UPPERMOST CRETACEOUS COALS

A PRELIMINARY STRUCTURAL AND MICROPALAEOBOTANICAL INVESTIGATION OF SOME UPPERMOST CRETACEOUS COALS FROM WESTERN CANADA.

By

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SCOPE AND CONTENTS: A preliminary examination of the structural features and plant microfossils which characterize coals from thin seams in the Uppermost Cretaceous formation of western Alberta. Descriptions of the structural units and microfossils are complemented by quantitative appraisals of plant microfossil associations. Suggestions of probable floral components which existed during Uppermost Cretaceous times and possibilities of seam correlation and separation are forwarded. Illustrated by five photographic plates.

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INTRODUCTION

The application of palaeobotanical and petrological techniques to the analysis of Mesozoic coals has not been emphasized in the study of coal petrography. Palaeozoic coals, however, have been investigated relatively thoroughly, and knowledge regarding coal structure and constitution has advanced comparatively. The increase in active petrological and micropalaeobotanical investigations of Palaeozoic coals has paralleled the economic importance attached to the mining of Carboniferous coal throughout every continent. In contrast, coal deposits from Mesozoic strata have not been markedly exploited, and this corresponds with a lag in directed scientific investigation.

During the past decade, the tendency to emphasize research on Palaeozoic coals has lessened. This is especially true in Canada and the United States, where the discovery of oil and mineral deposits in regions overburdened by Mesozoic strata, has promoted geological and palaeobotanical activity. Numerous coal seams are associated with Cretaceous and Tertiary strata in particular, and they are being utilized increasingly as aids in correlation and stratigraphy. Cretaceous coals are mined to a limited extent in the foothill and rocky mountain regions of Western Canada, and important Mesozoic coal deposits are known to exist in western United States. At present, oil is increasingly replacing coal as a source of heat and fuel, with the result that many Alberta and British Columbia coal mines are inactive or in short production. As new uses for coal are considered, evidence from palaeobotanical analyses will presumably relate to an evaluation of potentialities.

At the present time, information related to the structure and constitution of Mesozoic coals is rather scanty. Triassic coals have been investigated in the United States, Greenland, and more recently in Australia. Coals of Jurassic age from the United Kingdom, Scandinavia and India have been examined palaeobotanically. Microfossil analyses have been undertaken rather extensively on Cretaceous coals from Germany and Austria, and to a lesser degree on coal deposits from Greenland and Africa. In general, activity has been directed toward micropalaeobotanical examinations, and Mesozoic coals have remained almost uninvestigated from the petrological aspect.

The limited degree to which research efforts have been directed towards the evaluation of coal structure and composition, is partially a result of problems and difficulties associated with the nature of coal and the methods employed in its' investigation. The opaque matrix which has resulted from the decay and subsequent compression of plant tissue presents the investigator with complex difficulties. Furthermore, much of the original plant material has been distorted and biochemically transformed into an amorphous mass. Spores and pollens, which are otherwise remarkably resistant to physical and chemical influences, have frequently been altered as a result of the compacting of the organic medium. The original plant compounds, metabolites, and by-products, have formed a medium in which resistant material such as cuticles and lignified remnants have become embedded. The change and rearrangement of plant material, combined with the processes of coalification, have produced an opaque and resistant organic matrix from which it is exceedingly difficult to derive consistently abundant evidence concerning organized structure, especially macroscopically.

In attempting to solve these problems, investigators have employed various methods. Microscopic detail is often discernible if the coals are examined in thin sections by transmitted light. Under these conditions the matrix is translucent, and the observer may recognize constituents _in situ_. Other methods involving maceration techniques have been applied to all ranks and types of coals with varying degrees of success. This method of analysis, however, destroys the less resistant constituents in addition to altering the structural characteristics of the coal, and for this reason is usually limited to microfossil evaluations. Although these methods, with subsidiary modifications comprise only two of those employed in coal analyses, they serve to illustrate analytical difficulties in attempted investigations. The painstaking efforts required to resolve the problems existing in a proper evaluation of coal petrology and coal palaeobotany, are not generally recognized.

The term microfossil, as employed throughout the investigation, refers in a restricted manner, to plant spores and pollens. Animal microfossils, diatoms, desmids, woody fragments and leaf cuticles have been utilized in stratigraphical and correlation problems with varying degrees of success.

However, each group is associated with particular types of deposits, and none has been found entirely suitable in correlation of coals. Spores and pollens are present in almost all coals in varying degrees of abundance, and have been found applicable to stratigraphic zonations and correlation attempts. For this reason, plant microfossils have formed the basis for the micropalaeobotanical interpretation of the coal samples in the present consideration.

The objectives of the present investigation are three-fold. Firstly, an attempt is undertaken to explore previously uninvestigated Alberta coals to determine the extent to which palaeobotanical studies may be applicable. Variations in constitution and structure in coals have been previously recognized, and the degree to which palaeobotanical evidence is available varies correspondingly.

Secondly, an attempt is made to discover whether potential structural indices revealed in the Brazeau coals offer a basis for comparison and contrast with previously described Carboniferous coals. The ranks, types, and plant constituents which characterize various coals are important economically, in addition to providing an insight into coal composition and associated palaeoecological conditions. In this respect, previous investigations have indicated that microfossil species and frequency differences may exist within coal types. The evaluation of this possibility, is, therefore, associated with the objective of investigating structural features.

Thirdly, the present investigation attempts a systematic appraisal of the microfossil content within the coals. Plant microfossils have been utilized repeatedly in stratigraphy, and in the dating and delimitation of many geological horizons. Correlations of commercially important coal seams, mineral strata and oil shales are often dependent on an examination of associated plant microfossil groupings. Furthermore, information related to plant associations, plant structure, and palaeoecological conditions is frequently obtained through a careful investigation of microfossil types and associations. In order that this information be organized and of value, a systematic record suggesting classifiable data and systems is necessary. As an extension of the latter, the possibility of a quantitative appraisal is significant and would complement the qualitative data.

It is hoped that if these objectives can be met, the foundation will be laid for increased knowledge and understanding of the micro-constituent and structural ranges of Alberta coals. This realization will almost certainly assist in problems of coal correlation and stratigraphy of associated strata.

HISTORICAL

The Development of Coal Petrology. Information related to the petrology of coal has accumulated progressively throughout the last century. Since 1833, when the first published dissertation on coal composition appeared, the number of scientific papers dealing with the structure and constitution of coal has become extensive, with the result that pertinent literature has become somewhat exhaustive. In connection with this increase, certain trends in the interpretation of petrological evidence have developed, and a careful consideration of these trends is important in forming an appreciation of the significance of petrological investigations. To emphasize the important developments, however, and because the present investigation is fundamental in scope, the historical developments will be restricted to those contributions which are basic.

During the 19th century, interest became directed towards an understanding of the origin and constitution of coal. In 1833, Witham (57) applied thin sectioning methods to Lancashire coals, and noted what he termed "traces of organization." These traces were believed by Witham to be vascular tissue of monocotyledonous plants. Later observations, however, indicated that the vascular elements represented megaspores and microspores. In 1855, Franz Schulze developed a chemical maceration method which proved useful in separating plant constituents from coal matrices without extensively damaging the incorporated tissues (40). With modifications and refinements, these two methods of coal analysis have essentially formed the basis for the techniques which have been employed in coal petrology and micropalaeobotany to the present day.

The period from 1855 to 1900 was highlighted by two studies, although in general, little valuable information relative to coal petrology was forthcoming. During this time, Dawson (4) made extensive observations on the microscopic constituents of coal from the South Joggins area of Nova Scotia. He concluded that coal consisted chiefly of woody tissues such as bark, and that spores and reproductive tissues were minor ingredients. The presence of upright fossilized tree trunks with intact roots was interpreted by Dawson to be evidence supporting the "in situ" theory of coal deposition. This important study was followed in 1884 by investigations on coals from Russia and Saxony by Reinsch (34). His publication illustrated small organisms which were believed to be algal remains. These units were later identified as spores.

From the turn of the century to 1919, petrological examinations were mainly centred in America. In 1910, Jeffrey (13) developed a satisfactory method of preparing microtome thin sections, which he applied to coals of supposed algal origin. As a result, he revealed that the "algae" were actually spores and spore exines. Subsequently in 1913, White and Thiessen (54) referred to thin sectioning by grinding and polishing. This method was later perfected, and has been applied successfully to coals from deposits of various geological ages.

From 1919 to 1930, attention was mainly focused on the formulating of a suitable nomenclature to be applied to the structural units of coal and their associated constituents. This program was initiated by Stopes (46) in 1919, when she adopted the terms vitrain, clarain, durain and fusain for the four visible constituents of banded bituminous coal. These terms were accepted and applied by petrologists in England, Germany and France. In the United States, however, Thiessen and his co-investigators proposed the terms anthraxylon and attritus as accurate designations for two coal types. Although an International Congress for the study of the Stratigraphy of the Carboniferous Rocks at Heerlen in 1935 recommended that, with modifications, Stopes nomenclature be adopted, the differences noted above still exist.

As the development of a suitable terminology for recognizable types was continuing, information regarding microscopic constituents was accumulating. In the United States, Thiessen and his co-workers examined thin sections of Carboniferous coals from the commercially important seams in that country. (49) (50) (51) (52) (53). The resultant observations indicated that the "bright" coal, or anthraxylon, was mainly composed of distorted woody remains, whereas the attritus, or "dull" coal, consisted chiefly of microfossil concentrations and associated compounds, with interbedded lenticular deposits of anthraxylon.[1] This work has been

1. The woody remains refer to large limbs, trunks, and bark of trees. The term microfossil is employed in the broad sense to include spore, pollens, woody fragments, cuticles and needles. The associated compounds include resins, gums, pectins, tannins, etc., when present.

continued by Schopf (35) (37) (38), who has considered petrological evidence from coals of varying ages. The information resulting from this extensive program has provided valuable evidence regarding the structure and constitution of coal.

The period of petrological research in Europe from 1919 to 1930 was devoted mainly to the nomenclature of structural coal types, and as a result, coal classification, though better understood, was associated with problems of increased intricacy. Seyler and Stopes in England, R. Potonie in Germany, and Duparque in France contributed notably to the recognition and description of types in coal deposits from their respective countries. From 1930 onward, however, attention was mainly focused on micro-petrology and the identification of particular constituents within coals. Noteworthy contributions include those of Hickling (10), Hickling and Marshall (11) (12), Jongmans and Koopmans (14), Seyler (41) (42), and R. Potonie (22), besides many other investigations relating to coal compositions. At the present time, the number of petrological contributions emanating from Europe is decidely limited, and most recent knowledge on the subject is being mainly provided by American workers.

Analytical Methods using Microfossils. As was noted in connection with the history of coal petrology, the first recorded observation of plant micro-fossil material in coal was made in 1853. Since that date, many investigations have been directed toward microfossil evaluations. In the majority of cases, Palaeozoic coals have been selected for consideration. Because of this trend, which provided much information of a fundamental nature, analysis of Palaeozoic coals will be referred to mainly. Cretaceous coals, however, are presently under consideration, and emphasis will thus be placed on microfossil analyses of Mesozoic deposits.

It was previously recorded that Thiessen and his co-investigators examined thin sections of coal and noted the presence of spores embedded in the organic matrix. In England, Slater, Evans and Eddy (43) applied similar methods to English coals and recognized several spore types. In each case the results were important from the palaeobotanical aspect, but much valuable information pertaining to microfossil morphology was lost through limitations in the thin section technique.

In 1931, R. Potonie (24) described microfossil spores from Tertiary coal deposits in Germany. This analysis initiated the development of maceration techniques for the isolation of spores and pollen which have been successfully applied to many types of coal. Subsequently, Potonie, Ibrahim and Loose investigated microfossil types from coal deposits in Germany employing the same method. During the same period, Raistrick and Simpson (29), utilizing microfossils, attempted correlations of coal seams from the Northumberland district of England. They described and classified numerous spores depicting wide range in character. These were labelled and arranged with the aid of letters and numeral subscripts. This method was later extended by Raistrick to other English coal fields with reasonable success. More recently, American workers have applied chemical maceration methods to Palaeozoic coals in that country (30) (39) (18). The spore types encountere show marked similarities to those from English coals, and a general appreciation of spore associations and frequency of occurrence has resulted from these investigations.

Historical developments related to microfossil analyses of Mesozoic strata are few in number. The importance of microfossil evaluations in appraising the rapidly changing flora of Mesozoic periods, and to economic needs, has only recently been applied.

Probably the first account of microfossils associated with Mesozoic deposits was presented by Kirchheimer (15), who described plant microfossil types in Cretaceous coals from South Africa. Of particular interest was Kirchheimer's description of pollens belonging to the presently existing families of Betulaceae, Myricaceae and Pinaceae. Miner (20) investigated Cretaceous coals from Greenland and described spore types resembling those of the Gleichenites and Laccopteris ferns, which are commonly associated with Mesozoic deposits. Subsequently, Jurassic deposits in India were investigated by Rao (32), who recognized species of winged-pollen similar to those of modern conifer types. Simpson (45) examined Jurassic coals from Scotland and described numerous microfossils, most of which resemble conifer pollens. These developments, in the main, represent the extent of early micro-fossil investigations.

Spores associated with Triassic mineral deposits in the petrified forests of Arizona have more recently been described by Daugherty (3). In 1943, Rao recognized additional microfossils and sporangia from the Jurassic strata of India (33) and several identifiable Jurassic angiosperm pollens have been noted by Erdtman (9).

One of the most comprehensive recent examinations of Mesozoic microfossils has been undertaken by Thiergart (48). He has described spores and pollens from every Mesozoic stratum in Germany and Austria excepting the middle Cretaceous, and has summarized his account by presenting a table of microfossil frequency percentages within each stratum. The spores and pollens are represented by Pteridophyte, Gymonosperm and Angiosperm types within the 10-200 size range. By limiting the size range, Pteridophyte megaspores were excluded from the consideration.

Additional recent studies include an analysis of microfossil types by De Jersey (5) from the Ipswich coals of New Zealand, which are supposedly of middle Triassic age. As a result of this examination, eleven of the thirty-one types identified had been previously recognized by Dulhunty (6) in Permian coals from Queensland. Hence the delimitation of the Ipswich coals into middle Triassic has been questioned, and De Jersey is inclined to refer them to an earlier stratigraphic position.

In addition to the investigations of Mesozoic microfossil associations, numerous microanalyses of Tertiary coals have been undertaken. Among the more important may be cited the works of R. Potonie, Kirchheimer, and Thiergart in Germany, Wodehouse, Wilson and his co-investigators in the United States, and Simpson in England. The micropalaeobotanical studies directed towards Tertiary deposits have been somewhat more extensive than those in Mesozoic strata. This appears to be partially a result of the more widespread occurrence and availability of non-marine Tertiary deposits throughout most continental regions. If similar directive efforts could be applied to Mesozoic strata, valuable information with respect to evolutionary floral changes and stratigraphic delimitations would inevitably be forthcoming.

GEOGRAPHICAL AND GEOLOGICAL CONSIDERATIONS

The various coal samples were collected from Upper Cretaceous strata in the Entrance Map-area of Western Alberta (Lang (19)), which is located between latitudes 53° 15' - 15° 31', and between longitudes 117° 30' - 117° 45'. The area embraces part of the Athabaska River valley, and is traversed by the Edmonton-to-Jasper Canadian National Railways main line, and the Edmonton-to-Jasper provincial highway No.16, both of which facilitate accessability to regions of geological interest.

