Rept. Inves.* No. 91.

Scott, R. A., Barghoorn, E. S., and Leopold, E. S. 1960. How old are the angiosperms? *Amer. J. Sci.*, Bradley Volume, 258A: 284-299.

Shaw, A. B., 1964. *Time in Stratigraphy*. McGraw-Hill Book Company, Toronto. 365 pp.

Siegal, S. 1956. *Nonparametric Statistics for the Behavioural Sciences*. McGraw-Hill Book Co., Inc. New York, N. Y. USA.

Simoncsics, P. and Kedves, M. 1961. Palaeobotanical examinations on Manganese Series in Urkut (Hungary, Transdanubia). *Acta Universitatis Szegediensis, Acta Mineral.-Petrogr.* 14: 27-57.

Simpson, J. 1936. Fossil pollen in Scottish Tertiary coals. *Proc. Roy. Soc. Edinburgh*, 56: 90-108.

Singh, C. 1964. Microflora of the Lower Cretaceous Mannville Group, east-central Alberta. *Res. Coun. Alberta Bull.* 15. 238 pp; 28 pl.

Skarby, A. 1964. Revision of *Gleicheniidites senonicus* Ross. *Acta Universitatis Stockholmensis, Stock. Contrib. Geol.* XI: 59-77.

Smith, A. H. V. and Butterworth, M. A. 1967. Miospores in the Coalseams of the Carboniferous of Great Britain. *Special Papers in Palaeontology No. 1.* The Palaeontological Association, London, 324 pp.; 27 pls.

Srivastava, S. K. 1966. Upper Cretaceous microflora (Maestrichtian) from Scollard, Alberta, Canada. *Pollen et Spores*, 8(3): 497-552.

Srivastava, S. K. 1967a. Palynology of Late Cretacous mammal beds, Scollard, Alberta, Canada. *Palaeogeo. Palaeoclim. Palaeoecol.*, 3(1): 133-150, 3 pls.

____________ 1967b. Upper Cretaceous palynology; a review. *Bot. Rev.*, 33(3): 260-288.

Srivastava, S. K. 1968. Ephedralean pollen from the Upper Cretaceous Edmonton Formation of Alberta (Canada) and their palaeoecological significance. *Can. J. Earth Sci.*, 5(2): 211-221; 1 pl.

Stafleu, F. 1966. Tenth International Botanical Congress, Report Nomenclature Section. *Regnum Veget.*, 44.

Stanley, E. A. 1965. Upper Cretaceous and Paleocene plant microfossils and Paleocene dinoflagellates and hystrichosphaerids from northwestern South Dakota. *Bull. Amer. Paleont.*, 49(222): 1-384. 49 pl.

Staplin, F. L. Jansonius, J. and Pocock, S. A. J. 1965. Evaluation of some acritarchous hystrichosphere genera. *Neu. Jb. Geol. Paläont. Abh.* 123(2): 167-201; 3 pls.

Stelck, C. R. 1958. Stratigraphic position of the Viking sand. *Jour. Alberta. Soc. Petrol. Geol.* 6(7): 2-7.

__________, Wall, J. H., Bahan, W. G. and Martin, L. J. 1956. Middle Albian foraminifera from Athabaska and Peace River drainage areas of western Canada. *Alberta Research Council, Rept.* 75.

____________________ and Wetter, R. E. 1958. Lower Cenomanian foraminifera from Peace River area, Western Canada. *Alta. Res. Council, Geol. Div., Bull.* 2, pt. 1: 1-35; pl 1-4.

Stockmans, F. and Williere, Y. 1960. Hystrichosphères du Dévonien belge (Sondage de l'Asile d'aliénés a Tournai). *Senck. leth.*, 4(1- 6): 1-11; 2 pls.

Stover, L. E. 1962. *Taurocusporites*, a new trilete spore genus from the Lower Cretaceous of Maryland. *Micropaleontology*, 8(1): 55-59. 1 pl.

__________ 1963. Some middle Cretaceous palynomorphs from West Africa. *Micropaleontology*, 9(1): 85-94. 2 pls.

__________ 1964. Comparison of three Cretaceous spore-pollen assemblages from Maryland and England. *Palynology in Oil Exploration, S. E. P. M. Spec. Publ.* No. 11; 143-152.

Tappan, H. and Loeblich, A. R. Jr. 1965. Foraminiferal remains in palynological preparations. *Rev. Micropal.*, 8(2): 61-63.

Tappan, H. and Loeblich, A. R. Jr., 1967. "Studies on Mesozoic and Cainozoic Dinoflagellate Cysts", by R. J. Davey *et al.* Review. *J. Paleont.*, 41(4): 1030-1033.

Tasch, P. McClure, K. and Oftedahl, O. 1964. Biostratigraphy and taxonomy of a hystrichosphere dinoflagellate assemblage from the Cretaceous of Kansas. *Micropaleontology*, 10: 189-206; 3 pls.

Thiergart, F. 1949. Der Stratigraphische wert mesozoischer Pollen und Sporen. *Palaeontographica*, 89B: 1-33.

Thomson, P. W. and Pflug, H. 1953. Pollen und Sporen des mitteleuropäischen Tertiärs. *Palaeontographica*, 94B: 1-138; pls. 1-15.

Traverse, A. 1955. Pollen analysis of the Brandon Lignite of Vermont. *Bureau of Mines*, *Rept. Inves.* No. 5151.

—————— and Ginsberg, R. N. 1966. Palynology of the surface sediments of the Great Bahama Bank, as related to water movement and sedimentation. *Mar. Geol.*, 4(6): 417-459; 1 pl.

Tschudy, R. H., 1964. Palynology and time-stratigraphic determinations. *Palynology in Oil Exploration* *S. E. P. M. Spec. Publ.* No. 11: 18-28.

—————— and Veach, S. D. 1965. Plant and miscellaneous microfossils from the Thermopolis and Mowry shale. *U. S. G. S. Rept.*, *Open-file ser.* No. 806, 6 pp.; 4 pl.

Upshaw, C. F. 1964. Palynological zonation of the Upper Cretaceous Frontier Formation near Dubois, Wyoming. *Palynology in Oil Exploration*, *S. E. P. M. Spec. Publ.* No. 11: 153-168.

Valensi, L. 1955. Étude micropaléontologique des silex du Magdalénien de Saint-Armand (Cher). *Soc. Préhist. Fr.*, *Bull.*, 52(9/10): 584-596; 5 pls.

Valentine, J. W. and Mallory, B. 1965. Recurrent groups of bonded species in mixed death assemblages. *J. Geol.* 73: 683-701.

Vavrdova, M. 1964. Fossil microplankton from the Tesin-Hridiste series (Lower Cretaceous). Part I. Dinoflagellates. *Czech. Acad. Ved*, *Sbornik Geolgickych Ved*, *Rada Palaeontology*, P4: 91-104; 4 pls.

Vozzhennikova, T. F. 1961. A contribution to the problem of the taxonomy of fossil Peridinae. (Russian). *Dokl. Acad. Nauk. S. S. S. R.*, 139(6): 1461-1462.

Vozzhennikova, T. F. 1965. Introduction to the study of fossilized peridinid algae. (Vvedenie v izuchenie iskopaemykh peridineevykh vodoroslei). (Russian - English translation by K. Syers; ed. W. A. A. Sarjeant, issued 1967). *Nat. Lending Lib. Sci. Tech.*, Boston Spa, Yorkshire, England.

Wall, D. 1962. Evidence from recent plankton regarding the biological affinities of *Tasmanites* Newton 1875 and *Leiosphaeridia* Eisenack 1958. *Geol. Mag.*, 99(4): 353-362; 1 pl.

________ 1965. Microplankton, pollen and spores from the Lower Jurassic in Britain. *Micropaleontology*, 11(2): 151-190, pls. 1-9; 7 tables.

________ 1965. Modern hystrichosphere and dinoflagellate cysts from the Woods Hole region. *Grana Palynol.*, 6(2): 297-314.

________ and Dale, B. 1967. The resting cysts of modern marine dinoflagellates and their palaeontological significance. *Rev. Palaeobotan. Palynol.*, 2: 349-354; 1 pl.

_______ and Downie, C. 1963. Permian hystrichospheres from Britain. *Palaeontology*, 5(4): 770-784; 3 pls.

_______ Guillard, R. R. L. and Dale, B. 1967. Marine dinoflagellate cultures from resting spores. *Phycologia*, 6(2/3): 83-86, Figs, 1-4.

Wall, J. H. 1967. Cretaceous foraminifera of the Rocky Mountain foothills, Alberta. *Res. Council Alberta, Bull.* 20. 185 p; 19 pls.

Warren, P. S. and Stelck, C. R. 1958. Lower Cenomanian Ammonoidea and Pelycepoda from Peace River area, Western Canada. *Res. Council Alta., Geol. Div. Bull.* 2, pt. 2: 36-51; pls. 5-16.

Webb, J. B. 1964. Historical Summary. *In*: McCrossan, R. G. and Glaister, R. P., eds. *Geological History of Western Canada, Alberta Soc. Petrol. Geol.* 1964: 218-232.

Wetzel, O. 1926a. Die paläontologischen Befund im Feuerstein unter dem Mikroskop. *Mikrokosmos*, 19: 114-117; 12 text-figs.

__________ 1926b. Die farbenden und mineralischen Einschlüsse des Feuersteins. *Mikrokosmos*, 20: 42-44.

__________ 1932. Die Typen der baltischen Geschiebefeuersteine beurteilt nach ihrem Gehalt an Mikrofossilien. *Z. Geschiebeforsch.* 8: 129-146; 3 pls.

Wetzel, O. 1933. Die in organischer Substanz erhaltenen Mikrofossilien des baltischen Kreide-Feuersteins mit einem sediment-petrographischen und stratigraphischen Anhang. *Palaeontographica*, 77: 141-186 and 78A: 1-110

__________ 1922. Sediment - petrographischen Studien. 1. Feuerstein. *N. Jb. Mineral., u. s. w., Beil.*, 47: 39-92; 1 pl.

Weyland, H. 1951. Pflanzliche Makro- und Mikrofossilien aus dem untersenonen Ton von Quedlinburg. *Palaeont. Z.*, 24: 165.

__________ and Greifeld, G. 1953. Überstrukturbietende Blätter und pflanzliche Mikrofossilien aus dem untersenon Tonen der Gegend von Quedlinburg. *Palaeontographica*, 95B (1-3): 30-52; 8 pl.

__________ and Kreiger, W. 1953. Die Sporen und Pollen der Aaachener Kreide und ihre Bedeutung für die Charakterisierung des Mittleren Senons. *Palaeontographica*, 95B: 6-27.

Wickenden, R. D. T. 1949. Some Cretaceous sections along Athabaska River from the mouth of Calling River to below Grand Rapids, Alberta. *Geol. Survey Can.* Paper 49-15.

__________ 1951. Some Lower Cretaceous sections on Peace River below the mouth of Smoky River. *Geol. Survey Can.* Paper 51-16.

Williams, D. B. and Sarjeant W. A. S. 1967. Organic-walled microfossils as depth and shoreline indicators. *Marine Geology*, 5(5-6): 389-412.

Williams, G. L. 1963. Organic-walled microplankton of the London Clay. *Thesis*, University of Sheffield, Sheffield, England. 423 pp.

Wilson, L. R. 1946. The correlation of sedimentary rocks by fossil spores and pollen. *J. Sed. Petrol.* 16(3): 110-130.

__________ and Hoffmeister, W. S. 1952. Small foraminifera. *The Micropaleontologist*, 6: 26-28.

__________ and Webster, R. M. 1946. Plant microfossils from a Fort Union Coal of Montana. *Am. J. Bot.*, 33: 271-278; 2 pls.

Winslow, M. R. 1959. Upper Mississippian and Pennsylvanian megaspores and other plant microfossils from Illinois. *Ill. Geol. Survey Bull.* 86. 135 pp.

Wodehouse, R. P. 1935. *Pollen Grains*. McGraw-Hill Book Co., Inc.: 3rd printing, Facsimile of the 1935 edition.

Workman, L. E. 1959. The Blairmore Group in the subsurface of Alberta. Alberta Soc. Petrol. Geol. Guidebook, 9th Ann. Field Conf.: 122-129.

Zaklinskaya, E. D. 1962. The importance of angiosperm pollen for the stratigraphy of Upper Cretaceous and Lower Paleogene deposits and botanical-geographical provinces at the boundary between the Cretaceous and Tertiary systems. (Russian, Eng. summ.). First Intern. Conf. Palin. Tucson Rep. Sov. Palin. Akad Nauk S. S. S. R. Geol. Inst.: 105-113.

________________ 1963. The pollen of angiosperms and its significance in providing a basis for the stratigraphy of Upper Cretaceous and Paleogene strata. (Russian). Trudy Inst. Geol., 74; 258pp.; 44 pls.

## ADDENDUM

Pettitt, J. M. and Chaloner, W. G. 1964. The ultrastructure of the Mesozoic pollen *Classopollis*. Pollen et Spores, 6(2): 611-620; 1 pl.

Cookson, I. C. and Dettmann, M. E. 1958. Some trilete spores from Upper Mesozoic deposits in the eastern Australian region. Proc. Roy. Soc. Vict., 70: 95-128.

____________________________ 1959. Corrigenda to 'Some trilete spores...etc.'. Proc. Roy. Soc. Vict., 71(2): 138.

Krutzsch, W. 1963. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplankton-formen des nördlichen Mitteleuropas. Zentr. Geol. Inst. Berlin VEB Dtsch. Verl. Wiss. 1-3.

Pokrovskaya, I. M. and Stel'mak, N. K. (eds.) 1964. Atlas of Lower Cretaceous spore-pollen assemblages of the U.S.S.R. (Russian). VSEGEI, n.s., 124. 552pp., 69 pls.

Scott, R. A. 1960. Pollen of *Ephedra* from the Chinle Formation (Upper Triassic) and the genus *Equisetosporites*. Micropaleontology, 6: 271-276.

# APPENDIX I

## PLATES AND PLATE LEGENDS

All photographs are unretouched and are printed at a magnification of X500 unless otherwise noted.

Maceration, slide number and coordinates are given for all figured specimens with the exception of holotype specimens. These latter are given in the text (Part Two, Chapter III) under their appropriate headings.

## Plate 1

Figure 1. *Stereisporites antiquasporites* (Wilson & Webster) Dettmann, BW117/1: 542 - 949

2. *Stereisporites* sp. A., BW106/2: 203 - 1005.

3. *Stereisporites* sp. B., BW150/1: 505 - 1048.

4. *Deltoidospora juncta* (Kara-Murza) Singh, BW127/1: 514 - 1013.

5. *Dictyophyllidites* sp. A., BW106/2: 190 - 1019.

6. *Neoraistrickia truncata* (Cookson) Potonié, BW185/1: 499 - 1037.

7. *Neoraistrickia*? sp. A., BW122/1: 502 - 992.

8. *Acanthotriletes* sp. B., BW134/2: 450 - 1004.

9. *Todisporites major* Couper, BW181/3: 519 - 1071.

10. *Cyathidites major* Couper, BW107/3: 174 - 1093.

11. *Todisporites minor* Couper, several specimens from a closely associated spore mass, BW138/2: 365 - 1009.

12. *Cyathidites minor* Couper, BW80/2: 527 - 950.

13. *Deltoidospora hallei* (Miner) Potonié, BW79/2: 232 - 1034.

14. *Undulatisporites* cf. *U. undulapollis* Brenner, Imp. Oil Ltd. Slide 10-351/3: 323 - 1028.

15. *Baculatisporites comauensis* (Cookson) Potonié, BW113/2: 488 - 1125, X1000.

16. *Concavissimisporites variverrucatus* (Couper) Singh, BW170/1: 484 - 1111.

17. *Acanthotriletes varispinosus* Pocock, BW148/3: 524 - 999.

18. Cf. *Raistrickia* sp. A., BW123/1: 604 - 983.

19-21. *Biretisporites potoniae* Del. & Sprum.; 19-20. Proximal focus at two levels showing (19) raised membranous lips and (2) commissure on same specimen, BW152/3: 362 - 1003. (21) Equatorial view showing raised lips, BW154/3: 588 - 970.

Plate 1 Cont'd

Figure 22-23 and 28. *Acanthotriletes* sp. A.; 222-23. Proximal and distal foci on same specimen, BW145/1: 302 - 1013. 28. Proximal focus showing development of interradial crassitudes, BW189/1: 307 - 1027. All figures X1000.

Figure 24. *Biretisporites* cf. *B*. *deltoidus* (Rouse) Dettmann, BW103/1: 141 - 1116.

25. *Concavissimisporites punctatus* (Del. & Sprum.) Singh, BW120/1: 660 - 968.

26. *Deltoidospora psilostoma* Rouse, BW135/1: 614 - 995.

27. *Pilosisporites trichopapillosus* (Thiergart) Del. & Sprum., BW112/1: 597 - 1059.

29. *Cyclogranisporites* sp. A., proximal focus, BW138/2: 232 - 1016.

30. *Converrucosisporites* sp. A., BW137/1: 264 - 1035.

31 and 37. Cf. *Converrucosisporites* sp. C. (31) Proximal focus showing thickened margo. (37) Distal focus, same specimen showing fused verrucae; BW113/1: 566 - 1045.

32. *Foveosporites* cf. *F*. *canalis* Balme, BW183/3: 665 - 1049.

33. *Taurocusporites reduncus* (Bolk.) Stover, BW178/1: 671 - 973.

34. *Osmundacidites wellmanii* Couper, BW134/1: 456 - 980.

