ANALYSIS OF CERTAIN UPPER ORDOVICIAN ROCKS FOR MICROFOSSIL FRAGMENTS

PALAEOBOTANICAL ANALYSIS OF CERTAIN UPPER ORDOVICIAN SEDIMENTARY ROCKS EMPHASIZING MICROFOSSIL FRAGMENTS

By

WILLIAM JOHN THORNE, B.Sc.

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AUTHOR: William John Thorne, B.Sc. (McMaster University)

SUPERVISOR: Professor M.W. Radforth

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SCOPE AND CONTENTS: Several methods for the palaeobotanical analysis of inorganic rocks are developed and through the employment of these methods both microfossils and macrofossils have been recovered from certain Upper Ordovician Strata. These fragments are assigned to series, basing such designation upon their sources and individual morphological characteristics. The problematical identity and biological importance of these fragments is discussed, and their practical usage in problems of correlation is considered.

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INTRODUCTION

Since the turn of the century a great deal of emphasis in the field of palaeobotany has been placed upon the recovery, description and classification of plant microfossil fragments. This particular study is of both economic and academic importance and through recent intensification in this pursuit, major contributions have been made in both realms.

For the most part investigations have centered upon the economic application of the derived facts and have become manifest in stratigraphic correlation of both coal-bearing and oil-bearing strata. Coal-seam correlation which deals with the palaeobotanical analysis of organic sediments has been accomplished with a great degree of success in the United States, Scotland, India, Germany and more recently, here in Canada. Inorganic sediments such as shales, marls and sandstones have also been analysed and the results here have proven to be of application in correlation, pertinent to petroleum geology.

A survey of the results of these analyses indicates that distinguishable microfossil types occur in a variety of sediments, of both organic and inorganic nature, and that due to the morphological differences encountered these might well be classified on the basis of both structure and affinity. It is the concern for such fundamental appreciations that has given rise to this work. It is hoped that this investigation involving classification of microfossils will demonstrate itself in relationship and importance to the academic problems of evolution,

phylogeny and paleoecology of the plant kingdom throughout geologic time.

The expression "microfossil" may, by various definitions, include all floral and faunal remains of microscopic dimension or may prescribe only for particular microscopic entities of either floral or faunal affinity. Accordingly it is necessary to clearly define the scope of the expression as used within a particular account. In this case the expression is to be employed in the broader sense.

As correlation indices, microfossils have proved to be of major applicability. Their successful application is due to the generally resistant property of the cuticular or cutin-like material typical of spores, pollens, vascular plant epidermis, certain single-celled faunal remains and perhaps certain thallophytic remains. The degree of preservation resulting from this resistant material is accordingly great. Further, in the consideration of plant microfossils, and, to a certain extent, animal microfossils as correlation indices, one must appreciate the vast number disseminated from a single source and the wide range of distribution and propagation due to wind and to a lesser degree water transportation. In accordance with the foregoing, microfossils are to be found in a variety of depositional loci. It seems reasonable to ask whether microfossils lend themselves more thoroughly to stratigraphic correlation than do macrofossils which in comparison seem to be limited in their range and number of depositional loci.

It would appear that a profitable utilization of microfossils as correlation indices necessitates an appreciation of several factors of a biological character. Their presence within sediments of diverse origin

and their apparent morphological dissimilarities involves an appreciation of the evolution of the floras, the geographic distribution and migration of the floras and the ecological relationships of the plant forms. Faunal associations and lithologic characters are also pertinent to the thorough understanding of stratigraphic and sedimentary sequence which itself is directly related to the biology of the fossil plants.

Evidence has been all to the contrary that such remains might exist in inorganic strata of Upper Ordovician age. It is, therefore, the first objective to re-examine these strata employing new or modified methods of analysis. For, if such remains exist there is provided a new and promising source of information. The second objective is the examination, description and classification of microfossils isolated from the studied strata. The third objective is to validate these findings by dealing with the palaeoecology of the areas in question as evidenced by related geological, palaeogeographical and biological considerations. Fourthly, attention is directed towards the possible employment of these microfossils as correlation indices. The fifth and final objective deals with the broader aspects of the previous objectives, in pointing out the palaeobotanical significance and implications of the results from the standpoints of ecology and the possible origin of the land habit in the plant kingdom.

LIMITATIONS OF THE EXPRESSION "MICROFOSSIL"

Throughout literature dealing with the palaeobotanical microscopic examination and analysis of sedimentary matrices; both organic and inorganic, the expression "microfossil" has been applied with both broad (82) and delimited (63,47) meanings. In this account "microfossil" will be employed in the former sense and will refer to minute bodies of plant origin, minute bodies of probable invertebrate origin as well as those bodies of unknown origin. The term will, therefore, include desmids, diatoms, spores, pollens and remains of protozoan and graptolitic origin. Such a designation is felt necessary in this case due to the fact that the examples dealt with have not, for the most part, been previously described. Also it is not possible due to their fragmental nature and lack of definite relationship with macrofossil remains to discern with desirable certainty their phylogenetic affinities.

Accepted plant microfossils are characterized in general by their limited size range within a type, the thickness of the wall, degree and type of ornamentation, the possession of characteristic scars, markings, pores, apertures, their shape and symmetry and the presence or absence of auxiliary appendages such as bladders, wings, spines and tubercles.

Numerous factors must be weighed in a qualitative way, if microfossils are to be utilized to best advantage.

Depending upon the degree of cutinization, the geologic history, type of the embodying matrix and the severity of the macerating media,

microfossils vary in the degree of completeness of the final specimen. Some lend themselves quite well to macerating techniques whereas others will, with a few exceptions, be of a fragmentary nature in the final analysis. Generally, microfossils, derived from inorganic matrices, are of fragmental nature due to the fact that it is necessary to employ more severe macerating techniques than is the case with organic matrices. It should also be pointed out at this time that macerating media employed with inorganic rocks removes silica and calcium from the matrix, accordingly, only those microfossils which have cutinous or cutin-like "parts", generally preserved as a carbonaceous film, will render themselves to critical examination.

HISTORICAL

It is the intention in this section to recount briefly work which has previously been accomplished in the investigation and recovery of both plant microfossils and macrofossils from inorganic sediments. Although it is often the case that difficulty is encountered in attempting to associate the microfossils with the parent plant, their very presence within such reputedly unfossiliferous strata has given rise to a new and promising field of investigation and information.

This account may be roughly broken down into two sections. The first will outline the history of microfossil studies in both organic and inorganic strata of various geological ages. The second section will be a consideration of more recent discoveries of both microfossil and macrofossil remains within inorganic strata of Cambrian and other early Palaeozoic age.

(a) The Early Approach to Microfossil Studies.

Most investigation on microfossils has been in conjunction with the correlation of coal-seams and the use of microfossils as correlation indices in these organic strata. The beginning to this approach is to be noted in various parts of the world, in India (29,46,69), the United States (3,37,71, 74,83), England (33,59,60,61,62), Scotland (34,35), Germany 31,55) and more recently here in Canada (47,57,58,63).

The earliest recognition of plant microfossils in inorganic sediments is attributed to Dawson (In Wilson 82), who in 1871 described spore-like

bodies, which he named, "Sporangites" from the Kettle Point Shale of Devonian age in Southern Ontario. These were exceedingly numerous and could be easily seen with the naked eye. There was very little impetus given to further study of microfossil remains between the turn of the century and 1920 (37)

Following this interval of indifference, attention was directed towards the more economic aspects of the study. Analysis of organic strata was emphasized and the use of microfossils as correlation indices in coal and petroleum stratigraphic studies was begun.

Studies of classification and phylogeny resulted from the accumulation of quantities of data obtained in the earlier investigations. Classification systems were developed and a broadening of the scope of sediments studied ensued (21,22,34,61,79). The stress was now upon analysis more closely akin with fundamental palaeobotanical interests.

(b) Early Palaeozoic Plant Microfossil and Macrofossil Discoveries.

Investigations have been done on a small but world-wide scale and various authors have published accounts dealing with the occurrence of pre-Devonian plant remains. In some cases these remains have been discovered in shales, marls, tillites and dolomites, sediments of marine and non-marine origin which generally had been considered as unfossiliferous. For some time, the earliest vascular plant remains were those discovered in sediments of Middle Silurian age in Australia (44). However, since the time of their discovery in 1930, evidence to even older remains has come to view.

A Russian worker, Kryshtofovitich (42) has recently described vascular plant remains from strata of Cambrian age in Russia which he regards

as being a new lycopod genus. That such earlier plant forms existed in periods prior to the Silurian has long been the contention of many workers (28,30,36,45). It was realized through studies of known early Palaeozoic representatives, that the degree of ornamentation exhibited suggested even earlier ancestral types and a long line of evolutionary advance (47). To thoroughly appreciate these ancestral forms, some vascular, reproductive structures must be considered and by so doing, attention becomes focussed upon spore remains and other microfossils as evidenced in the earlier sediments.

It seems pertinent now to refer to selected considerations in detail.

Darrah (11) makes reference to trilete spores recovered from the Upper Cambrian "Kolm" or "Swedish Oil Shales". These spores are described as similar to pteridophyte spores and vary in diameter from 65μ to 75μ. The age of the embodying sediment is indisputable being dated with characteristic trilobite faunal remains. The sediment is more properly termed a "boghead" and is characteristic of oil Shales in that district.

Naumova (49) also records spores from the Lower Cambrian of Russia. These spores are 15μ to 25μ in diameter, some ranging to 75μ and exhibiting a typical vascular trilete scar. She has reputedly studied fifteen thousand representatives and has noted similarities in morphology to groups found within younger strata.

Kessinger (In Hoeg,30) discovered spores in the blue clay of Kunda in northwest Estonia. These clays are of Lower Cambrian age and the spores range in size from 21μ to 27μ with a few representatives up to 440μ.

He also refers to some spores of Silurian and Ordovician age, but these, unfortunately, are not described.

Recently a great deal of work has been accomplished in India. Studies instigated by Sahni who pioneered microfossil investigations in that country, refer to microfossils remains found in phyllitic shales of indisputed Cambrian age (In Hoeg 30). These spores were of a resistant nature and some bear the characteristic trilete scar. There is apparently reason, not conveyed to the writer directly, to regard these as originating in reworked material and therefore questionable.

Because of the inconclusiveness of this early work accompanied none the less by a reasonable amount of tantalizing evidence, the need for examining early strata is now very great.

Krausel (39), in a recent paper, deals with the problematical affinities of Ordovician spore-like microfossils. He also, in this paper, refers to the discovery by Eisenach of numerous spore-like structures, obtained by maceration, from Ordovician rocks in both the Baltic area and Germany.

Certainly it is now possible to speculate, perhaps even conclude, that organized plant forms having affinities to known vascular plants did exist prior to the Silurian Period. This tentative conclusion is verified in part by the numerous spores which have been discovered in sediments of early Palaeozoic age and the similarity in form and size of these spores to undisputed vascular spores of younger age. Similar investigations have been made into the nature of early algal and other non-vascular forms (2,3,23,28,64,65,54) and attempts have been made to establish possible

phylogenetic sequence in the early plant groups (38). It has been the chief aim of these studies to establish the evolutionary sequence preceding the actual attainment of the vascular land habit.

MATERIALS ANALYSED AND CIRCUMSTANCES OF THEIR OCCURRENCE

The samples described here were selected for analysis because of their age, conditions of sedimentation, accessibility and relative proximity to the laboratory. Some preliminary microfossil analyses have been carried out in this area upon sediments of Devonian age (48) and the results have been encouraging, particularly in the cases where shales have formed the embodying matrix. Accordingly, as the Upper Ordovician strata are characterized locally by a variety of shale facies, it was felt that these too might possibly yield helpful results when critically examined palaeobotanically. In view of the fact that a drill core, containing sediments of the same age, was obtainable, it has been possible to analyse these horizons over a larger area and to propose possible correlation of these areally separated strata on the basis of microfossil analysis. This then becomes the first approach towards satisfying the objectives of the work.

The following account summarizes the geologic aspects of the sampled strata and gives some information as to their extent and mode of occurrence in this area. (Pl. I, fig. 1).

(a) Source of Samples.

The samples selected for study were obtained from both outcrop areas and drill core. They represent sediment of Upper Ordovician age (Cincinnation Series) (Pl. I, fig. 2). Core was obtained by the Geology Department of this University from the Oliver Mining Division of the

United States Steel Corporation. This core included sediments of the Cincinnation series which were logged and geologically described by E.S. Spurgeon of McMaster University (73). The drill site was located in the Gore of Woodhouse township, Norfolk County, Southern Ontario. Chip samples of the Billings formation, Dundas-Meaford formation, and Queenston formation were obtained from this core. The actual position of sampling from the core was influenced by the presence of visible carbonaceous remains in the case of the Billings and Dundas-Meaford samples.