The Entrance region is situated within the Foothills belt immediately eastward from the Rocky Mountains, and contains outcropping strata ranging in age from Lower Cretaceous to Paleocene. Almost ninety per cent of the area, however, is composed of outcrops of uppermost Cretaceous (Brazeau) and Paleocene formations. It is reported by Lang (19) that Paleocene deposits in this region contain several coal seams which are potentially important commercially. This possibility is based on similarities of Paleocene deposits in the Entrance area which have been correlated with those southeastward, notably at coal-mining centres such as Coalspur and Mercoal. Additional evidence is afforded by former coal-mining operations at Drinnan, which is within Paleocene strata of the Entrance Map-area.

Underlying the Paleocene deposits, and separated from them by the Entrance conglomerate, is situated the Brazeau formation. The differentiation between Cretaceous and Tertiary strata is the result of the work of geologists who have been hampered by difficulties in stratigraphic sequence within these non-marine deposits. As stated by Lang (19), "The exact age and terminology of the Upper Cretaceous and early Tertiary non-marine stata and the precise delimitation of the Cretaceous-Tertiary boundary in many parts of Alberta are unsolved problems. They are made difficult by the great thickness of strata of fairly similar lithology, with few horizon markers and few fossils other than plant remains."

In order to provide a measure of correlation with the Uppermost Cretaceous and Lower Tertiary deposits, Bell (1) presented evidence from fossil plants collected throughout the area suggesting that strata overlying the Entrance conglomerate are Paleocene in age, while those immediately below are uppermost Cretaceous. This distinction is based upon stratigraphic variation in range of species. As a result, the Entrance conglomerate has been defined as the separating stratigraphic unit between Cretaceous and Tertiary strata throughout the Entrance Map-area.

The possibility of providing microfossil evidence which would support the existing separation of Cretaceous and Tertiary deposits was considered in connection with the present investigation. Unfortunately, however, all the available coal samples were collected from the Brazeau formation. Therefore, to undertake comparisons of microfossil species and frequency variations within samples of Cretaceous and Tertiary coal seams, has been impossible.

The brazeau formation is composed of approximately 6000 feet of interbedded sandstone, shale, and pebble conglomerate, and contains numerous thin coal seams (Lang (19). The seams are typically associated with carbonaceous shales, siltstones, silty shales and clay partings; although the pattern does not indicate a uniform sequence of deposition relative to each seam. The deposits associated with each seam, and hence with each sample, are listed in Table I.

TABLE I

SAMPLE	T154-1	T197-1(a)	T204-2(b)	T428-1and @ 204-1	@ 204-6
SEQUENCES AND DEPTHS OF ASSOCIATED DEPOSITS	Top	Top	Top	Top	Top
	11.2'-Grey buff weathered sandstone and bentonite in ½" sheets.	6'-buff weathered sandstone.	3.3'-Carbonaceous shale and thin coal seams. T 204-2(b)	18.7'-Yellow slabs of sandstone in 4" beds. Carbonaceous material throughout.	80' app. sandstones and shales.
	0.2'-Grey crumbly shale.	12'-alternating grey bedded and silty shale.	2.3'- Tan and fine-grained sandstone	1.5'- Coal seam T428-1 Base	4.0'- Green-grey silty shale with plant remains
	0.9'- Coal and Carbonaceous shale T154-1	4'-alternating coarse and fine-grained sandstone.	6.0'- Shale with clay ironstone	Top 15'- Fine-grained sandstone.	0.7'- Carbonaceous shale containing thin coal seam @ 204-6
	3.6'- light grey silty shale with plant fragments.	0.5'- Thin coal seam. T197-1(a)	1.0'- lens of silty shale.	3'- Grey sandstone and shale.	2.0'- bedded shale.
	0.7'-Carbonaceous shale	2½'- alternating coarse and fine-grained sandstone.	21'- Grey silty shales and tan sandstone. Lenses of carbonaceous material	10.2'- Grey silty shale and lenses of sandstone.	2.0'- fine-grained sandstone.
	0.8'- Soft green bentonitic shale	0.5'-Carbonaceous shale.		3.0'- Shale and thin coal seam. @ 204-1	73' app. grey sandstones and shales.
	1.0'- green embedded shale with plant fragments.				
	Base	Base	Base	Base	Base

PREPARATION PROCEDURES

Polished Surface Procedure. In this work, preparation of the coal samples for structural analysis was effected by employing the polished surface procedure. This method of investigation has been successfully applied by Duparque, Jongmans and other workers. It is especially valuable as a method of examining higher rank coals which have yielded to compression and compacting, and which possess a degree of opacity. However, for an accurate and complete appreciation of incorporated tissues within low and medium rank coals the thin section technique is preferable. Because only macroscopic associations of structural units within the coals are to be evaluated in the present investigation, the polished surface method along has been used throughout.

A detailed description of the polished surface technique has been given by Raistrick and Marshall (31), but is presented here in condensed form to facilitate reference.

If a preliminary examination of the sample reveals a tendency toward splitting or crumbling, embedding in paraffin or celloidin is recommended. Following this preparation, a flat surface along the desired plane or axis is exposed by cutting on a rotating circular blade. The irregularly flattened surface is subsequently ground with three sizes of carborundum powder or other abrasive. Care should be exercised to wash away all traces of abrasive before the next smaller size is used. This caution prevents scratches which would result from stray grains of a coarser abrasive.

When the surface is uniform, it is set aside to dry. The final polishing is achieved with jeweller's polishing powder or other non-abrasive compounds. In this condition, the surface is ready for examination.

Identification of structural features was accomplished by means of reflected light. An ordinary flexible tubing lamp is quite adequate, although sunlight or diffuse outdoor light are also suitable. For photographic purposes, two opposed floodlamps have been found applicable. However, a large angle of incidence is necessary to reduce glare.

During preparation, certain modifications and refinements in technique seemed helpful. The cutting and grinding processes sometimes crumbled the more friable coals along fracture lines and bedding planes. This difficulty may be successfully resolved by immersing the complete coal block in melted paraffin for 1 - 2 hours as recommended by Raistrick and Marshall. This process, however, exposed paraffin on the outer surface, necessitating the application of xylol after each carborundum change. This dissolved the surface of the paraffin and released the grains of abrasive. The interbedded paraffin also aided in preserving the surface, as naturally constituted, and avoided swelling and cracking during prolonged immersion in water.

A further modification in the procedure was attempted by introducing a pre-polishing step. This consisted of polishing the honed surface vigorously with refined sodium bicarbonate. The addition of this step to the procedure provided a semi-polishing effect and greatly facilitated the final polishing.

The preparation of polished sections is time consuming and somewhat laborious. To prepare a suitable surface requires between 2 - 3 hours. However, if pretreatment in paraffin is administered, several samples can be prepared at the same time. An effective procedure consists of applying one step to two or three samples before advancing to the next stage. This multiple application makes several preliminary preparations requiring individual treatment unnecessary, and thus saves time and effort.

Maceration Methods. Chemical maceration methods have been applied to coals of all ranks and ages. These methods have been directed at the separation of microscopic plant constituents from the surrounding matrix, and making them available for examination. Reagents have been chosen which will oxidize the embedding compounds and free the more resistant components. Various combinations of chemical reagents have been used successfully in performing this separation, and have had wide application in micropalaeobotanical analyses of coal.

(1) Bromine Method.

In the present investigation, two maceration methods were employed. The first consisted essentially of bromination, and has been described by Darrah (2). Undiluted liquid bromine (commercially prepared) was added to 5 - 10 mm. coal fragments for a period of 4 - 6 hours. Subsequently, the bromine was allowed to vaporize for 1 hour, and was replaced by 100 c.c. of concentrated nitric acid. This reagent was allowed to react for 8 - 10 hours, after which time, the liquid was decanted and replaced by 50 per cent ammonium hydroxide. Although not stated by Darrah, the optimum time for allowing the ammonium hydroxide to react has been found to be 8 - 12 hours.

(ii) Schulze's Solution Method.

The second maceration method was accomplished using a modification of the well known Schulze's solution, which consists of potassium chlorate dissolved in concentrated nitric acid. The reaction involves oxidation of the humic compounds which form the coal matrix. Detailed descriptions of this method have been presented by Raistrick and Marshall (31) and more recently by Kosanke (18). To effect the maceration, the powdered coal was mixed with an equal weight of crystallized potassium chlorate. To this mixture was added approximately 100 ml. of concentrated nitric acid, and the preparation was allowed to stand from 15 - 25 hours, depending upon the rank of the coal involved. After an appropriate period, the nitric acid was decanted, and replaced by 100 ml. of 10 per cent ammonium hydroxide which was allowed to remain for 5 - 10 hours. The final treatment consisted of the replacement of ammonium hydroxide by 2 per cent solution of potassium hydroxide for a period not exceeding 3 hours.

In each of the methods, care was taken to wash the sediment between reagent changes, and a suitable period was allowed for settling. To insure that more buoyant microfossils were removed from the liquid medium, each sediment was centrifuged. Centrifuging was particularly necessary after treatment with potassium hydroxide, which, in combination with humic matter, is more viscous than ammonium hydroxide.

The preparation of microscopic mounts was accomplished by using a mixture of 3 parts of corn syrup (d-glucose) and

2 parts of distilled water. To prevent fungal and bacterial contamination, a few drops of 5 per cent phenol were previously added. This method was successfully applied by Radforth (28) in the examination of spores from Carboniferous ferns. The use of corn syrup has several advantages over methods employing such media as glycerine jelly, diaphane and Canada balsam. The preparation of diluted corn syrup can be accomplished relatively rapidly, and may be applied to residues which have been stained with aqueous dyes without intermediate changes of alchol and xylol. In addition, the syrup dries quickly, which facilitates handling and storage. Orienting microfossils or removing debris may be undertaken after dissolving the syrup medium with water.

The photographic records were all obtained by means of transmitted light. The equipment used included a Bausch & Lomb binocular microscope, a Leitz Ipso attachment, and a Leica 35 mm camera. Size measurements were obtained with the aid of an ocular micrometer scale.

The bromine method was attempted because of the shorter time interval required for complete maceration, and because of the possibility of less severe reaction. The method has proved applicable to the more friable coals investigated. However, the time required for the bromine to accomplish maceration of the more durable and compact coals is lengthened considerably, and Schulze's solution has been found entirely suitable for maceration of these samples.

In order to ascertain and correlate the effectiveness of both maceration methods, each was applied to a portion of one sample of coal, and a count of 200 microfossil types

TABLE II

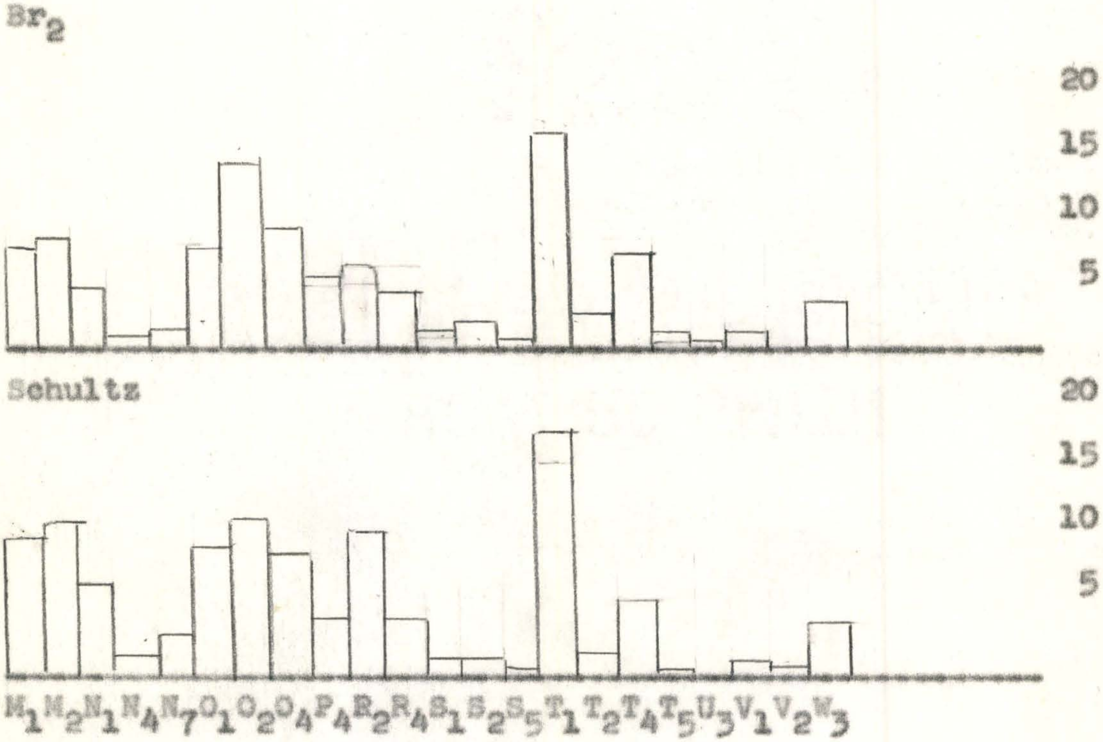
Comparison of Br_2 and Schultze's Methods

% frequency of microfossils in @ 204 - 6

REAGENT	M_1	M_2	N_1	N_4	N_7	O_1	O_2	O_4	P_4	R_2
Br_2	7.5	8.5	5	1	2	8	14	9.5	5.5	7
Schultz	9	10.5	6.5	1.5	2.5	8.5	11	8	3.5	9.5

REAGENT	R_4	S_1	S_2	S_5	T_1	T_2	T_4	T_5	U_3	V_1
Br_2	4.5	1.5	2	0.5	16	2.5	8	1	0.5	1
Schultz	3.5	1	1	0.5	18	2	5.5	0.5	--	1.5

REAGENT	V_2	W_3
Br_2	--	4
Schultz	1.0	3



was obtained from each sediment. The variation in frequency of occurrence was not greater than 3 per cent for any microfossil type, which indicates that the methods are closely equal in effecting maceration. A consideration of this evidence is important because several of the coal samples prepared for microfossil frequency determinations were macerated with bromine, whereas the remainder were subjected to the modified Schulze's solution. (See Table II)

In connection with both methods, the choice of kind and strength of alkali deserves comment. Ammonium hydroxide and potassium hydroxide have been applied by various investigators with favourable results reported for both. Raistrick (30) indicated that a ten per cent solution of K O H removed the material adhering to spores more readily than the equivalent concentration of NH_4OH. In the present investigation, this was confirmed. However, as previously noted, the K O H solution is more viscous, with a resultant tendency to suspend more buoyant microfossils. In attempting to resolve this complexity, a dilute K O H solution was added to the residue after the 5 - 10 hour treatment with NH_4OH. The addition of this dilute alkali was noted in most cases to afford greater clarity to the surface of the microfossils. In order to facilitate the deposition of suspended microfossils, each preparation was centrifuged for approximately one minute. This modification in alkali treatment has been helpful in the analysis of all the coal samples investigated, and the author recommends its' application.

With regard to the application of corn syrup as a mounting medium, additional advantages and disadvantages deserve evaluation. This is particularly important because the method has not been widely reported by micropalaeobotanical investigators. The use of diluted corn syrup eliminates the necessity of dehydration and subsequent alcohol and xylol changes associated with other mounting media in preparing the material for mounting. In addition, it has a comparatively low index of refraction, which reduces difficulties in observation and photography. A convenient method facilitating re-examination and alteration of the microfossils in the mount consists of breathing on the surface of the hardened medium. The increased moisture made available liquifies the corn syrup and allows the investigator to manipulate the microfossils at will. The application of a small droplet of water has a more drastic liquifying effect, and frequently results in turbulance, which moves the microfossils from the field of view.

The suggested procedural modifications have been discussed and reviewed at some length. However, many difficulties arise in the application of techniques to the analysis of coal, and a consideration of these difficulties appears to be important for future progress.