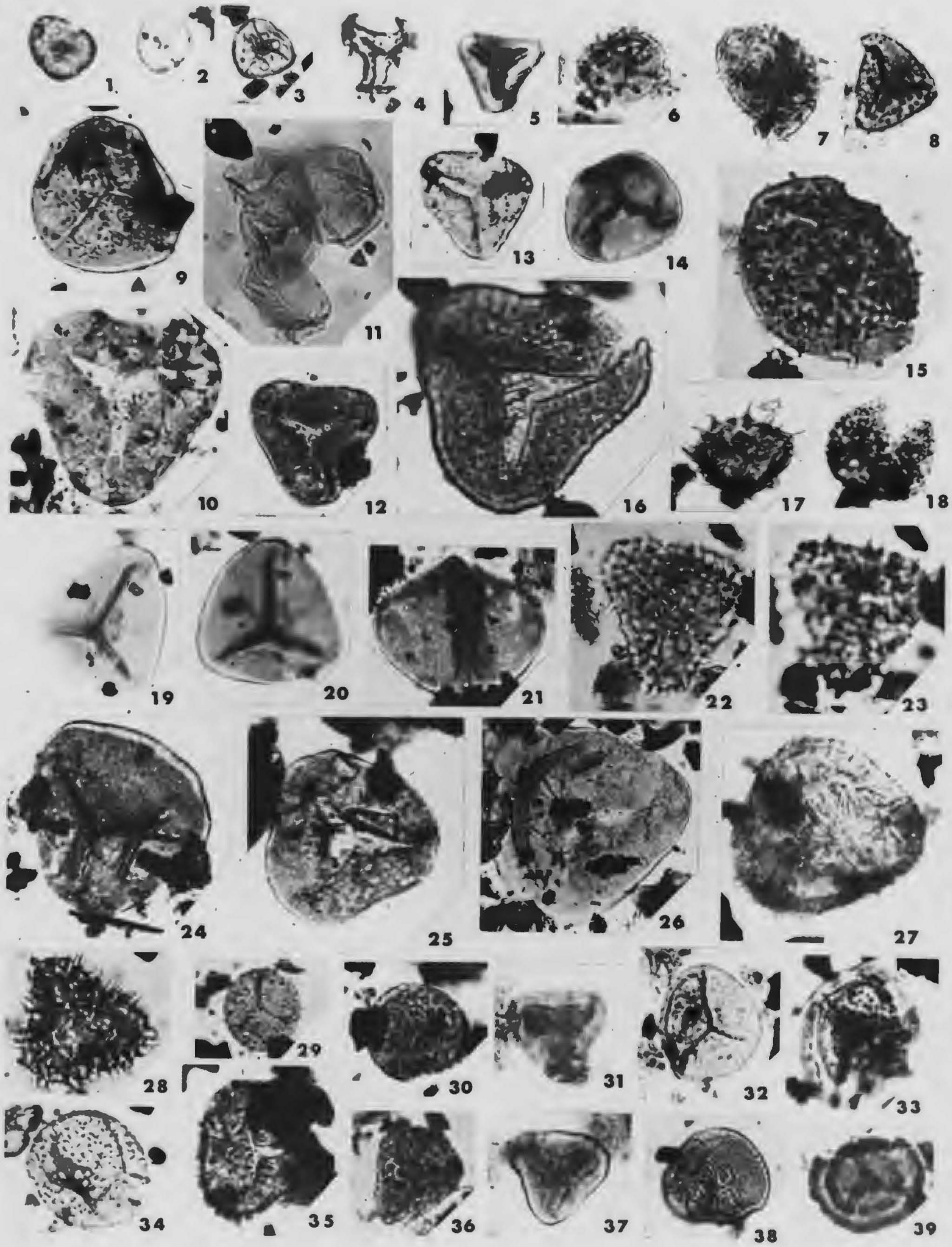
35. *Pilosisporites verus* Del. & Sprum., BW138/2: 592 - 1018.

36. *Converrucosisporites* sp. B., BW145/1: 605 - 1005.

38. *Lycopodiacidites* sp. A., BW185/1: 441 - 964.

39. *Taurocusporites segmentatus* Stover, BW178/1: 671 - 973.

1


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39

## Plate 2

Figure 1. *Pilosisporites trichopapillosus* (Thiergart) Del. & Sprum., BW139/1: 608 - 1110.

2. *Klukisporites variegatus* Couper, BW101/2: 377 - 1055.

3-4. *Cicatricosisporites* sp. A. (3) distal focus and (4) proximal focus showing raised laesurae; both X1000. BW105/2: 553 - 983.

5. *Taurocusporites minor* Singh, BW174/3: 409 - 1046.

6-7. *Dictyotriletes* sp. A. (6) Proximal focus showing ridge-like laesurae and (7) distal focus showing distal polar thickening and reticulum, same specimen; BW179/2: 410 - 987.

8. *Lycopodiumsporites marginatus* Singh, BW139/1: 612 - 977.

9 and 10. *Tigrisporites scurrandus* Norris. (9) distal focus showing distal polar thickening and rugulae, BW177/1: 632 - 1077. (10 proximal focus showing laesurae and rare proximal rugulae, BW170/1: 425 - 1124.

11. *Lycopodiumsporites austroclavatidites* (Cookson) Potonié, BW117/1: 280 - 996.

12. *Tigrisporites* sp. A., BW135/2: 336 - 958.

13. *Lycopodiumsporites reticulumsporites* (Rouse) Dettmann, BW151/3: 540 - 1130.

14. *Cicatricosisporites australiensis* (Cookson) Potonié, BW68/1: 366 - 937.

15-16. *Cicatricosisporites* sp. C. (15) Proximal focus showing raised laesurae and (16) distal focus showing distal muri pattern. BW134/1: 617 - 1041.

17. *Apiculatisporis*? sp. A., BW101/2: 447 - 975; proximal focus, X1000.

18 and 29. *Cicatricosisporites minutaestriatus* (Bolk.) comb. nov. (18) BW105/2: 498 - 1027, distal focus showing distal muri pattern, X1000. (29) BW178/1: 649 - 1039, proximal focus showing muri, laesurae and smooth contact area.

19-20. *RETICULISPORITES NORRISII* sp. nov. Holotype. (19) distal focus showing imperfect reticulum with elongate to irregularly shaped lumina (20) Proximal focus showing smooth contact region, muri confined to radial region.

Plate 2 cont'd

Figure 21-22. Proximal and distal foci respectively of unidentified verrucate trilete miospore. BW145/1: 593 - 973; X1000.

23. *Cicatricosisporites hughesi* Dettmann, BW182/2: 506 - 1098.

24 and 37. *Cicatricosisporites pseudotripartitus* (Bolk.) Dettmann. (24) BW187/1: 515 - 971. (37) Equatorial view, BW126/2: 534 - 1089.

25-26. *Appendicisporites* cf. *A. crimensis* (Bolk.) Pocock. (25) Proximal (26) distal focus of same specimen, BW135/2: 533 - 1047.

27. *Appendicisporites perplexus* Singh, BW167/1: 447 - 1115.

28 and 30. *Cicatricosisporites perforatus* (Baranov, *et al.*) Singh. (28) Proximal focus, BW182/2: 371 - 1010 and (30) Distal focus showing arcuate muri pattern, BW79/2: 306 - 1035, X1000.

31. *Cicatricosisporites* sp. B., BW138/2: 229 - 1073, showing widely spaced muri.

32-33. *Lycopodiumsporites*? sp. A. (32) Distal and (33) proximal foci showing sinuous lumina, both X1000. BW85/3: 516 - 1025.

34. *Cicatricosisporites* cf. *C. sewardi* Del. & Sprum., BW150/1: 421 - 967.

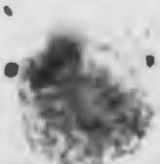
35. *Klukisporites pseudoreticulatus* Couper, BW137/1: 559 - 971.

36. *Microreticulatisporites uniformis* Singh, BW138/1: 304 - 1026.

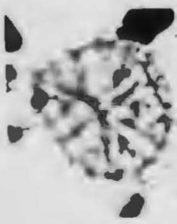

1

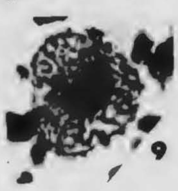

3

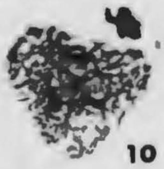

5


6


7


8

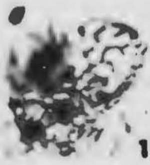

9


10


2

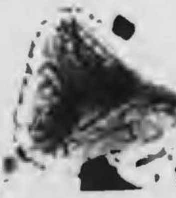

4

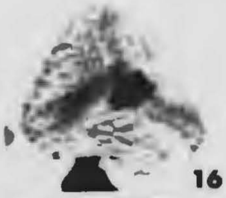

11


12


13


14


15


16


17


18

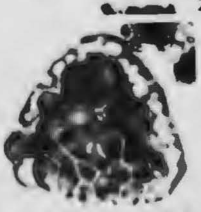

21

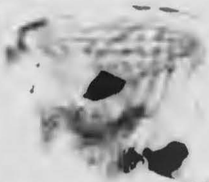

23


24


19

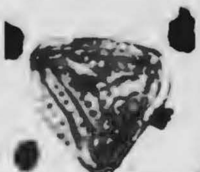

20


22

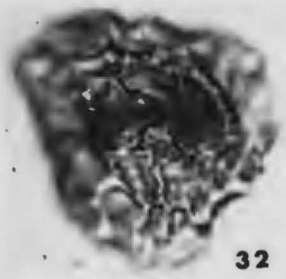

25


26


27

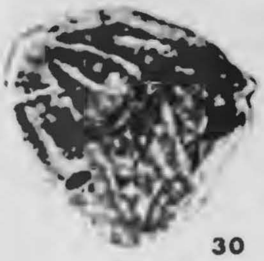

28


31

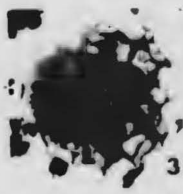

32

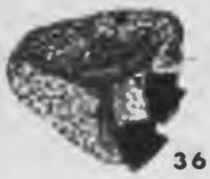

33


29


30


34


35


36


37

## Plate 3

Figure 1. *Trilobosporites* sp. A., BW106/2: 468 - 951.

2. *Trilobosporites apiverrucatus* Couper, BW147/2: 640 - 1074.

3. *Trilobosporites marylandensis* Brenner, BW170/1: 540 - 954.

4. *Trilobosporites* cf. *T. trioreticulosus* Cooks. & Dettm., BW112/1: 162 - 1084, portion of specimen showing sculpture, X1000.

5-6. *Camarozonosporites insignis* Norris. (5) Proximal focus showing smooth contact region and tricrassate structure and (6) distal focus showing rugulae, both X1000. BW190/1: 585 - 1111.

7. *Appendicisporites* sp. A., BW79/2: 543 - 1056, X1000.

8-9. *Sestrosporites pseudoalveolatus* (Couper) Dettmann. (8) Distal and (9) proximal foci of the same specimen, X1000. BW113/2: 583 - 1059.

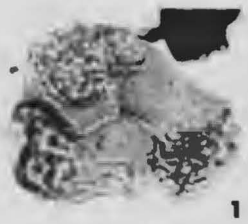
10-11. *Appendicisporites* sp. B. (10) distal and (11) proximal foci showing muri pattern, X1000. BW72/1: 271 - 1072.

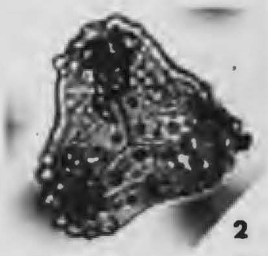
12. *Appendicisporites* cf. *A. matesovai* (Bolk.) Norris, BW112/2: 406 - 1130.

13-14 and 17. *Gleicheniidites senonicus* (Ross) Skarby. (13) BW106/2: 559 - 1128, (14) BW103/1: 530 - 1024, (17) BW122/1: 320 - 959 showing the variation in development of interradial crassitudes. All X1000.

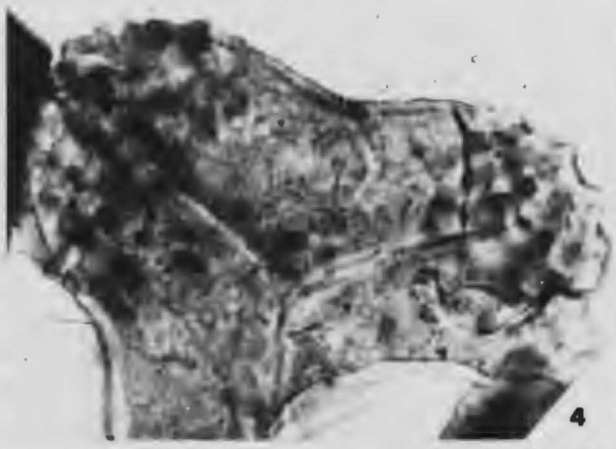
15-16. *Appendicisporites* cf. *A. unicus* (Markova) Singh, (15) Proximal and (16) distal foci, X1000. BW138/1: 305 - 1123.

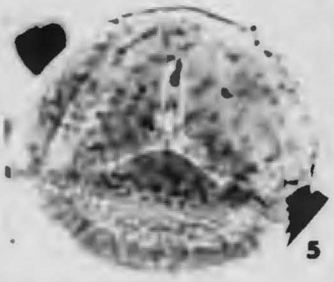
18. *Appendicisporites sellingii* Pocock, proximal view of slightly damaged specimen, BW138/2: 487 - 1129.


1


2

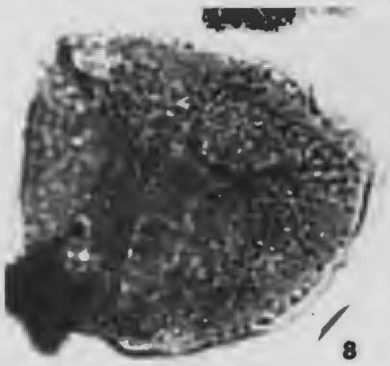

3


4

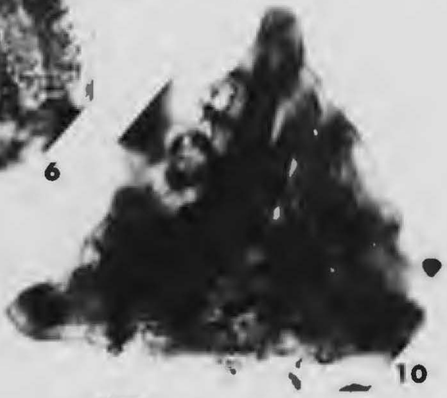

5

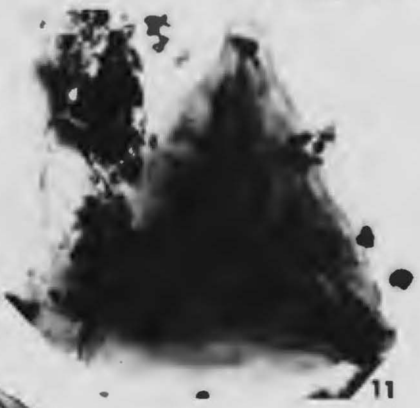

6


7


8


9


10


11


12


13


14


15


16


17


18

## Plate 4

Figure 1. Camarozonosporites sp. A., BW182/2: 547 - 1009, X1000.

2. Cingulatisporites reticingulus Brenner, BW170/1: 477 - 957, X1000.

3. Cingulatisporites ?saevus Balme, BW191/1: 502 - 961.

4. Cingutriletes clavus Balme, BW189/1: 347 - 991.

5. Cirratriradites teter Norris, showing distal granules and fenestrate zona, BW139/1: 480 - 995.

6-7. Cingulatisporites sp. B. (6) Distal focus showing anastomosing rugulae and (7) proximal focus showing thick cingulum, thickened margo and smooth proximal surface. BW151/3: 596 - 1059.

8. Densoisporites microrugulatus Brenner, BW166/1: 464 - 1015.

9-10. Cf. Cyclosporites sp. A. (9) Proximal focus showing triangular nexine, raised laesurae and smooth proximal surface, (10) distal focus showing irregular rugulae on sexine. BW178/3: 576 - 1079.

11-12. Cf. Kraeuselisporites sp. A. (11) Distal focus showing concentration of spines within central layer, arising from hexagonal bases and (12) proximal focus showing three-layered construction and raised membranous lips with gaping commissure. BW170/1: 643 - 1034.

13-14. Cingulatisporites sp. A. Slightly different proximal foci of same specimen, BW117/1: 517 - 1049.

15 and 23. Januasporites spiniferus (Singh) emend. (15) Complete specimen, BW170/1: 318 - 1026. (23) Specimen with nexine only preserved, focus on distal hilum, BW122/2: 405 - 1046.

16. Laevigatosporites ovatus Wilson & Webster, BW168/2: 506 - 980.

17. Densoisporites cf. D. balmei (Pocock) comb. nov., BW187/2: 627 - 1099.

18. Densoisporites sp. A., BW187/2: 537 - 1018.

19. Vitreisporites pallidus (Reissinger) Nilsson, BW66/1: 321 - 1046. X1000.

Plate 4 Cont'd

Figure 20. Cooksonites variabilis Pocock, BW170/1: 427 - 993.

21. Rouseisporites triangularis Pocock, BW170/1: 347 - 1018, showing radial equatorial invaginations and distal muroid ridges.

22. Aequitriradites spinulosus (Cooks. & Dettm.) Cooks. & Dettm., BW112/1: 318 - 1026.

24 and 30. Genus Undetermined sp. A. (24) Proximal focus showing smooth proximal surface and trilete mark with inner layer in focus. (25) Distal focus showing sculpture on outer layer. BW143/3: 456 - 1122.

25-26. Alisporites robustus Nilsson. (25) Equatorial view showing slightly inclined sacci and optical section of corpus, BW161/1: 398 - 1101. (26) Polar view, corpus relatively distinct, BW106/2: 362 - 945.

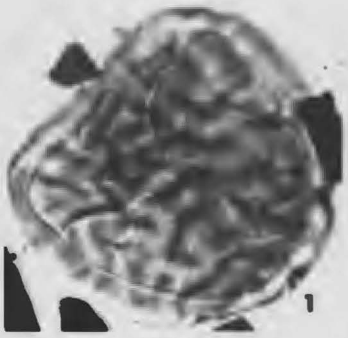
27. Rouseisporites reticulatus Pocock, BW170/1: 380 - 924.

28. Aequitriradites sp. A., BW139/1: 447 - 995.

29. Genus Undetermined sp. B., BW146/2: 457 - 1100.

31-32. Cerebropollenites mesozoicus (Couper) Nilsson. (31) Proximal and (32) distal focus showing thin distal exinal region. BW135/1: 474 - 1074.

33. Parvisaccites radiatus Couper, BW167/1: 564 - 1074.


1


2


3


4


5

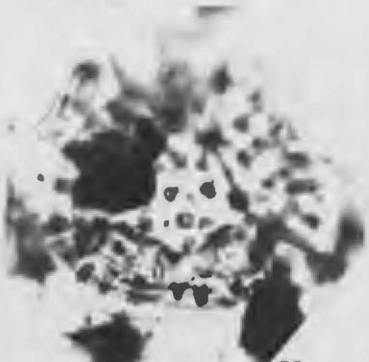

6

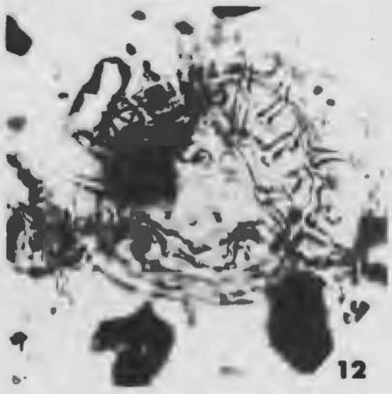

7

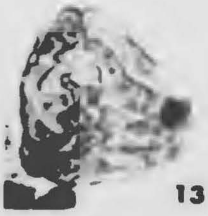

8


9


10


11


12


13


14


15

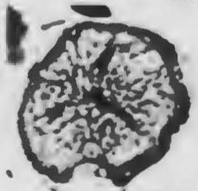

16

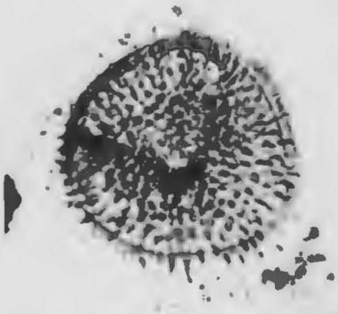

17

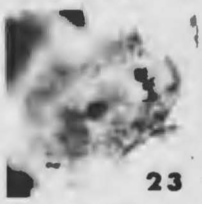

18


19


20


21


22


23


24

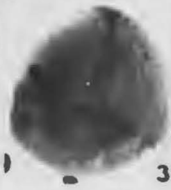

25


26

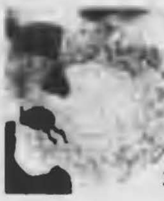

27


28


29


30


31


32


33

# Plate 5

Figure 1. *Alisporites minutus* Rouse, BW167/3: 561 - 1042, X1000.