Additional representative samples of this age were collected from exposed outcrop areas in the Toronto - Hamilton district. The localities of sites selected were based upon information from the Department of Mines and Resources stratigraphic map, No. 584 A.

Samples of the Billings formation were obtained from an outcrop on the bank of the Rouge River at a point just north of the Provincial Highway number two (No. 2), east of Toronto.

The Dundas formation was sampled from a fresh cutting at the Don Valley Brickyard, North York, Toronto.

The Queenston formation, exposed at numerous points throughout southern Ontario, was sampled at Bronte, Ontario, where outcrop occurs along the shore of Lake Ontario.

The Meaford formation, due to relative inaccessability and limited outcrop in this area (Pl. I, fig. 1), was not directly sampled but is considered in the core sample where it is examined in conjunction with the Dundas formation (73).

(b) Lithology and Correlation of Sampled Sediments

The Billings formation in southern Ontario is typically a black to brown bituminous shale, highly fossiliferous, and attains a thickness of one hundred to two hundred and fifty feet (100 - 250 ft.). Much pyrite occurs in the darker parts and the bituminous material appears to increase downward through the succession (5).

The formation is broken down further into the Collingwood, Gloucester, and Blue Mountain formations. The outcrop occurring on the Rouge River is correlated (Pl. I, fig. 2) as being Blue Mountain. The Billings formation in general is correlated with the Utica group of New York (76).

The Dundas formation is a greyish-blue, thinly bedded shale. In the studied sample, the shale was soft, grey, and had frequent hard bands of a calcareous nature. This formation is also highly fossiliferous and is divided into four zones on the basis of the faunal remains. The faunal remains are typically marine throughout.

The Dundas formation is correlated with the Lorraine group of New York and to the east with the Carlsbad of the Ottawa - St. Lawrence lowland. (76, 78).

The Meaford formation, which overlies the Dundas formation, is described as being arenaceous limestone with interbedded blue-grey shale. It is included in the Richmond Stage of the Upper Ordovician and is correlated with the Russell dolomitic limestone of the Ottawa - St. Lawrence lowland. It is not represented in New York.

In drill chips studied, no distinction is made between the

Dundas and Meaford formations, but rather the core is logged as Dundas-Meaford formation and is described as having a thickness of four hundred and sixty-six feet (466 feet) and consisting of uniform, flaggy, grey, dolomitic shale containing hard calcareous siltstone bands (5)(73).

The Queenston formation overlies in turn the Dundas-Meaford formation. It is characterised by uniform, non-fossiliferous red shales with occasional green mottling and hard, light grey, calcareous bands. The formation measures seven hundred and ninety-three feet (793 ft.) and marks the final deposition occurring in the Ordovician Period. The formation thins in a north-easterly direction and, due to its lack of marine fossils, the presence of ripple marks and cross-bedding, as well as its predominantly red colour, it is generally regarded as being a subaerial deposit (24,5).

In general, the Upper Ordovician deposits underlie most of Ontario and Eastern Quebec (4,5,50,79,80) and exhibit a decrease in thickness to the east (7,8,9). They are, for the most part, shaley in nature, ranging from the black bituminous shale of the Billings formation, through the limestone and shale of the Dundas-Meaford formation, to the red shale of the Queenston. Wilson (78) points out that the source area of all the Upper Ordovician deposits of Ontario, excluding the Billings, was to the south-east, most probably the Appalachian region. The Billings formation, on the other hand, is believed to have been derived from sediments whose source was to the north. Similar black shale, which can be correlated with the Billings, occurs in the Eastern Arctic, on Baffin Island, and also in Labrador.

To the knowledge of the author, there has been no detailed or preliminary investigations into the presence of microfossils in any of the forementioned strata.

(c) Palaeoecological Consideration of Shale Strata

In order to assess the possible presence of plant remains within a sediment it is desirable to appreciate the environmental situation of the basin of deposition. Three types of shale deposition are to be considered here. The Queenston shale with its typically red, non-marine sediment, the Dundas-Meaford a typically marine and limey shale and the Billings shale which is black, bituminous indicating deposition in brackish water (32).

The Queenston formation is considered as an aeolian deposit with materials evidently derived from a source area to the south-east. Due to its lack of marine faunal or floral remains, except in the basal beds, it is felt to be a terrestrial deposit throughout. The few basal faunal remains indicate early oscillations of land masses that permitted eastward extensions of the marine waters (24). The dominant red colour is generally considered indicative of an arid or humid climate and oxidation of the sediments due to exposure.

The Dundas-Meaford formation is a marine deposit. It is characterized by sediment of a calcareous nature and contains abundant faunal remains. Characteristic fauna include brachiopods, molluscs, sponges, bryozoa, corals, annelids, echinoderms and several graptolites (25,28, 51,52). Ruedemann (65) records and describes a variety of algal forms found within the Lorraine of New York, which is correlated with the

Dundas of Ontario. Also the graptolite Mastigograptus, described by Dr. Fritz (26,27) from the Dundas formation of Toronto, has been found in association with fucoid algal remains. The basin of deposition in this case was most probably a deep-water marine basin into which graptolitic and algal forms had been transported and subsequently deposited upon death. Accordingly, microfossils to be found within this deposit might include graptolitic thecae, resistant algal spores, Hystrichosphæridae or quite possibly transported vascular spores. The possibility of such off-shore transportation has been described by Erdtman (18).

The environmental conditions giving rise to the deposition of the two foregoing shale facies are quite simple to determine. However this is not the case with the bituminous black shale of the Billings formation. This black shale is termed a "mixed graptolite shale" (66) and contains an association of graptolitic forms and small benthonic forms including brachiopods, mollusks and trilobites.

The environmental situation suited to such black shale deposition has been studied by various workers (40,41,53,66,74,75) and several hypotheses have been proposed. Characteristics of the habitats of graptolites suggest the presence of algal forms (66) and the question arises whether such habitats are analogous to the littoral sea-weed forests or sargasso-sea conditions found to-day. Ruedemann (66) proposes that the black colour is due to the presence of algal forms and that the dendroid graptolites along with other plankton were in all probability attached to these algae.

Twenhofel (75) suggests that the conditions necessary for black

shale accumulation include deposition of organic material within an area of poor circulation and lack of oxygen where burial is sufficiently rapid to prevent total decomposition. The conditions could occur in lakes and ponds, deep appendages of the oceans, in shallow nearly tideless epicontinental seas and in land-locked or otherwise restricted basins. Krumbein (44) shares the views of Twenhofel in this respect.

Accordingly one might consider the Billings shales as sediments deposited within a basin of little current and limited circulation. The faunal assemblage reflects a littoral condition or a basin of deposition lacking bathyal deeps. Also the presence of algal forms is indicated. Accordingly, it is within a deposit of this type where preservation of plant microfossils might be expected. That such occurrence has been noted is recorded by Thiessen (74) and Twenhofel (75). These workers also lay emphasis upon the importance of shale study to develop a thorough understanding of the environmental conditions associated with the origin of petroleum.

The significance of the foregoing considerations is two-fold. In the latter two cases, the Dundas-Meaford shale and the Billings shale, conditions were ecologically suitable for the presence of plant forms and, hence, the subsequent deposition of associated microfossils. On the other hand, the Queenston shale does not represent environmental conditions suitable to the presence of such forms.

Secondly, the intention has been to indicate the necessity of interplay between biological and geological considerations when attempting to derive the palaeoecology as evidenced by a particular

deposit and its associated floral and faunal remains. This interplay of biology and geology in the derivation of palaeoecology is exhibited in the consideration of environmental conditions necessary for the survival of the organism (22). These conditions are exemplified by the presence or absence, abundance and associations of the organisms themselves. Changes in the external environment may be brought about by changes within the faunal and floral assemblages and these changes in turn are influenced by physical changes in the habitat. Accordingly, the geological factors of structural change, tectonism and deposition are related to, and influence the ecology of the organism and require consideration. For this reason it was felt practical to present a brief outline of the pertinent geology of the strata analysed in this work.

PROCEDURES FOR THE EXAMINATION OF ROCK SAMPLES AND RESIDUES

The isolation of plant fragments, both microfossil and macrofossil, for critical examination has been accomplished by a variety of techniques. In the main it has been necessary to chemically remove the rock matrix in order to free the organic specimen. The techniques described below have been developed, for the most part, by modifying, refining and augmenting procedures initiated by other workers and have been successfully employed in the experimental investigations of this account. Three techniques are described. The maceration technique and preparation of temporary slides are applicable in microfossil analysis. The third technique, the transfer method, has been used successfully in macrofossil examination. The procedures as outlined have been employed where shale or sediment of a shaley nature has been the embodying matrix. It will always be appreciated that circumstances may suggest slight alterations for individual cases.

(a) Maceration Technique

Fundamentally, techniques described by Wilson (78), Kosanke (61), Radforth (56), Rouse (63) and McGregor (48) were employed, with some modifications, in the preparation of materials for microscopic examination. The basic procedure for all matrices consisted of maceration of small rock fragments in, (i) hydrofluoric acid (reagent quality 48%), (ii) Schulze's reagent (consisting of concentrated nitric acid plus one-half gram ($\frac{1}{2}$ gm.) of potassium chlorate and (iii) final treatment by

boiling in 10% potassium hydroxide. Untreated samples were kept for reference in each case.

Prior to the application of acid the rock was broken down into sand-grain sized particles. About five cubic centimeters (5 cc.) of this crushed rock were placed in a suitable beaker and were covered with an excess of concentrated acid.

It was found that the amount of reagent required and the time of maceration varies with the type and nature of the various sediments prepared. Hydrofluoric acid was employed with all samples to bring about the dissolution of the embodied silica. This step necessitated the use of special containers, either copper or polyethlene, due to the highly corrosive property of the acid. The sample was placed in a fume hood during this stage for a period varying from eight to twenty-four hours (8 to 24 hr.) depending upon both the amount and nature of the matrix.

When the solution of particles is sufficiently completed, the acid is decanted and the residue is twice washed and centrifuged to remove traces of the acid. In cases where particles do not tend to settle upon centrifugation it has been found practical to add a slight amount of ammonium hydroxide to the solution, which breaks up the suspension and brings about thorough settling. This step, when included should again be followed be decanting, washing and centrifugation.

In some samples, in particular calcareous shales, it is necessary to add six molar hydrochloric acid (6 M.HCL) to dissolve the carbonates present. The time required for dissolution is again variable being dependent upon the amount and nature of the residue under treatment.

Following this step the sample must again be decanted, washed and centrifuged to remove traces of the acid.

The foregoing steps concerned mainly with the maceration of the embodying matrices, are followed by treatment with Schulze's reagent. The addition of this solution brings about oxidation, rendering the carbonaceous matter semi-transparent. Periodic checks of the residue may be made to ascertain the length of time necessary for best results. In cases where carbonaceous matter is concentrated within a rock fragment or where much of it is opaque, extended treatment in Schulze's is required. Time limits vary from five to ten minutes, depending upon the condition of the residue. If the time of treatment is overextended or the solution is too concentrated, carbonaceous matter may become completely lost to practical microscopic examination. Once again the residue should be thoroughly washed and centrifuged before proceeding with further steps in the preparation.

In many cases it is necessary to reduce flocculents particularly where organic compounds adhere to the cuticles which the investigator wishes to isolate: here further treatment is required. Using ten per cent potassium hydroxide (10% KOH) humic material is dissolved and freed from its adherence to the microfossils. This process may be hastened by heating above eighty degrees centigrade (80°C) and, apparently, this treatment does not injure the microfossils. After washing and centrifuging the residue is ready for mounting.

Throughout the foregoing procedures care should be taken not to overagitate the residue and thus minimize possible fragmentation and injury

to the more delicate microfossils.

(b) Preparation of Materials for Examination

Anticipating very low number of microfossils in given samples, it is thought that provision should be made for speedy preparation of large numbers of temporary slides. The corn syrup medium described by Radforth (56), Rouse (63), and McGregor (45) has been employed and has proven to be both a practical and facile method for work of this type. The procedure is as follows: a small drop of stain (when practical) is placed upon a clean slide and to this is added a drop of residue. This mixture is allowed to stand for a few seconds in order to allow absorption of the stain by the organic material. To this mixture a drop of corn syrup solution, in a dilution of three parts syrup to two parts water and a few drops of phenol, is added. This viscous solution is then spread evenly over the slide using a fine, clean glass probe and is allowed to stand and harden in a dust-free atmosphere.