BRAZEAU COAL STRUCTURE

In the petrological investigation of the Brazeau coals, an attempt has been made to indicate those features which can be appreciated from an examination of hand samples and polished surfaces. This has resulted in the recognition of rank, type, and maceral constituents within the coals, and has provided evidence as to structural features of Brazeau coals.

A survey of the samples made available for this investigation reveals that the coals are sufficiently different structurally to be validly separated for classification purposes. The differences relate to the rank, types, and macerals which form the structural character of each coal. The evidence gathered from the examination of various samples is presented here to show the range in structure associated with the Brazeau coals.

With respect to rank, samples shown in photographs in Plate I figs. 6 - 8, 10 - 11, 13 - 14 contrast with those shown in Plate I, figs. 1 - 4, 9 and 12. The former are comparatively uncompacted, and tend to separate easily along the longitudinal bedding planes. These are features characterizing sub-bituminous coals. The latter contrast with the first group in that they are harder, heavier, fracture cubically, but do not tend to crumble on handling or swell and crack on immersion in water. These are attributes of bituminous coals. Thus two ranks (sub-bituminous and bituminous) are present among the samples.

Of the four recognizable coal types occurring in banded bituminous coals from Palaeozoic deposits, only three have been identified in the Brazeau samples. These are vitrain, durain, and fusain. The "bright" coal type or clarain is apparently non-existent, and the typical banded appearance resulting from the presence of clarain is lacking in all samples examined.

Vitrain is the term used to describe the uniform, brilliant black coal type possessing a typical conchoidal fracture. This type composes the lower regions of sample T 204 - 2(d) (Plate I figs. 1 and 2), and the brilliant lustre and characteristic fracture of vitrain may be noted in Plate I, figs. 6, 11 and 14. The vitrain associated with the sub-bituminous samples is friable and unconsolidated, whereas that of the bituminous samples is comparatively resistant and compact. In addition, vitrain of the higher rank samples has a tendency towards fracturing rhomboidally as well as conchoidally. This may be noted in Plate I, figs. 1 and 2.

The term fusain is applied to charcoal-like layers or deposits which readily soil or blacken the fingers upon rubbing, and has been described as occurring in numerous Palaeozoic coals. This coal type is present to a limited extent in the Brazeau samples; being frequently associated with unconsolidated vitrain segments in the sub-bituminous samples. (Plate I, figs. 6 and 7) Unlike the fine powdery nature of fusain from Palaeozoic bituminous coals, the type found in the Brazeau samples is coarse, and feels somewhat gritty when rubbed between the fingers.

Durain is the term which has been applied to the light, grainy, and often laminated segments of Palaeozoic coals. This structural type forms a large part of the coal within the Brazeau samples. Durain segments may be noted in the samples shown in Plate I, figs. 3 - 5. Small lenses of vitrain are frequently scattered throughout the durain, which gives to this type its' laminated appearance. In some horizons, however, (top portions of sample shown in Plate I, fig. 5 and lower regions of fig. 9) the vitrain bands are either absent or form large lenticular masses within the durain, giving a uniform granular appearance to this type. The pebbled or grainy appearance is characteristic of durain within the Brazeau samples, and produces a background against which vitrain bands are easily recognized.

Clarain is the term applied to the coal type in Palaeozoic banded bituminous coals which constitutes alternating thin bands of vitrain and durain. A comparable coal type has not been recognized in the Brazeau samples. The inter-bedded vitrain and durain segments in the latter samples are usually thick and narrowly lenticular, and the banded condition characterizing clarain is not present.

The term "maceral" was proposed by Stopes and adopted by the International Congress to refer to individual constituents within coal types. The types vitrain and fusain are regarded as analogous to rock types, whereas the macerals vitrinite and fusinite are similar to minerals within the rocks. Clarain and durain are composed of maceral complexes, and no individual terms similar to vitrinite and fusinite have been applied to these constituents. The vitrinite bands referred to are identical in substance to vitrain, and the term simply indicates the manner in which the vitrain is associated with the other coal types. As an example of this differentiation, samples shown in Plate I, figs. 6 and 14 are composed of vitrain, whereas the thin lenticular masses of like substances in the samples shown in Plate I, figs. 1 - 4, 9, are termed vitrinite. This system of nomenclature is somewhat confusing and not entirely satisfactory, but is utilized throughout this investigation to preserve international uniformity in referring to coal structure.

The three coal types and constituent macerals are found in various associations throughout the samples. Figs. 1 - 5 in Plate I, indicate a typical orientation of lenticular vitrinite bands within a durain matrix. In sample T 204 - 2(d), (Fig. 1 and 2), the lower region is composed almost entirely of vitrain, whereas the upper portion consists of interbedded durain and vitrinite. In sample T 204 - 2(b), Figs. 3 and 4), and extensive durain mass grades upward into vitrain, with the transition zone indicating a somewhat gradual intermingling of the two types. Of particular interest in connection with the latter sample is the obvious association of small vitrinite lenses within the durain. Theламinated appearance resulting from the lenticular inclusions is in contrast to the uniform appearance of figs. 8 and 10, which are polished surfaces of durain in lower ranking samples.

A commonly occurring type association is illustrated in Plate I, figs. 6,7, and 11. Within these samples, fusain is found deposited between succeeding layers of vitrain, which produces a somewhat friable matrix. For this reason, the samples illustrated have been difficult to prepare for examination purposes, and polished surfaces have been impossible to obtain. In the outer regions of sample T 426 - 2, the fusain is particularly obvious, while in the central region, segments of vitrain have been freely exposed from the surrounding fusain.

Other associations of coal types existing within the samples are essentially combinations of the two main associations described above. In some cases, the bulk of the sample is durain, with vitrinite lenses forming a minor constituent, whereas in others, a converse association prevails. The tendency towards gradation is not so pronounced in vitrain-fusain complexes, but one constituent often forms a major part of the association.

Turning to considerations based on microfossils, reference might be made to the experience of other investigators. In correlating some Northumberland coal seams, Raistrick and Simpson (29) indicated that microfossil frequencies usually vary only slightly within differing coal types. During the course of the present investigation, variations in microfossil frequencies within the different coal types were noted during the preparation of most samples, and a evaluation of these variations has been considered to be of some significance.

To provide evidence of microfossil frequency differences, sample @ 204 - 6 was divided into four segments, and each was macerated with Schulze's solution. Segment (i) consisted of vitrain from the top portion of the sample, while segment (ii) was a mixture of vitrain from the three central durain layers. (Plate I, fig. 13). The third segment consisted of a combination of durain portions from the inter-vitrainous durain layers, and segment (iv) was obtained from the lower durain segment. In addition, a channel block was obtained which included portions of all the type layers from the sample. The histograms illustrated in Plate IV are based on counts of 200 microfossil specimens from each preparation, and are presented to show the significant frequency differences within the segments.

The histogram "characters" indicate several interesting features. The frequencies of the types represented in segments (i) and (ii) are similar, and indicate that certain microfossil types predominate. In the two segments of durain, the characteristic microfossils represent different types than in segments (i) and (ii), and the forms present in segment (iii) are somewhat different from those in segment (iv). An additional significant feature is the difference in the histogram "character" of the channel sample as compared to those "characters" of the segments.

In connection with the observed differences, it is apparent that the microfossil population varies somewhat widely from one horizon to another within a structural type. This variation is more pronounced in the durain segments of @ 204 - 6 than within those of vitrain. The frequencies within the channel sample suggest, additionally, that the microfossil population of a sample varies considerably with the relative amounts of the contained structural types. This fact is supported by the difference between the histogram character of the channel sample and that obtained by averaging the frequencies of the segments.

An evaluation of the frequency differences suggests that the microfossil contents of vitrain and durain in sample @ 204 - 6 are substantially different, and that the differences are such as to readily distinguish between the two types. Although this differentiation of structural types has been limited to observations in sample @ 204 - 6, evidence supporting the findings has been indicated from examinations of microfossil frequencies in various structural types within other samples. However, sufficient evidence has not been assessed to warrant the claim that all structural types of the Brazeau samples can be distinguished on the basis of microfossil frequency differences, but an indication that this is a possibility has been considered noteworthy.

DESCRIPTION AND CLASSIFICATION OF MICROFOSSILS

The classification of microfossils has been attempted by employing a similar method to that developed by Raistrick and Simpson (29) in the correlation of Northumberland coal seams. The method consists essentially of locating morphologically similar microfossils within groups designated by letters of the alphabet. The microfossil types which are assigned to each group are identified and separated by subnumbers. This method has been found suitable for classification and reference when large numbers of microfossils are involved.

In the present investigation, alphabetic letters L to W have been chosen as group designates. Subnumerals have been assigned to the microfossils placed within each group, with the result that specific microfossil types have been designated as L_1, L_2, L_3-- etc. Letters L to W were chosen to prevent confliction in reference between spores designated by letters

A to F by Raistrick and his co-workers, and the microfossils classified in the present investigation.

In conjunction with this artifical system of classification, an attempt has been made to include apparently related microfossil members within one group. For example, numerous microfossils have been encountered which possess bladders, are similarily ornamented, and closely resemble modern Conifer pollens. All such microfossil types are apparently related, and hence have been included within one group, namely group N. This system of grouping has resulted in a partially artifical classification, but is based fundamentally upon natural relationships among microfossil types.

In attempting to recognize, identify, and classify plant microfossils, several problems and difficulties are encountered. The consolidation and compression of plant material during coal formation have frequently flattened and distorted microfossils beyond recognition. Hence, distinguishing morphological features utilized in identification are not recognizable in many forms. This difficulty in recognition is particularly pronounced when the attempt to separate very similar microfossils is undertaken.

Microfossils deposited within coal seams have been invariably dissociated from parent fructifications. The lack of evidence indicating organic union between micro- and macrofossils has prohibited the designation of similar or identical botanical names to both forms. To provide for microfossil references, various systems of nomenclature and classification have been devised, with the result that in many cases, different names have been applied to identical forms.

In the present investigation, no attempt has been made to name the microfossils. Future examinations within Mesozoic coals and mineral deposits will probably increase the knowledge regarding microfossil forms and associations. If this possibility is realized, the adoption of a suitable nomenclature will be necessary and warranted. At the present time, however, the writer feels that less confusion will exist if letters and numeral subscripts are utilized as microfossil designations.

In the succeeding descriptions, the phrase"--Not previously described" is used to indicate that microfossils similar to the form being described have not been previously reported by micropalaeobotanists. Descriptions of Cretaceous microfossils are decidedly rare, and in many cases reference has been made to similar forms from Tertiary deposits.

GROUP L- Microfossils are small, bilateral, oval to elliptical in shape, generally levigate to punctate in ornamentation, and characterized by a monolete suture. The longitudinal dimension ranges from 12 to 35μ. Longitudinal folds are commonly present, which somewhat alter the characteristic appearance.

L_1- (Plate III) Elliptical; monolete; granular exine; furrow lips somewhat closely appressed throughout length. Average diameter 23μ, range of diameter 22 - 24μ.

Microfossils of type L_1 vary in frequency throughout the samples and appear to have a somewhat restricted range. Their occurrence appears to be associated with other members of the group, especially L_3.

L_2- (Plate II) Elliptical; monolete; levigate; furrow lips spread with slightly gaping extremities. Average diameter 25 μ; range of diameter 24 - 26 μ.

Type L_2 is moderately abundant in samples containing numerous vitrain bands, especially @ 204 - 1. There appears to be a resemblance of this type to Cycadopites described by Wodehouse (58). However, the drawings and description are not adequate for a more accurate identification.

L_3- (Plate II) Oval; monolete; levigate; furrow narrow with lips closed; longitudinal folds generally present, giving a lobed appearance to the microfossil. Average diameter 22 μ; range of diameter 21 - 23 μ.

Type L_3 has high frequency throughout the samples, especially in samples T 204 - 2(b) and @ 205 - 1. As with L_1 and L_2, this type appears to be associated with the vitrain bands. The only form reported which resembles L_3 is Pollenites cingulum (Castanopsis) recorded by Thiergart (47), although the longitudinal ridges and semi-transparent exine do not favour a close relationship to the latter species.

L_4- (Plate II - 2 figs.) Oblong; monolete; generally levigate, although often somewhat granular in ornamentation. Members are bilateral, and are often folded toward the longitudinal axis. Average diameter 33 μ; range of diameter 31 - 35 μ.

This microfossil occurs relatively infrequently throughout the samples, but when present, appears to be associated with vitrain bands. Pollenites lucifer, described by Thiergart (48) as a new species of

Bennettiteae, appears to be structurally closely related to this type.

L_5- (Plate III) Oval; possibly monolete; punctate; somewhat nut-shaped in appearance. Microfossil appears to be compressed medially, producing a dense central area. Prominent projections at both longitudinal extremities are characteristic. Average diameter 19 μ; range of diameter 18 - 20 μ.

This type was identified and recognized only in sample @ 205 - 1, which indicates a restricted range.--Not previously described.

L_6- (Plate III) Small; elliptical; germinal pore possibly at one extremity; punctate in ornamentation. Members of this type are bilateral, with a prominent clear region at one extremity. Average diameter 15 μ; range of diameter 12 - 18 μ.

L_6 is present moderately abundantly in sample T 197 - 1(a), but has not been recognized in other samples. In some members, the clear region at one terminus appears to resemble a germinal pore. This type is easily mistaken for L_3.--Not previously described.

L_7- (Plate II - 2 figs.) Oblong; possibly monolete; punctate; somewhat medially compressed, resulting in a central region of overlap. Average diameter 27 μ; range of diameter 25 - 29 μ.

L_7 has a high frequency of occurrence in sample T 204 - 2(b), and a moderate frequency in T 154 - 1(b). The germinal aperture has not definitely been observed, but it's presence as a monolete suture has been suggested in several examples.

This type appears to closely resemble Sporopollenites magnus R. Potonié dubius, described by Thiergart (48), and illustrated in his fig. 8, plate III. The size of Thiergart's specimen is 27.5 μ. Also similar is Pollenites pseudocingulum granulatum described by R. Potonié (25) and illustrated in Plate I, figs. 6, 19, 24, 26 and 27. The size range of Potonié's specimens is 26.8 - 28 μ.

GROUP M- Microfossils are small to medium in size, spherical to oval in shape; granulose to punctate in ornamentation; and generally possess folds or wrinkles. Germinal apparatus monolete if present; otherwise, members are alete. Symmetry bilateral..Size range 18 - 37 μ.

M_1- (Plate II - 2 figs.) Microfossils are oval, weakly monolete, slightly punctate and possess a bilateral symmetry. Diameter is 23 μ; range of diameter 23 - 24 μ.

This type has been found in varying frequencies in nearly all the samples, but occurs as a recordable frequency only in @ 204 - 6. Type M_2 is very similar to M_1, and is separated from the latter on a size basis. It is possible that members of these two types have been mistaken for one another.

In size and external appearance, this type resembles Pollenites problemacticus R. Potonié (25). Potonié's illustrations do not indicate the presence of a germinal aperture, which in M_1 is suggestive of a monolete suture.

M_2- (Plate II - 2 figs.) Microfossils are broadly oval to spherical, monolete, granulose to punctate, and posses bilateral symmetry. The furrow is frequently angled in the central regions. Diameter is 21 μ; range of diameter 20 - 22 μ.

This form closely resembles M_1, but is characteristically smaller in addition to being obviously monolete. Type M_2 is present in varying degrees in most samples, but is abundant in T 204 - 2(b) and to a lesser extent in ⊛ 204 - 6.

Type M_2 resembles Pollenites megagertrudae R. Potonié (25) which is 20 μ in size. It is also morphologically similar to Pollenites globiformis modestus R. Potonié (25) Plate II fig. 31, although the size of the latter is 30 - 30.5 μ.

