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# A Paleontological Study of the Gunflint Microfossil Assemblage

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## ABSTRACT

Precambrian microfossils discovered in nonferruginous cherts of the lower "algal" members of the Gunflint formation of southern Ontario are of great interest in the evolutionary scheme of primitive life. The environment of deposition of the deposit, and the indigenous and biogenic nature of the microfossil assemblage are considered. A discussion of the small but diversified assemblage, including twelve micro-forms, seven of which have not previously been reported, is presented.

## INTRODUCTION

This study was carried out by the writer as the second half of an honors project in the Geology Department of Oberlin College, Oberlin, Ohio, during the second semester of the 1962-1963 school year. Chert nodules from the lower "algal" members of the Gunflint formation, Ontario, were kindly obtained from Dr. Elso S. Barghoorn of Harvard University. The nodules, approximately 8 x 4 x 3 cm. in size, were extracted from a thin chert bed, varying from 2 to 12 inches in thickness, exposed near the bottom of the lower "algal" members on Schreiber Beach, 4 miles east of Schreiber, Ontario. Age determinations done on this Animikie-age formation, utilizing potassium-argon and rubidium-strontium decay ratios, have yielded consistant ages of 1900 million years ± 200 million years (Hurley, et. al., 1962).

The original discovery of microfossils in the Gunflint cherts was made by the late Dr. Stanley A. Tyler, of the University of Wisconsin, in 1952, and the first paper dealing with this discovery of the "oldest structurally preserved organisms that clearly exhibit cellular differentiation and original carbon complexes"(Tyler and Barghoorn, 1954), appeared in the April 30, 1954 issue of Science. In 1957 a second paper, dealing with the biochemical analysis of an antracitic coal from the Precambrian of northern Michigan, the results of which are applicable to the algal cherts of the Gunflint formation (Tyler, Barghoorn and Barrett, 1957, p. 1303), appeared in the October issue of the Bulletin of the Geological Society of America. A third paper, dealing in

some depth with the microfossil assemblage, the plates of which the writer has kindly been permitted to examine, is in preparation by Barghoorn at present and will be submitted for publication in the fall of 1963.

In this study the writer has attempted to establish the probable environment of deposition of the deposit, to establish that the material thought to be morphologically similar to existing organisms is indigenous to the chert and is biogenic in nature, and finally, to establish that a diversified floral and faunal assemblage is present. Although these related problems are necessary to a complete paleontological understanding of the now famous Gunflint assemblage, they have never been previously assembled by any author.

It should be noted at the outset, that, because of the limited time available for its completion, this study is preliminary and somewhat cursory in scope. Thus, the conclusions drawn from it, especially with regard to the possible affinities to modern organisms of the Precambrian micro-organisms which have been found, are necessarily tentative and subject to alteration at a later date. Further work will be carried out by the writer in the next four or five years and it is hoped that at that time these and other problems associated with this ancient chert deposit can be clarified.

## TECHNIQUES

The study of the chert nodules, and the organic material extracted from them, has been carried out utilizing a variety of techniques. The cellulose-acetate peel technique was used to free a thin layer of the chert and embedded microfossils for microscopic investigation; a maceration technique using concentrated hydrofluoric acid was used to free the insoluble organic material from the silicic matrix for further study; staining of the residue obtained from a hydrofluoric maceration with Safranin-O was used to establish the organic

nature of certain of the microfossils; the normal method of thin section preparation and transmitted light photomicrography were used to study the lithology and the microfossil assemblage; an ash determination, discussed in some detail in the text, was utilized to determine the percentage of combustible material in the chert; and observation of thin sections in polarized light was used to establish the nature of the mineral filling the dehydration-contraction cracks present in the chert.

## ACKNOWLEDGEMENTS

## DESCRIPTION OF SAMPLES

The Gunflint nodules studied consist of a dense, black, fine to medium grained chert, containing occasional carbonate rhombs, and many oolite-filled pockets which contain spherites, often exhibiting a "greenalite core surrounded by alternating layers of hematite, magnetite and/or chalcedony" (Gill, 1927, p. 703-705). Pyrite granules, lacking the alternating, concentric bands, are also present. Dehydration-contraction cracks are present, both cutting through the chert nodules and in the layered spherites (Plate I, 3). These cracks are filled with chalcedony similar to that of the matrix. Sections cut transverse to the bedding show brown, thin, irregular strata forming thimble shaped masses with oölite-filled depressions in between (Plate I, 1-2). In the writer's opinion, these thimble shaped masses were formed, much in the same manner as are similar structures formed by modern blue-green algae, by the upward phototrophic growth of the algal member of the assemblage. Microscopic investigation supports this view by revealing that the brown, irregular lines are composed of mats of both the algal and fungal members of the assemblage. During the growth of the thimble shaped structures, banded spherites are thought to have collected in the intervening depressions. Thus, in the opinion of the writer, the convex thimbles are thought to be directed upward and the intervening oölite-filled depressions are thought to be directed downward. See Figure 1 for a drawing of a section through the chert cut perpendicular to the strata.