To provide for the eventuality of lack of contrast in microfossil cuticles, once isolated, staining was contemplated. Stain has been employed by other workers (69,53) and yields fine results, particularly in dealing with transparent types and also in distinguishing microfossils from both inorganic and non-staining organic particles. Safranin red has been the stain most commonly used in this type of work.

In order to remove sediment from the centrifuge tube it has been found practical to insert a micropipette containing a drop or two of distilled water into the residue, ejecting the water and then drawing up water and residue. In some cases microfossils are found to be concentrated

at various depths in the tubes due to a differential segregation. The optimum depth for recovery varies with different samples and is discovered by inspection.

(c) Transfer Method

The transfer method primarily developed by Walton (77) with modifications by Ashby and employed with much success by Radforth (56) has been used with some additional modifications (10,11,43) in the preparation of possible plant macrofossils dealt with in this paper. The primary purpose of this method is to expose for examination the undamaged undersurface of the macrofossil and thus make possible, employing the Leitz Ultropak and reflected light, the observation of such minute appendages as hairs, spines, tubercles etc., which are usually broken off at the cleavage surface.

The steps followed in this technique are described as follows:

(i) The block or chip containing the fossil is roughly trimmed to a convenient size.

(ii) The fossil surface primarily etched with concentrated hydrofluoric acid for a few seconds by wetting in the acid.

(iii) The sample is gently washed with running water to remove dissolved material and then allowed to stand in a dust-free atmosphere until almost dry.

This step is based upon methods developed by Abbott (1) and Danse (11) and has been added to the original Walton method.

(iv) The etched surface is then coated with a suitable cellulose ester (cellulose acetate in amyl nitrate) after first wetting

the surface with the appropriate solvent. The coated sample is allowed to stand, with surface level, until it dries.

(v) The coated specimen is then attached to a clean slide using Canada balsam as cement and once again allowed to stand until dry and firm.

(vi) The back of the fossil, that is excess rock matrix, is ground away using carborundum powder, with caution being taken not to grind too near to the enclosed fossil. The entire preparation is then washed and dried.

(vii) The preparation is totally dipped into hot paraffin wax in order to protect the slide and balsam from the effects of the macerating acid. Prior to immersion in the wax, the rock matrix is wetted with water on the exposed upper surface to facilitate removal of the wax.

(viii) The matrix is then etched away by immersing the preparation in hydrofluoric acid (reagent quality 48%) for a period of 24 hours to several days. The time required is dependent upon the thickness and nature of the matrix.

This step is carried out in a fume hood using a polyethylene or copper container. It is practical to lean the slide, with the sample down, against the wall of the container. This allows the dissolved and loosened matrix to fall clear of the embodied fossil and also permits periodic observations of the progress being made.

(ix) When etching is complete the preparation is gently washed to

remove traces of acid and the wax is cleared away by a scalpel or knife.

The slide then may be observed using reflected or transmitted light.

If the fossil material does not lend itself to observation due to opacity it is sometimes feasible to bleach the carbonaceous material using drops of Schulze's solution.

Special provision was made for bituminous shale matrices in which it was found that small particles of bituminous matter clung to the film and rendered observation with transmitted light difficult. It was also found that highly carbonized material sometimes does not adhere firmly to the film and thus is lost in the maceration process.

The additional steps noticeably increase the success of the method. The primary etching provides a rough surface for adhesion and 'raises' the carbonaceous remains in relief, relative to the surface of the matrix. This allows the film to form not only on the surface of the material but also around it and thus aids in the consolidation of that material. Wetting the surface with solvent prior to coating with a cellulose film allows the film to flow into small cracks and perforations in the carbonaceous matter and accordingly aids in further consolidation and adherence.

RESULTS OF ANALYSIS

(a) Description of Observed Microfossils

A relatively large and unexpected number of microfossils were recovered from the rock samples. They displayed a wide variation in shape, colour, texture and size. In only a few cases did similarities exist between these new microfossils and those which had been described by other workers from contemporaneous and later sedimentary horizons.

In view of this fact it was found necessary to describe the individual specimen on the basis of its own morphology rather than assigning it to a category within an accepted scheme of classification. For this reason the microfossils described in this account have been assigned to a type grouping, the placement within a grouping being based upon presence within a particular stratum rather than being based upon morphological similarities between specimens. Undoubtedly the latter type of classification would be more informative to fundamental biological disciplines, however, before such a classification could be developed a greater number of representative specimens would have to be both isolated and critically studied.

The various types described below have been distinguished on the basis of size, shape, density, surface ornamentation, presence or absence of appendages and texture. The sample designation, for example "BR", refers to the source of the sediments from which the specimen was recovered. For other source area designations see Table I, p. 27.

TABLE I

Source Area Designations

BR - Billings formation, Rouge River, Ontario.

BC - Billings formation, core sample, Simcoe, Ontario.

DD - Dundas formation, Don Valley Brick Yard, Toronto.

DC - Dundas-Hesford formation, core sample, Simcoe.

There were no microfossils recovered from either the Queenston formation, sampled at Bronte or the Queenston formation sampled from the drill core.

Spore coat ornamentation and the presence of appendages are described in accordance with the descriptive criteria proposed by Kosanke (37). Designation of 'type' is not based upon possible affinity to plant forms but has been used to emphasize that different types do occur and that such types, due to these differences may be distinguished one from another.

In cases where it may prove feasible to propose possible affinities or similarities to types described by other workers this will be noted following the detailed descriptions.

The size indicated at the first of each description refers to the size of the photographed and diagrammetrically illustrated example. The size range denotes the largest and smallest dimensions that have been measured within a type. Where no size range is indicated only one example of that type has been observed in the prepared samples. The size

designations, small, medium and large refer respectively to types with the average dimensions being (a) less than 40 μ, (b) 40 μ to 80 μ and (c) greater than 80 μ.

As it has proved possible to isolate relatively few examples, it has been the practice to include under separate types representatives displaying only slight morphological differences. In such cases where designated types show similarities to other described types, this too is noted in the description.

All type specimens found in either or both of the Billings formations sampled are designated by the letter "B". Those found in either the Dundas-Waford formation from the drill-core sample or the Dundas formation of the Don Valley Brick Yard are designated by the letter "D". In cases where types occur in both Dundas and Billings formations the designations "B" or "D" denote that the majority of the examples were found in one or the other formation.

(i) Microfossils Recovered from the Billings Formation

These microfossils are designated by the letter "B" suffixed by the type number (example B_1). Photographs of the type microfossils and accompanying diagrams of the same are to be found on Plates II, III and IV. Occurrence within the various strata sampled is to be found in TABLE II, pp. 42,43,44. In all 125 representatives have been assigned to various types within the Billings or "B" series.

1. B_1 - B_{11} medium size, 49 μ by 43.75 μ, spinose, yellow-brown, size range 49 μ to 42 μ. Similar in many respects to the Recent dinoflagellate cyst, Gonimulax polyhedra (Braarud) (21)

2. B_2 - BR; medium size, 78.75 μ by 70.0 μ, subrectangular, levigate, brown-yellow, bilaterally symmetrical, size range 87.5 μ to 43.75 μ. This type is similar in size and shape to types B_{10}, B_{12}, B_{24}, D_{12}, D_{22}, and D_{23} and due to its shape and possible aperture it may or may not be of graptolitic origin.

3. B_3 - BC; medium size, 52.5 μ, circular, yellow-brown, granulose, wall irregular.

4. B_4 - BR; small in size, 31.5 μ, circular, brown, levigate, wall regular slightly spinose, range 31.50 μ to 45.7 μ.

5. B_5 - BR; medium size, 61.25 μ by 68.25 μ circular, yellow-brown, reticulate.

6. B_6 - BR; medium size, 61.25 μ by 49 μ, brown, reticulate, egg-shaped, range 70 μ to 49.0 μ. This microfossil is apparently made up of two distinct portions. One half is dark brown in colour the other half is yellow. Reticulum is more visible on yellow portion than on brown portion.

7. B_7 - BC; medium size, 78.75 μ by 61.25 μ, oval in shape, brown, levigate to reticulate in ornamentation.

8. B_8 - BR; small in size, 35.0 μ by 38.5 μ, brown-yellow, levigate, folded, oval, range 35.0 μ to 96.4 μ. This type is distinguished by the longitudinal fold which runs the length of the specimen and appears dark brown as contrasted with the yellow-brown of the specimen proper.

9. B_9 - BR; large in size, 96.25 μ, round, predominantly yellow with a darker circular portion towards the centre interior, levigate and thin walled, range 96.25 μ to 122.5 μ.

10. B_{10} - BR; medium size, 57.7 μ by 70.0 μ, subrectangular, folded brown, range 62.25 μ to 73.7 μ. This microfossil is similar in shape to B_2, B_{12}, B_{24}, D_{12} and shows similarity in colour and texture to B_{11} and B_{18}. Thus the possibility exists that these forms may represent thecae of graptolitic origin (26,68).

11. B_{11} - BR; medium size, 62.5 μ, round, brown, wall irregular, folded, range 80.0 μ to 61.25 μ. This microfossil is similar to B_{18} and together with it, may represent the apertural portion of a graptolitic theca. Other similarities were indicated in B_{10}.

12. B_{12} - BR; medium size, 78.75 μ by 70.0 μ, oval, brown, wall irregular, ornamentation levigate. Similarities to other microfossils discussed under B_{10} and possible graptolitic affinity noted.

13. B_{13} - BR; medium size, 70.0 μ by 82.0 μ, oval, folded, reticulate brown, range 82 μ to 41 μ. Examples fragmental.

14. B_{14} - BR; medium size, 47.2 μ by 73.5 μ subrectangular, folded, brown-yellow, levigate, range 75.25 μ to 47.2 μ. Two distinct colour portions, yellow-brown and dark brown. Similar in this latter respect to B_{18}.

15. B_{15} - BR; medium to large, 31 μ round, brown, granular, apparently fragmental, range 93 μ to 31.4 μ.

16. B_{16} - BC; medium, 78.75 μ by 34.0 μ, round, brown-yellow, levigate, definite inner concentric ring which appears darker brown. Similarities to other microfossils and possible graptolitic affinity discussed under B_{11} and B_{10}.

17. B_{17} - BC; medium size, 44 μ by 45.7 μ, round, brown, levigate.

18. B_{18} - BR; medium size, 61.25 μ by 70.0 μ, brown-yellow, levigate (granular) oval to subrectangular, range 78.75 μ to 56 μ. Somewhat similar to B_{14}.

19. B_{19} - BR; small in size, 21 μ, round, yellow, levigate. Possible pore present, appears darker in colour.

20. B_{20} - BR; large in size, 100 μ, round, yellow, semi-transparent, levigate, folded, margin irregular, range 115 μ to 60.5 μ.

21. B_{21} - BR; medium, 52.5 μ by 61.25 μ, oval, dense, brown, granulose, stalk-like processes on either side of main body.

22. B_{22} - BR; medium, 45.5 μ by 42.0 μ, oval, yellow-brown, levigate-reticulate, possible aperture present.

23. B_{23} - BR; medium, 78.75 μ by 70.0 μ, egg-shaped, both dense and translucent portions; colours brown and yellow, dense portion granulose, translucent portion levigate and folded, range 78.75 μ to 61.25 μ.

24. B_{24} - BR; medium size, 78.75 μ by 56.0 μ sub-rectangular, brown, dense granulose, range 96.0 μ to 61.25 μ. Similar in

size, shape and density to B_{10}. However, there is variation in pattern of ornamentation. Most probably of graptolitic origin.

25. B_{25} - BR; large in size, 131.25 μ by 87.5 μ spore-like portion is oval in shape, with elongate stalk, colour brown and yellow; spore-like portion has brown elliptical portion at point of junction with stalk, overall ornamentation is levigate to granulose, size range 61.25 μ to 131.25 μ. Microfossils similar in size, shape and colour have been recovered from Ireton formation of the Devonian Period, Central Alberta (48).

26. B_{26} - BR; medium size, 70.0 μ to 68.5 μ, round, yellow-brown, levigate, folded, range 82.25 μ to 61.25 μ. Small portion of microfossil has reticulate ornamentation, possible aperture at one end, wall distinct and smooth.

27. B_{27} - BC; medium size, 52.5 μ by 68.25 μ, oval, levigate, folded, yellow-brown, wall thin. A definite pattern is present in the central portion of this microfossil which appears brown when examined using transmitted light. Only one specimen observed.

28. B_{28} - BC; medium size, 61.5 μ by 56.0 μ, pear-shaped, levigate, definite wall, yellow-brown, folded distinct aperture at apical end, "folds" surrounding aperture are brown in colour as contrasted with yellow-brown of the microfossil proper, range 79 μ to 56 μ. This microfossil is

similar in many respects to D_5.