M_3- (Plate II - 2 figs.) Microfossils are spherical, possibly monolete, punctate, and bilaterally symmetrical. Folds are frequently numerous, and tend to contort the appearance. Diameter is 27 μ; range of diameter 26 - 28 μ.

The monolete opening has not been definitely recognized as a structural feature of Type M_3, but is suggested in several specimens. This difficulty in recognition is partly a result of the presence of numerous folds and wrinkles, and of the deep staining qualities of the microfossil.

Type M_3 is present in moderate frequency in samples T 428 - 1, ⊛ 204 - 1, and ⊛ 204 - 6. As indicated in Plate V, it is apparently associated with the vitrain of sample ⊛ 204 - 6.

Microfossil type M_8 was originally distinguished from M_3 on morphological differences. Additional observations have resulted in a re-identification of M_8 as type M_3. Therefore, the description which characterized M_3 should also be applied to M_8. Illustrations of the latter type (Plate III 2 figs.) have been retained for purposes of uniformity.

M_4- (Plate II - 1 fig.) Microfossils are spherical to oval; monolete; weakly punctate; and bilaterally symmetrical. Folds are frequently numerous. Average diameter 31 μ; range of diameter 28 - 34 μ.

This microfossil type is similar to M_3 and M_5, and is intermediate in size. The monolete condition is suggested in several specimens, but is indifinite in others due to numerous folds in the microfossil exine.

Type M_4 is moderately present in samples T 204 - 2(b), ● 204 - 1, and ● 204 - 6, and appears to be associated with the durain portions of each sample.

This microfossil closely resembles Pollenites magnus dubius, described by R. Potonié and Venitz (27), (Plate II figs. 20 - 21), from the Miocene of Germany. Thiergart (47) identified the same species from Tertiary coals of the Senftenberg region of the same country. (Plate 23, figs. 1 - 2).

M_5- (Plate II - fig. 1) Description essentially as noted for M_4. Average diameter 35.5 μ; range of diameter 34 - 37 μ.

Microfossil type M_5 is closely related to M_4, and the description applied to the latter may be considered adequate to identify M_5. The consistently larger size and the occurrence limited to sample T 428 - 1 indicate that M_5 may have stratigraphical significance. It is probable that M_3, M_4 and M_5 are different species of the same genus, which would account for the morphological similarities and differences in size.

M_6- (Plate II - 1 fig.) Oval to oblong; monolete; punctate; and bilaterally symmetrical. Lateral folds frequently present. The original shape before fossilization was probably spherical. Average diameter 21 μ; range of diameter 19 - 23 μ.

Microfossil type M_6 is limited in occurrence to durain portions of sample @ 204 - 6. The lateral folds and deep amber colour are characteristic of this type and facilitate identification.--Not previously described.

M_7- (Plate II - 1 fig.) Oval to spherical; alete; coarsely granulose to punctate; bilaterally symmetrical. The exine is comparatively thick and entire. Average size 25 μ; range of diameter 24 - 26 μ.

Type M_7 is present in T 154 - 1 moderately abundantly, and occurs infrequently in T 197 - 1(a). Folds and other distinctive structural features are generally lacking, a fact which contrasts M_7 to other members of the Group, and facilitates identification.--Not previously described.

M_8- (Plate III - 2 figs.) This microfossil type has been identified as type M_3, which has been previously described.

M_9- (Plate III - 1 fig.) Oval; monolete; coarsely granulose to punctate; and bilaterally symmetrical. Folds and overlaps frequently distort the appearance. Average diameter 35 μ; range of diameter 33 - 37 μ.

Type M_9 is present only in sample T 428 - 1, and is difficult to identify because of extensive folds and overlaps which distort the general shape and appearance.--Not previously described.

M_{10}- (Plate III - 1 fig.) Spherical; possibly tricolpate; coarsely granulose; bilaterally symmetrical. Ridges form an irregular pattern on the exine. Average diameter 25 μ; range in diameter 24 - 26 μ.

M_{10} is found infrequently in sample T 204 - 2(b). The pattern of ridges or furrows on the exine suggest a tricolpate germinal apparatus, but it is possibly monolete. If the tricolpate condition existed in the originally expanded microfossil, the symmetry would be radial. This difficulty at identification has probably arisen because of the flattening of the microfossil during coalification.--Not previously described.

M_{11}- (Plate II - 1 fig.) Spherical; possibly tricolpate; finely granulose; radially symmetrical. One or two furrows frequently present on exine. Average diameter 18.5 μ; range of diameter 18 - 19 μ .

This microfossil type was found to have a recordable frequency is sample T 204 - 2(c), which has not been quantitatively considered. Microfossils have a tricolpate germinal apparatus, but as with M_{10}, this fact is difficult to evaluate.--Not previously described.

M_{12}- (Plate III - 1 fig.) Spherical; tricolpate; granulose; radially symmetrical. Three lobes characteristically present, although often obscure. Average diameter 25 μ; range in diameter 21 - 29 μ.

Type M_{12} is present to a limited extent in sample

T 428 - 1, but has not been observed in other samples. There is a possibility that N_{12} is the same species as U_2 (Plate III - 2 figs.) However, their general appearance is dissimilar, and the tricolpate condition is not as easily obvious in the former types.--Not previously described.

GROUP N- Microfossils belonging to this group are characterized by the presence of two wings or bladders, which are attached to the main portion or body cell. The bladders vary in size, shape, and position of attachment. The germinal apparatus consists of single suture, although this is usually obscure. The ornamentation is papillate, reticulate, or verrucose, and varies with the type. The symmetry is bilateral throughout the group. The measurements of body length range from 32 μ in N_1 to 119 μ in N_8.

N_1- (Plate II - 1 fig.) Two bladders attached anteriorly and laterally, producing a sub-triangular outline. The ornamentation is distinctly papillate. Exine fold characteristically covering monolete suture. Body length 32 μ; bladder width 12 μ; width between bladder apices 52 μ.

Type N_1 is found abundantly in T 197 - 1(a) and moderately frequently in @ 204 - 6, although it's presence has been noted in most samples containing large vitrinite lenses. The two types N_1 and N_2 are often difficult to distinguish because of marked similarities. The two examples were chosen to contrast the two types.--Not previously described.

N_2- (Plate II - 1 fig.) Two bladders laterally attached, producing a rectangular outline. Ornamentation papillate. The exine is raised along borders of the monolete suture. Body dimensions 42 x 18 μ; bladder dimensions 26 x 18 μ; width between bladder apices 58 μ.

This type is present in samples T 197 - 1(a), @ 204 - 1, and @ 204 - 6. As indicated previously, accurate distinctions in identity between N_2 and N_1 are difficult. Size variations and differences in bladder orientation suggest that the two types represent two distinct species, although further substantiating evidence is required.--Not previously described.

N_3- (Plate III - 1 fig.) Two small bladders located laterally. Body coarsely granulose; bladders reticulate. Single linear suture along anterior crown. Body dimensions 51 x 40 μ; bladder dimensions 30 x 28 μ; overall length between bladder apices 70 μ.

Type N_3 is frequently found in sample @ 204 - 1, although numerous distorted exines resembling N_3 are present. In all specimens, the bladders are noticeably smaller than the body. (Contrast to N_5 and N_6).--Not previously described.

N_4- (Plate III - 1 fig.) Two bladders anteriorly and laterally attached. Ornamentation reticulate. Monolete suture on crown. Body dimensions 47 x 28 μ; bladder dimensions 25 x 21 μ; overall length 61 μ.

Type N_4 resembles closely, and may easily be mistaken for type N_3. It is present to a limited extent in @ 204 - 6, but was not in other samples. A similar microfossil has been identified as Pinus sp.by Simpson (44) Plate I, fig. 4.

N_5- (Plate III - 1 fig.) Two bladders attached in midline, with body cell segments overlapping. Central monolete suture. Ornamentation densely reticulate. Dimensions of body 47 x 31 μ; of bladders 60 x 32 μ.

Only one specimen was located throughout the samples; that being found in @ 205 - 1. The morphological similarity of this microfossil to species of Florinites described by Kosanke (18) from the Pennsylvanian of Illinois, is particularly noteworthy. The orientation of the bladders with respect to the body indicate a probable evolutionary relationship between the two groups. Florinites diversiformis (Kosanke (18) plate 12 fig. 5) presents a marked resemblance to type N_5.

Microfossil type N_5 is very probably a species of Podocarpus. Both Simpson (44) Plate II fig. 5, and Thiergart (47) Plate 24 fig. 7, have illustrated pollen grains identified as Podocarpus. The specimens illustrated are very similar to N_5.

N_6- (Plate III, 1 fig.) Two bladders larger than, and completely overlapping the body. No germinal aperture observed. Body coarsely granulose; bladders reticulate. Diameter of body 70 μ; of bladders 88 x 53 μ; overall 115 μ.

Several specimens of type N_6 have been recognized in samples @ 204 - 1, @ 205 - 1, and T 428 - 1. However, the frequency of such large and friable microfossils would probably be greater if less severe maceration methods could be successfully employed.

Numerous illustrations of bladder microfossils from coal have been presented by various authors. There is little doubt that N_6 is a species of Picea, which has been frequently identified from Mesozoic and Tertiary coals. Picea-pollenites alatus R. Pot. illustrated by Thiergart (47) Plate 24 fig. 5, and (48) Plate III fig. 16, is particularly similar to type N_6.

N_7- (Plate III - 1 fig.) Two large bladders attached medially to separated body. Germinal aperture obscured. Ornamentation reticulate. Dimensions of body 54 x 49 μ; bladders 56 x 44 μ; overall 93 μ.

Type N_7 is associated with samples @ 204 -1, T 197 - 1(a), and T 154 - 1, although only single specimens have been recognized in each case. The rectangular outline and bladders equal in width to the body are identifying characteristics.

Microfossil type N_7 undoubtedly represents the pollen of a genus of Abietineae, and resembles the modern Picea and Pinus pollens. Pinus haploxylon-typus Rudolph, described and illustrated by Thiergart (48) Plate III, fig. 17 - 18, has an almost identical appearance to N_7.

N_8- (Plate III - 2 figs.) Two large bladders attached laterally to body and often overlapping. Germinal aperture obscure. Ornamentation reticulate. Average dimensions of body 117 x 78 μ.

Single specimens of type N_8 have been located in samples T 428 - 1 and T 197 - 1(a). The large size of this type presents difficulties in obtaining unbroken specimens from the maceration sediments. The occurrence of segments of exines and bladders which resemble those of N_8 is frequent in some mounts, which suggest a probably greater original frequency of this type.

Similarities of N_8 to N_6 are apparent, and indicate that these two types are possibly species of the same genus. There is a marked resemblance of both microfossil types to Picea-pollenites alatus R. Pot. (Thiergart (47) Plate 24, fig. 5 and (48) Plate III fig. 16.)

N_9- (Plate III - 1 fig.) Bladders indistinct; appressed dorso-ventrally to body; Germinal aperture monolete on proximal surface; ornamentation coarsely granulose to verrucose. Dimensions of intact portion 86 x 60 μ.

The presence of the folded and appressed bladders is somewhat obscure in the illustration, but has been definitely observed by variable focusing. Type N_9 has been located in samples @ 205 - 1, T 428 - 1 and T 197 - 1(a), and is more frequent than other accessory microfossils of group N.

A specimen of pollen described and illustrated as Pinus sp. by Simpson (44) Plate I, fig. 3 is somewhat similar in size and appearance to N_9.

N_{10}- (Plate III - 1 fig.) Two bladders laterally attached; somewhat overlapping the body. Germinal aperture monolete; ornamentation reticulate. Dimensions of body 35 x 30 μ; of bladders 33 x 28 μ; overall length 56 μ.

Single specimens have been observed in samples T 428 - 1 and T 204 - 2(b), but the occurrence of the microfossil is strictly limited. The morphological features of N_{10} indicate the Gymnosperm character of the type, and it appears very similar to modern pollens of the Pinaceae. The orientation of bladders and body resembles the condition found in Pinus-pollenites labdicus R. Pot.; described and illustrated by Thiergart (47) Plate 24, fig. 4, and Pinus scopulipites described by Wodehouse (58).

N_{11}- (Plate III - 1 fig.) Bladders laterally folded and appressed to body. Body granulose; bladders papillate to verrucose. Germinal aperture monolete. Dimensions of body 61 x 37 μ; of bladders 61 x 31 μ.

Several specimens have been located in sample T 197 - 1(a) and a single specimen was found in T 428 - 1. The frequency of occurrence is, however, generally low. The appressed and overlapping bladders usually make an accurate identification and a separation from other group members difficult.

Thiergart (48) Plate I, fig. 12, has illustrated a microfossil form which resembles N_{11} in shape and orientation of parts. He has identified this species as Pollenites alatus R. Pot. If Thiergart's identification is accurate, type N_{11} is very similar to types N_6 and N_8. However, additional information is required before a valid appraisal of this relationship can be attempted.

GROUP O- Microfossils are oblong or broadly elliptical; obviously monolete; generally levigate, granulose, or weakly punctate, in ornamentation; and bilaterally symmetrical. The length dimension ranges from 35 - 68 μ.

Group O Microfossils are the most widespread and abundant of all the types within the Brazeau coals. In addition, they possess a degree of uniformity not generally recognizable throughout the other groups. The characteristic "bean" shape and the wide, often gaping germinal aperture, facilitate spotting and identification. In order to eliminate repetition in description, only those features which are necessary to contrast types will be noted in the following descriptions. The size measurements have been generally utilized as the basis for type distinction.

Microfossils closely resembling members of group O have been reported as occurring in various geological horizons. The description of similar forms from Palaeozoic coals would seem to indicate a Pteridophyte relationship. This indication is supported by evidence gained from evaluations of modern pteridophyte microfossils. As an example, Erdtman (8) has illustrated spores associated with ferns such as _Asplenium_, _Athyrium_, and _Polypodium_, which are very similar to members of Group O. However, until direct evidence from investigations of macrofossils and their associated microfossils is forthcoming, a valid appreciation of the relationship of Group O types cannot be realized.

O_1- (Plate II - 2 figs) Ornamentation granulose. Monolete suture narrowly open; length of suture 19 μ. Length range of microfossil 34 - 40 μ; width range 25 - 29 μ.

Type O_1 is very abundant in samples @ 205 - 1 and @ 204 - 6, but is present to a limited extent in most samples. A characterizing features is the deep amber colour of the exine, to which safranin dye is not adsorbed.

Laevigato-sporites punctatus described by Kosanke (18) is morphologically similar to type O_1, although slightly larger is size (Plate 5, fig.3).

O_2- (Plate II - 2 figs.) Ornamentation levigate. Monolete suture gaping; length of suture 30 μ. Range of length 44 - 50 μ, average width 35 μ.

This microfossil is associated with every sample, and is moderately abundant in T 197 - 1(a) T 428 - 1 and @ 205 - 1. Type O_2 closely resembles Laevigato-sporites ovalis described by Kosanke (18) Plate 5, figs. 6 - 7, from Pennsylvanian coals of Illinois. The size of this species, however, is somewhat larger than that of O_2.

O_3- (Plate II - 2 figs.) Ornamentation coarsely granulose. Monolete suture closed, with lips forming ridges; length of suture 19 - 23 μ. Range of length 39 - 45 μ; of width 24 - 31 μ.

This microfossil type is present in samples T 428 - 1, T 204 - 2(c) and T 204 - 2(b). The frequency of occurrence is approximately 6 per cent in T 204 - 2(c) and approximately 4 per cent in T 204 - 2(b).

Type O_3 has structural features resembling spores of both fossilized and modern species of Polypodiaceae. However, the granulose ornamentation of type O_3 suggests that the form represents the endospore of the original Polypodium spore; the perispore having become detached at maturity. This process is known to occur in spores of modern Pteridophytes which are similar to Polypodium.-- Not previously described.