2. *Alisporites grandis* (Cookson) Dettmann, BW149/3: 589 - 1125; large specimen.

3-4. *ABIETINEAEPOLLENITES AEQUISACCUS* sp. nov. Holotype. (3) Proximal focus on corpus. (4) Distal focus on sacci roots.

5. *Alisporites microsaccus* Couper, BW181/3: 580 - 1026.

6. *ABIETINEAEPOLLENITES AURITUS* sp. nov. Holotype, distal focus on distal sacci roots.

7. *Abietineaepollenites* sp. A., distal focus; Imp. Oil Ltd. Slide 10-349/2: 346 - 1004.

8. *Pityosporites constrictus* Singh, BW170/1: 359 - 934.

9. *Cedripites canadensis* Pocock, BW85/4: 561 - 1113.

10 and 14. *Phyllocladidites* sp. A. (10) Equatorial view showing insertion of small sacci, sacci inflated; BW103/1: 185 - 1030. (14) Oblique distal view of another specimen, sacci not inflated; BW106/2: 420 - 953.

11 and 15. *Pinuspollenites* sp. A. (11) Proximal view showing corpus; BW131/1: 676 - 1030 (15) Equatorial view showing envelopment of corpus by strongly inclined sacci; BW132/1: 328 - 1058.

12. *Parvisaccites amplus* Brenner, BW191/1: 602 - 1074.

13. *Cedripites cretaceus* Pocock, BW111/3: 455 - 1072.

16. Unidentified bisaccate form, BW136/1: 645 - 937.

17. *Rugubivesiculites* sp. A., BW188/1: 669 - 1051.

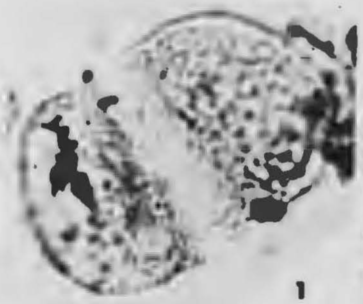
18. *Podocarpidites* cf. *P. ellipticus* (Cookson) Potonié BW167/3: 314 - 1057.

19. *Piceaepollenites?* sp. A., BW134/1: 536 - 972.

20. *Abietineaepollenites* sp. B., BW134/1: 591 - 1057.

21. *Phyllocladidites* sp. B., 135/2: 329 - 1069, X1000.

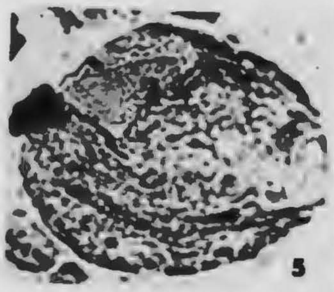
22. *Ephedripites patapscoensis* Brenner, Imp. Oil Ltd. Slide 10-354/1: 385 - 986.

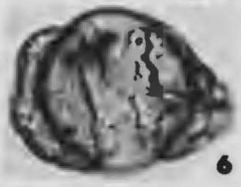

1


2


3

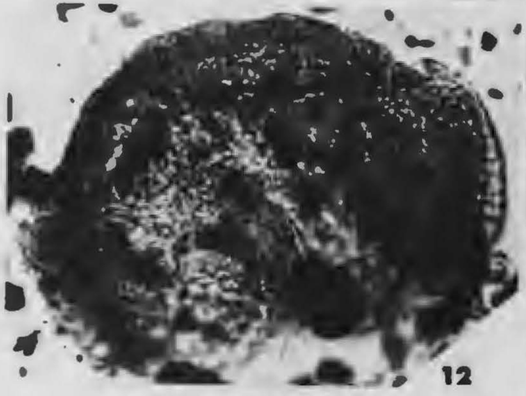

4

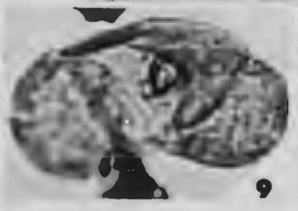

5


6


7


8


12

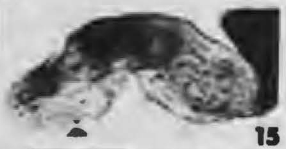

9


10

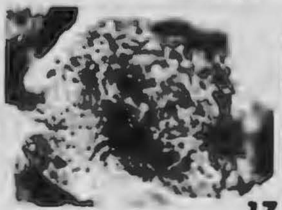

11

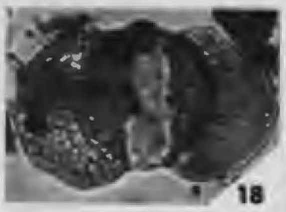

13

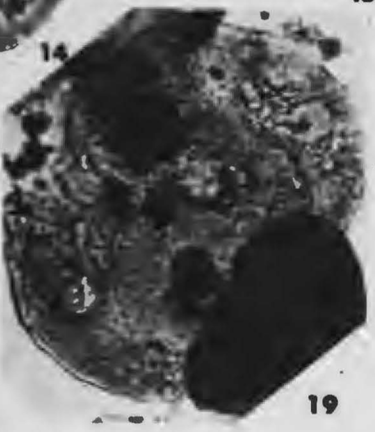

14

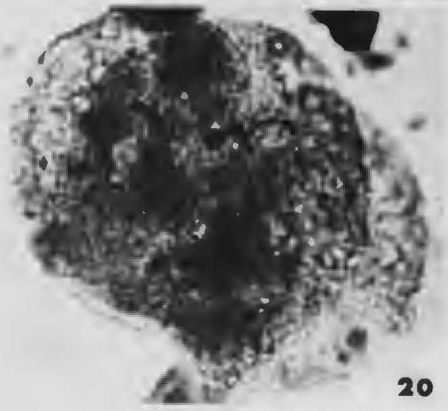

15


16


17


18


19


20


21


22

# Plate 6

Figure 1. Rugubivesiculites sp. A., BW174/3: 329 - 973; X1000.

2. Rugubivesiculites rugosus Pierce, BW113/2: 255 - 978.

3. Phyllocladidites sp. B., BW168/2: 345 - 1010; X1000.

4. Podocarpidites sp. B., BW68/1: 192 - 1042.

5. Inaperturopollenites hiatus (Potonié) Thoms. & Pfl., BW139/1: 480 - 977.

6. Inaperturopollenites dubius (Pot. & Ven.) Thoms. & Pfl., BW85/4: 440 - 1096.

7. Eucommiidites troedssonii Erdtman, BW136/2: 567 - 1016.

8. Cornaceiopollenites parvulus (Groot & Penny) comb. nov., BW126/2: 421 - 965, X1000.

9. Podocarpidites multesimus (Bolk.) Pocock, BW180/2: 486 - 1066.

10. Podocarpidites biformis Rouse, BW106/2: 621 - 1037.

11-12. Rugubivesiculites cf. R. reductus Pierce. (11) Proximal focus showing reduction of rugulae on proximal corpus and well developed frill, BW113/2: 498 - 931; X1000. (12) Another specimen with less marked frill and reduction of proximal rugulae, BW112/1: 262 - 1097.

13. Rugubivesiculites sp. B., BW168/1: 540 - 1072.

14. Podocarpidites canadensis Pocock, BW180/2: 578 - 1110.

15. Sequoiapollenites sp. A., BW191/1: 383 - 951.

16. Eucommiidites minor Groot & Penny, BW105/1: 634 - 1079.

17. Laricoidites magnus (Pot.) Pot., Thoms. & Thierg., BW76/2: 164 - 1067.

18. Podocarpidites sp. A., BW111/2: 407 - 951.

19. Clavatipollenites minutus Brenner, BW174/3: 291 - 1050, X1800.

20-25. Liliacidites sp. A., BW167/3: 428 - 1012; X1000; two foci showing detail of the pila. (20) High focus on sculpture. (25) Focus on sulcul opening.

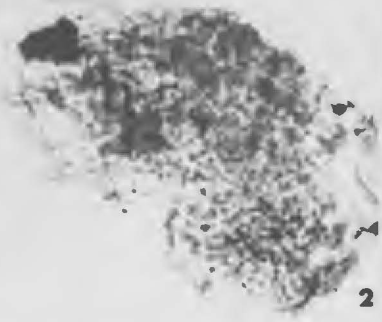
Plate 6 Cont'd

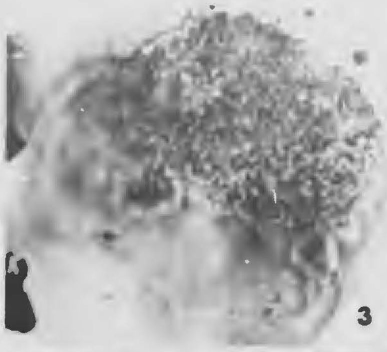
Figure 21-22. Cf. *Clavatipollenites* sp. A. (21) High focus on reticulate pattern (22) Focus on pila. BW170/1: 667 - 1097; X1000.

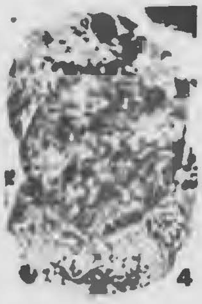
23-24. *Liliacidites* cf. *L. textus* Norris. (23) Focus on sulcul opening. (24) Focus on pilate heads and reticulum; BW166/3: 465 - 1037; X1000.

26. *Araucariacites australis* Cookson, BW187/2: 384 - 1003, X1000; granulate exine visible.

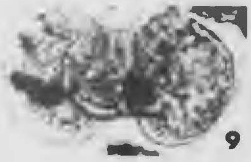

1

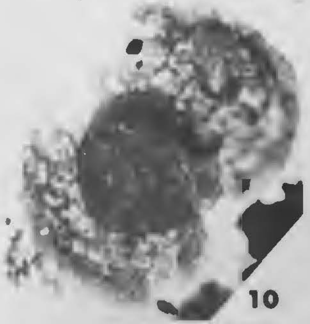

2

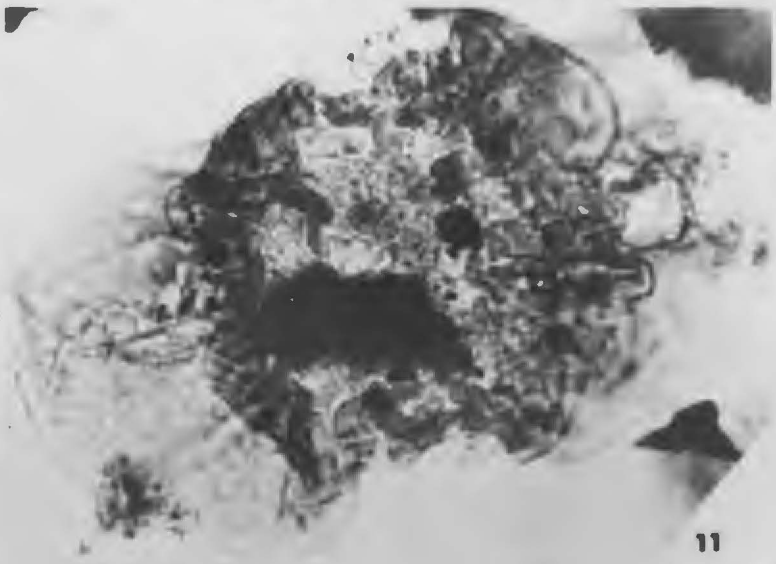

3


4


5


9


10

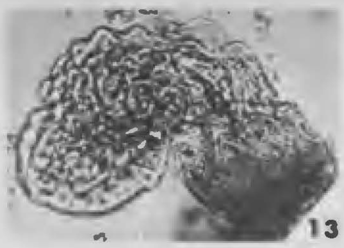

11


6


7


8


12


13


14

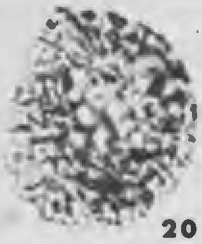

15


16


17


18


19


20

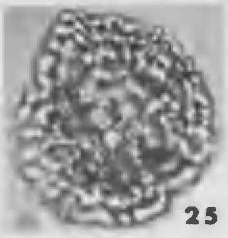

26


21


22


23


24


25

## Plate 7

Figure 1-3 and 15. Tricolpites vulgaris (Pierce) comb. nov. (1-3) Equatorial view; three foci on same specimen, BW166/1: 596 - 1000, X1800. (15) Polar view, high focus on reticulation, BW168/2: 516 - 1098, X1800.

4-5. Tricolpites paraneus (Norris) comb. nov. (4) Equatorial view, high focus on radially arranged lumina with one colpus visible, BW150/1: 304 - 1046; X1800. (5) Polar view with three colpi visible, BW144/2: 636 - 1039; X1800.

6-7. Tricolpites prosimilis (Norris) comb. nov. (6) Equatorial view, high focus on reticulation, BW144/2: 644 - 961. (7) Smaller specimen, equatorial view, focus on colpi and slight polar thickenings, BW160/3: 380 - 980. Both specimens, X1800.

8-9. Tricolpites sp. A. (8) High focus showing outline of muroid elements, X1800. (9) Same specimen, focus on lumina of reticulum. BW179/1: 313 - 928; X1800.

10, 16 and 21. Reticulitricolpites sagax (Norris) comb. nov. (10) Polar view, three colpi in view, BW143/3: 615 - 1044. (16 and 21) Equatorial views at different foci of same specimen showing retipilate structure at high and medium focus, BW161/1: 414 - 1081; X1800.

11 and 17-18. RETICULITRICOLPITES CRASSUS sp. nov. (11) Polar view showing colpi and apocolpal thickening of nexine, BW177/1: 551 - 1078. (17-18) Holotype, equatorial view, high and low faci respectively showing the retipilate structure and crassinexinous exine; X1800.

12-14 and 19. Reticulitricolpites georgensis (Brenner) comb. nov. (12-14) Polar view; high, medium and optical section foci respectively showing retipilate structure; BW179/1: 566 - 1001. (19) Equatorial view showing reduction of lumina size on apocolpia and at polar regions; BW168/2: 447 - 1009. Both X1800.

20. Clavatipollenites hughesi Couper, BW167/3: 313 - 1107; part of a larger mass of specimens showing pilate ornament and retipilate structure; X1800.

23 and 25. Reticulitricolpites sp. A. (23) Polar view, focus on pilate elements; BW174/3: 371 - 1059 (25) Oblique polar view, colpi partly in focus, BW179/1: 379 - 946.

23. Cycadopites carpentieri (Couper) Singh, BW105/1: 647 - 1112.

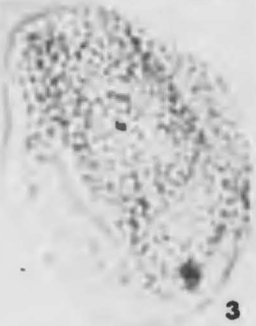
Plate 7 Cont'd

Figure 24. Cycadopites fragilis Singh, Imp. Oil Ltd. Slide 10-350/1: 274 - 1090.

26. Cycadopites follicularis Wilson & Webster, BW141/3: 344 - 999.


1


2

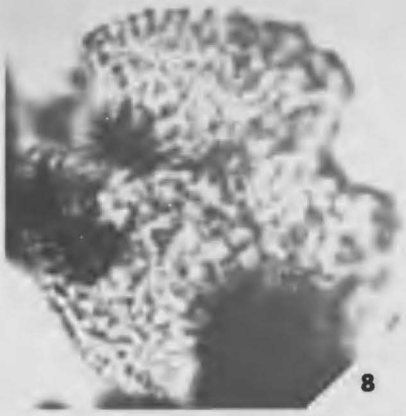

3

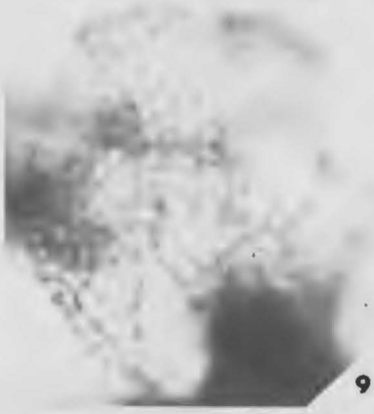

4


5


6

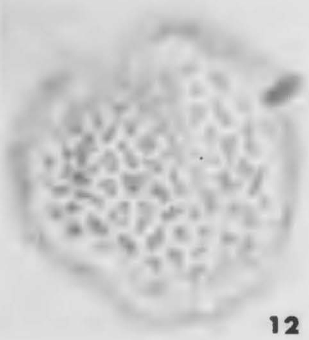

7


8


9

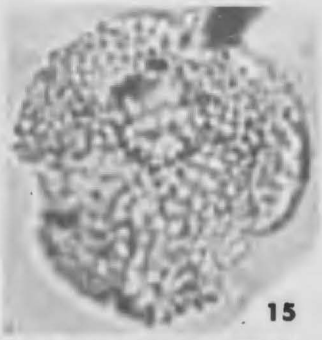

10


11


12


13


14


15


16


17


18


19


20


21


22


23


24


25


26

## Plate 8

Figure 1-3. Tricolporate? Forma A. High, medium and optical foci showing the reticulum and equatorial situated ora? associated with colpi, BW179/1: 496 - 1008; X1800.

4. *Cornaceoipollenites* sp. A. Oblique equatorial view, focus on colpi, BW174/3: 550 - 1012: X1000.

5. Tricolpate Forma A. Focus on simple, long colpi; grain large; BW152/3: 322 - 1028. X1000.

6. Tricolpate Forma B. Two of three colpi visible running nearly or to the poles, the third visible to right as dark line; BW117/1: 425 - 1019; X1000.

7. Periporate? Forma A. Focus on three of the ?pores; BW161/1: 641 - 1024; X1800.

8. *Classopollis torosus* (Reissinger) Balme, BW138/2: 369 - 1010; X1000.

9. *Classopollis* cf. *C. minor* Pocock & Jansonius, BW178/1: 611 - 1001, X1000.

10. *Classopollis* cf. *C. pflugi* Pocock & Jansonius, BW143/2: 447 - 927; X1000.

11 and 18. *Micrhystridium* cf. *M. piliferum* Deflandre. (11) BW113/1: 432 - 935; X1000. (18) Specimen showing split in the mid-line, BW137/1: 203 - 1032; X1000.

12. *Veryhachium* cf. *V. collectum* (Deunff) de Jekowsky, BW128/1: 277 - 1005, X1000.

13. *Cycadopites* sp. B., BW143/1: 405 - 956.

14. *Cycadopites formosus* Singh, BW134/1: 647 - 991.

15. *Schizosporis reticulatus* Cooks. & Dettm., BW182/2: 511 - 1071.

16. *BALTISPHAERIDIUM PLANISPINUM* sp. nov. Holotype, X1000 with seven processes visible.

17 and 20. *Baltisphaeridium* cf. *B. debilispinum* Wall & Downie. (17) BW114/3: 369 - 965. (20) BW142/2: 566 - 965, specimen showing pronounced basal expansion of processes. Both X1000.