(ii) Microfossils Recovered from the Dundas and Dundas-Moaford Formations

These microfossils are designated by the letter "D" suffixed by the appropriate type number (example - D_1). Photographs of the type microfossils and accompanying diagrams of the same are to be found on Plates V,VI,VII. Occurrence within the various strata sampled is to be found in TABLE II, pp. 42,43,44. In all, 87 representatives have been assigned to the Dundas or "D" series.

The variations found within this series contrast with the types found in the Billings series. In this case microfossils displaying possible affinity to graptolites are greatly reduced and there is the occurrence of some types which have been described as Hystrichosphaeridae (39). These will be dealt with in more detail later in this paper.

1. D_1 - DD; large in size, 103 μ by 131 μ, elliptical, levigate, yellow-brown, folded, thin-walled.
2. D_2 - DD; medium size, 81.25 μ, egg-shaped, reticulate, possesses definite circular aperture, wall distinct, yellow-brown, range 105 μ to 81.25 μ. Similar in shape and possession of aperture to D_5 and B_{28}.
3. D_3 - DD; medium size, 73.4 μ, subcircular, levigate, folded, brown and yellow portions, range 81.25 μ to 73.4 μ.
4. D_4 - DC; medium size, 49 μ by 47.5 μ circular, strongly reticulate, yellow-brown, range 78.75 μ to 21.0 μ.
5. D_5 - DC; medium size, 81.25 μ by 52.25 μ egg-shaped, levigate,

yellow, folded, possesses definite circular aperture, which is surrounded by a distinct ring. This microfossil is similar to D_2 and B_{28} in some respect and may be a detached graptolitic theca, range 75.1 μ to 32.5 μ.

6. D_6 - DC; medium size, 43.75 μ, triangular, obverruiculate, yellow, three extensions of apices, range 43.75 μ to 35.0 μ. This microfossil has been illustrated in a publication by Kraucol (39). In this publication it is described as Hystrichosphaeridae, but unfortunately no size range is given.

7. D_7 - DC; large in size, 157.5 μ, oval, levigate, yellow-brown, thick-walled, variation in density towards centre.

8. D_8 - DC; medium size, 35 μ, levigate, two distinct portions, central brown portion with distinct wall surrounded by equatorial rim which is yellow in colour and relatively thin.

9. D_9 - DC; medium size, 43.75 μ, circular, ciliated, yellow-brown, main body slightly reticulate, range 35 μ to 52 μ.

10. D_{10} - DC; medium size, 54.3 μ, levigate, yellow, egg-shaped, translucent, has small circular aperture at one end.

11. D_{11} - DC; medium size, 42.0 μ by 38.3 μ, round, yellow, levigate, range 70 μ to 38.3 μ. This microfossil possesses an aperture at one end which is surrounded by darker brown rim. From this rim there radiates back, many

from the aperture, four brown folded extensions.

12. D_{12} - DC; medium size, 47.2 μ by 66.5 μ sub-rectangular, brown, folded, appears to be moderately granulose, range 66.5 μ to 42.0 μ. This example is similar in shape and density to D_{24}, D_{10} and D_{12} but in specimens examined has a smaller size range. Folding is similar to that found in D_{20} but size range and shape differ somewhat.

13. D_{13} - DC; medium size, 52.25 μ by 47.2 μ, round, decidedly reticulate, yellow brown, range 61.25 μ to 35.0 μ. Similar in some respects to D_4 but is essentially different in the degree and type of reticulation.

14. D_{14} - DC; medium, 35.0 μ by 31.5 μ, oval, levigate, yellow translucent having more dense marginal portions, range 56 μ to 31.5 μ.

15. D_{15} - DC; small in size, 28.0 μ by 22.7 μ, ovoid, reticulate, brown to yellow. Only one example observed.

16. D_{16} - DC; small in size, 26.25 μ by 24.5 μ, round, levigate, yellow-brown, distinct wall with indentation at one end, range 28 μ to 24.5 μ.

17. D_{17} - DC; small in size, 31.6 μ by 24.5 μ, reticulate, sub-rectangular, yellow-brown, have distinct wall.

18. D_{18} - DC; small in size, 22.2 μ round, yellow with broken wall which appears denser upon examination, levigate to granulose, range 22.2 μ to 22.7 μ.

19. D_{19} - DD; medium size, 43.75 μ, round, granulose, yellow, distinct

wall broken and irregular, range 63 μ to 43.75 μ

20. D_{20} - DD; medium size, 70.0 μ by 66.5 μ, subrectangular, yellow-brown, levigate, folded, distinct wall present. Similar in some respects to D_{12}. Only one specimen observed.

21. D_{21} - DD; medium size, 66.5 μ by 78.75 μ, oval triangular with two short processes on either end, brown, dense, granulose, range 78.75 μ to 56.6 μ.

22. D_{22} - DD; medium size, 70 μ by 56 μ subrectangular, brown, dense, granulose. Similar in many respects to D_{24}, D_{10}, D_{12} and D_{12}, possesses distinct rimmed aperture and has thick wall.

23. D_{23} - DC; medium size, 70 μ by 61.25 μ, semi-transparent yellow-brown, rectangular, folded, levigate, bilaterally symmetrical, range 82.3 μ to 61.25 μ. Very similar to D_2 but differs in pattern of folds and lacks possible operculum of D_2. Quite possibly a detached graptolite theca.

24. D_{24} - DD; medium, 82.3 μ by 63.0 μ, oval, yellow-brown, folded, levigate, size range 102 μ to 56 μ, distinct wall.

25. D_{25} - DC; medium size, 43.75 μ, round, granular, yellow-brown, distinct wall, range 82.5 μ to 37.5 μ.

26. D_{26} - DD; medium, 43.75 μ, round, Levigate, thick wall with thin less dense perimeter, yellow-brown, range 82.5 μ to 35 μ.

27. D_{27} - DD; small, 26.25 μ round with distinct wall and five-rayed structure radiating from centre and joining wall at

circumference, yellow-white in colour, only one specimen observed.

28. D_{28} - DD; small, 21 μ, yellow, semitransparent, round, levigate, wall distinct and denser than central portion , range 43.75 μ to 21.0 μ.

29. D_{29} - DD; medium size, 52.5 μ, round, finely granulose, yellow, only one specimen observed.

30. D_{30} - DD; large, 92.7 μ round, levigate with brown internal folds and thick dense wall surrounded by narrow yellow perinator, only one specimen observed.

31. D_{31} - DD; medium size, 56 μ, round to oval, granulose with some suggestion of reticulation, yellow, semitransparent, folded, range 65 μ to 56 μ.

(b) Carbonaceous Macrofossil remains

In conjunction with the recovery of microfossils from the sampled strata, analysis was undertaken to establish the identity of several macrofossil remains found to be present in both the Billings and Dundas formations. (Transfer Method p. 23) These remains were preserved as carbonaceous films in the shale partings and exhibited dichotomous branching similar to that displayed in early vascular plant representatives.

The specimens selected for study were fragmental in nature with portions of the main axis ranging in width from 0.2 mm to 1.6mm. A particularly well preserved specimen was discovered in the Billings formation drill-core sample (2620 foot level) which exhibited five distinct dichotomies and was 5.5 cm. in length. (Pl. VIII, fig. 1).

Individual branches in this specimen varied in width from 0.1mm to 1.5 mm. This specimen had previously been described (73) as a possible plant fragment and due to such designation a great deal of interest was aroused as to its true identity.

Smaller fragments, similar in structure to the above were recovered from the limey-shale of the Dundas formation of the Don Valley Brick Yard. These fragments in length from 3.0 mm. to 6.0 mm. being of a more fragmental nature than those occurring in the Billings formation. The width of the individual compressed branches ranged from 0.1 mm. to 0.2 mm. (Pl. VIII, fig. 2).

Subsequent critical examination of the internal structure, where possible, and the surface structure using the Leitz Ultropak and Relief condenser, made several observations possible. The branches appeared composed of several layers which could be distinguished on the basis of colour variation. The outer layer appeared more dense and dark in colour than the inner, light in colour, less dense layers. Externally the fragments were pitted with the pore varying in dimension. In some specimens it was further possible to discern laminated structure with the individual laminae or bands being perpendicular to the long axis. This latter observation was made possible by the bleaching of several specimens. Further, ends of the dichotomies and the main "stem" proper were ragged and showed no evidence of being a complete structure.

For the most part the specimens were black in colour and very fragile and did not allow further, more critical examination of the internal structure. Observations of this structure was accomplished by the examination of the broken ends of some, less dense, branches.

SIGNIFICANCE OF CERTAIN MICROFOSSILS AND ASSOCIATED CARBONACEOUS REMAINS

Much significance of the results of analysis lies in the fact that morphologically distinct microfossils do exist in these strata. This and the fact that the microfossils occurred in such encouraging numbers gives rise to the possibility of generalizing with regards to the morphological variety and size ranges observed. Further, with a consideration of associated floral and faunal remains one may propose the possible affinity of some representatives.

For the macrofossil remains, the significance depends upon point of view which in this case is related to objectives already outlined (p. 3). As the following account will reveal additional significance for this selected group is in relation to another study.

(a) Microfossils

(i) Morphological Variations

The microfossils display variations in size, shape, colour, external markings, appendages and texture. Those observed lie within the size range of 20 μ to 200 μ with the majority being of medium size and lying within the size range of 40 μ to 80 μ. The colour following maceration and preparation, without stain, varies from white-transparent to dark brown. The predominant colour observed was yellow to light brown with the more dense portions, such as wall structure and folded areas, appearing a dark brown. Shape of the individuals ranged from

circular to sub-rectangular with some forms being triangular and pear-shaped to oval. In this characteristic approximately 75% of the representatives studied were of circular or oval shape with those of triangular or sub-triangular form being least common. In some forms openings within the wall were present which may or may not be considered as apertures, but in no case was a trilete scar, typical of pteridophytic spores, evident. Variations in surface ornamentation occurred and accordingly it was possible to describe such features as spinose, granulose, reticulate and levigate. The majority of forms studied showed little distinct surface ornamentation, however, spinose, granulose and reticulate types did occur particularly within the Dundas formation.

The fact that distinguishable microfossils do occur within these strata permits speculation and consideration as to their possible employment as bed-markers or index fossils in stratigraphic correlation.

(ii) Microfossils as Index Fossils

Before a microfossil or macrofossil may be considered as an index fossil which may be practically employed in stratigraphic correlation certain criteria must be satisfied. First, the fossil must have limited vertical extent. Secondly, the fossil must be easily identifiable, and occur abundantly. Thirdly the fossil must have wide lateral range, and finally it must lend itself to simple methods of preparation. These criteria are satisfied, in part, by the microfossils described from the sediments studied. They, the microfossils, occur in a variety of recognisable forms. They have lateral extent to some degree and lend themselves to simple observation.

However, their vertical extent has not been definitely established in this preliminary work. Four strata have been sampled, with the occurrence of certain types being noted in all but one (Queenston formation). Table II, pp. 42,43,44, illustrates the occurrence of the various microfossil types within the sampled strata. As no representatives were recovered from the Queenston formation, this stratum is not included in the table. Microfossil types with more than three representatives occurring within the samples derived from a particular source are indicated by means of a large letter "X", those with less than three representatives by the small letter "x".

A good index fossil occurs abundantly. In number of microfossils observed from the sources studied the incidence of recovery was low; being of the order of 10 or less recognizable specimens per slide. In microfossil work dealing with later Palaeozoic and more recent deposits, histogram abundance charts showing percentage occurrence are usually based upon the observation of 150 representative specimens per slide or sample (17,57,58). Accordingly it is evident that such work in the case of these earlier sediments is not practical at this time. Due to the fact that fewer microfossils are expected from these strata it may prove necessary to readjust the basis for percentage abundance counts. Also the fact that fewer types occur in these strata than in later strata should make microfossil correlation of the earlier strata somewhat easier.

It is to be expected that application of these microfossils will prove practical in the future when further investigation of this type of sediment has been carried out. With reference to their occurrence

(Table II, pp.42 ,43,44) it is evident that some types appear to be limited to particular strata. In a preliminary sense it is possible to distinguish between the three main strata studied in this area on the basis of their microfossil content. Whether this would be applicable to all strata of these formations will of course depend upon the extent and results of future investigations wherein a greater number of sediments of wider areal extent are studied.

TABLE II

MICROFOSSIL OCCURRENCE

SAMPLE SOURCE

TYPE	Billings core	Billings Rouge River	Dundas-Seaford core	Dundas Don River
B1		x		
B2	X	X	x	
B3	x			
B4	x	x		
B5		x		
B6		x		
B7	x			
B8	x			
B9	x	x		
B10	X	x		
B11	X	X		
B12		x		
B13		x		

TABLE II (Cont.)