## ENVIRONMENT OF DEPOSITION

The Physical and chemical environment of deposition of the chert deposit must be established so that the ecological affinities of the organisms present in the assemblage may be reasonably inferred.

Figure 1

Section through cert nodule cut perpendicular to strata.
Dark straight lines indicate dehydration-contraction cracks.
Dark irregular lines indicate mats of mycelia and algal filaments.
Blue-green algae grew in the "up" direction, in an analogous
manner to the way some present-day blue-greens grow, forming
thimble shaped masses. Thus, the convex thimbles are thought
to point upward. Oölites, precipitated from the shallow
marine environment, collected in the depressions between the
thimble shaped masses. Thus, the concave spherite-filled
depressions are thought to point downward. (See Plate I, 1-3,
for photomicrographs of related structures.)
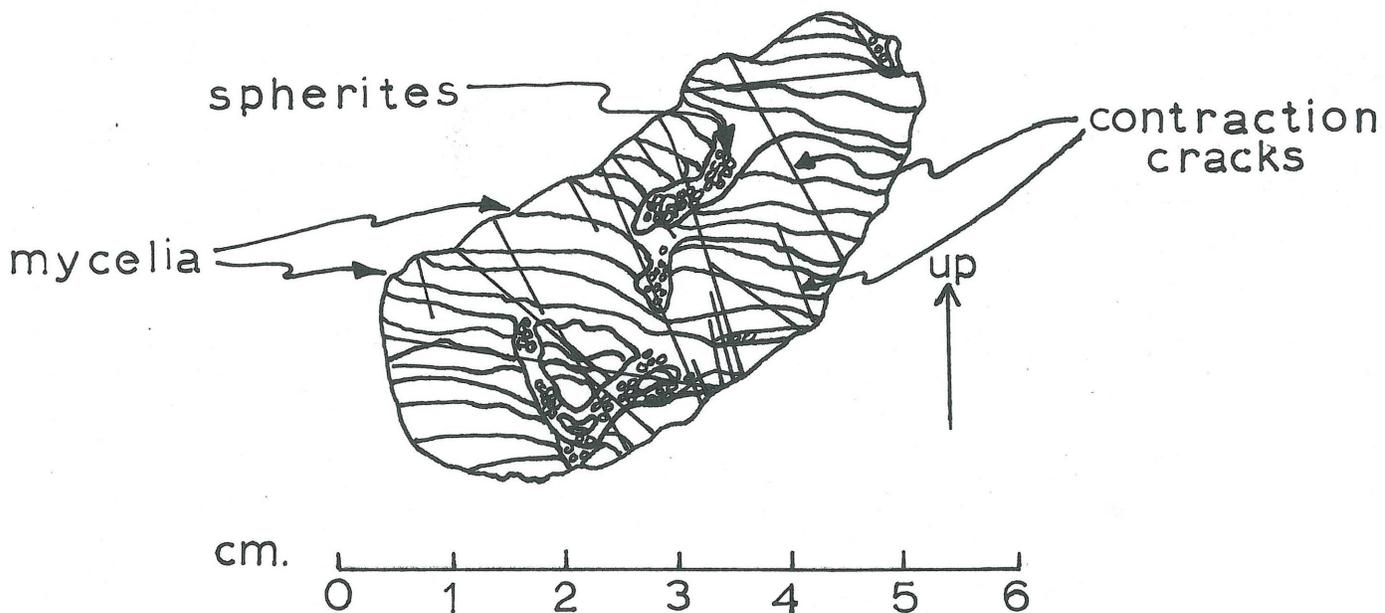


Section Perpendicular To Strata

THE PHYSICAL ENVIRONMENT. From converging arguments it is believed that the organisms present in the Gunflint chert lived in a shallow, marine environment, most probably not beneath the wave base, and close enough to the surface to utilize penetrating light. There are several reasons for believing this. First, it seems probable that the spherites exhibiting alternating, concentric layers of hematite, magnetite and/or chalcedony surrounding the greenalite core, were kept in suspension by disturbances in shallow water, or that they were swept up after original deposition and had additional layers of the minerals added, the banding being due to rhythmic precipitation of these substances. Further, it has been noted that this type of spherite is found only in the algal facies and in a lower intraformational conglomerate (Gill, 1927, p. 703), the latter of which has been termed the Kakabeka formation (Moorhouse, 1960, p. 7). It is well established that the conglomerate was formed in a shallow water environment (Gill, 1927, p. 703) and thus, the conditions requisite for the formation of this type of spherite are thought to have been identical in both instances. It is noted that the spherites exhibit dehydration-contraction cracks filled by chert similar to that of the matrix, as, according to Gill do other types of granules present in the Gunflint (Gill, 1927). Further, there is no evidence of deformation due to tectonic activity in the area of deposition and only minor gravity faults appear to have occurred since Gunflint-times (Moorhouse, 1960). Thus, it seems improbable that there has been any considerable alteration of these spherites since original consolidation of the matrix. The fact that delicate, micro-organisms have been preserved in the chert would further confirm this analysis.