O_4- (Plate II - 3 figs.) Ornamentation levigate. Monolete suture narrow or slightly gaping; ridges bordering suture not prominent; length of suture 19 - 25 μ. Range of length 36 - 44 μ; of width 28 - 35 μ.

Microfossils of this type are very similar to those of type O_2, except for their smaller dimensions. A species closely resembling O_2 has been identified by Thiergart (47) as Sporites haardti, R. Pot. & Ven. (Plate 22, fig. 17). Both Thiergart and Potonié and Venitz have questioned the relationship of this species to the Polypodiaceae.

O_4 is one of the most consistently occurring microfossil types, and has been found in a frequency of over 5 per cent in every sample except T 204 - 2(b). This consistency of occurrence suggests the possible suitability of this type in correlation attempts within the Brazeau thin seams.

O_6- (Plate II - 1 fig.) Ornamentation levigate. Monolete suture wide or gaping; lips of suture prominently ridged; length of suture 32 - 34 μ. Range of length 55 - 58 μ; of width 31 - 34 μ.

Microfossil type O_6 is associated to a limited extent with samples T 197 - 1(a), ● 205 - 1, and O 204 - 6. It is frequently folded or contorted, but the large size facilitates recognition.

Spores similar to type O_6 have been described and identified by Kosanke (18) as Laevigato-sporites latus

(Plate 5, fig. 11). The size of Kosanke's holotype is 63 x 54.6 μ, and therefore, is slightly larger than type O_6.

O_7- (Plate III - 1 fig.) Ornamentation levigate. Monolete germinal aperture gaping; lips prominent and elevated; length of suture variable. Range of length 67 - 71 μ; of width 46 - 54 μ.

This type is very similar to O_6, O_4 and O_2, but is characterized by it's larger size. Single specimens have been located in samples T 204 - 2(b) and T 204 - 2(c), and a low frequency exists in @ 205 - 1. Differentiation between O_6 and O_7 is often difficult because of the narrow size difference. In addition, modifications in appearance frequently result from folding or compression.

O_9- (Plate III - 1 fig.) Ornamentation levigate to finely granulose. Monolete suture closed; lips slightly ridged; length of suture 32 μ. Length 63 μ, width 39 μ.

Only one specimen of type O_9 was found throughout the samples. The distinctive dimensions and granulose ornamentation suggest that O_9 is a different species from the other members of group O. However, the possibility of O_9 being the same spore type as O_6 or O_7 should be considered in evaluating the botanical or stratigraphical importance of this type.

O_{10}- (Plate III - 1 fig.) Ornamentation granulose or weakly punctate. Monolete suture 22 μ. Length 68 μ; width 44 μ.

Only one specimen of O_{10} has been observed through the samples; that being located in @ 205 - 1. The weakly punctate ornamentation suggests that this type is distinctive from others of the group. In general appearance, O_{10} resembles <u>Laevigato-sporites robustus</u>, described and illustrated by Kosanke (18) Plate 5, fig. 9. However, the dimensions of this species are 101.8 x 73.5 μ, which are considerably larger than those of O_{10}. This indicates that the parent plants were probably not very closely related.

<u>GROUP P-</u> Microfossils assigned to this group are characterized by an extended oblong shape; a monolete germinal aperture; bilateral symmetry; and a size range from 28 - 61 μ. The ornamentation is typically levigate, granulose, or punctate. In shape and general appearance, Group P microfossils resemble those of group L. The separation of type microfossils into these two artificial groups has been made on the basis of size difference. This method of recording does not attempt to associate related forms, but is a convenient procedure for facilitating reference to certain types.

P_1- (Plate III - 1 fig.) Broadly oval to oblong in shape; granulose; monolete; and distinctly folded along the longitudinal median plane. Range of length 42 - 45 μ; in width 33 - 38 μ.

Type P_1 has been found associated to a limited extent with the durain segments of samples @ 204 - 6, T 428 - 1, T 204 - 2(c) and T 204 - 2(b). The median fold or bladder? is characteristically present on this type.

Various descriptions have been presented with respect to pollens of the Cycadeae and Bennettiteae, although clear illustrations of these types are very few in number. However, evidence is in favour of types such as P_1, P_2, P_9, and several L group types, being related to pollens from these classes.--Not previously described.

P_2- (Plate III - 1 fig.) Broadly oval to oblong; punctate; monolete median fold frequently present. Range of length 31 - 35 μ; of width 21 - 24 μ.

Type P_2 is very similar in morphology to P_1, but is distinguished from the latter by smaller dimensions. It has been located in samples @ 205 - 1, T 428 - 1 and T 204 - 2(b); having a frequency of approximately 4 per cent in the last-mentioned sample.--Not previously described.

P_3- (Plate III - 1 fig.) Oval to oblong; coarsely granulose; monolete; terminal fold present or absent. Range of length 35 - 38 μ; of width 25 - 27 μ.

This microfossil type has been recorded from samples @ 204 - 1, T 204 - 2(c). The shape, size, and monolete condition of type P_3 suggest that it is an identical species to O_1. An explanation for the possibly mistaken identity may be found in the presence of folds and the more granulose ornamentation, which are generally associated with type P_3.

P_4- (Plate II - 2 figs.) Oval to oblong; finely granulose; monolete germinal aperture ridged; longitudinal folds and creases frequently present. Range of length 28 - 33 μ; of width 14 - 20 μ.

Type P_4 is moderately abundant in samples T 154 - 1 and T 428 - 1. In the unstained condition, it is somewhat transparent and difficult to locate and identify. The longitudinal folds and creases are usually present and somewhat characterize this type.

Microfossil forms somewhat similar to P_4 have been described and illustrated by Thiergart (47) as Pollenites polyformosus (Plate 23 figs 6 - 11), and a possible relationship of this species to either Sequoia or Cryptomeria has been indicated.

P_5- (Plate III -1 fig.) Originally oblong; alete or monolete; granulose exine characteristically split into two somewhat equal halves. Range of length 33 - 37 μ; of width 28 - 32 μ.

Type P_5 has been observed limitedly in samples ® 204 - 6 (vitrain), T 204 - 2(b) and T 204 - 2(c). The split exine suggests that an internal structure has been ejected.

This microfossil is very similar to Taxodium hiatipites Wodehouse (58), which discovered in the Green River shales of western United States, and more recently by Wilson and Webster (56) in a Fort Union coal from Montana. In German tertiary deposits, a similar species described as Pollenites hiatus R. Potonié, has been reported by Potonié (24) Potonié and Venitz (27) and Thiergart (47) (48).

P_6- (Plate III - 1 fig.) Oblong; alete; levigate; 2 longitudinal median ridges characteristically present. Range of length 36 - 41 μ; of width 14 - 17 μ.

Microfossil type P_6 has been encountered only in sample T 428 - 1, and the frequency of occurrence is approximately 4 per cent. This form is frequently folded or twisted, and is easily mistaken for R group types. However, the two prominent and elevated longitudinal ridges faciliate identification.--Not previously described.

P_7- (Plate III - 1 fig.) Broadly oval to oblong; coarsely granulose; monolete; folds sometimes present. Range of length 43 - 46 μ; of width 26 - 29 μ.

Several specimens of type P_7 have been found in samples T 204 - 2(b), T 204 - 2(c) and T 428 - 1. A longitudinal fold or overlap is sometimes present, which gives to P_7 a similar appearance to P_1 and P_2.--Not previously described.

P_9- (Plate III - 1 fig.) Oblong to lanceolate; coarsely granulose; monolete; overlapping folds characteristically present. Range of length 46 - 54 μ; of width 20 - 27 μ.

Several specimens of type P_9 have been observed in samples T 428 - 1 and @ 204 - 6(iv). The appearance and morphology of this type resemble those of L_7, but the larger dimensions of the former distinguish the two microfossil types.--Not previously described.

P_{10}- (Plate III - 1 fig.) Extendedly oblong; alete; levigate and transparent; two lateral longitudinal ridges characteristically present. Range of length 58 - 63 μ; of width 19 - 26 μ.

Two specimens of this type were observed in sample T 154 - 1. The resemblance of P_{10} to P_6 is particularly noteworthy, and only the larger dimensions associated with the former permit a differential identification. The parallel ridges are prominent, and serve as distinguishing features between these two types and members of group R.--Not previously described.

P_{11}- (Plate III - 1 fig.) Oblong; monolete; punctate or weakly verrucose; lips of open monolete suture slightly ridged; lateral folds present. Length 46 μ; width 28 μ.

One specimen was found in each of samples T 154 - 1 and T 428 - 1. However, P_{11} is similar in several aspects to P_1, P_2 and P_7, and there is a strong possibility that these types have been mistaken during the process of identification.--Not previously described.

GROUP Q- Microfossils are small; subtriangular in shape; levigate, granulose or punctate in ornamentation; radially symmetrical; and possess three germinal apertures or pores. The largest or length diameter ranges from 21 μ in Q_7 to 44 μ in Q_2.

Microfossil types of group Q are particularly interesting because they are typically associated with Angiosperms. The appreciation of Mesozoic Angiosperm pollens is significant, because it was during this period that the Gymnosperms were decreasing in importance and primitive Angiosperms began to flourish. In the present investigation, groups Q and U are composed of Angiosperm pollen types, and the proportion of these types to those related to Gymnosperm and Pteridophyte microfossils may easily be assessed.

Q_1- (Plate III - 1 fig.) Levigate to weakly granulose; 3 germinal pores; elevated ridges connecting pores, and faint circular marking present in central region. Pores triangular in outline; lips thickened and elevated around pores. Range of diameter 27 - 35 μ (measured from terminal pore to opposite apex between pores).

The occurrence of Q_1 has been limited to three specimens in T 428 - 1 and one in T 204 - 2(b). Q_1 is the smaller of the two species Q_1 and Q_2, which are morphologically identical. The presence of the three pores insures accurate identification of this type.

Similar microfossils have been recorded as: Betula claripites Wodehouse (58), and the same species by Wilson and Webster (56); Pollenites bituitus R. Potonié (26), and again by Thiergart (47).

Q_2- (Plate III - 1 fig.) The description of type Q_1 may be applied satisfactorily to this microfossil. The dimensions of Q_2 are 44 x 35 μ.

Only one specimen has been observed throughout the samples. The greater size of this type differentiates it from Q_1; although morphologically the two types are identical.--Not previously described.

Q_3- (Plate III - 3 figs.) Sub-triangular to oval; coarsely granulose; 3 pored; germinal apertures elliptical to circular; germinal lips thickened and ridged. Folds are frequently present. Range of diameter 34 - 36 μ.

Type Q_3 has been encountered only in sample T 428 - 1. It is distinguishable from Q_1 and Q_2 by the more granular nature of the exine, the elliptical pores, and the less prominent pore lips.

Similar microfossils to Q_3 have been identified by Wodehouse (58) as Hicoria viridi-fluminipites (Fig. 29), by Wilson and Webster (56) as Carya viridi fluminipites (Fig. 13), and by Thiergart (48) as Carya sp. (Plate IV/V, fig. 58). These identifications have been based on similarities between the microfossils and pollens of modern species of the Juglandaceae family.

Q_4- (Plate III - 1 fig.) Subtriangular; levigate; 3 pored; germinal apertures not prominent; pore lips elevated. Faint ridges connecting pores sometimes evident. Diamter 23μ.

Only one specimen of Q_4 has been recorded throughout the samples. The absence of prominent pores and the smaller size serve to distinguish this microfossil type from Q_1 and Q_2.

A similar form to Q_4 has been described by R. Potonié (25) as Pollenites coryphaeus punctatus (Plate II figs. 7 and 11). The size range of Potonié's specimens is 22.8 - 26μ.

Q_5- (Plate II - 1 fig.) Spherical to subtriangular, levigate; 3 pored; germinal apertures inconspicuous; pore lips protruding slightly from entire exine. Range of diameter 33 - 38μ.

Type Q_5 has been recorded frequently in sample T 154 - 1, and to a limited extent in T 204 - 2(b). The inconspicuous nature of the pores together with frequent folds make identification difficult.

The general morphology of Q_5 resembles modern pollens of Carpinus and Corylus. (Erdtman (8)). Fossil forms resembling Q_5 have not previously been described.

Q_6- (Plate III - 1 fig.) Subtriangular; coarsely granulose; 3 pored; germinal apertures notch-like; borders or lips not thickened. Range of diameter 24 - 27 μ.

Several specimens of type Q_6 have been observed in sample T 204 - 2(b), but the type has not been recognized in other samples.

Similar microfossil forms have been described by Wodehouse (58) and Wilson and Webster (56) as Momipites coryloides Wodehouse; by Simpson as Corylus sp.; and by R. Potonié as Pollenites pseudofagus (25). These specimens were recorded as occurring comparatively frequently in the Tertiary deposits investigated, and the limited occurrence in the Brazeau coals is suggestive of a smaller population of parent plants in Uppermost Cretaceous times.

Q_7- (Plate III - 1 fig.) Subtriangular; strongly punctate to verrucose; 3 pored; the pore lips thickened and extended radially. Range of diameter 20 - 22 μ.

Type Q_7 has been recorded only in sample T 204 - 2(b). The ornamentation and extended pores facilitate the identification of this type.--Not previously described.

GROUP R- Microfossils are large; generally rectangular in outline; levigate; transparent; asymmetrical (possibly bilaterally symmetrical in the original uncompressed condition); and alete. Folds and wrinkles are commonly present. Length range 28 - 91 μ.

Microfossil types assigned to group R are frequently present in various horizons throughout the coal samples.

The members are easily identified by their transparency and folded condition. A germinal aperture has never been observed in the numerous specimens investigated, although there is a possibility that the folds and wrinkles either serve as germinal outlets or have obscured the original germinal apertures.

Microfossils resembling group R types have rarely been recorded as occurring in coals. A similar form has been described as Pollenites magnus by R. Potonié (26) and Larix?-pollenites magnus R. Pot. by Thiergart (47). It seems probable that group R microfossils have a closer relationship to Larix pollens than to other spores or pollens. Palaeozoic spores of Calamospora have been described by Kosanke (18), and show a marked similarity to group R types. However, the presence of the trilete germinal aperture in Calamospora spores is prohibitive in an attempt to determine the affinity of group R microfossils.

R_1- (Plate II - 1 fig.) Levigate; alete; several folds commonly present. Diameter range 26 - 33 μ.

R_1 is the smallest member of the group, and has been frequently recorded in samples T 154 - 1 and T 428 - 1. The frequent folds tend to obscure the characteristic features, but the general morphology of the type indicates a relationship to the other members of the group.--Not previously described.

R_2- (Plate II - 1 fig.) Description essentially as noted under Group R. Range of diameter 35 - 44 μ.

A high frequency of occurrence of type R_2 has been recorded from every segment of sample @ 204 - 6 except IV. This type closely resembles the other members of the group, but is delimited on the basis of size range.--Not previously described.

R_3- (Plate III - 2 figs.) Description essentially as noted under group R. Range of length 61 - 70 μ.

Type R_3 has been delimited from other members of group R on the basis of size range. This artificial separation was attempted in order to provide separate categories which might aid in correlation attempts and facilitate reference. However, members of groups R_2, R_3 and R_4 are morphologically identical, and probably were associated with the same genus. Isolated specimens have been recorded in several samples.--Not previously described.

R_4- (Plate II - 3 fig.) Description essentially as noted under group R. Range of greatest diameter 56 - 74 μ.

Type R_4 has been found abundantly associated with all segments of sample @ 204 - 6 except (IV). As stated previously, type R_3 appears very similar to type R_4, and the two forms are probably identical. The large size and multiple folds are characteristic of this microfossil.--Not previously described.