TYPE	Billings core	Billings Rouge River	Dundas-Hanford core	Dundas Don River
B14		x		
B15		x		
B16	x	x		X
B17	x			
B18	x	x		
B19		x		
B20	x	X		
B21		x		
B22		x		
B23		x		
B24	x	X		x
B25	x	x		
B26	x	x		
B27	x			
B28	X			
D1				x
D2				X
D3				x
D4			X	X
D5			x	
D6			x	
D7			x	
D8			x	

TABLE II (Cont.)

TYPE	Billings core	Billings Rouge River	Dundas-Hosford core	Dundas Don River
D9			X	
D10			x	
D11	x		x	x
D12			X	
D13			X	x
D14			x	
D15			x	
D16			x	x
D17			x	
D18			x	x
D19				x
D20				x
D21				x
D22				x
D23			x	
D24			x	x
D25			x	x
D26			x	X
D27				x
D28				x
D29				x
D30				x
D31				x

(b) Macrofossils

The results of analysis allow the formulation of a conclusion as to the identity of the carbonaceous macrofossils remains. The significance of such identification is two-fold. First, the fact that these remains exhibit structure not characteristic of early plant structure indicates that growth form may be misleading in the classification of early carbonaceous remains. Accordingly it is necessary to critically examine all such remains before attempting to propose definite classification.

Secondly, in view of the fact that identification has proved possible, one may suggest relationship between some macrofossils and certain microfossils. It is in this connection that the study of these remains has the most significance upon the consideration of the microfossils. Accordingly it is thought reasonable to discuss the identity of these remains and to indicate the significance of their occurrence in association with the microfossils and their resultant influence upon the proposal of possible affinities.

(i) Identity of associated carbonaceous remains

The structure and form observed is that typical of dendroid (branching) graptolites and in the case of the specimens recovered from the Don Valley Brickyard, these have been previously described by Dr. Fritz (26) as Mastigograptus gracillimus (Lesquereux). It has not been possible to positively assign specific connotation to the specimens recovered from the Billinga drill-core sample. However, due to both structural characteristics and reference to the presence of the genus

Mastigograptus (15,68) within these sediments and sediments of the same age, the specimen is most probably a representative of that genus or a closely related genus. The fact that it is graptolitic and not floral in nature is indisputable.

(ii) Significance of Identity

It is upon the basis of this identification that it is now possible to propose affinity for certain of the microfossils described earlier. In the description of Mastigograptus gracillimus (Lesquereux) (26) reference is made to, "brown, elongate, triangular appendages which were clearly conical in shape originally." Further, it is indicated that, "the proximal end is distinctly contracted into a narrow tube with thicker wall. These are easily detached and lost due to the small base of attachment, but it is also quite evident that the basal tubes were attached directly over the pores observable in the branches from which the appendages have been stripped." The microfossil types subsequently referred to as graptolitic show structure and shape similar to that described above. Furthermore, the pore structure evident upon the branches of the described graptolite is readily visible in the carbonaceous fragments studied (Pl. VIII, figs. 1 and 2).

In accordance with such observations it is reasonable to conclude that those microfossils exhibiting the presence of a single pore or aperture might be classified as detached thecae of some dendroid graptolite. Into this classification the microfossil types, $B_2, B_{10}, B_{11}, B_{12}, B_{16}, B_{24}, B_{25}, B_{28}$ and $D_2, D_5, D_{12}, D_{20}, D_{22}, D_{23}$ fall most readily.

With the elimination of the suggested graptolitic microfossils and those either classified as Hystrichosphaeridae or showing similar structure (these include the types B_1, B_7, B_{14}, B_{18}, B_{23}, D_3, D_7, D_9, D_{10}, D_{11}) we are left with several representatives about which classification is uncertain. Either they are representatives of advanced algae, concerning which evidence of morphology is at best inconclusive, or they represent spore groups of 'provascular' plants. It is in such a proposal that an understanding of the palaeoecology of the sedimentary basin is necessary.

DISCUSSION AND SUMMARY

Speculation on the identity and possible affinity, which is desirable for some of the problematical microfossils, can probably be approached best through a consideration of morphological attributes. The shape, ornamentation and size range of those fragments is of the same order as indisputed plant spores which have been described from both younger and older strata. The evident resistant nature, to both decomposition with time and macerating agents, suggests a cutinous or cutin-like composition of the wall which is generally accepted as a characteristic of the more advanced plant forms. Upon the basis of these observations it seems reasonable to suggest that these fragments might well be the spore-bodies of advanced algal or provascular plant representatives. Such speculation is by no means unfounded as numerous workers have proposed that through evolution algae gave rise to the terrestrial and vascular plant forms. These proposals have arisen with evidence derived from considerations of the vegetative portions of the plant bodies as observed in fossil remains from the early palaeozoic strata. Accordingly it is plausible that phylogenetic sequence may also be ascertained from considerations of microfossils.

The possibility that advanced algal forms were ancestral to and preceded vascular forms at some time prior to the age of the earliest vascular plant remains which have been recovered (Psilophyton princeps - Silurian) has been proposed by several authors (12,13,14,16,71). The

presence of algal representatives, described as advanced forms, within sediments of the same age and deposited under conditions similar to those studied, supports the contention that these microfossils are the spores of these or associated algae. That these algae are to be considered as "advanced" forms is based upon the evident resistant nature and similarity in morphology to spores of later age for which affinity has been proposed.

The view that early sediments contained more vascular plants than was thought to have been the case (58) is further substantiated by the results of this account. It is evidence of this nature that lends itself to an appreciation of the time when vascular plants had their origin.

Some space has been given to the palaeoecological considerations of the shale strata from which these microfossils were recovered. In dealing with this topic the intention was to direct attention to the possible environment of these earlier forms and thereby indicate that conditions were ecologically suited to the development of semi-terrestrial or advanced provascular forms. The nature of the sediments suggest a relatively shallow, epicontinental basin of deposition characterized by fluctuating water level. The faunal association and colour of the sediments further supports this contention and is indicative of brackish conditions and semi-isolation of the basin. With this environmental situation existing, morphological advancement in thallophytic forms could have tended towards vascularization of internal tissues and cutinization of epidermal tissues. In intermediate forms these stages might possibly have been preceded by the formation of a cuticular wall

about the reproductive structures as protection from desiccation. The proposition that the latter existed is, in part, based upon the presence of these resistant bodies and the lack of identifiable macroscopic vegetative remains. Further the black colour of the shale sediments is thought by some workers to be due to the presence of carbonaceous particles embodied in the matrix which originated in the decomposition of algal forms.

Before the proposal may be accepted there are several important factors which must be considered in addition to the foregoing. First, the proposal is purely speculative in that unrecorded intermediate forms are intimated. Secondly, although some algae have life cycles similar to those of the higher plant groups and possess a sporophytic stage, the spores produced have structure dissimilar to vascular spores and are either motile upon being released from the sporangium or mature and germinate within the sporangia. They are not described as being of a resistant composition.

It is from algal forms such as the Rhodophyta and Phaeophyta that terrestrial forms are believed to have developed (16,71). Accordingly one must somehow account for the appearance of resistant spores in the early land plants and, therefore, unless this condition is to be considered a spontaneous development then it is necessary to interject intermediate stages in evolution. As the remains of the vegetative portions of these intermediate forms have not been recovered or perhaps recognized one must assume that their composition was such that preservation was not widespread or characteristic. There remains

therefore, two possible conclusions. First, either that intermediate forms did not exist or secondly, that intermediate forms did exist and that these forms were characterized by algal-like vegetative portions, lacking cuticularization and vascular tissue but showing evolutionary advancement in the formation of resistant spores. It is on the basis of this latter conclusion that the speculation, as to the identity of certain microfossils, previously inferred has been developed. Further this speculation is supported by the fact that the problematical microfossils are not characterized by a trilete scar, a marking considered typical of the majority of vascular plant spores. The lack of this scar could be considered as indicative of a stage in spore development where maturation takes place after the breakup of the primary spore tetrad, a condition to be found in certain brown algae. That resistant compounds which are non-cutinous may be found in algae is borne out by the fact that the zygotes of Desmidiaceae are found well preserved in Ordovician and younger strata. The resistant property in this case is due to the secretion of pecten within an inner cellulose wall. Whether or not such speculation may be considered as a contribution will of course have to be determined by further investigation. However, the proposal should stimulate thinking dealing with the problem of the development of the land habit in the plant kingdom.

Emphasis in this paper has been placed upon the recovery and investigation of several microfossils of Upper Ordovician age. It is hoped that with the application of procedures developed in this work increased numbers of fossils will be made available augmenting the

assemblages revealed in the present work.

It is also hoped that larger numbers of microfossil and macrofossil remains will be available to enhance basic morphological evidence established here. Also it seems desirable to emphasize that, because analytical methods presented here afford the observation of relationships between micro- and macrofossils, these methods will come into general use to enhance this kind of result.

Further, it is obvious that the way for progress in geologic correlation is established through the disclosure that microfossils do exist in these early strata as useful correlation agents.

It can no longer be regarded as wise judgment to claim that any strata are unfossiliferous without appropriate analysis. Indeed, the evidence provided here strongly supports the view that all palaeozoic sedimentary rocks should be critically examined for new information additional to that provided here which will throw some light on the development of the land habit from the biological and the temporal aspects.

If these can be regarded as contributions there is justification in suggesting that further emphasis be placed on the approach developed here to exploit lithology, palaeoecology and fundamental botany to arrive at the identity of early organisms.

Dated: May 11, 1955.

REFERENCES

1. ABBOTT, M.L., A Palaeobotanical Transfer Method. Jour. Paleont., vol. 24. 1950.

2. ANDREWS, H.J., J.R., Ancient Plants and the World They Lived In. Comstock Publishing Co., Inc., Ithaca, N.Y. 1947.

3. ARNOLD, C.A., An Introduction to Paleobotany. McGraw - Hill Book Co., Inc., N.Y. 1947.

4. CALEY, J.F., Contributions to the Study of the Ordovician of Ontario and Quebec; Pt.2, The Ordovician of Manitoulin Island, Ont. Geol. Surv. Canada. Mem. 202, pp. 21 - 91. 1936.

5. _____, Palaeozoic Geology of the Toronto - Hamilton Area. Geol. Surv. Canada, Mem. 224. 1940.

6. _____, Palaeozoic Geology of the Brantford Area, Ontario. Geol. Surv. Canada, Mem. 226. 1941.

7. _____, Palaeozoic Geology of the London Area, Ontario. Geol. Surv. Canada. Mem. 237. 1943.

8. _____, Palaeozoic Geology of the Windsor - Sarnia Area, Ontario. Geol. Surv. Canada, Mem. 240. 1945.

9. COHEE, GEORGE V., Cambrian and Ordovician Rocks in Michigan Basin and Adjoining Areas. Bull. Amer.Assoc. Petroleum Geol., vol.32, No.8, pp. 1417 - 1448. 1948.

10. DANZE, J., Sur Quelques Methodes d'Introspection Paleobotanique. Bull. de la Soc. de Botanique du Nord de la France, T. 6, No. 1, 1953. Ext. de la Seance du 11 Mars 1953.

11. _____, Une nouvelle methode de transfert des limbes fossiles Carboniferes. Ext. du C.R.S. de la Soc. Geol. de la France, No. 11, seance du 15 Juin 1953.

12. DARRAH, W. C., Spores of Cambrian Plants. Science, vol. 86, pp. 154 - 155. 1937.

13. DORF, E., Lower Devonian Flora from Beartooth Butte, Wyoming. Bull. Geol. Soc. America, vol. 45, pp. 425 - 440. 1934

14. _____, A new occurrence of the Oldest Known Terrestrial Vegetation from Beartooth Butte, Wyoming. Bot. Gaz., vol. 95, No. 2, pp. 240 - 257. 1933.

15. DYER, W.S., The Paleontology of the Credit River Section (Ontario). Ont. Dept. Mines, 32nd Ann. Rept., vol. 32, pt. 7, pp. 47 - 88. 1925.

16. EAMES, A.J., Morphology of Vascular Plants (Lower Groups). McGraw-Hill Book Co., Inc., N.Y. and London, 1936.

17. ERDTMAN, G., Pollen Statistics; a new research method in palaeo-ecology. Science, vol. 73, pp. 399 - 401. 1931.

18. _____, Pollen grains recovered from the atmosphere over the Atlantic. Meddel Goteborg Bot. 12. 1937.

19. _____, An Introduction to Pollen Analysis. Chronica Botanica Co. 1943.

20. _____, Pollen Morphology and Plant Taxonomy. Waltham, Mass. Chronica Botanica Co. 1952.