19. *Monosulcites* sp. B., BW105/1: 370 - 1108; focus on sulcus.

21. *Pterocystidiopsis* sp. A., BW134/1: 480 - 1003.

Plate 8 Cont'd

Figure 22-23. Monosulcites sp. A. (22) High focus and (23) focus on sulcul opening; BW106/2: 281 - 986; X1000.

24. Circulina cf. C. parva Brenner. Focus on proximal trilete scar. BW154/3: 635 - 1020.

25. Cycadopites sp. A., BW134/1: 516 - 1096.

26. Exesipollenites tumulus Balme. Focus on faintly developed distal pore and slight surrounding thickening; BW138/2: 532 - 1039, X1000.

27. Platymorph Forma A., BW118/1: 683 - 1094.

28-29. BALTISPHAERIDIUM TURBINATUM sp. nov. (28) Holotype, X1000. (29) Another specimen, spines longer, a few bifid; BW147/2: 375 - 1035, X1000.


1


2


3


4


5


6


7


8


9


10


11


12


13


14

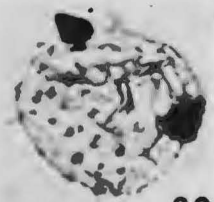

15


16


17


18


19


20


21

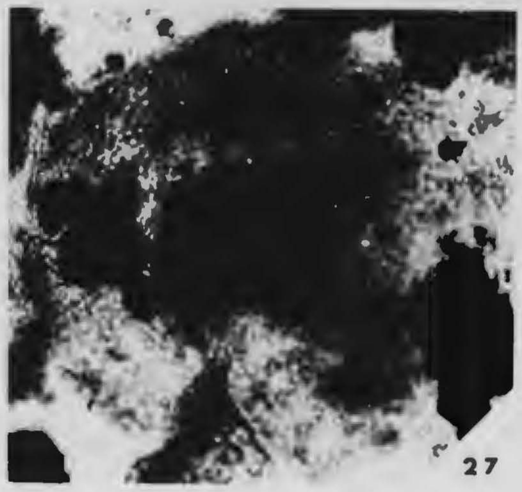

22


23


24


25


26


27


28


29

## Plate 9

Figure 1-2. BALTISPHAERIDIUM RALLUM sp. nov. Holotype, foci on more proximal and distal surfaces, X1000.

3. Veryhachium sp. B., BW131/1: 367 - 1140, X1000.

4. Veryhachium? sp. D., BW131/1: 609 - 1080, X1000.

5. Micrhystridium sp. A., BW143/1: 613 - 1041.

6. Veryhachium europaeum Stockmans & Williere, BW75/2: 346 - 945, X1000.

7. Veryhachium sp. C., BW75/2: 190 - 1032, X1000.

8-9. VERYHACHIUM INIQUUM sp. nov. Holotype, two foci showing insertion of spines, X1000.

10. Veryhachium reductum forma breve de Jekowsky, BW148/1: 374 - 969, X1000.

11. Pterospermopsis australiensis Defl. & Cooks., BW173/1: 338 - 1136, X1000.

12. Pterospermopsis sp. A., BW151/1: 552 - 998.

13. Micrhystridium sp. B., BW186/1: 615 - 1018, X1000.

14. Leiosphaeridia sp. A., BW80/2: 353 - 1027.

15. Cf. Leiofusa sp. B., BW171/2: 530 - 1131, X1000.

16. Veryhachium reductum forma trispinoides de Jekhowsky, BW176/1: 330 - 1084, X1000.

17. Veryhachium sp. A., BW75/2: 625 - 940, X1000.

18. Leiofusa jurassica Eisenack, BW106/2: 208 - 1126, X1000.

19. Pterospermopsis sp. C., BW114/1: 303 - 945.

20. Pterospermopsis? sp. D., BW117/1: 322 - 1081, X250.

21-22. Pterospermopsis sp. B. (21) Viewed by ordinary light and (22) by phase contrast; BW111/2: 165 - 1102; X1000.

23. Leiofusa sp. A., BW137/1: 193 - 982.

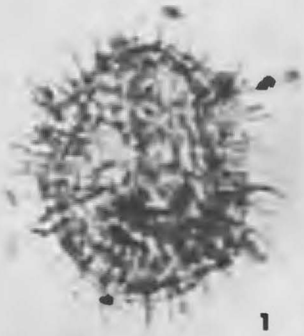
24. Leiosphaeridia sp. F., BW72/1: 471 - 971.

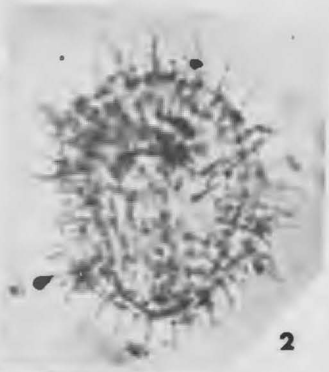
Plate 9 Cont'd

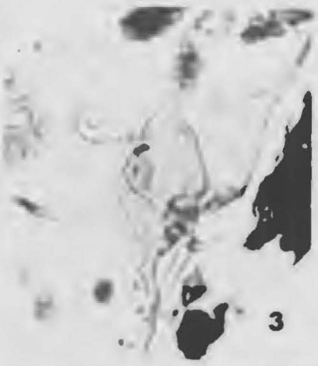
25 and 28. Palaeostomocystis fragilis Cooks. & Eisen. (25) Large specimen showing detail of apical break; BW127/1: 576 - 939. (28) Smaller specimen showing longitudinal fold, BW1117/1: 246 - 974.

26. Leiofusa cf. L. lidiae Gorka, BW140/1: 297 - 988; X250.

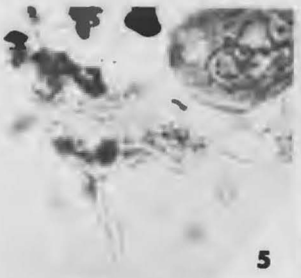
27. Leiosphaeridia sp. C., BW75/2: 465 - 1107.


1

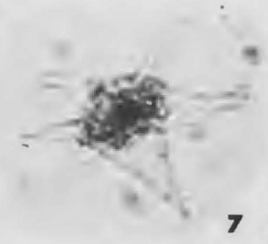

2

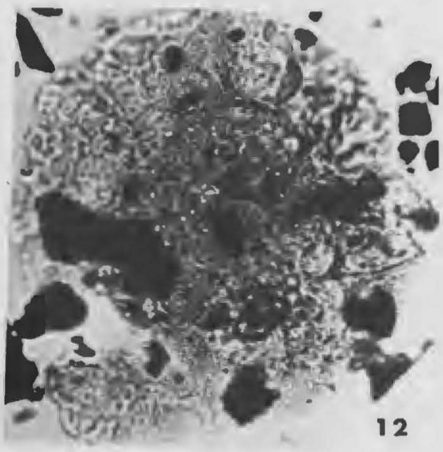

3


4


5

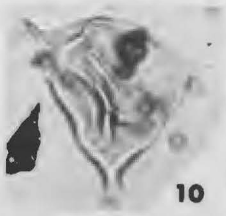

6

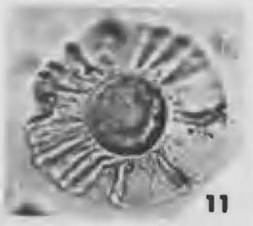

7


12


8


9


10


11


13

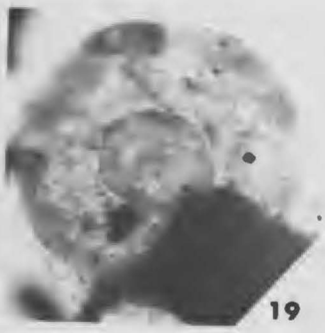

14


15

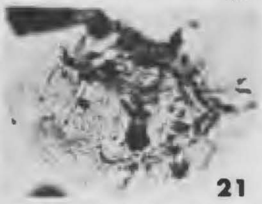

16

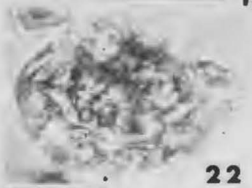

17


18

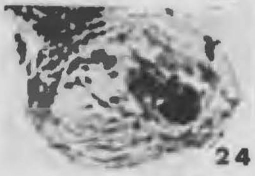

19

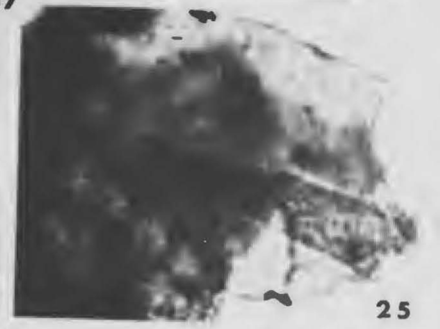

20

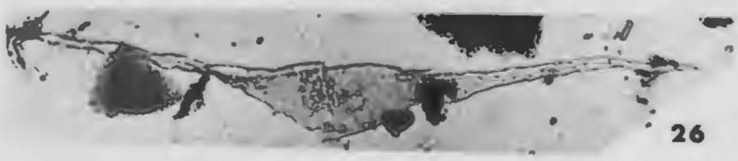

21


22


23


24


25


26


27


28

# Plate 10

Figure 1. Leiosphaeridia sp. G., BW120/1: 537 - 115.

2. Metaleiofusa sp. A., BW137/1: 375 - 1022, X1000.

3. ?Metaleiofusa sp. B., BW137/1: 265 - 1003, X1000.

4. Canningia sp. A., Imp. Oil Ltd. Slide 10-349/2: 414 - 1033.

5-6. MICRODINIUM OPACUM sp. nov. Holotype. (5) Dorsal focus and (6) ventral focus; both X1000.

7. Leiosphaeridia sp. B., BW160/3: 351 - 984.

8. Leiosphaeridia sp. D., BW78/3: 305 - 942.

9. Cyclopsiella? sp. A., BW156/1: 643 - 1065.

10-13. MICRODINIUM? CRISTATUM sp. nov. (10) Specimen with apical archaeopyle by ordinary light. (11) Same specimen by phase contrast, BW75/2: 593 - 1103; X1000. (12-13). Holotype specimen. (12) Dorsal surface by transparence. (13) Ventral surface.

14. Acritarch Forma A., BW77/1: 456 - 1090.

15. Leiosphaeridia sp. E., BW115/2: 365 - 1062.

16. Fromea amphora Cooks. & Eisen., BW182/2: 626 - 965.

17-19. Dactylodinium jaegeri (Alberti) comb. nov. (17-18) Different foci of incipient operculum formation, BW144/3: 649 - 1052; X1000 (19) Complete specimen showing early development of operculum formation, BW106/2: 354 - 1096.

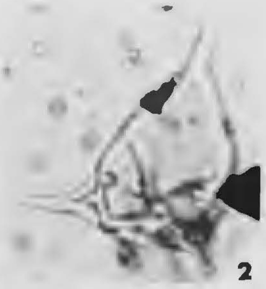
20. Dactylodinium sp. A., BW78/3: 453 - 960; X250.

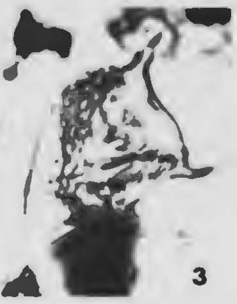
21. Canningia? sp. B., BW143/1: 428 - 989.

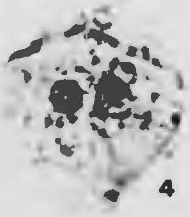
22. Tenua? sp. B., BW147/1: 387 - 1105.

23. Tenua sp. A., BW135/1: 658 - 1042.

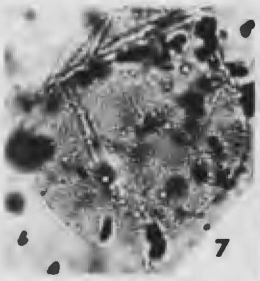

1

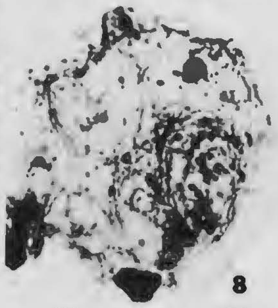

2


3


4

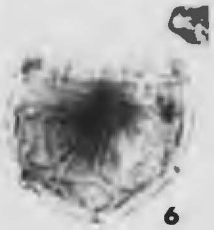

5

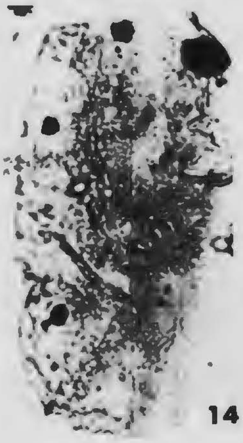

7

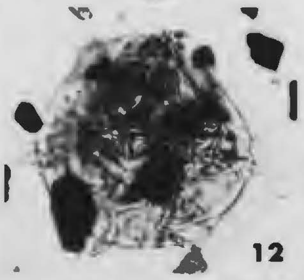

8


9

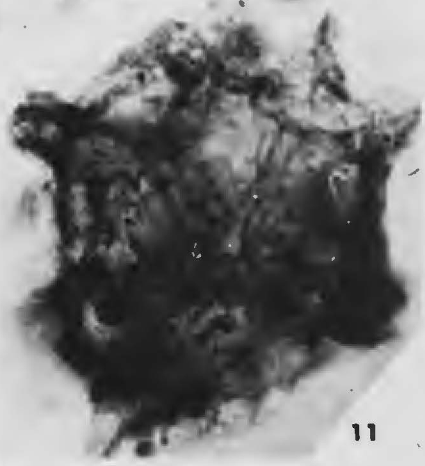

10

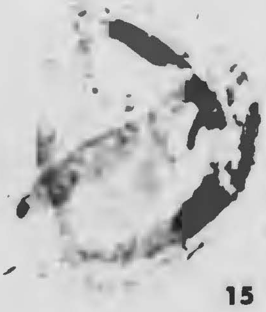

6


14

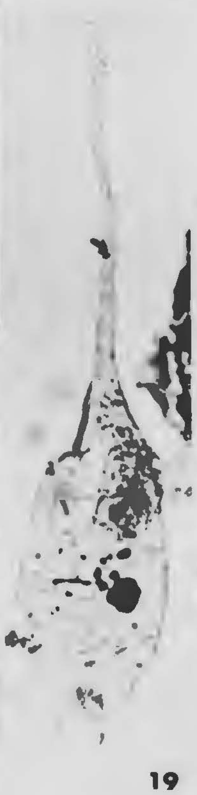

12


13

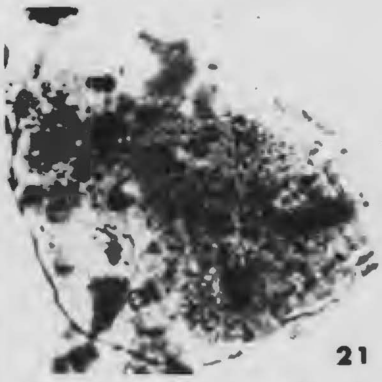

11


15

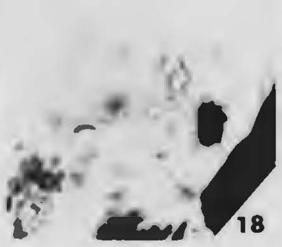

17

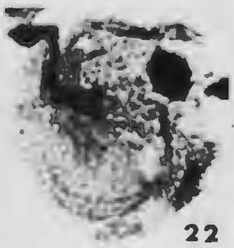

19

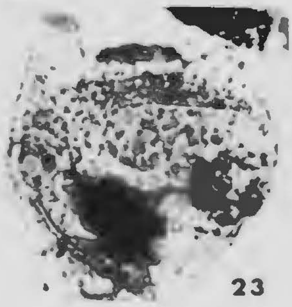

20


21


16


18


22


23

## Plate 11

Figure 1. Tenua? sp. C., BW105/1: 370 - 1126; X1000.

2 and 8. TENUA LONGISPINA sp. nov. Holotype. (8) X1000 showing detail of spines.

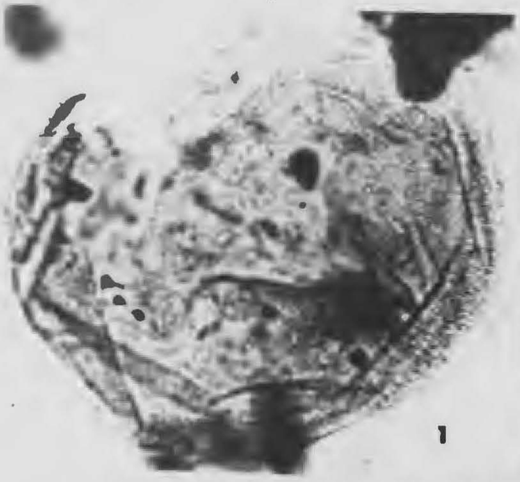
3 and 10. CANNINGIA CRASSA sp. nov. (3) Holotype, X1000. (10) Another specimen showing development of apical archaeopyle and operculum structure; BW124/1: 595 - 1098.

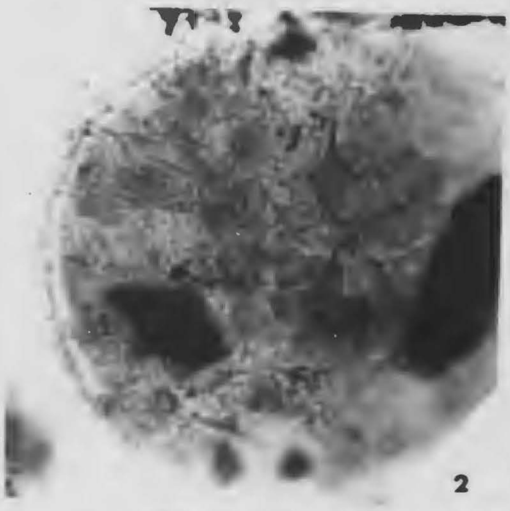
4-6. GONYAULACYSTA GLOBOSA sp. nov. (4) Specimen without well-defined tabulation, BW117/1: 523 - 1028. (5-6) Holotype specimen. (5) Ventral surface by transparence. (6) Dorsal surface; note "pseudosutures" paralleling the actual plate sutures.

7. Tenua? sp. B. Specimen showing spine morphology, BW106/2: 605 - 946; X1000.

9. Fromea sp. A., BW168/1: 622 - 1029.

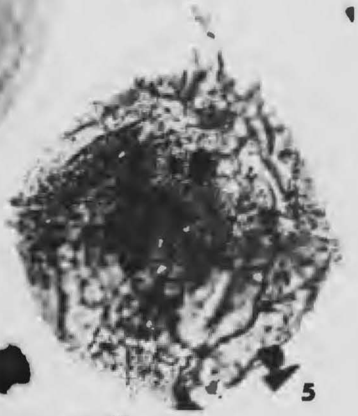
11-12. GONYAULACYSTA AUCTIFICA sp. nov. Holotype specimen. (11) Ventral surface and (12) dorsal surface by transparence; note small plate 2a just above archaeopyle and missing portion of cingulum at base of archaeopyle.