R_5- (Plate III - 1 fig.) Description essentially as noted under group R. Range of greatest diameter 88 - 93 μ.

Several specimens of type R_5 have been observed in sample T 204 - 1. The photomicrographs of R_5 and R_6 were obtained from unstained specimens, which accounts for the differences in appearance between them and the previously described types.--Not previously described.

R_6- (Plate III - 2 figs.) Description essentially as noted under group R. Range of greatest diameter 58 - 69 μ.

Type R_6 has been found to occur in sample T 204 - 1 to a limited extent. The size range suggests that this type is the same as R_3 and R_4. The differences in appearances are partially a result of the unstained condition of R_6.--Not previously described.

GROUP S- Microfossils are small to very large; subtriangular in outline; levigate, punctate, reticulate or coarsely striate in ornamentation; characteristically trilete; radially symmetrical; and infrequently folded. The size range from 25 μ in S_6 to 110 μ in S_9.

Members of group S have been recorded as occurring in varying frequencies throughout the Brazeau coal samples. The presence of the trilete germinal aperture indicates that the microfossils of the group are spores of Pteridophytes, and most of the types have been described previously in association with coals of various ages.

S_1- (Plate III - 2 figs.) Coarsely striate, with striations parallel and forming a characteristic pattern; trilete, with the triradiate ridges extending to the periphery; folds sometimes present. Range of diameter 50 - 64 μ.

Type S_1 has been observed to a limited extent in samples T 204 - 2(b) and T 204 - 2(c). The pattern of parallel striations facilitates identification. The exine of this type is dark amber to black in colour, which necessitates the use of strong transmitted light for microscopic investigation.

Similar microfossils have been described as Mohria-type by Thiergart (48) Plate III figs. 39, 40. Plate IV/V figs. 6 - 8, 15 - 17, 26, 28. Although Thiergart's specimens are morphologically identical to S_1, the size range is considerably smaller; being 38 - 50 μ. The frequency of occurrance of this microfossil type was considerably higher in the German and Austrian coals than in the Brazeau samples.

S_2- (Plate III - 1 fig.) Reticulate, with reticulation ridges extending beyond the periphery; trilete; the triradiate grooves extending closely to the peripheral regions. Range of diameter 44 - 47 μ.

Single specimens of S_2 have been recorded in samples T 204 - 2(b) and T 204 - 2(c), and a limited frequency was observed in all segments of ® 204 - 6.

A similar microfossil has been described as Lycopodium sp. by Thiergart (48) from the Wealden (Lower Cretaceous) of Germany. The diameter of Thiergart's specimen is 41 μ, which indicates a close affinity of this type to S_3. In the present analysis, S_2 and S_3 have been separated on a size basis. The two types, however, are morphologically identical, and there is a strong possibility that they represent the same species of microspore.

S_3- (Plate III - 1 fig.) Description essentially as noted for S_2. Range of diameter 37 - 43 μ.

Type S_3 has been recorded as occurring to a limited extent in samples T 204 - 2(b) and ® 204 - 6. As noted in connection with S_2, this microfossil closely resembles *Lycopodium sp.* described by Thiergart (48).

S_4- (Plate III - 1 fig.) Weakly punctate; trilete, with triradiate grooves extending approximately two-thirds of the distance to periphery; length of triradiate groove 11 μ. Range of diameter 27 - 36 μ.

Type S_4 has been recorded as occurring frequently in sample T 204 - 2(b), and to a limited extent in samples T 154 - 1 and T 197 - 1(a).

Similar microfossil forms have been described and illustrated from German Jurassic coals by Thiergart (48), and grouped under the name *Pollenites triangulatus* Thiergart. The presence of the trilete germinal aperture is indicative of a Pteridophyte or Bryophyte affinity. However, Thiergart has suggested a relationship of this type to the Bennettiteae, but has questioned the validity of the affiliation.

S_5- (Plate III - 1 fig.) Levigate to granulose; trilete, the triradiate grooves slightly ridged and extending to the periphery; length of grooves 23 μ. Range of diameter 48 - 55 μ.

Type S_5 closely resembles S_4, but is characteristically larger than the latter microfossil. The occurrence of S_5 has been recorded to a limited extent in sample T 197 - 1(a) and segments (iii) and (iv) of sample T 204 - 6.

Pollenites triangulatus Thiergart (48), mentioned in connection with S_4, has a size range of 32 - 53 μ, and resembles type S_5 in addition to showing similarities to S_4.

S_6- (Plate II - 1 fig.) Granulose; trilete, with the triradiate grooves somewhat elevated and extending approximately one-half the distance toward the periphery; average length of grooves 8 μ. Range of diameter 23 - 26 μ.

Microfossil type S_6 has been recorded frequently in samples ⊕ 205 - 1 and T 204 - 2(c), and to limited extents in samples ⊕ 204 - 6 and T 204 - 2(b). The smaller size range distinguishes readily between S_6 and S_4, which are morphologically similar.

Kirchheimer (16) and Thiergart (47) (48) have identified microfossils similar to S_6 as species of Sphagnum. A similar fom has been described and illustrated as Sphagnum antiquasporites Wilson and Webster (56), as occurring in the Kolarich coal (Paleocene) of Montana. The size range and morphological characteristics suggests that type S_6 is the same species of Sphagnum as that found in the Montana deposit.

S_7- (Plate III - 2 fig.) Generally spherical to oval in shape; coarsely granulose; trilete, with triradiate germinal grooves extending approximately two-thirds distance towards the periphery; average length of trilete grooves 11 μ. Range of diameter 35 - 39 μ.

S_7 has been found moderately abundant in sample T 154 - 1 and infrequently present in sample T 204 - 2(b). The coarsely granulose ornamentation and size range aid in distinguishing this microfossil from type S_4 and S_6.

Similar microfossils have been described as Sporites neddeni R. Potonié (23) and subsequently by Thiergart (47).

The size of these specimens is 36 μ, which is evidence of a close relationship between Sporites paddeni and S_7. Thiergart has suggested that this spore is associated with members of the Cyatheaceae family of ferns.

S_8- (Plate III - 1 fig.) Large; levigate to finely granulose; trilete, with the triradiate germinal fissures extending to the periphery; average length of fissures 33 μ. Range of diameter 72 - 85 μ.

Microfossil type S_8 has been frequently observed in samples @ 204 - 1 and to a lesser extent in segments (ii) and (iv) of sample @ 204 - 6. The smaller dimensions serve to distinguish this type from S_9.

Microfossil types similar to S_8 have been described as Sporites adriennis R. Pot. mesozoicus by Thiergart (48). The size range of this species is 40 - 70 μ, and hence is considerably smaller than that observed for S_8.

S_9 (Plate III - 1 fig.) Very large ; levigate; trilete, with the triradiate germinal grooves extending approximately three-quarters the distance towards the periphery; length of germinal grooves 47 μ. Dimensions of microfossil 110 x 84 μ.

Only one specimen was accurately identified as type S_9; that being recorded in sample @ 205 - 1. Numerous ruptured, fractured or otherwise distorted forms resembling S_9 have been observed, but none has been positively identified. The dimensions of S_9 are sufficiently larger than those of S_8 to suggest that the two forms are distinct. However, that the two types were originally associated with closely related parent plants is highly probable.--Not previously described.

GROUP T- Microfossils are generally large; spherical, oblong, or rectangular in outline; verrucose or setaceous in ornamentation; trilete, with the triradiate ridges moderately open and ridged; radially symmetrical; and frequently folded or overlapped. The largest diameter ranges from 34 μ in T_7 to 71 μ in T_3.

Group T microfossils, and more specifically T_1 and T_4, are among the most commonly found in association with the Brazeau coals. The types are readily identified by the characteristic verrucose-setaceous ornamentation and the large size. The trilete germinal aperture is rarely observable, but to clarify the morphological characteristics of the group members, specimens showing the germinal apparatus have, in most cases, been chosen as illustrations

T_1- (Plate II - 2 figs.) Spherical or rectangular in outline; setaceous; trilete, the triradiate grooves extending approximately two-thirds the distance to the periphery; average length of grooves 18 μ. Range of diameter 40 - 49 μ.

T_1 has been recorded as being moderately abundant in all segments of sample ⊕ 204 - 6 and in samples T 204 - 2(c) and ⊕ 205 - 1. The occurrence of this microfossil type appears to be associated with the vitrain segments of most samples.

A similar form has been described and illustrated as Lycopodium?-sporites primarius Wolf, by Thiergart (47) who has suggested the affinity of that microfossil to recent species of Lycopodium. The size of Thiergart's specimen is 45μ, and the trilete germinal aperture is faintly visible.

T_2- (Plate III - 3 figs) Description essentially as noted for T_1. Average length of trilete grooves 22μ. Range of diameter 60 - 67μ.

Type T_2 has been recorded in moderate frequencies from samples ⊛ 204 - 1, ⊛ 205 - 1, and all segments of ⊛ 204 - 6. This microfossil is distinguishable from T_1 by it's larger dimensions.--Not previously described.

T_3- (Plate III - 1 fig.) Rectangular to oblong; setaceous; trilete?; folds frequently present. Range of diameter 69 - 74μ.

Several specimens of type T_3 have been recorded in samples T 197 -1(a) and ⊛ 204 - 6(iv). This form is distinguished from T_2 by it's larger size, but it is possible that the two types represent identical species of microfossils.--Not previously described.

T_4- (Plate II - 3 figs.) Oblong to broadly lanceolate in outline; verrucose; trilete?; longitudinal folds frequently present. Range of length 45 - 54μ.

Microfossil specimens of type T_4 have been frequently recorded in samples T 197 - 1(a), ⊛ 205 - 1, and ⊛ 204 - 6(iv); and to a lesser extent in samples ⊛ 204 - 6 and ⊛ 204 - 6(ii). The trilete germinal apparatus, which is characteristic of group T, has not been recognized in T_4 microfossils. The other morphological features, however, indicate that T_4 is related to other members of the group.--Not previously described.

T_5- (Plate III - 2 figs.) Oblong to rectangular; setaceous; trilete?; folds frequently present. Range of length 51 - 56μ.

T_5 has been recorded as occurring moderately frequently in samples T 204 - 2(b) and T 204 - 2(c). This type has been distinguished from other members of the group by it's size range. There is a possibility, however, that T_5 is an identical microfossil type to T_2, T_3 or T_6.--Not previously described.

T_6- (Plate III - 1 fig.) Spherical; verrucose; trilete? or monolete?; folds frequently present. Diameter 56μ.

Only one specimen of type T_6 has been recorded as occurring in the samples; that being associated with T 197 - 1(a). T_6 resembles T_1 and T_2 in general morphology, and is possibly affiliated with these types. The verrucose or coarsely granulose ornamentation indicated in the illustration is possibily a result of incomplete maceration. If T_6 has no botanical relationship to other T group types, the similar morphological characteristics of T_6 to the other members somewhat justify the placement of that form in group T.--Not previously described.

T_7 (Plate III - 1 fig.) Description essentially as noted under T_1. Range of diameter 32 - 37μ.

Several specimens of type T_7 have been encountered in samples T 204 - 2(c) and ● 204 - 6(iv). This type is similar to the other T forms, but is decidedly smaller is size. No trilete opening has been clearly identified, but suggestions of such a germinal aperture have been observed on one specimen.--Not previously described.

GROUP U- Microfossils are generally small; characteristically tricolpate; levigate, granulose, pitted, or striate in ornamentation; radially symmetrical; and infrequently folded. The diameter ranges from 14 microns in U_1 to 44 microns in U_5.

Microfossils within group U have been encountered comparatively infrequently throughout the Brazeau coal samples. As previously noted in connection with group Q, the microfossils within groups Q and U have been identified as pollen associated with dicotyledonous parent plants. The low frequency of occurrence of pollen types from these two groups is in direct contrast to the comparatively high frequency of pollens and spores from other groups. The evaluation of this contrast is important in a consideration of changing floras during Mesozoic and Tertiary times.

U_1- (Plate III - 2 figs.) Small; pitted or scrobiculate ornamentation; tricolpate; with the three colpae visible on the proximal surface. Range of diameter 14 - 16μ.

Type U_1 has been found associated only with sample T 204 - 2(b), in which five specimens have been encountered. The typical tricolpate configuration and scrobiculate ornamentation are distinctive, and indicate the dictyledonous affinity of this type. In general morphology, U_1 resembles modern pollens of the Caryophyllaceae and Chenopodiaceae families.--Not previously described.

U_2 - (Plate III - 2 figs.) Moderately small; tricolpate; coarsely granulose to punctate in ornamentation. Distortion of original pattern frequently resulting from folds and overlapping. Range of diameter 19 - 23 μ.

Several specimens of type U_2 have been recorded from samples @ 204 - 1, T 428 - 1 and T 154 - 1. The three deeply cleft lobes facilitate identification of this type, in addition to indicating a relationship to dicotyledonous pollens.

A microfossil similar to U_2 has been described as *Pollenites exactus facetus* R. Pot. by Thiergart (47) from Tertiary coals of Germany. The size range of Thiergart's specimens, however, is 12 - 21 μ, which is a considerably larger range than has been recorded for U_2.

U_3 - (Plate III - 1 fig.) Subtriangular; reticulate; distinctly tricolpate, the 3 colpae frequently distended. Range of diameter 27 - 38 μ.

Type U_3 has been recorded as occurring frequently in sample T 428 - 1, and to a limited extent in sample @ 204 - 1 and @ 204 - 6(iii). The reticulate ornamentation and larger size range serve to distinguish this type from U_2.

Microfossils similar to U_3 have been described by Simpson (44) as *Bucklandia sp.* (34 μ); by R. Potonié (24) as *Pollenites laesus* (30.4 μ); and by Thiergart (47) as *Pollenites laesus* R. Pot. (28.5 - 39 μ). The widespread occurrence of this form suggests that the present dicotyledonous plants had a somewhat extensive range during upper Cretaceous and Tertiary ages.

U_4- (Plate III - 1 fig.) Subtriangular; levigate; tricolpate, the colpae frequently separated; ridges typically present on exine. Range of diameter 34 - 38 μ.

Several specimens of type U_4 have been recorded in sample @ 205 - 1, but the microfossil type has not been recognized in other samples. The ridged exine and levigate surface serve to distinguish this form from U_3.--Not previously described.

U_5- (Plate III - 1 fig.) Broadly triangular; striate; tricolpate, with the 3 colpae typically flared at their apices. Range of diameter 40 - 46 μ.

Type U_5 has been recorded infrequently in sample @ 205 - 1, and a single specimen was encountered in sample @ 204 - 6(i). The large dimensions, finely striate ornamentation, and gaping colpae serve as distinguishing features of this form.--Not previously described.

U_6- (Plate III - 1 fig.) Triangular; granulose; tricolpate, the 3 colpae appressed. Microfossil extensively folded. Diameter 21 μ.

Only one specimen of U_6 has been recorded from the samples; that being encountered in @ 204 - 6(iii). It is possible that this microfossil is trilete rather than tricolpate, but further evidence would have to be obtained to accurately evaluate the morphological characteristics.--Not previously described.

<u>GROUP V</u>- Microfossils are oval or elliptical to oblong in shape; monolete or alete; punctate to punctate-reticulate in ornamentation; and bilaterally symmetrical.

The largest dimensions ranges from 28 μ in V_2 to 61 μ in V_4.

The microfossil types within group V have been encountered throughout the samples in various frequencies, but the extent to which they are present in any sample is comparatively limited. The morphological characteristics suggest that the types are spores which were originally associated with Pteridophyte parent plants.

V_1- (Plate III - 1 fig.) Oblong; densely punctate-reticulate; monolete. Range of length 36 - 44 μ.