21. _____, On Pollen Grains and Dinoflagellate Cysts in the Firth of Gullarn, S.W. Sweden. Sartryck ur Botaniska Notiser 1954. Lund. 1954.

22. FENTON, C.L., View points and Objects of Paleoecology. Jour. Palaeontology, vol. 9., No. 1. Jan. 1935.

23. _____, and FENTON, M.A., Pre-Cambrian and Paleozoic Algae. Geol. Soc. Amer. Bull., vol. 50, pp. 89 - 114. 1939

24. FOERSTE, A.F., Upper Ordovician Formations in Ontario and Quebec. Geol. Surv. Canada, Mem. 83, No. 70. 1916.

25. _____, Upper Ordovician faunas of Ontario and Quebec. Geol. Surv. Canada, Mem. 138, pp. 1 - 255. 1924.

26. FRITZ, M.A., The Stratigraphy and Paleontology of Toronto and Vicinity. 32nd. Ann. Rept. Ont. Dept. Mines, pt. 7. 1923.

27. _____, The Stratigraphy and Palaeontology of the Workmans Creek Section of the Cincinnation Series of Ontario. Trans. Roy. Soc. Can., vol. 3, ser. 20, sect. 4, pp. 77 - 107. 1926.

28. FRY, W. L. and BANKS, H.P., Three New Genera of Algae from the Upper Devonian of New York. Jour. Paleont., vol. 29, No. 1, pp. 37 - 44, pls. 9, 10. 1955.

29. GHOSH, A.K., and SEN, J., A Study of the Microfossils and the Correlation of some productive coal seams of the Raniganj coal field, Bengal, India. Trans. Mining, Geol. and Metallurgical Inst. of India, vol. 43, No. 2. 1948.

30. HOEG, O.A., The Origin of Vascular Plants, Psilophytales and Nematophytales. University Oslo, Norway.

31. IBRAHIM, A.C., Sporen formen des Aegirhorizonts des Ruhr- Reviers: Dissertation, Berlin; privately pub. 1933 by Konrad Triltsch Wurgburg. 1933.

32. KULE, J., Preliminary Report on the Clay and Shale Deposits of Ontario. Geol. Surv. Dept. Mines, Mem. 142, No. 123. 1924.

33. KIDSTON, R., and LANG, W.H., On Old Red Sandstone Plants showing Structure from the Rhynie Chert Bed, Aberdeenshire. Trans. Roy. Soc., Edinburgh. 1921.

34. KNOX, E.M., The spores of Pteridophyta, with observations on microspores in coals of Carboniferous Age. Bot. Soc, Edinburgh, Trans. and Proc., vol. 32, No. 3, pp. 438 - 466. 1938.

35. _____, The spores of Bryophyta compared with those of Carboniferous Age. Bot. Soc. Edinburgh, Trans. and Proc., vol. 32, No. 4, pp. 477 - 487. 1939.

36. _____, The spores of Lycopodium, Phylloglossum, Selaginella and Isoetes and their value in the Study of Microfossils of Palaeozoic Age. Trans. Proc. Bot. Soc. Edinburgh, vol. 35, No. 3, pp. 207 - 357. 1950.

37. KOSANKE, R.M., Pennsylvania spores of Illinois and their use in correlation. Ill. Geol. Surv. Bull., No. 74. 1950

38. KRAUSEL, R., Discussion on the earliest known terrestrial vegetation. Abstracts of Communications, 5th. Int. Congr. Bot., Cambridge, Eng., pp. 294 - 295. 1930.

39. _____, Sind die palaozoischen Hystrichosphaerideen Einzellar oder Pflanzensporen? Senkenbergiana. (Senkenb. Naturf. Ges.), 21 (5-6), pp. 358 - 363, 2 figs. 1939.

40. KRUMBEIN, W.C., Shales and their Environmental Significance, Jour. Sed. Pet., vol. 17, No. 3. 1947.

41. _____, and SLOSS, L.L., Stratigraphy and Sedimentation. W.H. Freeman and Co., San Francisco, Calif. 1951.

42. KRYSHTOFOVICH (in FRY, W.L. and PARKS, H.P.) Three new genera of Algae from the Upper Devonian of New York. Jour. of Paleon., vol. 29, No. 1, pp. 37-44. 1955.

43. LACEY, W.S., Methods in Palaeobotany, Arbroath. T. Buncle and Co., Ltd. (North Western Nat.). 1953.

44. LANG, W.H., and COOKSON, I., On a Flora, etc., in Rocks of Silurian Age, from Victoria, Australia. Phil. Trans. Roy. Soc. Lond., Ser. B, 224. 1935.

45. LECLERCQ, S., Are the Psilophytales a Starting or a Resulting Point? Svensh Botanisk Tedskrift, B.D. 48, H. 2. 1954.

46. MEHTA, K.R., Microfossils from a Carbonaceous shale from the Pali beds of the South Rewa Gondwana Basin. Nat. Acad. Sci. India Proc., vol. 14, pp. 125 - 141. 1944.

47. McGREGOR, D.C., The Investigation of Plant Microfossils from selected Upper Mesozoic and Devonian Rocks Important in Canadian Oil Stratigraphy. McMaster University, M.Sc. Thesis. 1953

48. _____, Reference is made to findings which will be incorporated within a forthcoming thesis for the degree, Ph.D., McMaster University.

49. NAUMOVA, S.N., Spory nizhnego Kombriya, Akad. Nauk. U.S.S.R. Ser. Geol., vol. 12, No. 4, pp. 49 - 56. 1949.

50. O'KULITCH, V.J., Contributions to the Study of the Ordovician of Ontario and Quebec, pt. 4; The Black River group in the Vicinity of Montreal. Geol. Surv. Canada, Mem. 202, Pub. 2427, pp. 119 -

130. 1936.

51. PARKS, W.A., The Stratigraphy and Correlation of the Dundas Formation. Ont. Dept. Mines, 32nd Ann. Rept., pt. 7, 1923.

52. _____, The Stratigraphy and Paleontology of Toronto and Vicinity, pt. 6; Stratigraphy and Correlation of the Dundas Formation. Ont. Dept. Mines, 32nd Ann. Rept., vol.32, pp. 89 - 116. 1925.

53. _____, Ordovician Black Shales. Trans. Roy. Soc. Canada, 3rd Ser., vol. 22, sec. 4, pp. 39 - 92. 1928.

54. PIA, J., (in HIRMER), Thallophyta: Handbuch der Palaobotanik, Munchen und Berlin. 1927.

55. POTONIE, R., und GERHARD KREMP, Die Gattungen der palaozoischen Sporae dispersae und ehre Stratigraphie. Geol. Jb. Band 69, s. 111 - 194, 17 Taf., 5 Abb., Hannover. 1954.

56. RADFORTH, N.W., An Analysis and Comparison of the Structural Features of Dactylotheca Plumosa artis sp. and Senftenbergia ophiodermatica Goppert sp. Trans. Roy. Soc. Edinburgh. 1938

57. _____, and ROUSE, G.E., The Classification of recently discovered Cretaceous plant microfossils of potential importance to the stratigraphy of Western Canadian coals. Can. Jour. Bot., vol. 32, pp. 187 - 201. 1954.

58. _____, and McGREGOR, D.C., Some Plant Microfossils important to Pre-Carboniferous Stratigraphy and contributing to our knowledge of the Early Floras. Can. Jour. Bot., vol. 32, pp. 601 - 621. 1954.

59. RAISTRICK, A., The Correlation of Coal Seams by Microspore content.

Part. 1. The seams of Northumberland. Trans. Inst. Mining Engineers, vol. 88, pt. 3. 1934.

60. _____, The Microspore Analysis of Coal. The Naturalist. 1935

61. _____, The Microspores of coal and their use in correlation, etc. Compte rendu du deuxieme Congres pour l'avancement des etudes de Stratigraphie Carbonifere. 1937.

62. _____, and SIMPSON, J., The Microspores of some Northumberland coals and their use in the correlation of coal-seams. Trans. Inst. Mining Engineers, vol. 86, pt. 4, pp. 225 - 235. 1933.

63. ROUSE, G.E., A preliminary structural and micropalaeobotanical investigation of some uppermost Cretaceous coals from Western Canada. Unpublished thesis for the degree M. Sc., McMaster University. 1952.

64. RUEDEMANN, R., Some marine algae from the Trenton limestone of New York, N.Y. State Mus. Bull. 133, No. 453, pp. 194 - 210, pls. 1 - 3. 1909.

65. _____, The Utica and Lorraine formations of New York. Part 2, Systematic Paleontology. N.Y. State Mus. Bull., No. 262, pp. 1 - 140, pls. 1 - 13. 1925.

66. _____, Paleozoic plankton of North America. Geol. Soc. Amer., Mem. 2. 1934.

67. _____, Ecology of Black Mud Shales of Eastern New York. Jour. Paleontology, vol. 9, No. 1. 1935.

68. _____, Graptolites of North America. Geol. Soc. Amer., Mem. 19. 1947.

69. SAHNI, B., Palaeobotany in India VI. Jour. Ind. Bot. Soc., 26(4): 241 - 273. 1947.

70. SCOTT, D.H., Extinct Plants and Problems of Evolution. MacMillan and Co. Ltd., London. 1924.

71. SCHOPF, J.M., WILSON, L.R., and BENTALL, R., An annotated Synopsis of Palaeozoic Fossil Spores and the Definition of Generic Groups. Illinois Geol. Sur. Rept. Inv. 91. 1944.

72. SPROULE, J.C., Contributions to the Study of the Ordovician of Ontario and Canada. pt. 3. A Study of the Cobourg formation (Ontario and Quebec). Geol. Surv. Canada, Mem. 202, pub. 2427, pp. 93 - 117. 1936.

73. SPURGEON, E.S., A Preliminary Study of Diamond Drill Core from Norfolk County, Ontario. Unpublished thesis for the degree B. Sc., McMaster University. 1954.

74. THIESSEN, R., Origin and composition of certain oil shales. Econ. Geol., vol. 16, pp. 289 - 300. 1921.

75. TWENHOFEL, W.H., Environment in Sedimentation and Stratigraphy. Geol. Soc. Am. Bull. vol. 42, pp. 407. 1931.

76. _____, Correlation of the Ordovician Formations of North America. Geol. Soc. Am., vol. 65, No. 3. 1954.

77. WALTON, J., An Introduction to the Study of Fossil Plants. Adam and Charles Black, 4, 5 and 6 Soho Square, London W.1. 1953.

78. WILSON, A.E., Geology of the Ottawa - St. Lawrence Lowland, Ontario and Quebec. Geol. Surv. Canada, Mem. 241. 1946.

79. _____, CALEY, J.F., SPROULE, J.C., and O'KULITCH, V.J., Contributions to the Study of the Ordovician of Ontario and Quebec. Geol. Surv. Canada, Mem. 202. 1936.

80. _____, STEWARD, and CALEY, Sedimentary Basins of Ontario, Possible Sources of Oil and Gas. Roy. Soc. Canada, sec. 4, vol. 35, pp. 167 - 185. 1941.

81. WILSON, C.L., The Telome Theory. Bot. Rev., vol. XIX, No. 7. 1953.

82. WILSON, L.R., Correlation of sedimentary rocks by fossil spores and pollens. Jour. Sed. Petrology, vol. 16, No. 3, pp. 110 - 120. 1946.

83. WODEHOUSE, R.P., Pollen Grains. McGraw - Hill Book Co., Ltd., New York and London. pp. 574. 1935.

EXPLANATION OF PLATES

PLATE I - Fig. 1. Sketch map of source area of samples.

Fig. 2. Geologic sequence of Upper Ordovician Strata in Ontario.

PLATE II - Microfossil photographs of the Billings "Series".

PLATE III - Diagrams of microfossils of the Billings "Series", Types B_1 - B_{16}.

PLATE IV - Diagrams of microfossils of the Billings "Series", Types B_{17} - B_{26}

PLATE V - Microfossil photographs of Dundas-Meaford "Series".

PLATE VI - Diagrams of microfossils of Dundas-Meaford "Series", Types D_1 - D_{16}.

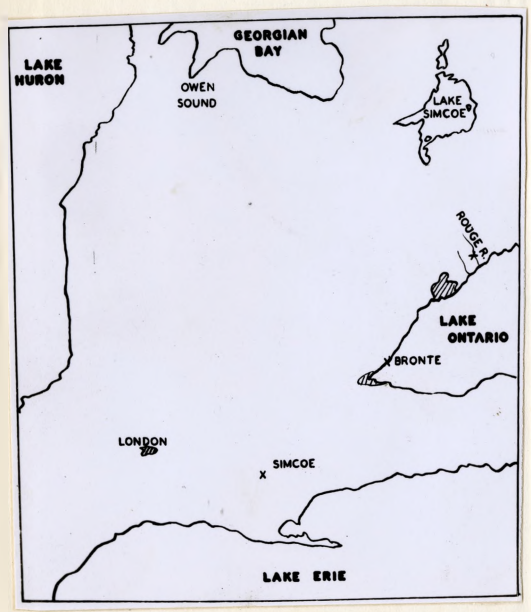
PLATE VII - Diagrams of microfossils of Dundas-Meaford "Series", Types D_{17} - D_{31}.