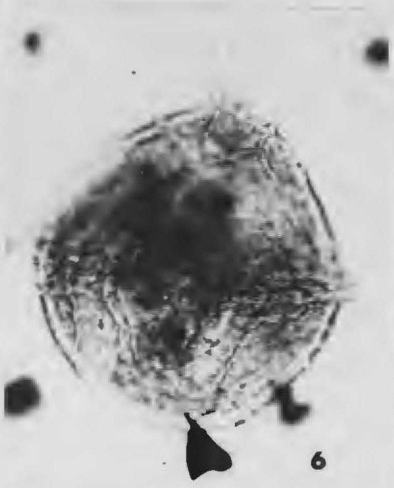

1

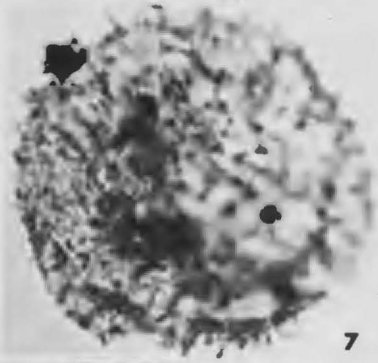

2

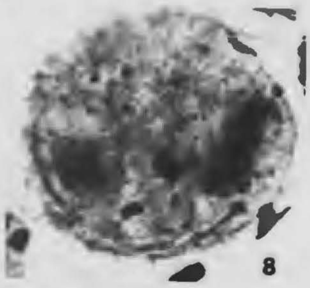

3


4

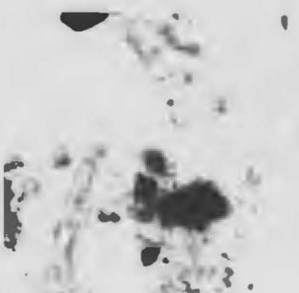

5

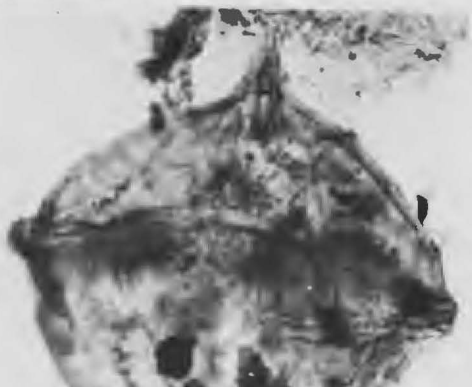

6

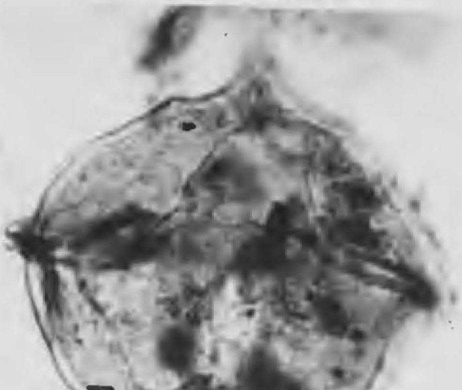

7


8


9


10


11


12

## Plate 12.

Figure 1-2. GONYAULACYSTA OBESA sp. nov. (1) BW103/1: 201 - 1078 (2) Holotype showing some of the ventral plating pattern.

3-4. GONYAULACYSTA FRAGOSA sp. nov. Holotype specimen. (3) Proximal surface. (4) Distal surface by transparence in phase contrast, X400.

5-8. GONYAULACYSTA VILLOSA sp. nov. (5) Holotype, dorsal view by transparence. (6) Holotype, distal surface. (7) Distal surface of another specimen showing ventral tabulation pattern; note thick sutures and robust cingulum. BW105/2: 182 - 961. (8) Antapical view of a different specimen; plate 1'''' in focus to right center of the figure; BW106/2: 218 - 1058.

9. Gonyaulacysta orthoceras Eisenack. Distal surface by transparence, BW106/2: 426 - 1027.

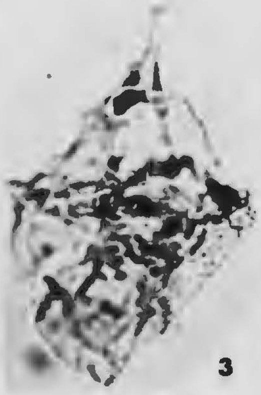
10. Gonyaulacysta sp. B. Incomplete specimen showing part of distal surface and cingulum; BW76/2: 218 - 1096.

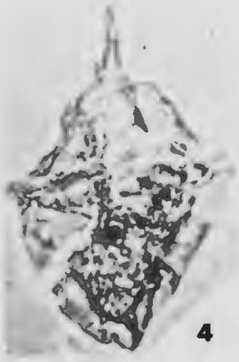
11. Pareodinia? sp. A., BW141/1: 518 - 1022.

12-13. Palaeoperidinium cretaceum (Pocock) emend. (12) Complete specimen and (13) same specimen, X1000 showing margin of apical archaeopyle; BW185/1: 367 - 1091.


1


2

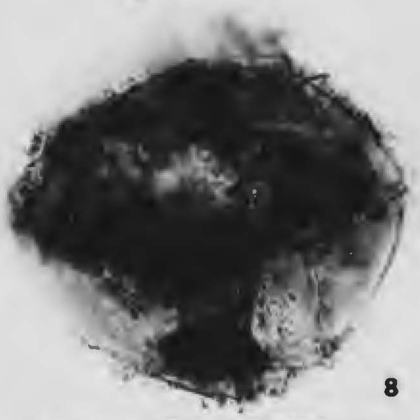

3


4

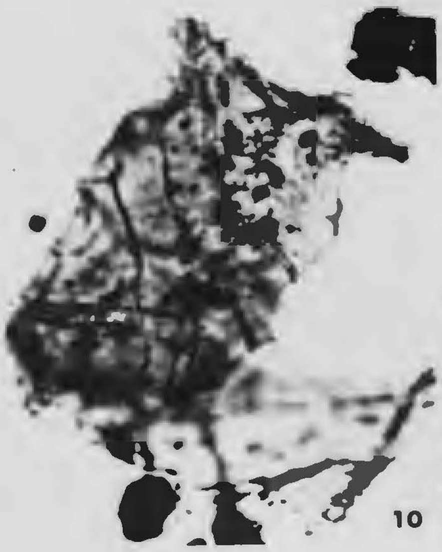

5

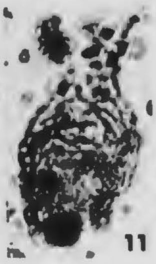

6

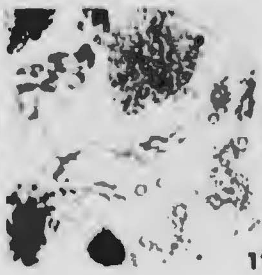

7


8


9


10


11


12


13

# Plate 13

Figure 1. Gonyaulacysta sp. A., BW169/1: 364 - 998.

2. Gonyaulacysta granulata (Singh) comb. nov., BW73/1: 456 - 1084.

3. Trichodinium sp. A., BW120/2: 675 - 1098; X1000 showing precingular archaeopyle, visible to left center of figure as smooth region.

4 and 7. Proximate Cyst Forma A. (4) Dorsal surface and (5) distal surface by transparence; intercalary plate obscured by debris partible but visible in strong transmitted light; BW103/1: 441 - 1011; X1000.

5. Palaeoperidinium sp. A., BW174/3: 376 - 925; X1000.

6 and 10-11. OLIGOSPHAERIDIUM TOTUM sp. nov. (6 and 10) Holotype specimen. (6) Complete specimen showing habit of processes. (10) X1000 showing outline of apical archaeopyle (11) Another specimen showing apical archaeopyle, BW1113/2: 395 - 1039.

8. Hystrichosphaeridium stellatum Maier, BW144/2: 476 - 943.

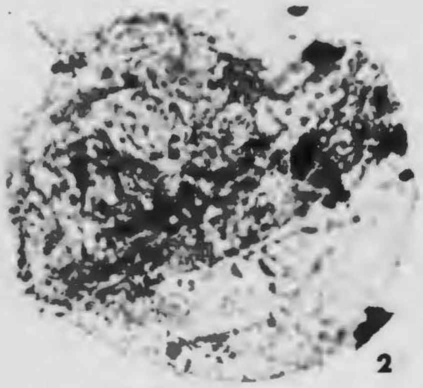
9. OLIGOSPHAERIDIUM MINOR sp. nov. Holotype specimen.

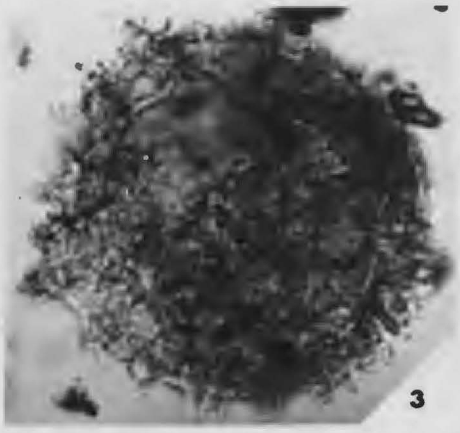
12. Palaeoperidinium cretaceum (Pocock) emend., BW80/2: 253 - 1005.

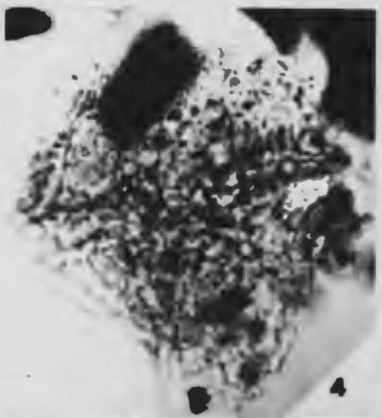
13. Unidentified hystrichosphaerid form.

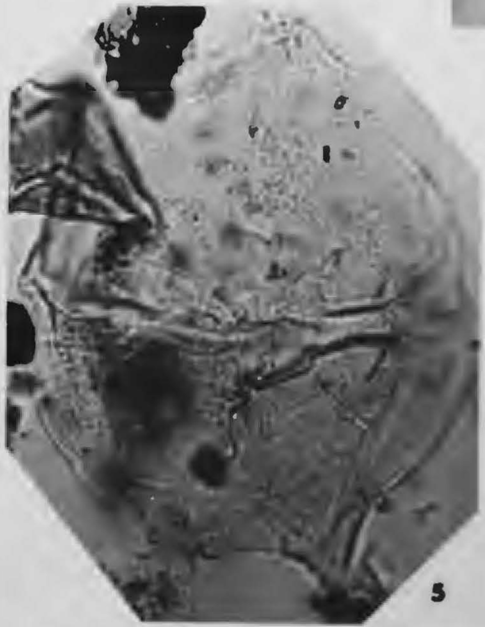
14. Litosphaeridium? sp. A., BW184/3: 412 - 1095; X1000.

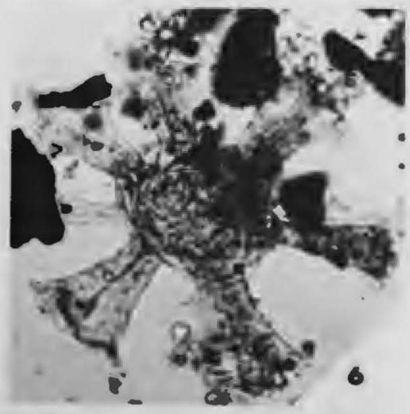

1

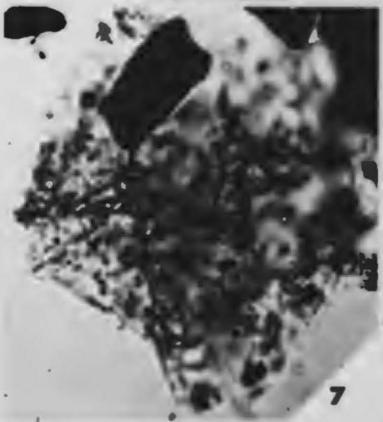

2


3


4


5


6


7

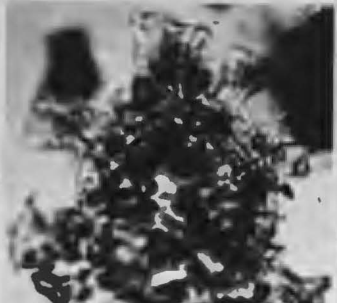

8


9


10


11


12


13


14

## Plate 14

Figure 1. *GONYAULACYSTA GLOBOSA* sp. nov., BW106/2: 160 - 1122, ventral view of damaged specimen showing some of ventral tabulation pattern.

2. *Oligosphaeridium* cf. *O. pulcherrimum* Defl. & Cooks., BW136/1: 614 - 1122.

3. *Oligosphaeridium complex* (White) Davey & Williams, BW75/2: 553 - 1059, X1000.

4. *Oligosphaeridium* sp. A., BW124/2: 476 - 1122.

5-6. *HYSTRICHOSPHAERIDIUM CYLINDRATUM* sp. nov. (5) Holotype. (6) Different specimen, BW189/1: 396 - 1018.

7. *Oligosphaeridium anthophorum* (Cooks. & Eisen.) comb. nov., Imp. Oil Ltd. Slide 10-349/2: 466 - 1029.

8. *Hystrichosphaeridium* sp. C., BW120/1: 575 - 1042.

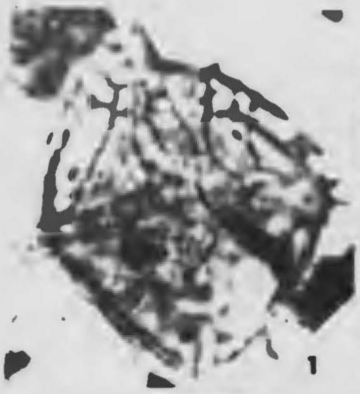
9. *Oligosphaeridium* sp. B., BW124/1: 437 - 1012.

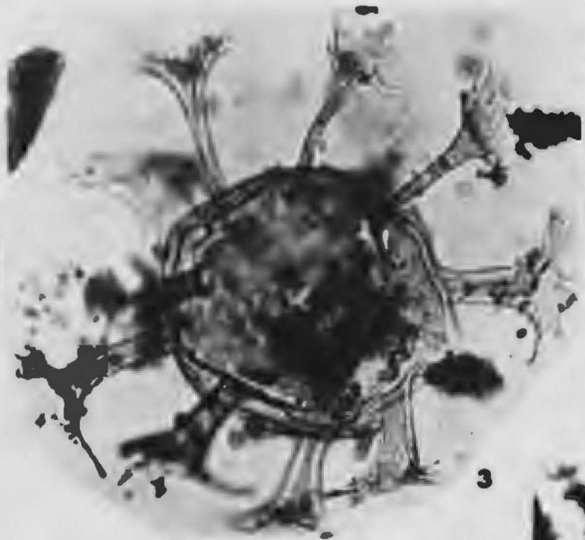
10. *Oligosphaeridium irregulare* (Pocock) comb. nov., BW172/2: 447 - 1045.

11. *Oligosphaeridium*? sp. C., BW189/1: 369 - 971; X1000, part of specimen showing orthogonal extensions of apices.

12. *Hystrichosphaeridium*? sp. D., BW80/2: 257 - 1019.

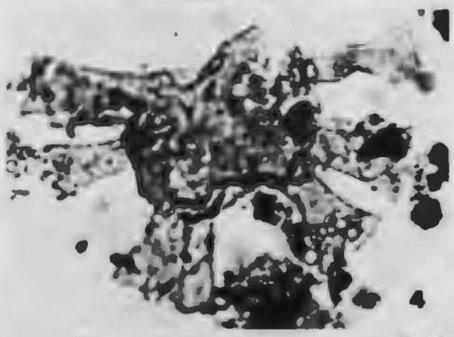
13. *Tanyosphaeridium* sp. A., BW72/1: 460 - 936; specimen with apical archaeopyle.

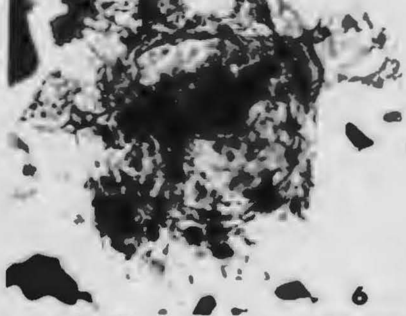

1

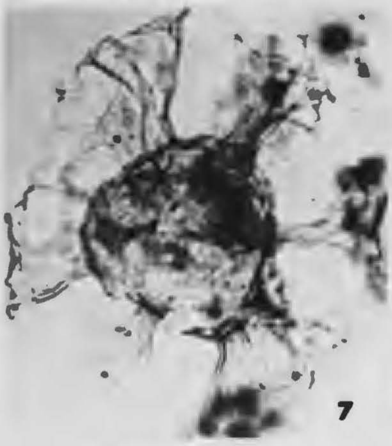

3

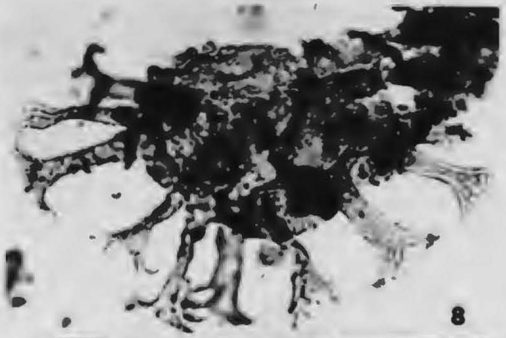

5


2


4


6


7

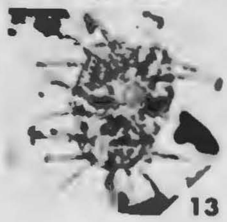

8


9


10


11


12


13

## Plate 15

Figure 1. Hystrichosphaeridium sp. B., BW124/1: 310 - 1037.

2. Polysphaeridium sp. A., BW191/1: 405 - 990.

3-4. Achomosphaera sp. A. (3) Dorsal and (4) ventral foci; BW85/4: 459 - 1066.

5 and 8. Achomosphaera sp. B. (5) Ventral focus and (8) dorsal focus by transparence, X1000. Precingular opening (archaeopyle) visible to the right center of the specimen; sulcul trace visible in (5). BW131/2: 508 - 1086.

6. Hystrichosphaeridium sp. A., BW148/1: 344 - 1001.

7. CORONIFERA ADMIXTA sp. nov. Holotype specimen, X1000.

9. Diphyes sp. A., Imp. Oil Ltd. Slide 11-470/1: 428 - 1005. X1000.

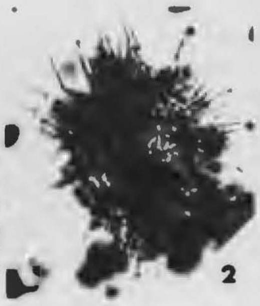
10. Hystrichosphaera cf. H. cornuta Gerlach, BW112/1: 460 - 934, showing apical horn.

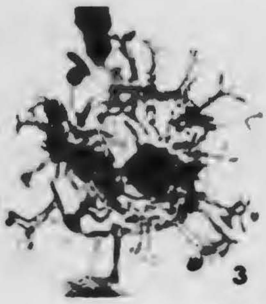
11 and 14. Systematophora schindewolfi (Alberti) comb. nov. (11) BW105/1: 403 - 1067. (14) Apical-antapical orientation, BW127/1: 428 - 1039.