Type V_1 has been recorded to a limited extent in samples T 204 - 2(b), T 204 - 2(c), T 197 -1(a), and @ 204 - 6(iii). V_1 is very similar in size and appearance to V_3, and there is a possibility that the two forms are similar species. The direction of compression could account for the apparent differences, which exist between the two microfossils.--Not previously described.

V_2- (Plate III - 1 fig.) Oval; punctate-reticulate; alete. Range of length 27 - 34 μ.

Several specimens of type V_2 have been recorded as occurring in samples T 428 - 1 and segments (ii) and (iii) of sample @ 204 - 6. V_2 is distinguishable from V_1 and V_3 by it's smaller size and apparent lack of a monolete germinal aperture.--Not previously described.

V_3- (Plate III - 1 fig.) Oblong or somewhat "bean" shaped; densely punctate-reticulate; monolete. Range of length 47 - 55 μ.

V_3 has been recorded as occurring to a limited extent in sample T 204 - 2(b). The morphology of this type is very similar to V_1, and it is probable that the two microfossil forms originated from identical or similar parent plants.

A microfossil similar to V_3 has been described by Thiergart (47) as Polypodium-sporites alienus R. Pot., which has a length dimension of 53.5 μ. However, the ornamentation of this species is more broadly reticulated than that of V_3. Erdtman (8) has described several spores of modern Polypodium species which resemble type V_3. This evidence indicates that type V_3, and possibly all V types, represent spores of Polypodium or closely related genera.

V_4- (Plate III - 1 fig.) Elliptical to oblong; punctate; monolete? and frequently ridged or overlapping along the midline. Range of length 56 - 64 μ.

Several specimens of microfossil type V_4 have been recorded as occurring in sample T 197 - 1(a). The large size and coarse reticulations serve as features distinguishin[g] V_4 from other types of group V. The central region is more finely ornamented than the outer limited, and appears to be depressed. The presence of a monolete germinal aperture has been suggested in this region.--Not previously described.

GROUP W- Group W has been constructed in order to accommodate microfossils which are morphologically distinct from other forms. No relationship whatsoever exists between the four microfossil types, and sufficient dissimilarities exist between these members and the other microfossils to warrant their inclusion within a miscellaneous grouping.

W_1- (Plate III - 1 fig.) Oval in shape; setaceous in ornamentation; germinal aperture possibly tricolpate or monolete; radially symmetrical. Range of length 32 - 34 μ.

Three specimens of W_1 have been recorded in sample T 428 - 1. In none of these microfossils was the germinal aperture apparent. However, in the specimen illustrated in Plate III, evidence of a single suture was observed, which indicates either a tricolpate or monolete type of aperture.--Not previously described.

W_2- (Plate III - 1 fig.) Spherical; distinctly spinose, the spines forming a regular pattern on the exine; tricolpate; the colpae frequently forming concentric rings or not visible. Range of diameter 23 - 27 μ.

Numerous specimens of W_2 have been observed in sample T 204 - 2(b). The spinose ornamentation serves as a distinguishing morphological feature in this type. The concentric circle pattern indicated in the illustration in Plate III was not observed in the other specimens, and probably has resulted from the colpae being oriented in the concentric fashion during compression.

Type W_2 is similar to modern pollens of the Nymphaeaceae as described and illustrated by Erdtman (8). The similar species, however, have been identified as having a monocolpeate germinal aperture, which is not suggestive of a close relationship between W_2 and pollens of the Nymphaeaceae family.--Fossil forms not previously described.

W_3- (Plate II - 2 figs.) Oval, levigate; germinal aperture not present, although breaks in the exine have been observed; symmetry bilateral; folds frequently present. Range of greatest dimension 13 - 17 μ.

W_3 has been frequently encountered in samples @ 204 - 6(iii) and has a limited occurrence in samples T 204 - 2(b) and T 154 - 1. Two and three W_3 microfossils are usually grouped and joined together, although single members have been frequently observed. Notches in the rim of the microfossil are common, and are probably connected with the mode of germination. The tetrad grouping suggests that W_3 microfossils are microspores of Pteridophyte or Bryophyte origin.--Not previously described.

W_4- (Plate III - 1 fig.) Spherical; levigate; transparent; germinal aperture consisting of one pore; bilaterally symmetrical. Diameter 39 μ.

Only one specimen has been identified as W_4; that occurring in sample T 154 - 1. However, the other transparent microfossils have been observed in that sample, and there is a possibility that the germinal pore has been obscured as a result of folding in some specimens.

The morphology of W_4 suggests that this type is related to monocotyledous pollens. The presence of the single germinal pore resembles the condition found in modern pollens of the Gramineae and Cyperaceae families. Fossil forms similar to W_4 have not been described, although Thiergart (48) has described and illustrated a monocotyledonous microfossil of the Palmae, which he has termed Palmenpollen.

QUANTITATIVE CONSIDERATIONS OF MICROFOSSILS

The third objective of the present investigation includes a quantitative examination of microfossil frequency associations within the coal samples. Two main reasons exist for a consideration of this evidence. (1). The numerous spores and pollen which have been encountered indicate that certain types are predominantly associated with the Brazeau thin seams, and definite patterns of microfossil associations have been noted as occurring within the samples. These observations are considered to be applicable to an evaluation of palaeoecological factors which existed during uppermost Cretaceous times. (2) The problem of recognizing the upper Cretaceous-Tertiary boundary throughout the Entrance area, together with possibilities of correlations within Cretaceous coal seams, suggest that a quantitative appreciation of microfossil associations and frequencies is desirable.

To provide evidence of microfossil frequencies, counts were obtained from maceration preparations of 7 samples. The samples were primarily divided into segments based on coal types present, and the histograms illustrated in Plate V represent averages of counts from all segments within the samples. Early in the investigation, it was noted that vitrain segments require a longer and more vigorous maceration than do the durain portions. The method of separately macerating segments ensures that complete microfossil separations may be obtained from each horizon.

The percentage frequency of each microfossil is based on a count of 200 specimens, and only those types occurring in a frequency of 6 per cent or higher have been recorded. Following the procedure of Raistrick and Simpson (29), the term "general microfossils" is applied to these microfossils having a frequency of 6 per cent or higher. Those types occurring less frequently than 6 per cent are termed "accessory microfossils". To facilitate reference, the "general microfossils" have been illustrated in Plate II, and the "accessory" types are represented in Plate III.

The most notable feature resulting from an appraisal of the histograms is the wide variation in frequencies of the general microfossils exhibited within the samples. In no two cases are the histogram "characters" sufficiently alike to indicate that close relationships existed in the original distributions of plants in the pre-coal organic deposits associated with each seam. To insure accuracy in the determinations, duplicate macerations were performed on most samples, and the results were such as to confirm the indication that the quantitative differences in microfossil distributions exist.

The most consistently occurring microfossils are those of group O, especially types O_2 and O_4. These two forms are present in every sample except T 204 - 2(b), although O_2 does not have a recordable frequency in sample T 154 - 1. Members of groups L and M are also strongly represented in most samples, but wider variations exist in the types occurring. Microfossil types of the remaining groups have a scattered occurrence throughout the samples.

In assessing the significance of the histogram records, the problem of relating microfossils to original parent plants presents difficulties in evaluating palaeoecologic factors. Previous investigations have indicated that most types within groups L and M are probably pollens of primitive Gymnosperms, as represented by the Cycadaceae, Bennettitineae and Taxodineae. Group N types are closely related to modern Conifer pollens, while O, R, S, and T microfossils indicate relationships to various Pteridophyte plants. Angiosperm pollens, other than Q_5, are not present in sufficient numbers to warrant a consideration quantitatively.

On the basis of this incomplete and generalized evidence, it would be unwise to attempt a detailed discussion of the floras which existed during deposition of the coal seams. However, when knowledge regarding microfossil-macrofossil relationships becomes more advanced, much valuable information with respect to plant associations and climatic factors during uppermost Cretaceous times will possibly be forthcoming. The evidence which has been obtained so far, indicates that a predominantly Pteridophyte-Gymnosperm flora existed during uppermost Cretaceous times within the Entrance area, and that Angiosperms were still a minor component of that flora.

Correlation Possibilities: In correlation attempts within English coal seams, Raistrick (30) found that seven spore types were suitable for including within "general" spore diagrams, while numerous other types were useful as "accessory" spores. The same number of "general" spore designates has been utilized more recently by Knox (17) in correlations of Carboniferous coals in Scotland. In the United States, Kosanke (18) correlated Pennsylvanian seams from Illinois using 146 species of spores representing 20 genera, and no attempt was made to separate the forms into "general" and "accessory" types. Each of these correlations has been directed toward Carboniferous coals, and attempts at correlating Mesozoic strata using plant microfossils have been unreported.

The results of the present microfossil analysis indicate that if a system essentially similar to the one developed by Raistrick is to be utilized in correlations of Cretaceous coals, many more microfossil designates will be necessary as "general" types. In lieu of the more varied floras which had evolved by Cretaceous times, this is to be expected. The evidence would seem to indicate that for attempted correlations of Cretaceous, and possibly of all Mesozoic coals, the adoption of a system similar to that used by Kosanke would be desirable. However, more information pertaining to microfossil associations and distributions must be acquired before correlation attempts are undertaken.

CONCLUDING DISCUSSION

The structural examination of the Brazeau coals has indicated that the rank varies from sub-bituminous to bituminous. This determination suggests that the original organic deposits have been subjected to a moderate degree of metamorphism and compression, factors which are important in appreciating the degree to which coalification of the plant components has advanced. The rank of the samples indicates, additionally, that Brazeau coals might possibly be important from the standpoint of utilizing the coal for fuel. Coals of similar rank have long been preferred as fuel to lignites and peats, because they provide a more complete combustion and a greater production of heat. However, seam thickness, rather than rank, would probably be the limiting factor in any assessment of economic potentialities within the Brazeau seams.

The identification of three of the four recognizable coal types and associated macerals in the samples, suggests that the Brazeau coals are structurally similar to Palaeozoic coals already investigated. However, the absence of clarain and the presence of coarse fusain in the Brazeau samples as revealed in this work, are two features which differentiate the former coals from Palaeozoic bituminous coal types. The vitrain, vitrinite, and durain are structurally similar in both coals. A more extensive knowledge of structural similarities might possibly be gained by the application of thin section techniques to the Brazeau coals.

The occurrence of essentially equal proportions of vitrain and durain throughout the samples suggests that the plant constituents entering into the formation of the two types during coalification were present in somewhat equal proportions. Thin sections prepared from Pennsylvanian coals have shown that woody fragments and associated compounds are the major components of vitrain, whereas softer tissues and attrital material constitute durain (49) (53). The presence of the two types in both Pennsylvanian and upper Cretaceous coals suggests that similar plant components entered into the formation of coal during both periods of deposition. However, any similarities would necessarily be structural in nature, as the flora of the two geologic periods are distinctly contrasted with respect to phylogenetical relationships among the existing plants.

As noted in the description of coal types, the association of fusain and vitrain appears to be common throughout the Brazeau samples. The fact that the two types are alternately interbedded suggests that they were closely associated during initial stages of coalification. It is a matter of conjecture as to whether the two types have resulted from alterations of similar plant components due to variable chemical or physical influences. Knowledge related to variable coalification has not been sufficiently advanced to substantiate this as a probability, and experimental evidence is required to understand the processes involved in the formation of coal types.

The clarain coal type, which has been recognized as a commonly occurring structural component in Palaeozoic coals from various countries, is notably unrecognizable in the Brazeau samples examined. In this connection, however, a suggestion that particular associations of vitrain and durain may be preliminary stages in the formation of clarain appears significant. In sample @ 204 - 6, shown in Plate I, fig. 13, vitrain and durain segments alternate in a similar fashion as in clarain found in Palaeozoic banded bituminous coals. In the latter, however, the alternate segments are thinner and closer together, producing a series of bright and dull stripes. The alternation of vitrain and durain in sample @ 204 - 6 suggests that if further compacting of these segments and compression of the coal occurred, a condition similar to that found in clarain might result. In view of this evidence, it seems possible that the clarain found in banded bituminous coals was organized originally in a manner similar to the vitrain-durain association in sample @ 204 - 6, and that prolonged exposure of the latter to pressures and heat has resulted in transformation into clarain.

The examination of microfossil frequencies in the coal types suggests that they are sufficiently variable to justify the differentiation of Brazeau coal types on the basis of microfossil type and frequency differences. If the identity and macrofossil relationship of each microfossil is established, evidence of the plant types and associations involved in the formation of the three coal types will inevitably be forthcoming. However, sufficient information pertaining to microfossil-macrofossil relationships is not available at the present time to realize this possibility.

The recognition of ninety-two microfossils throughout all the samples demonstrates that spores and pollens are substantial components of the Brazeau coals. This fact is particularly significant in view of a recent unsuccessful attempt by Newmarch (21) to separate microfossils from Kootenay (Lower Cretaceous) coals from the Crowsnest Pass area in sufficient numbers to be useful for correlation purposes. The frequency of a few microfossils per slide, as reported by Newmarch, is in direct contrast to the several hundred specimens obtained per slide from maceration preparations of the Brazeau samples. In view of the difficulty encountered in macerating vitrain in the Brazeau coals, it is entirely possible the Kootenay coals contain a predominance of this type, which may account for the low microfossil frequencies obtained by Newmarch.

In considering natural relationships of the Brazeau microfossils, evidence suggesting apparent relationships only can confidently be offered. This is mainly due to a lack of knowledge with respect to the relationships of microfossils to parent plants. Other investigators have attempted to link microfossils from Mesozoic and Tertiary coal deposits to spores and pollens associated with existing plants. This has resulted in the recognition of natural relationships of many microfossil forms resembling certain of those being presently considered. However, the relationships of many of the Brazeau microfossils are uncertain, and the assigning of these forms to natural groups is difficult and possibly inaccurate. Suggested affiliations are offered on the basis of similarities of Brazeau microfossils to pollens and spores of extinct and living plant groups. In this way, it is hoped that knowledge of the flora which existed during uppermost Cretaceous times in the Entrance area may be gained.

On the basis of evidence accumulated, microfossil members of groups L, M, N, and P appear to represent pollens of extinct and modern Gymnosperms. Group L microfossils are similar to forms assigned to Cycadales and Bennettitales. Members of group M have not been clearly identified or correlated, but possibly resemble pollens of extinct species of Ginkgo, and related genera of Ginkgoales. Group N forms are very similar to pollens of the Abietineae, and particularly those representing genera of the family Pinaceae. Microfossils of group P appear to be related to pollens of Sequoia, Taxodium, and Cryptomeria, although sufficient forms of these genera have not been identified to accurately substantiate this correlation.

Microfossils assigned to groups O, R, S, T, and V, have apparent relationships with spores of Pteridophytes, with the exception of S_6, which has been identified as a form similar to spores of Sphagnum, and therefore is representative of the division Bryophyta. Microfossils assigned to group O are similar to endospores of extinct species related to modern species of Polypodium. Group R spores are possibly spores of extinct species of Equisetales, whereas those of groups S and T show marked similarities to spores of both modern and extinct ferns. Members of group V appear to be perispores of species related to Polypodium, although it is possible that they are actually spores of other Pteridophytes.

The morphological characteristics of microfossils in groups Q and U indicate that these forms are related to modern Angiosperm pollens. Members of the former group are very similar to pollens of plants of the Betulaceae and Juglandaceae, whereas those of group U appear related to pollens of the Caryophyllaceae and Chenopodiaceae. Positive identification of the relationships of microfossils within the latter group is difficult, however, because of widespread changes which have occurred in the flora from Mesozoic times to the present.