PLATE VIII - Fig. 1. Branch of Mastigograptus from Don Valley Brick Yard Toronto.

Fig. 2. Mastigograptus (?) from Billings drill-core sample, Simcoe.

PLATE I

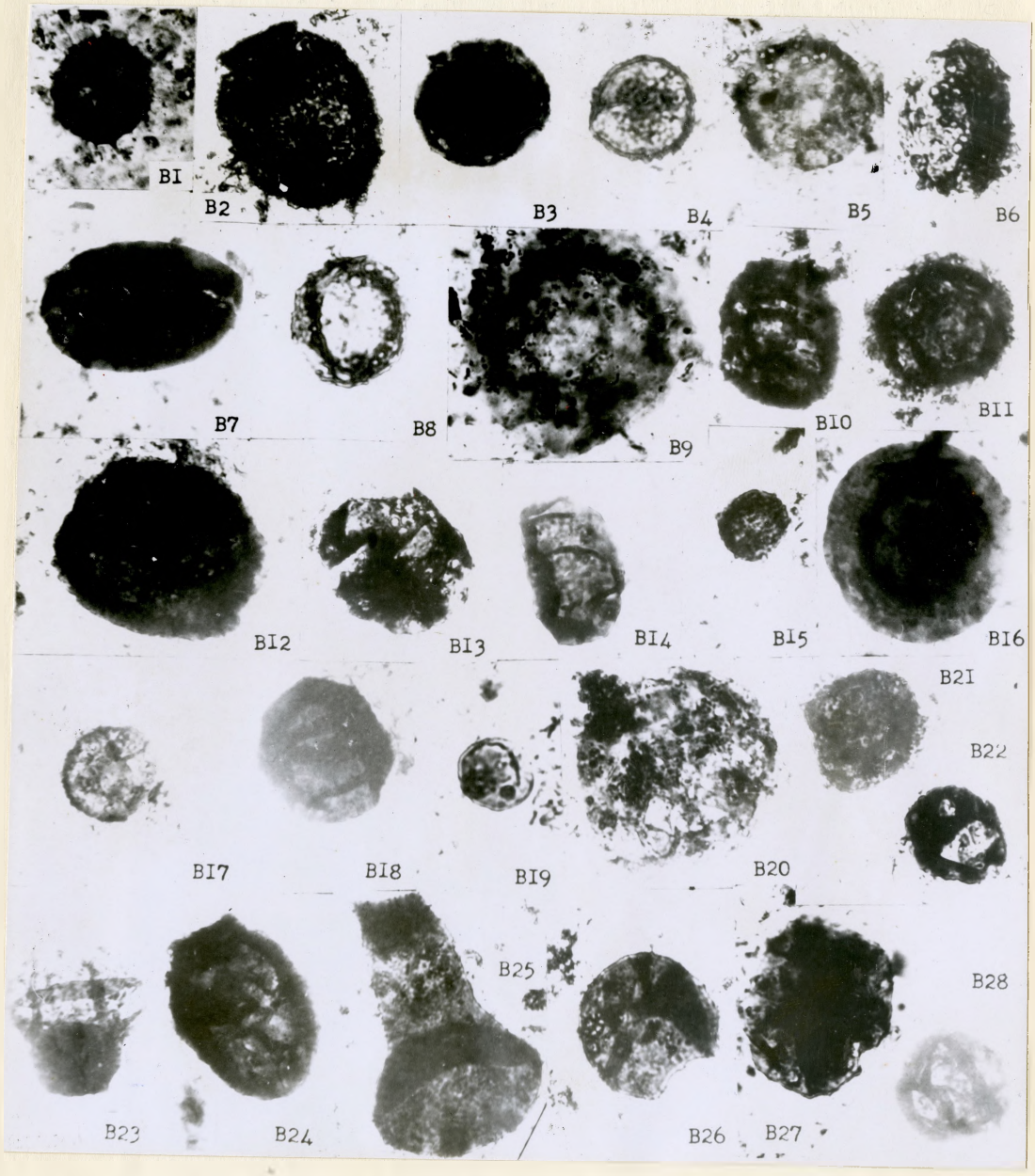
1.



2.

EPOCH	SERIES	STAGE	FORMATION
UPPER ORDOVICIAN	CINCINNATIAN	GAMA - CHIAN	QUEENSTON red shale
		RICHMONDIAN	MEAFORD shale&limestone
		MAYSVILLE	DUNDAS shale&limestone
		EDENIAN	BILLINGS shale: BLUE MTN. shale; GLOUCESTER shale; COLLINGWOOD

PLATE II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B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
B12
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B14
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B27
B28

PLATE III

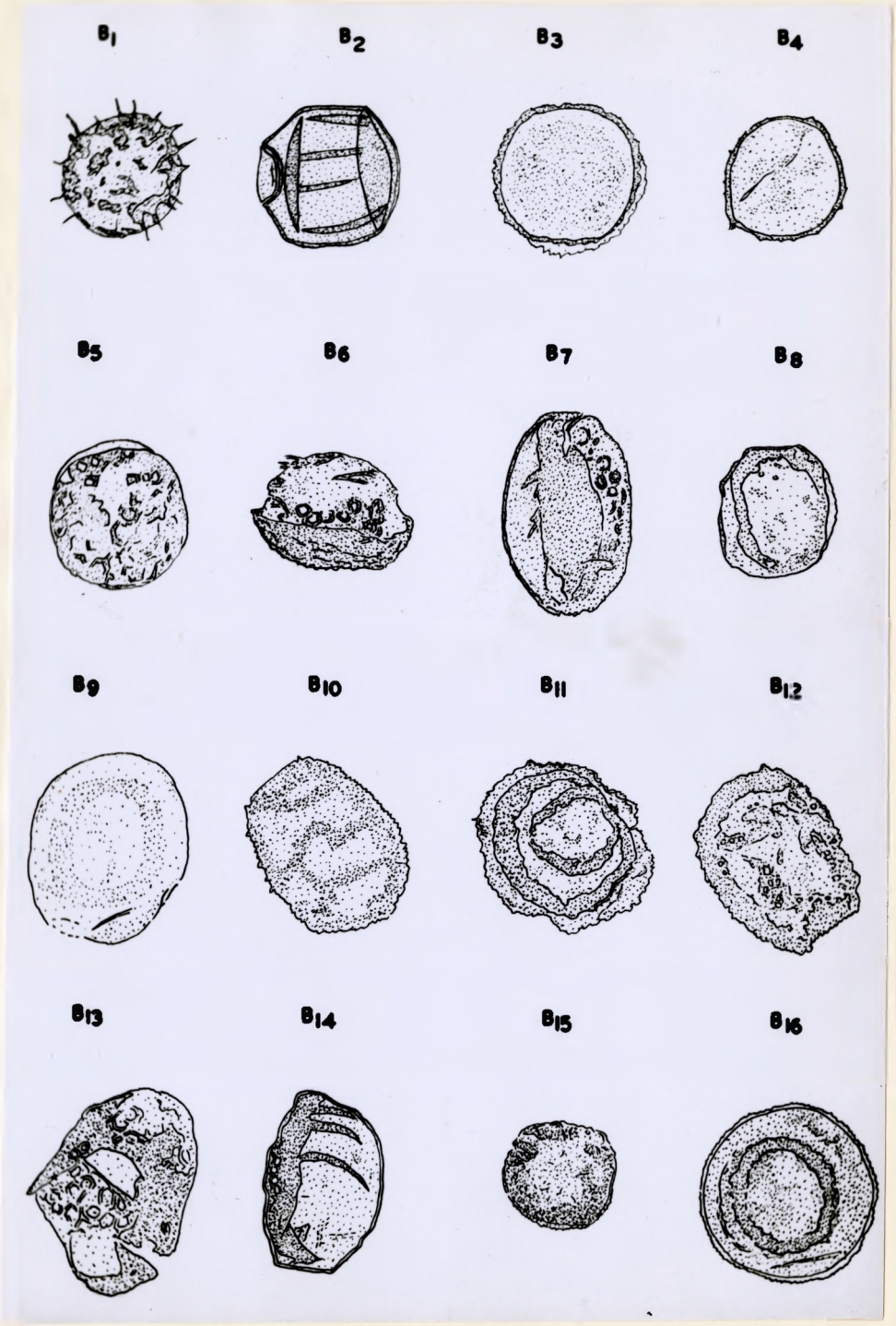


PLATE IV

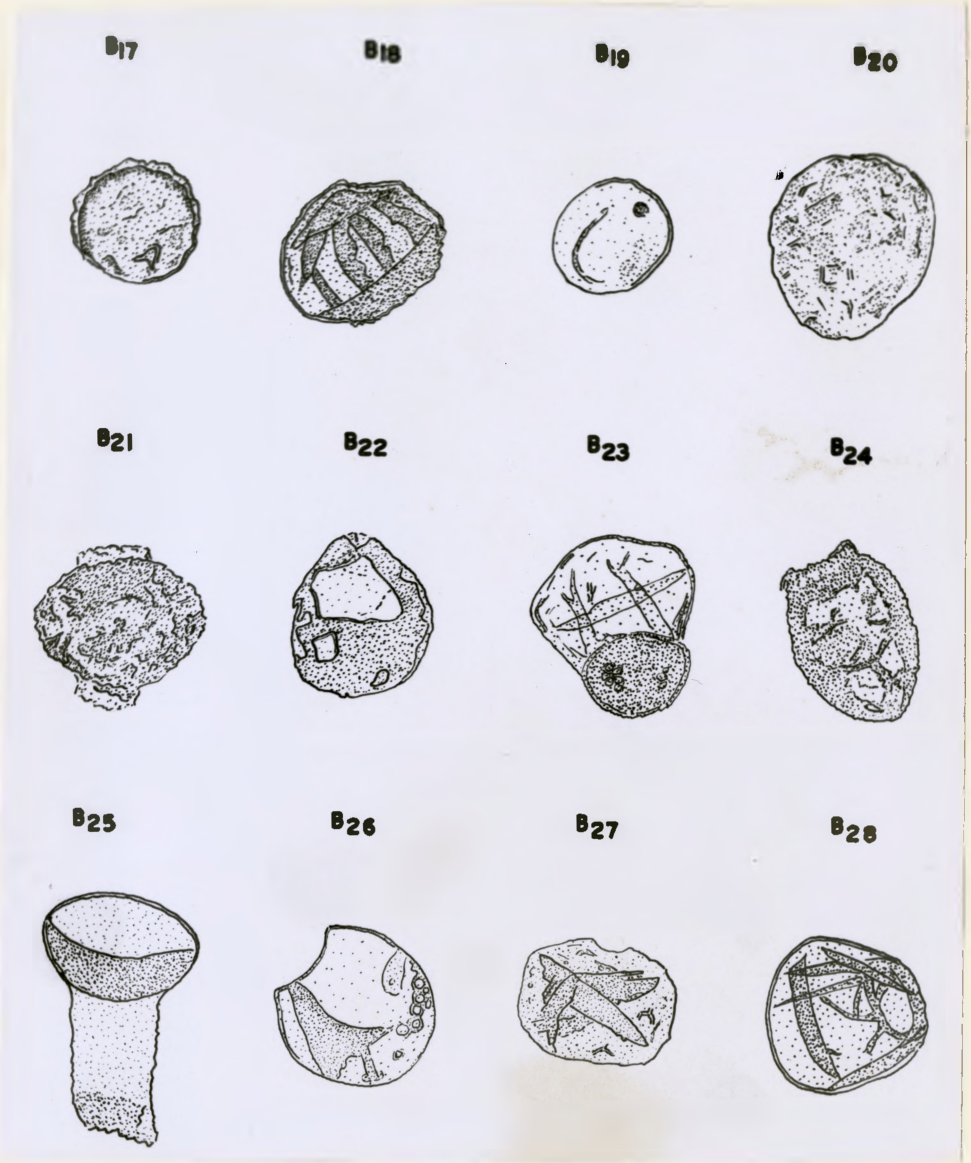
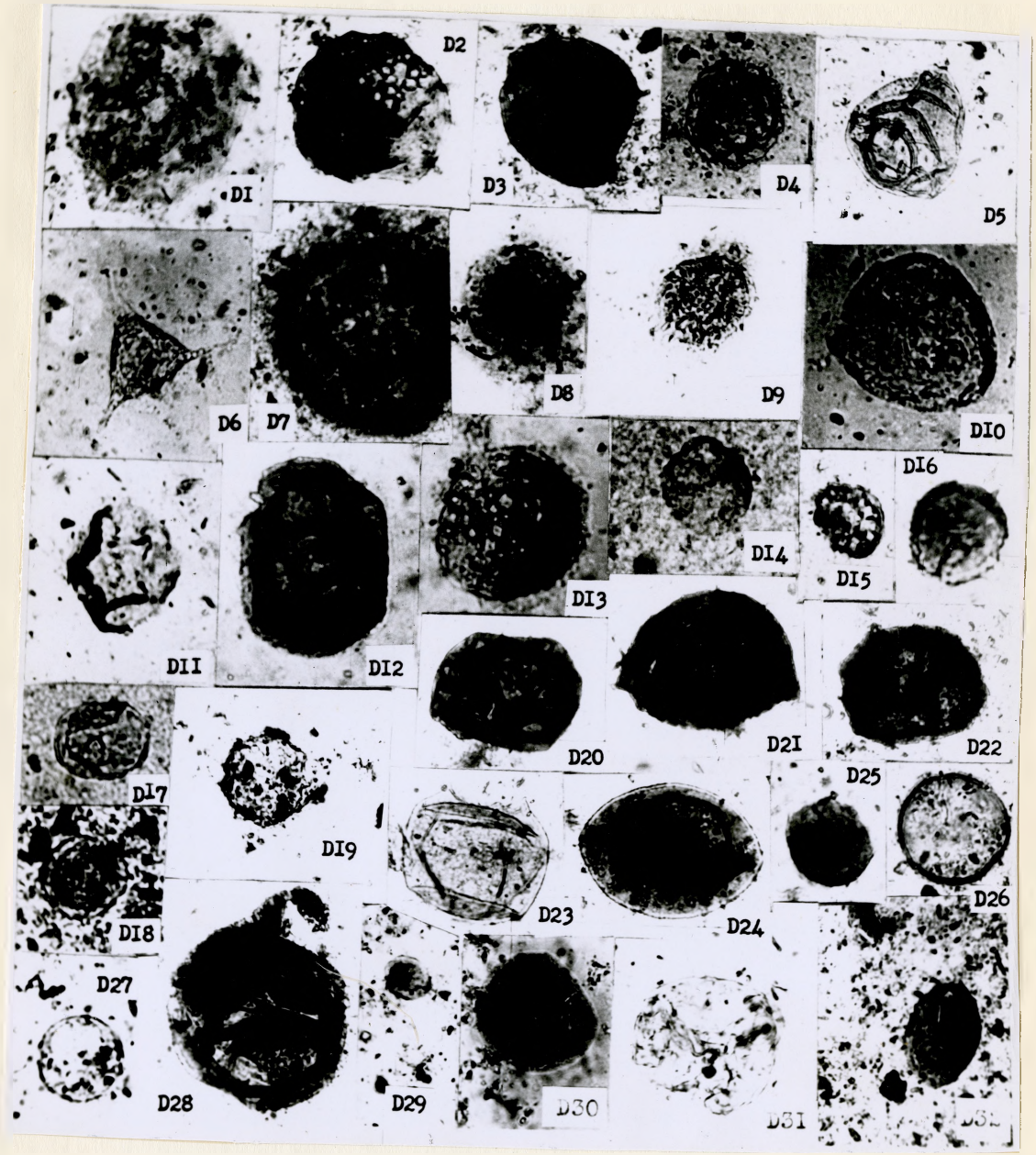