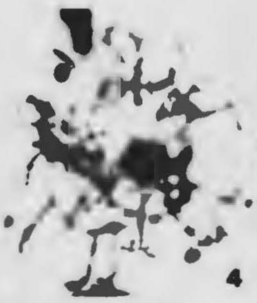
12. Cyclonephelium cf. C. compactum Defl. & Cooks., BW106/2: 478 - 923.

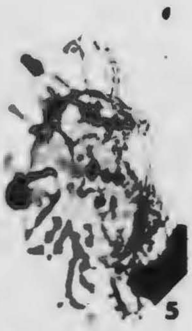
13. Tanyosphaeridium sp. B., BW75/2: 233 - 1005; X1000.


1

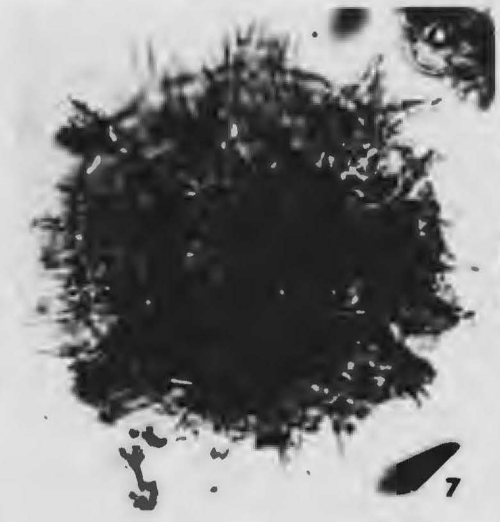

2


3

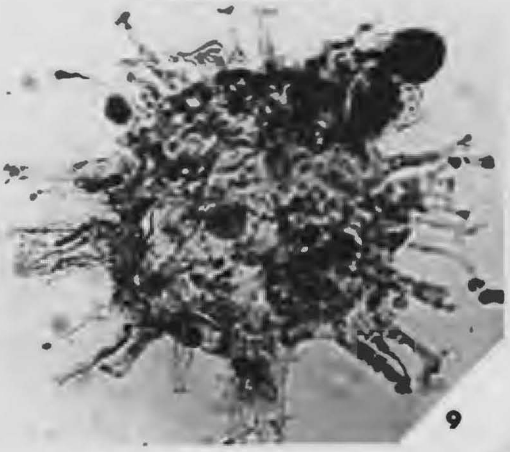

4


5

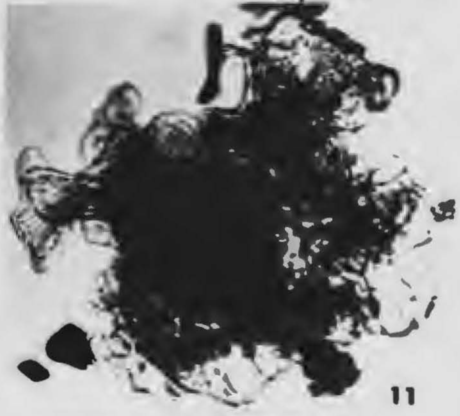

6


7

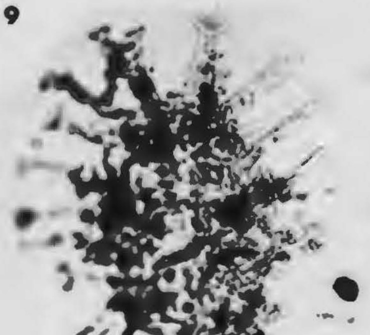

8

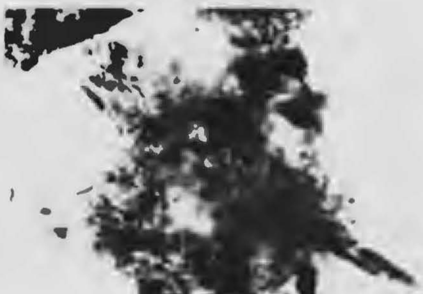

9


10

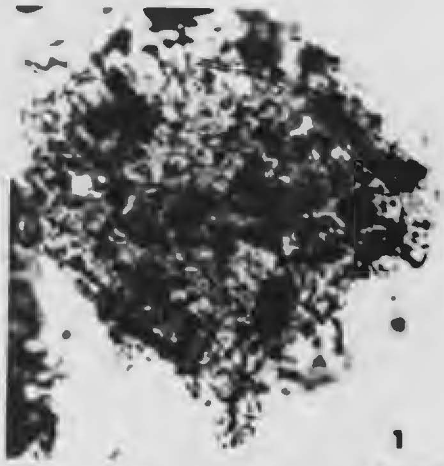

11

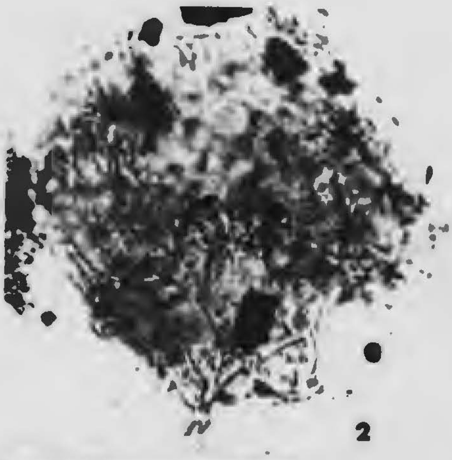

12

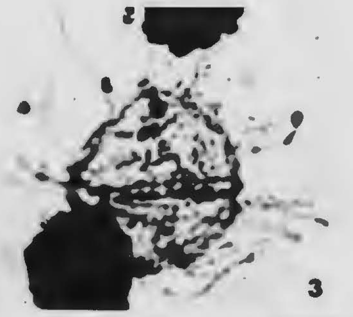

13

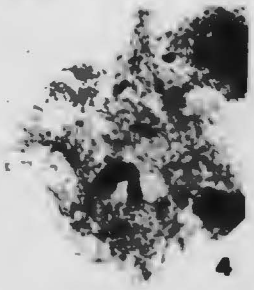

14

16


1

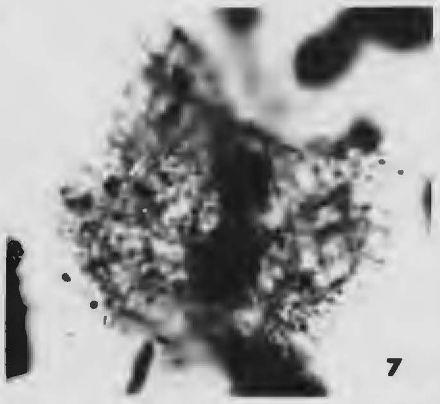

2


3


4

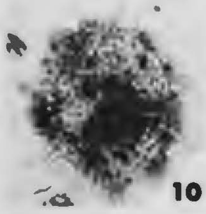

5

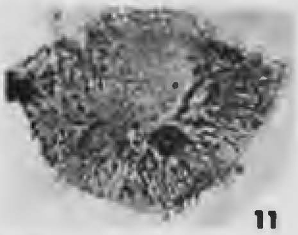

6

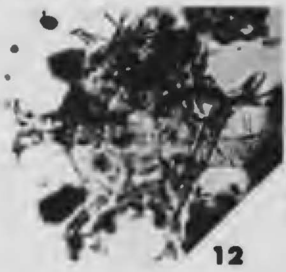

7


8


9


10

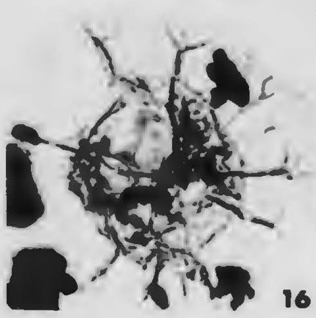

11


12

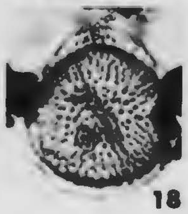

13


14


15

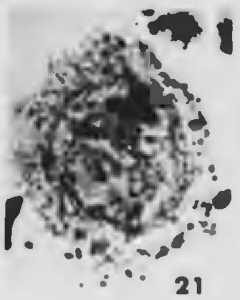

16


17


18


19


20


21

# Plate 16

Figure 1-2. *Cyclonephelium* sp. A. (1) Dorsal and (2) ventral foci of same specimen showing barren distal sulcul area; BW180/2: 516 - 941.

3 and 6. *Hystrichodinium* sp. A. (3) Specimen showing transverse girdle trace, BW106/2: 543 - 1069. (6) Another specimen, X1000 showing precingular archaeopyle; BW85/4: 589 - 1084.

4. *Cyclonephelium* cf. *C. compactum* Defl. & Cooks., BW181/3: 550 - 1046.

5 and 13. *Hystrichosphaera* cf. *H. buccina* Davey & Williams. (5) BW154/3: 355 - 1057. (13) Another specimen, X1000 showing detail of processes; BW151/3: 341 - 1058.

7-8 and 10. *Cometodinium multispinosum* (Singh) comb. nov. (7) BW146/3: 648 - 1023 and (8) BW123/1: 416 - 1023, both X1000 showing apical archaeopyles. (10) Complete specimen showing dense cover of processes; BW106/2: 279 - 1003.

9. *Hystrichosphaera cingulata* O. Wetzel, BW131/1: 432 - 1104.

11. *Cyclonephelium* sp. D., BW85/4: 416 - 942.

12. *Callaiosphaeridium asymmetricum* (Defl. & Courtev.) Davey & Williams, BW72/1: 238 - 1040.

14. *Cyclonephelium* sp. C., BW107/3: 502 - 1103.

15. Unidentified specimen belonging to the Discoasteraceae, BW187/2: 529 - 968; X1000.

16. *Hystrichosphaera ramosa* (Ehr.) Davey & Williams, BW85/4: 608 - 1126.

17-18. *Chlamydophorella* sp. A. (17) Optical section and (18) focus on two-layered structure and supporting processes. BW174/3: 357 - 1043.

19-20. *Chlamydophorella nyei* Cooks. & Eisen., BW174/3: 333 - 952. (19) Optical section showing outline of two layers and (20) focus on supporting processes.

21. *Kalyptea monoceras* Cooks. & Eisen., BW106/2: 573 - 1042; apical horn of inner body visible in top central part of figure.

## Plate 17

Figure 1-6. TOOLONGIA ALATA sp. nov. (1) Oblique apical view showing part of dorsal plating pattern, BW179/1: 386 - 1070. (2) apical view showing cyst body and cingular ledges, focus in cingulum plane; BW85/3: 615 - 918. (3-6) Holotype specimen in apical (3 and 5) and antapical focus (4 and 6). Figs. 3 and 4 are phase contrast, X400.

7. Kalyptea? sp. A., BW103/1: 197 - 1116.

8. Tenua? sp. D.; BW72/2: 480 - 1082, X1000.

9. Kalyptea? sp. B., BW144/2: 603 - 986.

10. Spinidinium? sp. C., BW144/3: 557 - 946.

11. Proximo-chorate Cyst Forma B. (11) Specimen showing apical archaeopyle, X1000; BW105/2: 277 - 937.

12-14. SPINIDINIUM VESTITUM sp. nov. Holotype specimen. (12) Focus on outer layer and archaeopyle. (13) Focus on inner layer and intercalary archaeopyle. (14) Focus on ventral surface by transparence showing sulcus and ventral portion of transvers girdle.

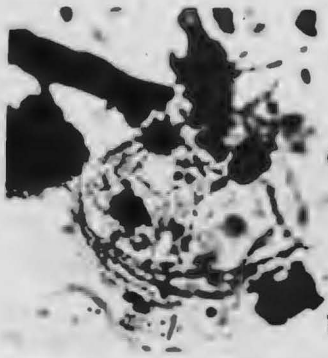
15-16. DEFLANDREA DIGNITOSA sp. nov. Holotype specimen. (16) Ventral surface showing sulcus trace. (17) Dorsal surface by transparence showing enlarged archaeopyle and transverse girdle trace. Capsule evident in both foci.

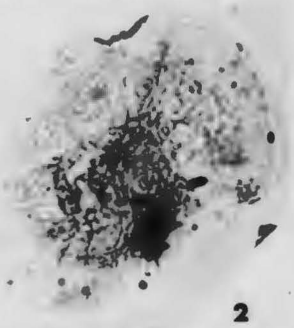
17. Chitinous inner lining of foraminifera. BW159/1: 498 - 1096; proloculum and approximately eight chambers present.

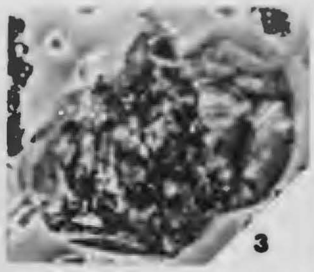
18. Proximo-chorate Cyst Forma A with ?precingular archaeopyle; BW146/3: 315 - 1098.

19. Dingodinium cerviculum Cooks. & Eisen., BW113/2: 642 - 1014.

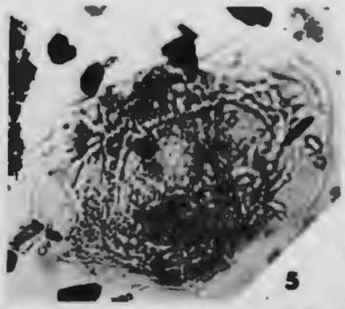
20. Hexagonifera? sp. A., BW143/1: 377 - 960.

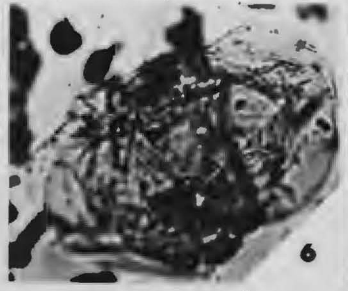

1

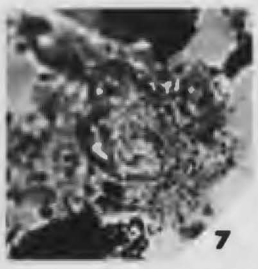

2


3


4


5


6


7


8


9


10


11


12

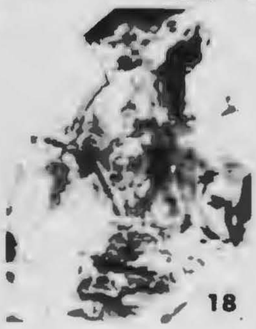

13

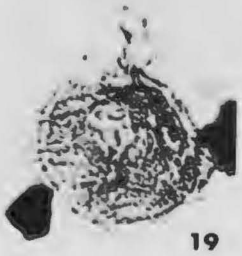

14

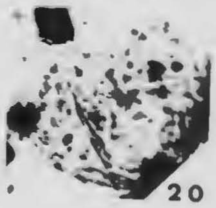

15


16


17


18


19


20

## Plate 18

Figure 1. *SPINIDINIUM VESTITUM* sp. nov., BW191/1: 343 - 1035; phase contrast, X1000 with operculum of outer layer in cavity between two layers.

2 and 7. *Aptea* cf. *A. polymorpha* Eisenack. (2) Focus on reticulate network and (7) on two layers in optical section, same specimen; BW131/1: 643 - 1110.

3 and 4. *Aptea* dr. *A. polymorpha* Eisenack. Two specimens without outer layer present showing shape and archaeopyle formation. (3) Operculum just separated, BW113/1: 331 - 1032. (4) BW167/3: 588 - 1131.

5 and 11. *PSEUDOCERATIUM EXPOLITUM* sp. nov. (5) Holotype specimen. (11) Another specimen showing development of apical archaeopyle, operculum still present; BW117/1: 263 - 1050.

6. *Hexagonifera*? sp. A., BW146/1: 377 - 1075; sulcul notch visible, apical archaeopyle present.

8 and 10. *Odontochitina operculata* (O. Wetzel) Defl. & Cooks. (8) Complete specimen with operculum still present, archaeopyle incipient; X250. BW105/1: 269 - 1112. (10) specimen with apical archaeopyle and distinct sulcul notch, ventral view; BW106/2: 463 - 1093.

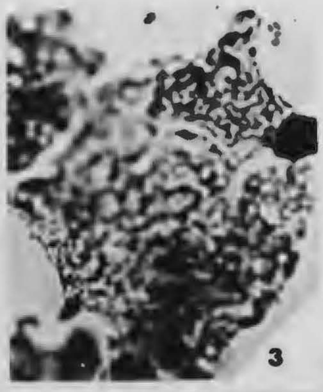
9. *Spinidinium* sp. B., BW146/1: 422 - 1114: elongate specimen showing helicoid transverse girdle, ventral view.

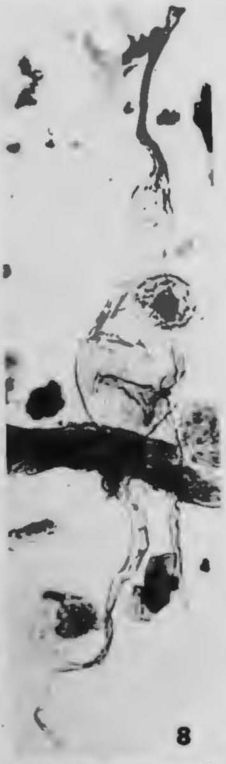
12. Dinophyceae? Incertae Forma A., BW76/2: 245 - 964, showing characteristic system of folds.

13. *Spinidinium* sp. A., BW117/1: 452 - 1038.

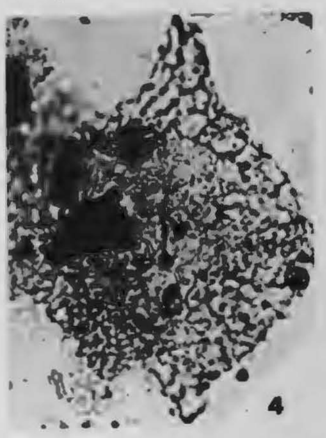

1

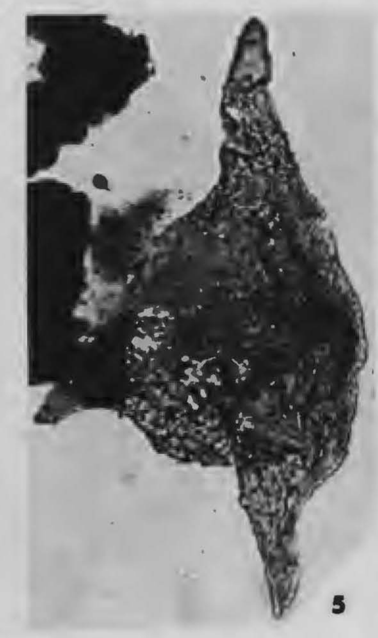

2


3


8


7


4


5


6


9


10

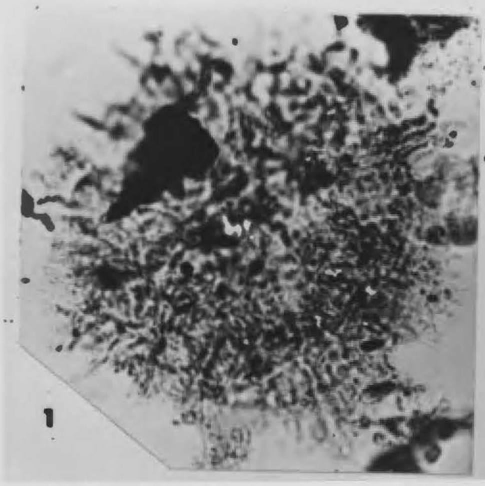

11


12

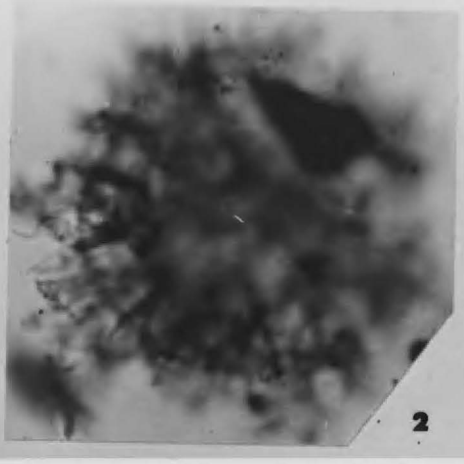

13

# Plate 19

Figures 1-2. Cyclonephelium sp. B. (1) Dorsal focus, apical archaeopyle to the northwest and (2) ventral focus, apical archaeopyle to northeast (same specimen rotated) showing ventral sulcul region and bases of some process complexes. BW124/2: 281 - 1109; both X1000.