The recognition of numerous microfossils indicates that the flora was varied with respect to existing plant types during the period of deposition of the Brazeau coals. The predominance of microfossil types associated with Gymnosperms and Pteridophytes suggests that the flora consisted mainly of associations of parent plants of these two groups. The comparatively low proportion of pollens possessing Angiosperm characters indicates that monocotyledons and dicotyledons formed a minor part of the flora. This evidence supports the theory that a predominantly Gymnosperm-Pteridophyte floral complex existed during uppermost Cretaceous times, and that Angiosperms had not yet evolved into the dominant floral constituent.

The wide variations in microfossil types and frequencies found throughout the samples may be applicable to future attempts at correlating or separating the thin seams within the Brazeau formation. Consistently occurring "general" microfossil types such as O_2 and O_4, suggest that a possibility exists of correlating the Brazeau seams by establishing uniformity of frequency percentages as indicated by histograms. This possibility, however, will be dependent on the uniformity of occurrence of microfossil types as established in histogram records of many samples from each horizon.

Of the two possibilities, that of seam separation appears more practicable on the basis of the evidence obtained. The wide variations in types and frequencies of most microfossils from one seam to another suggest that the seams could be readily separated. The histogram characters of all the samples investigated are sufficiently variable as to facilitate separation of thin coal seams within the Brazeau formation. Additional significance becomes attached to this evidence when the separation of stratigraphic horizons containing thin coal seams is considered, and where similarities and differences in histogram characters might possibly form the basis for delimitations of major geological formations.

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Explanation of Photographs

PLATE I

Figure 1. - Polished surface of sample T 204 - 2(d) showing an association of vitrain and durain. The characteristic rhomboidal fracture of the vitrain and coarse appearance of the durain are obvious. Bituminous. X 1.5

Figure 2. - Enlarged photograph of sample T 204 - 2(d). X 1.75

Figure 3. - Polished surface of T 204 - 2(b), showing vitrain (top) grading into durain, and lenticular vitrinite intrusions within the latter. Bituminous. X 0.8

Figure 4. - Enlarged photograph of sample T 204 - 2(b). The vitrinite lenses are more obvious than in Fig. 3. X 0.9

Figure 5. - Polished surface of sample T 204 - 2(a). The lower regions of durain contain numerous vitrinite lenses which are noticeably lacking in upper regions. The slightly separated bedding planes appearing as longitudinal cracks are obvious. Bituminous X 0.8

Figure 6. - Irregular surface of sample T 154 - 2(e) showing vitrain interbedded with fusain. The wide separations between vitrain layers originally contained fusain. Note the rhomboidal or somewhat conchoidal fracture of the vitrain. Sub-bituminous. X 1.2

Figure 7. - Flattened surface of sample T 426 - 2 in which the fussin and vitrain are interbedded. The former type is clearly recognizable in the outer regions; the central area showing exposed vitrain. Sub-bituminous. X 1.4

Figure 8. - Polished surface of sample T 154 - 2(b) showing unconsolidated durain. The numerous cracks (bedding planes) are characteristic of durain in sub-bituminous Brazeau coals. X 0.7

Figure 9. - A portion of a polished surface of sample T 204 - 1 showing vitrinite lenses within durain which has a typical "pebbly" appearance. Bituminous. X 1.6

Figure 10.- Polished surface of sample T 428 - 1 showing numerous bedding planes within a sub-bituminous vitrain-durain matrix. X 0.7

Figure 11.- Irregular surface of sample @ 150 showing comparatively uncompacted vitrain layers. The rhomboidal and conchoidal fractures characteristic of bituminous vitrain are noticeably lacking. Sub-bituminous. X 0.9

Figure 12.- Polished surface of sample T 204 - 2(c) showing vitrain in upper regions grading into durain containing vitrinite lenses. The separated bedding planes and transverse fracture planes are obvious. Bituminous. X 0.95

Figure 13.- Polished surface of sample @ 204 - 6 showing alternating vitrain and durain layers. Bituminous X 0.8

Figure 14.- Polished surface of sample T 154 - 2(a) showing irregularly fractured vitrain more consolidated than within other sub-bituminous samples.
X 1.4

PLATE II

Microfossil Designation	Dimensions (Microns)	Sample	Slide	Co-ordinates
L_2	25 x 18	T 154 - 1	C_r-16	17.3 : 149.6
L_3 (i)	23 x 16	T 204 - 2(b)	C_s-30	12.8 : 144.9
L_3 (ii)	21 x 16	● 204 - 1	C_u--8	37.0 : 158.1
L_4 (i)	32 x 18	● 204 - 1	C_u--8	30.55: 158.2
L_4 (ii)	34 x 17	T 428 - 1	C_s-50	43.2 : 158.8
L_7 (i)	26 x 17	T 204 - 2(b)	C_s-23	19.2 : 145.35
L_7 (ii)	26 x 17	T 204 - 2(b)	C_s-29	29.92: 160.0
M_1 (i)	23 x 19	● 205 - 1	C_t--4	19.6 : 144.2
M_1 (ii)	23 x 18	● 205 - 1	C_t--5	43.3 : 159.6
M_2 (i)	21	● 205 - 1	C_t--5	48.8 : 156.0
M_2 (ii)	21 x 18	T 204 - 2(b)	C_s-18	30.8 : 159.85
M_3 (i)	27	● 204 - 6(i)	C_s-52	19.7 : 155.5
M_3 (ii)	26 x 21	● 204 - 1	C_u--8	17.9 : 145.5
M_4	31 x 26	T 204 - 2(b)	C_s-18	18.0 : 158.6
M_5	35	T 428 - 1	C_s-43	25.4 : 153.6
M_6	23 x 18	● 204 - 6(iii)	C_s-55	4.9 : 154.35
M_7	26 x 23	T 197 - 1	C_s-32	14.7 : 148.0
M_{11}	18.5	T 204 - 2(c)	C_s--3	27.3 : 159.45
N_1	53x46x32	T 204 - 2(c)	C_r--6	17.4 : 152.15
N_2	58 x 42	T 197 - 1	C_s-31	17.65: 152.8
O_1 (i)	39 x 28	● 205 - 1	C_t--5	39.7 : 161.7
O_1 (ii)	35 x 26	● 205 - 1	C_t--5	15.4 : 144.2
O_2 (i)	49 x 35	● 205 - 1	C_t--5	13.1 : 144.0
O_2 (ii)	35 width	● 204 - 1	C_u-13	35.3 : 163.6
O_3 (i)	44 x 30	● 205 - 1	C_t--5	47.9 : 162.1
O_3 (ii)	40 x 25	● 205 - 1	C_t--7	50.9 : 156.0

Designation	(Microns)	Sample	Slide	Co-ordinates
O_4 (i)	33 x 42	T 154 - 1	C_r-16	29.2 : 147.6
O_4 (ii)	38 x 28	T 428 - 1	C_s-48	40.2 : 163.3
O_4 (iii)	40 x 33	T 204 - 2(b)	C_r-13	50.85: 152.6
O_6 (X 340)	56 x 33	T 428 - 1	C_s-43	19.0 : 154.5
P_4 (i)	28 x 19	T 428 - 1	C_s-39	44.95: 145.8
P_4 (ii)	29 x 16	T 204 - 2(c)	C_s-14	31.1 : 148.55
Q_5	35 x 30	T 154 - 1	C_r-16	36.0 : 148.65
R_1	28	⊙ 204 - 1	C_u--8	43.4 : 157.5
R_2	40	⊙ 204 - 6(i)	C_s-51	12.9 : 148.05
R_4 (i)	58 x 51	⊙ 204 - 1	C_u--8	35.7 : 158.1
R_4 (iii)	63	⊙ 204 - 1	C_u--9	29.0 : 163.7
S_6	25	T 204 - 2(c)	C_r--7	37.65: 148.8
T_1 (i)	44 furrow 18	⊙ 205 - 1	C_t--7	53.9 : 152.7
T_1 (ii)	40 x 30	⊙ 205 - 1	C_t--5	48.0 : 160.8
T_4 (i)	52 x 45	⊙ 205 - 1	C_t--5	48.6 : 149.8
T_4 (ii)	52 x 33	⊙ 205 - 1	C_t--7	73.6 : 163.7
T_4 (iii)	47 x 32	T 204 - 2(b)	C_s-23	9.0 : 148.3
W_3 (i)	14 x 12	⊙ 204 - 6(iii)	C_s-55	33.2 : 143.7
W_3 (ii)	17 x 15	T 154 - 1	C_r-15	26.9 : 152.6

Range of magnification 250 - 325X for all microfossils unless otherwise noted.

PLATE III

Microfossil Designation	Dimensions (Microns)	Sample	Slide	Co-ordinates
L_1	23 x 15	T 204 - 2(b)	C_r-13	50.75: 150.5
L_5	19 x 14	⊙ 205 - 1	C_t--5	40.3 : 160.7
L_6	24 x 12	T 197 - 1	C_s-31	39.0 : 156.8
M_8 (i)	27	⊙ 204 - 1	C_u--8	39.4 : 157.75
M_8 (ii)	28 x 19	⊙ 204 - 1	C_u--8	6.8 : 156.1
M_9	37 x 32	T 428 - 1	C_s-39	41.3 : 145.7
M_{10}	26	T 204 - 2(b)	C_s-29	47.9 : 157.15
M_{12}	21	T 428 - 1	C_s-40	45.25: 147.8
N_3	70 x 27	⊙ 204 - 1	C_u-13	33.2 : 162.3
N_4 (X430)	61 x 28	⊙ 204 - 6(i)	C_s-53	6.65: 149.5
N_5	61 x 47	⊙ 205 - 1	C_t--5	17.5 : 145.6
N_6	115 x 70	⊙ 205 - 1	C_t--5	21.8 : 144.1
N_7	93 x 54	⊙ 204 - 1	C_u-14	15.9 : 146.45
N_8 (i)	119 x 93	T 428 - 1	C_s-50	16.3 : 145.9
N_8 (ii)	115 x 63	⊙ 205 - 1	C_t--4	56.75: 149.1
N_9	86 x 60 of portion remaining.	T 428 - 1	C_s-39	47.4 : 146.5
N_{10}	56 x 35	T 428 - 1	C_s-39	29.3 : 163.2
N_{11}	61 x 37	T 428 - 1	C_s-40	44.0 : 157.2
Φ_7	68 x 52	⊙ 205 - 1	C_t--5	41.8 : 157.7
O_9	63 x 39	T 428 - 1	C_s--47	29.4 : 156.2
P_1	44 x 35	T 154 - 1	C_r-16	11.6 : 149.6
P_2	32 x 23	T 204 - 2(b)	C_s-18	14.0 : 160.4
P_3	35 x 26	T 204 - 2(b)	C_s-23	49.25: 150.9

Microfossil Designation	Dimensions (Microns)	Sample	Slide	Co-ordinates
P_5	35 x 31	O 204 - 6(i)	C_s-51	19.7 : 147.45
P_6	39 x 16	T 428 - 1	C_s-43	10.4 : 156.7
P_7	45 x 28	T 204 - 2(c)	C_r--4	19.7 : 155.5
P_{10}	61 x 22	T 154 - 1	C_r-16	34.45: 147.0
P_{11}	46 x 28	T 428 - 1	C_s-50	25.9 : 163.2
Q_1 (X340)	35 x 26	T 428 - 1	C_s-48	31.1 : 155.1
Q_2	44x35x35	T 428 - 1	C_s-40	39.6 : 157.0
Q_3 (i)	35 x 26	T 428 - 1	C_s-50	53.5 : 149.7
Q_3 (ii)	35 x 24	T 428 - 1	C_s-48	32.0 : 155.5
Q_3 (iii)	35 x 26	T 428 - 1	C_s-39	30.0 : 146.9
Q_4	23 pore to end	T 428 - 1	C_s-47	43.2 : 155.3
Q_6	26 pore to end	T 204 - 2(b)	C_s-29	44.1 : 162.1
Q_7	21 x 19	T 204 - 2(b)	C_s-18	18.2 : 148.85
R_3 (i)	61 x 35	O 204 - 6(i)	C_s-51	14.45: 152.4
R_3 (ii)	70 x 35	O 204 - 1	C_u--8	32.4 : 157.8
R_5	91 x 65	T 204 - 1(a)	C_s--1	55.0 : 153.3
R_6 (i)	60 x 35	T 204 - 1(a)	C_s--1	36.0 : 160.1
R_6 (ii)	68 x 38	T 204 - 1(a)	C_s--1	35.6 : 160.0
S_1 (i)	63 x 51	T 204 - 2(b)	C_r-13	50.9 : 149.55
S_1 (ii)	61 x 59	O 204 - 6(iii)	C_s-56	22.1 : 144.1
S_2	46	O 204 - 6(i)	C_s-54	26.4 : 145.0
S_3	41	O 204 - 6(i)	C_s-52	52.0 : 159.1
S_4	33 x 28	T 204 - 2(b)	C_s-21	38.6 : 156.9
S_5 (X540)	53 x 40 furrow 1 - 25	O 204 - 6(i)	C_s-52	40.0 : 152.7

Microfossil Designation	Dimensions (Microns)	Sample	Slide	Co-ordinates
S_7 (i) (X340)	38 furrow 1 - 21	⊙ 205 - 1	C_t--7	26.0 : 163.2
S_7 (ii)	35 tri-lete arm 11 long	⊙ 204 - 6(i)	C_s-54	39.2 : 144.9
S_8	84 pore to end	T 204 - 2(c)	C_r--4	21.4 : 153.0
S_9 (X260)	110 x 84 largest L & W	⊙ 205 - 1	C_t--7	10.45: 163.45
T_2 (i)	61 tri-lete arm 22	⊙ 204 - 6(iii)	C_s-56	33.1 : 143.6
T_2 (ii)	65 x 53 largest furrow 23	⊙ 204 - 6(i)	C_s-51	36.9 : 147.45
T_2 (iii)	66 x 42	⊙ 204 - 6(i)	C_s-54	18.2 : 156.2
T_3	70 x 44	O 204 - 6(i)	C_s-54	25.0 : 145.0
T_5 (i)	56 x 42	T 204 - 2(b)	C_s-22	53.95: 149.8
T_5 (ii)	53 x 39	O 204 - 6(i)	C_s-51	45.8 : 147.8
T_6	56 x 49	T 197 - 1	C_s-33	30.0 : 149.4
T_7	34 x 29	T 204 - 2(c)	C_s-14	34.35: 150.2
U_1 (i)	14	T 204 - 2(b)	C_s-27	13.2 : 150.45
U_1 (ii)	14	T 204 - 2(b)	C_s-27	13.2 : 150.45
U_2 (i)	23	T 154 - 1	C_r-16	35.95: 148.75
U_2 (ii)	22	T 428 - 1	C_s-47	42.9 : 155.7
U_3	28	⊙ 204 - 1	C_u-13	4.9 : 154.5
U_4	35	⊙ 204 - 1	C_u-13	32.8 : 162.3
U_5	44 x 27	O 205 - 1	C_t--7	49.3 : 155.7
U_6	21 x 12	O 204 - 6(iii)	C_s-56	33.3 : 143.35
V_1	39 x 26	T 204 - 2(c)	C_r--7	34.15: 158.1
V_2	28 x 21	T 428 - 1	C_s-48	18.5 : 161.7

Microfossil Designation	Dimensions (Microns)	Sample	Slide	Co-ordinates
V_3	47 x 30	T 204 - 2(b)	C_s-22	36.35: 147.5
V_4	61 x 37	T 197 - 1	C_s-31	38.55: 160.55
W_1 (X330)	33 x 28	T 428 - 1	C_s-48	31.2 : 154.8
W_2	26	T 204 - 2(b)	C_s-16	25.2 : 149.4
W_4	39 x 35	T 154 - 1	C_s-37	25.9 : 157.75

Range of magnification 250 - 325X for all microfossils unless otherwise noted.