PLATE V


D1
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D31

PLATE VI

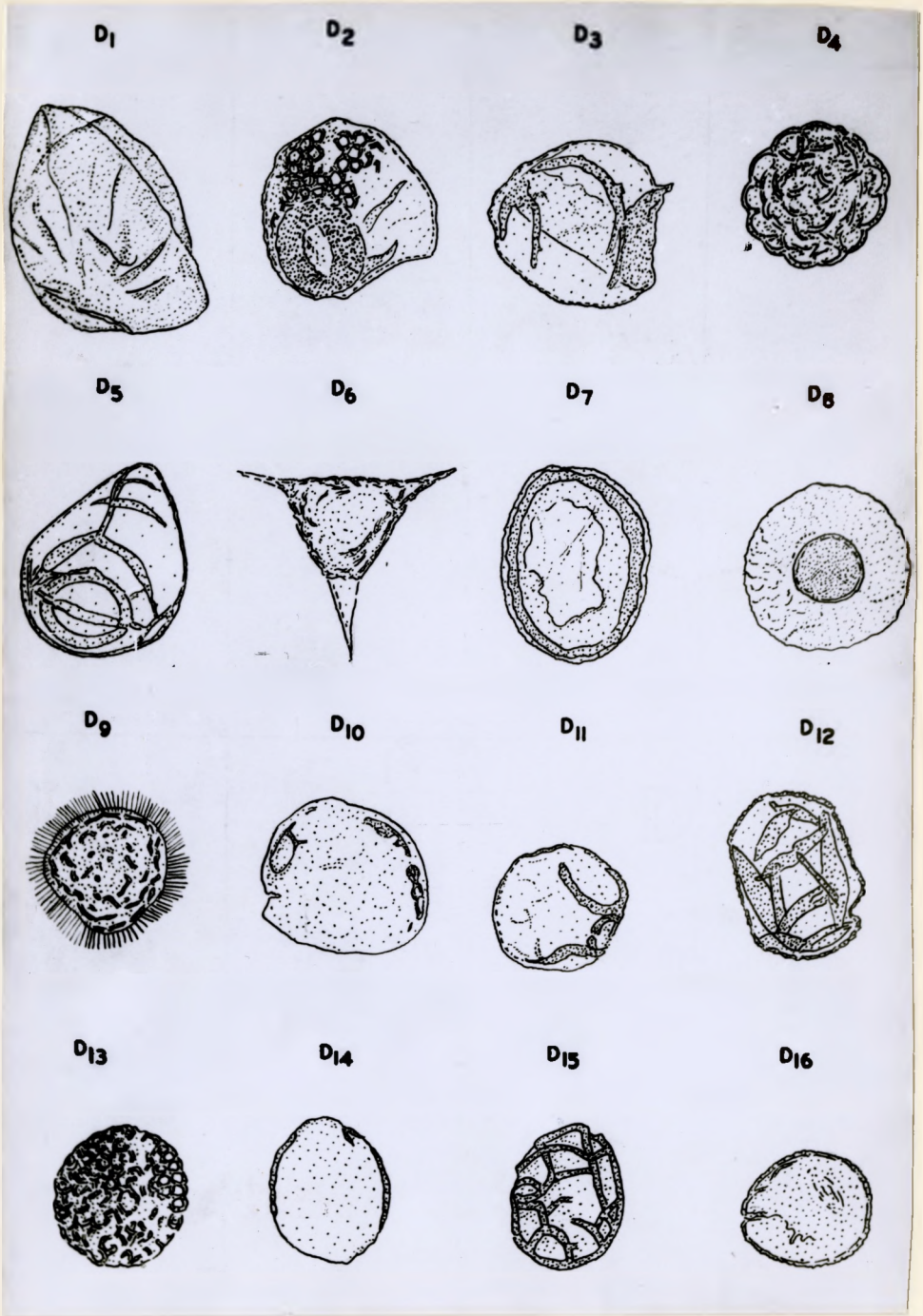


PLATE VII

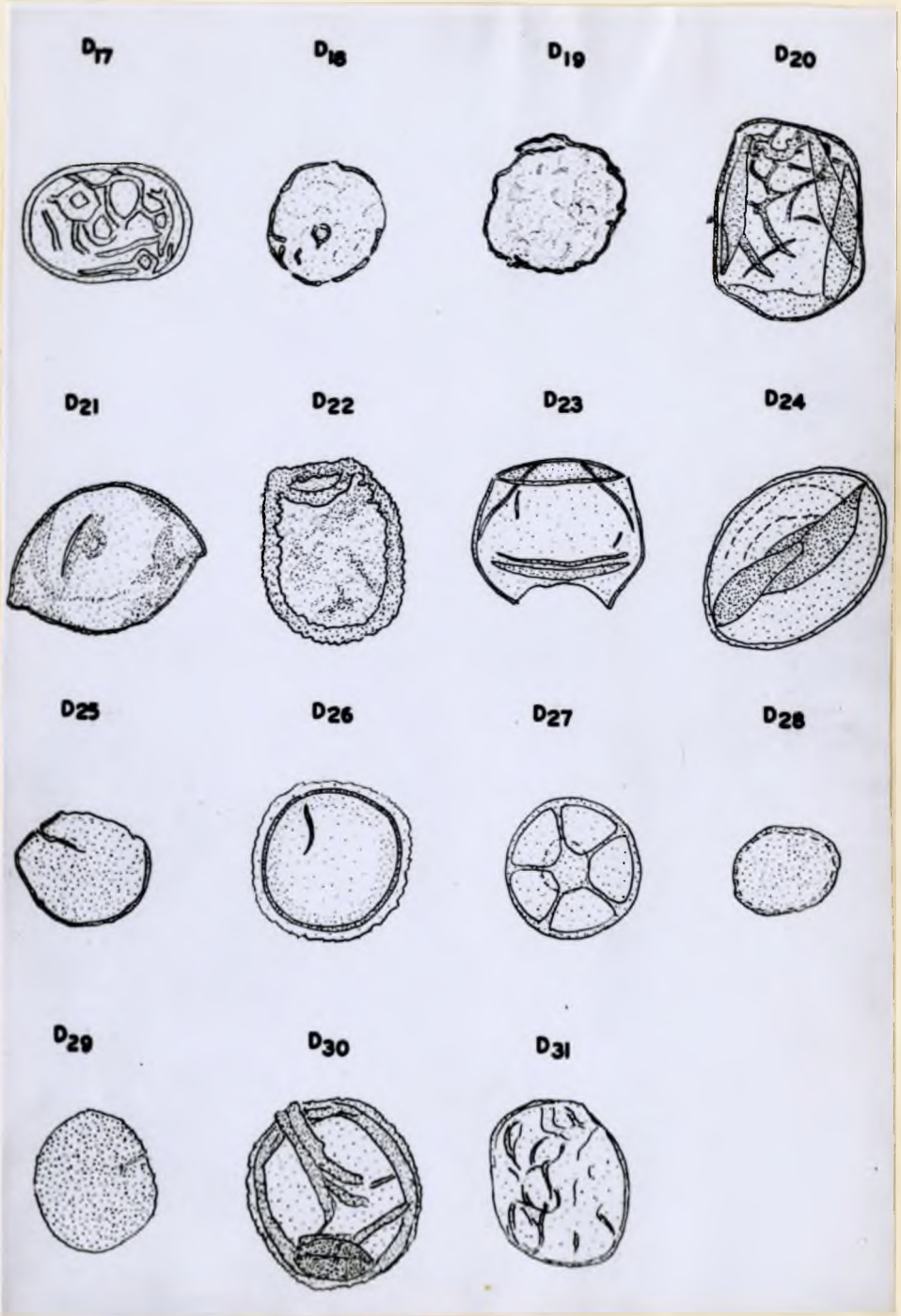
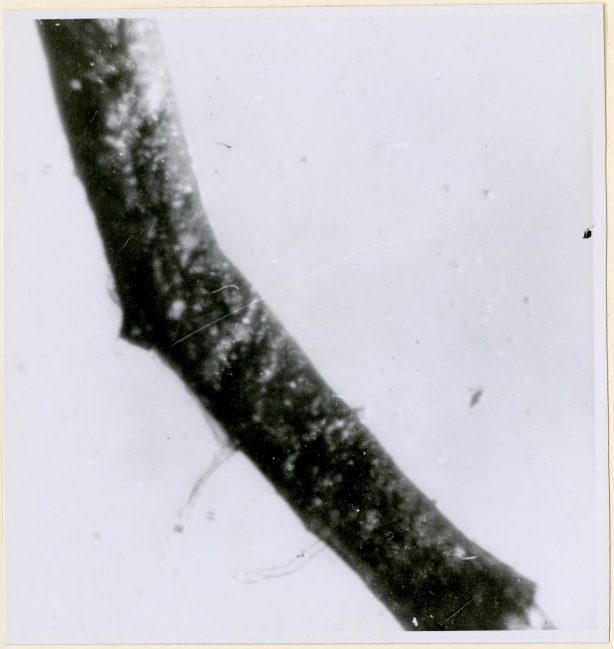


PLATE VIII

1.



2.