1



2

## APPENDIX II

## DESCRIPTION OF SAMPLES

### IMPERIAL BATTLE LAKE NO. 1 WELL

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| GRAND RAPIDS FORMATION | | |
| 5520-5530 | BW 66 | Light greyish-white, fine to medium-grained sandstone (greywacke), "salt and pepper" appearance, with brownish iron stains. Very thin silty laminae. |
| 5507-5517 | BW 67 | Light greyish-white, fine-grained sandstone (subgreywack) with "salt and pepper" aspect and brown iron stains and ferrous mineral fragments. Thin silty and carbonaceous laminae. |
| 5502-5507 | BW 68 | Light greyish-white, fine to medium-grained sandstone (subgreywacke), with "salt and pepper" aspect. Thin carbonaceous laminae; grading into silty shale laminae near top of interval. |
| 5502 | BW 192 | Medium grey siltstone or silty shale, finely laminated, with occasional cross laminae. |
| 5499-5502 | BW 69 | Medium grey siltstone. |
| 5486-5493 | BW 70 | Dark grey silty shale with fish scale fragments; some light grey fine-grained sandstone with fish scale fragments. |
| 5479-5486 | BW 71 | Dark grey silty shale with discontinuous mud laminae having occasional pyrite crystals; light grey, very fine-grained sandstone or silty sandstone with plant fragments and carbonaceous laminae. |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| JOLI FOU FORMATION | | |
| 5477-5479 | BW 72 | Light grey shale or silty shale with a few plant fragments; dark bluish-grey shale near top of interval. |
| 5475-5476 | BW 72 | Dark bluish-grey, finely laminated shale. |
| 5472-5475 | BW 172 | Dark bluish-grey fissile shale with white efflorescence patches. |
| 5465-5470 | BW 74 | Dark bluish-grey fissile shale or fissile black shale. |
| 5452-5462 | BW75 | Dark bluish-grey fissile shale; some black shale laminae. |
| 5447-5452 | BW 76 | Dark bluish-grey shale, fissile. |
| 5440-5447 | BW 77 | As above. |
| 5430-5440 | BW 78 | As above. |
| 5420-5425 | BW 79 | Dark grey, finely laminated, fissile shale with some mica-rich laminar planes. |
| 5415-5420 | BW 80 | Dark-grey fissile shale, finely cross-laminated at base becoming silty towards top of interval, showing light grey siltstone, in part cross-laminated with discontinuous mud laminae. |
| VIKING FORMATION | | |
| 5411-5415 | BW 81; BW 118 | Medium dark grey silty shale. |
| 5409-5411 | BW 87; BW 119 | As above. |
| 5400-5409 | | No recovery. |
| 5389-5399 | BW 88 | Medium grey siltstone or silty shale with thin, discontinuous clay laminae; some gently inclined cross laminae. |
| 5375-5385 | BW 89 | Medium grey siltstone with irregular thin clay laminae. |
| 5365-5370 | BW 131 | Medium grey siltstone with irregular, discontinuous clay laminae; occasional fish scales and pyrite crystals. |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 5355-5365 | BW 90 | Medium grey siltstone. |
| 5342-5345 | BW 84 | Medium light grey siltstone with mud laminae irregularly distributed. |
| 5327-5342 | | No recovery. |
| UPPER SHALE UNIT | | |
| 5319-5327 | BW 91; BW 132 | Dark grey to black fissile shale with fish scale fragments; laminae faintly undulating. |
| 5309-5319 | BW 92 | Dark grey or black shale with white efflorescence patches. |
| 5304-5309 | BW 93; BW 120 | Dark grey or black shale with thin laminae visible. |
| 5294-5304 | BW 82; BW 121 | Dark grey fissile shale with pyrite crystals; silty shale laminae with intercalated, discontinuous clay laminae. |
| 5284-5294 | BW 83; BW 122 | Dark grey to black shale with white efflorescence. |
| 5274-5284 | BW 95; BW 123 | Dark grey to black shale. |
| 5265-5274 | BW 96; BW 124 | Dark grey to black fissile shale. |
| 5259-5265 | BW 97; BW 125 | Medium light grey to grey silty shale. |
| 5249-5259 | BW 98; BW 126 | Dark grey shale, laminated; some micaceous planes and occasional silty laminae. |
| 5239-5249 | BW 99; BW 127 | Dark grey or black fissile shale with silty laminae and white efflorescence patches. |
| 5234-5236 | Imperial Oil Ltd. Slide 11-453-LT. | No description available. |
| 5226-5234 | BW 100; BW 128 | Dark grey or black fissile shale with thin parallel laminae. |
| 5216-5226 | BW 82; BW 129 | Medium grey silty shale with abundant fish scales (1-2μ in diameter; dark grey or black shale at the 5225-5226 footage). |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| **KISSINGER IMPERIAL CHIGWELL NO. 1 WELL** | | |
| **JOLI FOU FORMATION** | | |
| 4943.1 | BW 85 | Dark grey, finely laminated, slightly silty shale. |
| 4933.3 | BW 105 | Dark grey, finely laminated, fissile shale. |
| 4923.3 | BW 106 | As above. |
| 4913.2 | BW 107 | Light grey siltstone beds (1-2 cms.) with irregular clay laminae, continuous over low undulations of silty beds. Small silt casts enclosed by mud laminae. |
| 4903.3 | BW 101 | Dark grey siltstone with discontinuous clay laminae. |
| **VIKING FORMATION** | | |
| 4893.1 | BW 108;<br>BW 115 | Medium light grey siltstone laminae or thin beds (about 1 cm.) with thin clay laminae and some cross-lamination. |
| 4883.7 | BW 109;<br>BW 116 | Medium dark grey siltstone with thin clay laminae; some cross-lamination present. |
| 4874.7 | BW 110 | Medium dark grey siltstone with light grey, very fine-grained sandstone laminae and thin clay laminae; some cross-lamination. |
| 4862.9 | BW 102 | Dark grey siltstone with irregular fine discontinuous clay laminae. |
| 4853.6 | BW 111 | Dark grey indurated siltstone with discontinuous clay laminae. |
| **UPPER SHALE UNIT** | | |
| 4846.2 | BW 112 | Dark grey to black fissile shale with thin parallel laminations. |
| 4832.7 | BW 103 | As above. |
| 4823.5 | BW 113 | Dark grey to black fissile shale. |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 4813.3 | BW 114 | Dark grey to black fissile shale with parallel to cross-laminae. |
| 4803.0 | BW 104;<br>BW 117 | Dark grey to black fissile shale. |

## ANGLO-CANADIAN OIL COMPANY WABAMUN NO. 1 WELL

### JOLI FOU FORMATION

| | | |
|---|---|---|
| 4622-4632 | BW 171 | Dark grey fissile shale weathering dark bluish-grey. |
| 4573-4583 | BW 184 | Medium grey shaly siltstone with irregular clay laminae; some cross-lamination and small clay casts present; a few course and pyrite crystals noted. |

### VIKING FORMATION

| | | |
|---|---|---|
| 4558-4568 | BW 185 | Medium grey siltstone with discontinuous clay laminae, clay casts, lamination highly irregular. Small pyrite crystals and fish scales present. |
| 4538-4548 | BW 186 | As above. |
| 4494-4502 | BW 187 | Medium grey siltstone with irregular clay laminae and clay casts; clay laminae sometimes enclose silt casts. Microscours and cross-laminae common. Fish scales. |

### UPPER SHALE UNIT

| | | |
|---|---|---|
| 4469-4479 | BW 188 | Dark grey slightly silty, fissile shale. |
| 4439-4449 | BW 189 | Dark grey fissile shale; occasional thin laminae visible. Medium grey siltstone laminae with clay present in microscours. |
| 4399-4409 | BW 190 | Dark grey to black, fissile shale, slightly calcareous. |
| 4369-4379 | BW 191 | Dark grey fissile shale with occasional thin medium grey siltstone laminae. |

## IMPERIAL GROSMONT NO. 1 WELL

### GRAND RAPIDS FORMATION

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 1573-1574 | BW 139 | Light grey, finely laminated siltstone with carbonaceous fragments and some medium dark brown bituminous, fine-grained sandstone with dark grey carbonaceous laminae. |
| 1536-1537 | BW 138 | Dark grey fissile shale, laminated, with small laminated silt casts and slightly silty shale laminae. |
| 1521-1528 | BW 170 | Light grey finely laminated siltstone with some light grey fine- or very fine grained sandstone laminae containing plant fragments. |

### JOLI FOU FORMATION

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 1516-1517 | BW 137 | Dark grey to black shale with small pyrite crystals. |
| 1510-1515 | BW 173 | Dark grey to black shale with some light grey shale siltstone having clay laminae and small clay casts. |
| 1500-1505 | BW 176 | Medium dark grey shale with calcite inclusions. |
| 1486-1490 | BW 177 | Medium dark grey fissile shale. |

### PELICAN FORMATION

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 1475-1485 | BW 183 | Very dark grey shale and silty shale with some finely laminated light grey siltstone. |
| 1469-1474 | BW 182 | Dark grey shale near the base of the interval becoming interlaminated with medium light grey siltstone. Silty layers may develop small casts and the shale laminae may become irregular. |
| 1455-1460 | BW 178 | Dark grey shale with some silty shale laminae and small silty casts. |
| 1428-1438 | BW 179 | Medium grey shale and silty shale. Slightly calcareous. |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 1408-1422 | BW 180 | Dark grey shale, grey silty shale and grey siltstone with irregular shale laminae. Some light grey, very fine-grained, poorly consolidate sandstone. Slightly calcareous. |
| 1402-1408 | BW 181 | As above. |

UPPER SHALE UNIT BASE: Approximately 1398 foot level.

## IMPERIAL GROUARD NO. 1 WELL

### PROBABLY PEACE RIVER FORMATION, CADOTTE MEMBER.

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 1397-1402 | BW 174 | Medium grey very fine-grained sandstone with irregular mud laminae and small silty casts; sandstone poorly consolidated. |
| 1394-1397 | BW 169 | Dark grey laminated shale, friable; some silty shale concretions in the shale. Light grey fine grained sandstone laminae and medium grey fine-grained sandstone beds present. |

### JOLI FOU FORMATION

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 1389-1394 | BW 168 | Medium grey shale with some silty laminae; cross lamination present. |
| 1384-1389 | BW 167 | As above. |
| 1379-1384 | BW 166 | As above. |

## IMPERIAL SPIRIT RIVER NO. 1 WELL

### PEACE RIVER FORMATION: HARMON MEMBER

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 2670-2680 | BW 153 | Coaly shale, followed by dark grey shale with thin coaly laminae and then by light grey fine-grained sandstone with carbonaceous fragments. |
| 2650-2660 | BW 133 | Dark grey shale, finely laminated with some thin silty laminae. |
| 2625-2635 | BW 154 | Dark grey silty shale. |
| 2600-2610 | BW 134 | Dark grey or very dark grey silty shale or shale, laminated, the laminae easily parted. |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| PEACE RIVER FORMATION: CADOTTE MEMBER | | |
| 2590-2600 | BW 135 | Dark grey finely laminated siltstone, parallel laminae. |
| 2570-2575 | BW 155 | Light grey fine-grained protoquartzite, poorly consolidated, with some light brownish grey fine-grained sandstone. |
| 2555-2560 | BW 156 | As above. |
| 2540-2545 | BW 157 | Light grey fine-grained protoquartzite, poorly consolidated, with some laminae or medium light grey siltstone. |
| PEACE RIVER FORMATION: PADDY MEMBER | | |
| 2535-2538 | BW 158 | Very light greyish-white, fine-grained protoquartzite or "subgreywacke" ("lithic" sandstone), poorly consolidated, with a few carbonaceous fragments. |
| 2515-2520 | BW 159 | Very light, greyish-white protoquartzite; light greyish-white fine-grained sandstone with carbonaceous laminae, interlaminated with dark grey micaceous siltstone and fissile shale. |
| 2490-2500 | BW 160 | Light grey, fine-grained sandstone, poorly consolidated; light grey, finely laminated, very fine grained sandstone or siltstone with carbonaceous fragments; some coaly shale. |
| 2470-2480 | BW 136 | Dark grey argillaceous siltstone. |
| 2450-2460 | BW 161 | Poorly consolidated mudstone; medium grey shale; some fine-grained grey subgreywacke; and complexly laminated siltstone with shale and carbonaceous laminae. |
| 2440-2445 | Not available. | |
| SHAFTESBURY FORMATION: LOWER SHAFTESBURY FORMATION | | |
| 2420-2430 | BW 140 | Medium dark grey silty shale with siltstone laminae and some fish scale fragments. |

| FOOTAGE | MACERATION NUMBER | DESCRIPTION |
|---|---|---|
| 2380-2390 | BW 145 | Medium dark grey silty shale with siltstone laminae; some cross-lamination. |
| 2350-2660 | BW 146 | Dark grey shale, very finely laminated, somewhat fissile; occasional siltstone laminae, cross-laminae, the mud laminae continuous. |
| 2330-2340 | BW 147 | Dark grey shale or silty shale with some siltstone laminae; cross-lamination present. |
| 2284-2294 | BW 141 | Medium dark grey silty shale with occasional silty laminae and small silt casts. |
| 2249-2259 | BW 148 | Dark bluish grey shale with silty laminae; fissile. |
| 2221-2231 | BW 149 | As above. |
| 2191-2202 | BW 142 | Dark bluish grey silty shale with some siltstone laminae, microscouring and cross-laminated. |
| 2161-2171 | BW 150 | Dark bluish grey silty shale. |
| 2132-2142 | BW 151 | As above. |
| 2103-2113 | BW 143 | Dark grey to black shale or silty shale. |
| 2074-2082 | BW 152 | As above. |
| 2045-2055 | BW 144 | Dark grey to black fissile shale. |

# APPENDIX III

## LIST OF TAXA DESCRIBED

| CODE NUMBER | TAXON |
|---|---|
| 01 | Stereisporites antiquasporites |
| 02 | S. sp. A. |
| 03 | S. sp. B. |
| 04 | Todisporites minor |
| 05 | T. major |
| 06 | Cyathidites australis |
| 07 | C. minor |
| 08 | Deltoidospora hallei |
| 09 | D. psilostoma |
| 10 | D. juncta |
| 11 | Undulatisporites cf. U. undulatipollis |
| 12 | Biretisporites potoniaei |
| 13 | B. cf. B. deltoidus |
| 15 | Dictyophyllidites sp. A. |
| 101 | Concavissimisporites punctatus |
| 121 | C. variverrucatus |
| 104 | Osmundacidites wellmanii |
| 114 | Baculatisporites comaumensis |
| 115 | Neoraistrickia truncata |
| 122 | Neoraistrickia? sp. A. |
| 113 | cf. Raistrickia sp. A. |
| 118 | Acanthotriletes varispinosus |
| 117 | Acanthotriletes sp. A. |
| 116 | Acanthotriletes sp. B. |
| 120 | Pilosisporites trichopapillosus |
| 119 | Pilosisporites verus |
| 106 | Cyclogranisporites sp. A. |
| 112 | Apiculatisporis? sp. A. |
| 109 | Converrucosisporites sp. A. |
| 111 | Converrucosisporites sp. B. |
| 110 | cf. Converrucosisporites sp. C. |
| 201 | Foveosporites cf. F. canalis |
| 234 | Lycopodiacidites sp. A. |
| 223 | Taurocusporites reduncus |
| 202 | T. segmentatus |
| 203 | T. minor |

| CODE NUMBER | TAXON |
|---|---|
| 204 | Tigrisporites scurrandus |
| 230 | T. sp. A. |
| 207 | RETICULISPORITES NORRISII sp. nov. |
| 205 | Dictyotriletes sp. A. |
| 208 | Microreticulatisporites uniformis |
| 209 | Klukisporites variegatus |
| 210 | K. pseudoreticulatus |
| 211 | Lycopodiumsporites austroclavatidites |
| 212 | L. reticulumsporites |
| 213 | L. marginatus |
| 206 | Lycopodiumsporites? sp. A. |
| 215 | *Cicatricosisporites* *minutaestriatus* (Bolkh.) COMB. NOV. |
| 216 | C. australiensis |
| 217 | C. hughesi |
| 218 | C. pseudotripartitus |
| 219 | C. perforatus |
| 222 | C. cf. C. sewardi |
| 231 | C. sp. A. |
| 232 | C. sp. B. |
| 233 | C. sp. C. |
| 401 | Trilobosporites apiverrucatus |
| 403 | T. marylandensis |
| 402 | T. cf. T. trioreticulosus |
| 404 | T. sp. A. |
| 501 | Appendicisporites perplexus |
| 502 | A. sellingii |
| 503 | A. cf. A. crimensis |
| 507 | A. cf. A. matesovai |
| 508 | A. cf. A. unicus |
| 506 | A. sp. A. |
| 510 | A. sp. B. |
| 601 | Gleicheniidites senonicus |
| 602 | Sestrosporites pseudoalveolatus |
| 603 | Camarozonosporites insignis |
| 604 | Camarozonosporites sp. A. |
| 701 | Cingutriletes clavus |
| 704 | Cingulatisporites reticingulus |
| 705 | C. ?saevus |
| 702 | C. sp. A. |
| 703 | C. sp. B. |
| 751 | Cirratriradites teter |
| 752 | cf. Kraeuselisporites sp. A. |
| 301 | Densoisporites microrugulatus |
| 302 | *Densoisporites* cf. *D.* *balmei* (Pocock) COMB. NOV. |
| 304 | D. sp. A. |
| 305 | cf. Cyclosporites sp. A. |

| CODE NUMBER | TAXON |
|---|---|
| 951 | Laevigatosporites ovatus |
| | *Januasporites* (Pocock) EMEND |
| 901 | *Januasporites spiniferus* (Singh) EMEND |
| 902 | Aequitriradites spinulosus |
| 907 | A. sp. A. |
| 903 | Rouseisporites reticulatus |
| 904 | R. triangularis |
| 905 | Cooksonites variabilis |
| 130 | Genus Undetermined sp. A. |
| 753 | Genus Undetermined sp. B. |
| 10001 | Cerebropollenites mesozoicus |
| 10112 | Vitreisporites pallidus |
| 10101 | Alisporites grandis |
| 10102 | A. robustus |
| 10103 | A. minutus |
| 10104 | A. microsaccus |
| 10105 | Parvisaccites radiatus |
| 10106 | ABIETINEAEPOLLENITES AEQUISACCUS sp. nov. |
| 10107 | ABIETINEAEPOLLENITES AURITUS sp. nov. |
| 10120 | A. sp. A. |
| 10121 | A. sp. B. |
| 10122 | Pityosporites constrictus |
| 10108 | Pinuspollenites sp. A. |
| 10109 | Piceaepollenites? sp. A. |
| 10110 | Cedripites cretaceus |
| 10111 | C. canadensis |
| 10151 | Phyllocladidites sp. A. |
| 10152 | P. sp. B. |
| 10153 | Podocarpidites cf. P. ellipticus |
| 10160 | Podocarpidites canadensis |
| 10161 | P. multesimus |
| 10162 | P. biformis |
| 10155 | P. sp. A. |
| 10154 | P. sp. B. |
| 10156 | Rubivesiculites rugosus |
| 10157 | R. cf. R. reductus |
| 10158 | R. sp. A. |
| 10159 | R. sp. B. |
| 10201 | Inaperturopollenites hiatus |
| 10202 | I. dubius |
| 10203 | Laricoidites magnus |
| 10210 | Sequoiapollenites sp. A. |
| 10204 | Araucariacites australis |
| 10301 | Eucommiidites troedssonii |
| 10302 | E. minor |
| 10351 | Ephedripites patapscoensis |

| CODE NUMBER | TAXON |
|---|---|
| 10401 | Clavatipollenites minutus |
| 10402 | C. hughesii |
| 10403 | cf. C. sp. A. |
| 10404 | Liliacidites cf. L. textus |
| 10405 | L. sp. A. |
| 10501 | Cycadopites fragilis |
| 10502 | C. follicularis |
| 10503 | C. carpentieri |
| 10504 | C. formosus |
| 10505 | C. sp. A. |
| 10506 | C. sp. B. |
| 10507 | Monosulcites sp. A. |
| 10508 | M. sp. B. |
|  | *Tricolpites* (Cookson ex Couper) EMEND |
| 10704 | *Tricolpites* *vulgaris* (Pierce) COMB. NOV. |
| 10702 | *Tricolpites* *paraneus* (Norris) COMB. NOV. |
| 10705 | *Tricolpites* *prosimilis* (Norris) COMB. NOV. |
| 10709 | Tricolpites sp. A. |
|  | RETICULITRICOLPITES gen. nov. |
| 10701 | *Reticulitricolpites* *sagax* (Norris) COMB. NOV. |
| 10703 | *R.* *georgenis* (Brenner) COMB. NOV. |
| 10707 | RETICULITRICOLPITES CRASSUS sp. nov. |
| 10708 | R. sp. A. |
| 10706 | *Cornaceoipollenites* *parvulus* (Groot & Penny) COMB. NOV. |
| 10710 | C. sp. A. |
| 10711 | Tricolpate Forma A. |
| 10712 | Tricolpate? Forma B. |
| 10713 | Tricolporate? Forma A. |
| 10714 | Periporate? Forma A. |
| 10801 | Circulina cf. C. parva |
| 10803 | Classopollis torosus |
| 10806 | C. cf. C. minor |
| 10807 | C. cf. C. pflugii |
| 10805 | Exesipollenites tumulus |
| 10902 | Schizosporis reticulatus |
| 20001 | Pterocystidiopsis sp. A. |
| 20102 | Platymorph Forma A. |
| 20404 | Baltisphaeridium cf. B. debilispinum |
| 20401 | BALTISPHAERIDIUM RALLUM sp. nov. |
| 20402 | BALTISPHAERIDIUM PLANISPINUM sp. nov. |
| 20403 | BALTISPHAERIDIUM TURBINATUM sp. nov. |
| 20406 | Micrhystridium cf. M. piliferum |
| 20407 | M. sp. A. |
| 20405 | M. sp. B. |
| 20503 | VERYHACHIUM INIQUUM sp. nov. |

| CODE NUMBER | TAXON |
|---|---|
| 20502 | V. reductum *forma* trispinoides |
| 20510 | V. reductum *forma* breve |
| 20505 | V. cf. V. collectum |
| 20504 | V. europaeum |
| 20501 | V. sp. A. |
| 20506 | V. sp. B. |
| 20507 | V. sp. C. |
| 20508 | V.? sp. D. |
| 20703 | Pterospermopsis australiensis |
| 20704 | P. sp. A. |
| 20701 | P. sp. B. |
| 20702 | P. sp. C. |
| 20705 | P.? sp. D. |
| 20751 | Leiofusa jurassica |
| 20752 | Leiofusa cf. L. lidiae |
| 20753 | L. sp. A. |
| 20754 | cf. Leiofusa sp. B. |
| 20755 | Metaleiofusa sp. A. |
| 20756 | ?Metaleiofusa sp. B. |
| 20801 | Leiosphaeridia sp. A. |
| 20802 | L. sp. B. |
| 20803 | L. sp. C. |
| 20804 | L. sp. D. |
| 20805 | L. sp. E. |
| 20806 | L. sp. F. |
| 20807 | L. sp. G. |
| 20901 | Palaeostomocystis fragilis |
| 20906 | Cyclopsiella? sp. A. |
| 20903 | Acritarch Forma A. |
| 21001 | MICRODINIUM OPACUM sp. nov. |
| 21002 | MICRODINIUM? CRISTATUM sp. nov. |
|  | DACTYLODINIUM gen. nov. |
| 21101 | *Dactylodinium jaegeri* (Alberti) COMB. NOV. |
| 21102 | D. sp. A. |
| 21104 | CANNINGIA CRASSA sp. nov. |
| 21103 | Canningia sp. A. |
| 21105 | Canningia? sp. B. |
| 21201 | Fromea amphora |
| 21202 | Fromea sp. A. |
| 21206 | TENUA LONGISPINA sp. nov. |
| 21207 | Tenua sp. A. |
| 21208 | Tenua? sp. B. |
| 21205 | Tenua? sp. C. |
| 22952 | Tenua? sp. D. |

| CODE NUMBER | TAXON |
|---|---|
| 21301 | GONYAULACYSTA GLOBOSA sp. nov. |
| 21302 | GONYAULACYSTA OBESA sp. nov. |
| 21303 | GONYAULACYSTA AUCTIFICA sp. nov. |
| 21304 | GONYAULACYSTA VILLOSA sp. nov. |
| 21309 | GONYAULACYSTA FRAGOSA sp. nov. |
| 21305 | Gonyaulacysta orthoceras |
| 21310 | *Gonyaulacysta* *granulata* (Singh) COMB. NOV. |
| 21308 | G. sp. A. |
| 21307 | G. sp. B. |
| 21406 | Trichodinium sp. A. |
| 21407 | Pareodinia? sp. A. |
| 21702 | Proximate Cyst Forma A. |
| 21706 | *Palaeoperidinium* *cretaceum* (Pocock) EMEND. |
| 21703 | Palaeoperidinium sp. A. |
| 22001 | Litosphaeridium? sp. A. |
| 22006 | OLIGOSPHAERIDIUM TOTUM sp. nov. |
| 22005 | OLIGOSPHAERIDIUM MINOR sp. nov. |
| 22008 | Oligosphaeridium complex |
| 22012 | *Oligosphaeridium* *anthophorum* (Cookson & Eisenack) COMB. NOV. |
| 22011 | O. cf. O. pulcherrimum |
| 22029 | *Oligosphaeridium* *irregulare* (Pocock) COMB. NOV. |
| 22003 | O. sp. A. |
| 22010 | O. sp. B. |
| 22009 | O.? sp. C. |
| 22015 | HYSTRICHOSPHAERIDIUM CYLINDRATUM sp. nov. |
| 22014 | H. stellatum |
| 22013 | H. sp. A. |
| 22016 | H. sp. B. |
| 22018 | H. sp. C. |
| 22017 | Hystrichosphaeridium? sp. D. |
| 22020 | Tanyosphaeridium sp. A. |
| 22022 | T. sp. B. |
| 22023 | Polysphaeridium sp. A. |
| 22025 | Diphyes sp. A. |
| 22026 | CORONIFERA ADMIXTA sp. nov. |
| 22027 | Callaiosphaeridium asymmetricum |
| 22028 | Systematophora schindewolfi |
| 22301 | Achomosphaera sp. A. |
| 22302 | A. sp. B. |
| 22303 | Hystrichosphaera ramosa |
| 22308 | H. cingulata |
| 22309 | H. cf. H. cornuta |
| 22312 | H. cf. H. buccina |
| 22313 | Hystrichodinium sp. A. |

| CODE NUMBER | TAXON |
|---|---|
| 22501 | Cyclonephelium cf. C. compactum |
| 22506 | C. sp. A. |
| 22502 | C. sp. B. |
| 22504 | C. sp. C. |
| 22503 | C. sp. D. |
| 22951 | *Cometodinium multispinosum* (Singh) COMB. NOV. |
|  | *Toolongia* (Cookson & Eisenack) EMEND. |
|  | (*Toolongia medusoides* (Cookson & Eisenack) EMEND.) |
| 22961 | TOOLONGIA ALATA sp. nov. |
| 22311 | Proximo-chorate Cyst Forma A. |
| 21003 | Proximo-chorate Cyst Forma B. |
| 23101 | Chlamydophorella nyei |
| 23102 | C. sp. A. |
| 23201 | Kalyptea monoceras |
| 23202 | K.? sp. A. |
| 23203 | K.? sp. B. |
| 23252 | Hexagonifera? sp. A. |
| 23301 | DEFLANDREA DIGNITOSA sp. nov. |
| 23310 | SPINIDINIUM VESTITUM sp. nov. |
| 23311 | Spinidinium sp. A. |
| 23312 | S. sp. B. |
| 23313 | S.? sp. C. |
| 23302 | Dingodinium cerviculum |
| 23501 | Aptea cf. A. polymorpha |
| 23502 | PSEUDOCERATIUM EXPOLITUM sp. nov. |
| 23503 | Odontochitina operculata |
| 23901 | Dinophyceae? Incertae Forma A. |

# APPENDIX IV

## COMPUTER PROGRAM

```
C     RECURRENT SPECIES ANALYSIS - BINØMIAL TEST APPRØACH
C     THIS PRØGRAM GIVES THE PRØB ØF ØBTAINING THE ØBSERVED NUMBER ØF
C     JØINT ØCCURRENCES ØF EACH PØSSIBLE PAIR ØF SPECIES AND ALSØ THE
C     PRØB ØF ØBTAINING THAT MANY ØR MØRE (IFØBS GT EXP) ØR THAT MANY
C     ØR LESS(IF ØBS LT EXP).
C     REQUIRED DATA DECK SET UP-
C       -1 CARD GIVING NØ SAMPLES NSAMP AND NØ SPECIES NSPP
C       -4 CARDS GIVING FACTØRIAL 1 TØ 32
C       -1 CARD FØR EACH SPP GIVING SP NØ IN CØL 1-3 AND ØCCURRENCE(1)
C         ØR NØN-ØCCURRENCE(0) IN EACH SAMPLE IN CØ L 6-(NSAMP+5)
C     IF NSAMP GT 32 ØR NSPP GT 100 DIMENSIØN AND FACT(I) MUST BE
C     CHANGED
C
      DIMENSIØN IDATA(100,32),FACT(32)
 1000 FØRMAT(2I5/(8F10.6))
 1001   FØRMAT(1H1,109HSPECIES NØ                                NUMBER ØF ØCCURRENC
     1ES                                  PRØB ØF ØBS NØ JØINT ØCC/1H+,
     2119H  M    N            M    N     PRØB ØF      EXP NØ        ØBS
     3NØ             PRØB ØF ØBS      PRØB(X GE ØBS     PRØB (X/1H+,
     4121H                                JØINT ØCC    JØINT ØCC      JØINT
     5 ØCC           NØ JØINT ØCC     NØ JØINT ØCC)    LE NØ ØBS))
 1002   FØRMAT(1H0,I4,I5,8X,2F5.0,F11.5,F12.3,F13.0,15X,F10.6,F17.6)
 1003   FØRMAT(1H0,I4,I5,8X,2F5.0,F11.5,F12.3,F13.0,15X,F10.6,17X,F14.6)
 1004   FØRMAT(1H1)
 1005 FØRMAT(5X,75I1)
      READ(5,1000)NSAMP,NSPP,(FACT(I),I=1,32)
      DØ 5 ISPNØ=1,NSPP
    5 READ(5,1005)(IDATA(ISPNØ,J),J=1,NSAMP)
      DØ 7 I=1,32
    7 FACT(I)=2.3026*FACT(I)
      M=1
      NLINES=0
   10 M=M+1
      K=M+1
      IF(M.EQ.NSPP)GØ TØ 35
      DØ 30 N=K,NSPP
      AM=0.0
      X=0.0
      AN=0.0
      DØ 15 L=1,NSAMP
      IF(IDATA(M,L).EQ.1)AM=AM+1.0
      IF(IDATA(N,L).EQ.1)AN=AN+1.0
      IF(IDATA(M,L).EQ.1.AND.IDATA(N,L).EQ.1)X=X+1.0
   15 CØNTINUE
      SAMP=NSAMP
      PMN=(AM*AN)/(SAMP*SAMP)
      IX=X
      IDUM1=SAMP-X
      DUM2=1.0-PMN
      EXPX=PMN*SAMP
      DUM1=IDUM1
      ALØPMN=ALØG(PMN)
      ALØD2=ALØG(DUM2)
      ALØGPX=FACT(NSAMP+1)-FACT(IDUM1+1)-FACT(IX+1)+X*ALØPMN+DUM1*ALØD2
```

```
      PX=EXP(ALØGPX)
      PXCUM=PX
      IF(IX.EQ.0.ØR.IDUM1.EQ.0)GØTØ29
      PXCUM=0.0
      IF(EXPX.GE.X)GØTØ25
      DØ 20 IXPØSS=IX,NSAMP
      IDUM1=NSAMP-IXPØSS
      DUM1=IDUM1
      XPØSS=IXPØSS
      ALØGPX=FACT(NSAMP+1)-FACT(IXPØSS+1)-FACT(IDUM1+1)+XPØSS*ALØPMN+
     1DUM1*ALØD2
      PXCUM=PXCUM+EXP(ALØGPX)
   20 CØNTINUE
      GØ TØ 29
   25 DØ 28 IXPØSS=0,IX
      IDUM1=NSAMP-IXPØSS
      DUM1=IDUM1
      XPØSS=IXPØSS
      ALØGPX=FACT(NSAMP+1)-FACT(IXPØSS+1)-FACT(IDUM1+1)+XPØSS*ALØPMN+
     1DUM1*ALØD2
      PXCUM=PXCUM+EXP(ALØGPX)
   28 CØNTINUE
   29 IF(NLINES.EQ.0)WRITE(6,1001)
      NLINES=NLINES+1
      IF(NLINES.EQ.27)NLINES=0
      IF(EXPX.GE.X)WRITE(6,1003)M,N,AM,AN,PMN,EXPX,X,PX,PXCUM
      IF(EXPX.LT.X)WRITE(6,1002)M,N,AM,AN,PMN,EXPX,X,PX,PXCUM
   30 CØNTINUE
      GØ TØ 10
   35 WRITE(6,1004)
      STØP
      END
```

| SPECIES NO M | SPECIES NO N | NUMBER OF OCCURRENCES M | N | PROB OF JOINT OCC | EXP NO JOINT OCC | OBS NO JOINT OCC |
|---|---|---|---|---|---|---|
| 1 | 56 | 2. | 2. | 0.00592 | 0.154 | 0. |
| 1 | 57 | 2. | 2. | 0.00592 | 0.154 | 0. |
| 1 | 58 | 2. | 2. | 0.00592 | 0.154 | 0. |
| 1 | 59 | 2. | 2. | 0.00592 | 0.154 | 0. |
| 1 | 60 | 2. | 17. | 0.05030 | 1.308 | 2. |
| 1 | 61 | 2. | 14. | 0.04142 | 1.077 | 2. |
| 1 | 62 | 2. | 4. | 0.01183 | 0.308 | 1. |
| 1 | 63 | 2. | 2. | 0.00592 | 0.154 | 0. |
| 1 | 64 | 2. | 10. | 0.02959 | 0.769 | 1. |
| 1 | 65 | 2. | 15. | 0.04438 | 1.154 | 2. |
| 1 | 66 | 2. | 10. | 0.02959 | 0.769 | 2. |
| 1 | 67 | 2. | 11. | 0.03254 | 0.846 | 2. |
| 1 | 68 | 2. | 15. | 0.04438 | 1.154 | 2. |
| 1 | 69 | 2. | 10. | 0.02959 | 0.769 | 1. |
| 1 | 70 | 2. | 11. | 0.03254 | 0.846 | 1. |
| 2 | 3 | 3. | 4. | 0.01775 | 0.462 | 0. |
| 2 | 4 | 3. | 6. | 0.02663 | 0.692 | 3. |
| 2 | 5 | 3. | 2. | 0.00888 | 0.231 | 0. |
| 2 | 6 | 3. | 14. | 0.06213 | 1.615 | 3. |
| 2 | 7 | 3. | 3. | 0.01331 | 0.346 | 1. |
| 2 | 8 | 3. | 2. | 0.00888 | 0.231 | 1. |
| 2 | 9 | 3. | 4. | 0.01775 | 0.462 | 0. |
| 2 | 10 | 3. | 2. | 0.00888 | 0.231 | 1. |
| 2 | 11 | 3. | 6. | 0.02663 | 0.692 | 2. |
| 2 | 12 | 3. | 3. | 0.01331 | 0.346 | 0. |
| 2 | 13 | 3. | 14. | 0.06213 | 1.615 | 3. |
| 2 | 14 | 3. | 3. | 0.01331 | 0.346 | 0. |

```
           PROB OF OBS NO JOINT OCC
PROB OF OBS          PROB(X GE OBS          PROB (X
NO JOINT OCC         NO JOINT OCC)         LE NO OBS)

   0.857012                                 0.857012

   0.857012                                 0.857012

   0.857012                                 0.857012

   0.857012                                 0.857012

   0.238276            0.378695

   0.202022            0.293077

   0.228490            0.266211

   0.857012                                 0.857012

   0.363071            0.541990

   0.215330            0.321875

   0.138368            0.178920

   0.155594            0.206922

   0.215330            0.321875

   0.363071            0.541990

   0.370025            0.576948

   0.627705                                 0.627705

   0.026388            0.031090

   0.793105                                 0.793105

   0.142623            0.217277

   0.247602            0.294244

   0.184666            0.206898

   0.627705                                 0.627705

   0.184666            0.206898

   0.120573            0.151662

   0.705761                                 0.705761

   0.142623            0.217277

   0.705761                                 0.705761
```