Second, the fact that some members of the assemblage appear to be algal in nature would necessitate that the organisms lived close enough to the surface

to be able to absorb penetrating light and thus carry on photosynthesis. Limiting depth for modern organisms of this type is largely determined by light penetration and is generally less than 60 feet (Goodwin, 1956, p. 571). Third, that the organisms did not live beneath the wave base is inferred from the fact that similar modern organisms are known to flourish only in shallow water where agitation by wave action promotes the exchange of gases and nutriments. And fourth, Goodwin notes from the examination of lateral facies relationships that the lower "algal" members were deposited in a shallow basin bordering open sea-water at the northeastern extent of its area, the marine basin constituting an extended arm of the Animikie sea (Goodwin, 1956, p. 591). Further, the presence of greenalite, in an analogous manner to the interpretation of the presence of glauconite, is taken as an indication of marine conditions.

THE CHEMICAL ENVIRONMENT. The presence of hematite is thought to be an indication that the depositional environment was oxidizing in nature (Dunbar and Rodgers, 1961, p. 212). In the chert studied this can easily be attributed to the oxygen by-product of the photosynthetic algae in the assemblage. Whether the atmosphere was oxidizing in nature, i.e. whether free oxygen had appeared by this time in the evolution of the atmosphere, cannot be determined from the material studied because it is easily conceivable that the oxidizing nature of the samples studied was a local phenomenon dependent only on the photosynthetic algae. Goodwin, however, believes that the atmosphere was oxidizing during the formation of the hematite and magnetite bearing spherites, as determined by him from studies of the Gunflint facies which have shown that the ferric state of oxidation was reached during precipitation and lithification rather than by later weathering or other alteration (Goodwin, 1956, p. 590-591).

Further, Goodwin states that the preponderance of ferrous iron minerals together with the quantitative absence of reducing agents in the Gunflint (the algal facies excepted) indicate that iron was transported and deposited largely in the ferrous state (Goodwin, 1956, p. 590-591). This strongly implies the presence of an acid environment which appears to have resulted from large-scale discharge of acid volcanic solutions into the basin of deposition (Goodwin, 1956, p. 591). In support of this hypothesis Barghoorn has noted the finding of pyroclastic material in the thin section material prepared by J. M. Schopf (Barghoorn, personal communication, April, 1963).

Although an oxidizing environment is inferred in the Gunflint chert, the presence of the reducing-indicator, pyrite, seems to present no problem. It is the writer's opinion that as organic matter sank to the basin bottom its accumulation caused the formation of a localized reducing environment, thus permitting the formation of pyrite. The granules, which notably lack the rhythmic concentric bands of the spherites formed in more shallow water, then accumulated in the preserved chert facies. The preservation of the ferric iron in this reducing environment is probably due to the protective layers of chalcedony which, in all cases observed, appear to completely surround the hematite layers.

## MODE OF PRESERVATION

The fact that micro-organisms of such a delicate nature as those discovered have been preserved after nearly two-billion years warrants explanation. The fidelity of preservation is attested to by the comparison of the quality of preservation of the Gunflint assemblage with that of the celebrated Rhynie chert deposit of the  middle Devonian of Scotland (Tyler and Barghoorn, 1954). As mentioned above, acidic solutions, mainly constituted of silicic material,

were deposited by volcanic activity into the shallow marine basin. This silicic material, thought by Gill to have been carried in a finely divided colloidal condition (Gill, 1927), permeated the interstices of the floral mats, thus encasing them, following lithification, in chert, micro-crystalline quartz. After original deposition the chert has, in general, undergone no alteration due to land movements, and thus the original material is preserved much as it was when it was deposited. Only minor alteration of the contents of the chert has occurred, and this is due to the dehydration of the silicic matrix, leaving as evidence the contraction cracks present in the matrix and in many of the spherites. According to Barghoorn, who has attempted to duplicate these dehydration phenomena in the laboratory, the dehydration of the silicic matrix has probalby caused the shrinking of the original organic material to between 1/2 and 1/3 of its original size (Barghoorn, personal communication, April, 1963), and has thus obliterated much of the very fine detail present in the original unaltered material.

## INDIGENOUS NATURE OF THE MICROFOSSILS

In view of the fact that much criticism has been directed toward some investigators dealing with unusual microfossil discoveries, especially those dealing with the "organic" remains reported in carbonaceous chondrites (Fitch, et al., 1962) and those claiming to have discovered viable bacteria of great age (ZoBell, 1946, p. 92-93), it is appropriate to dispel any doubt as to whether such criticism could be justifiably directed toward the work done on the Gunflint assemblage. The most important of those criticisms leveled against other investigators is that the micro-organisms which they have reported are actually due to modern contamination and are thus not indigenous to the rock with which they are working. For several reasons it is believed that such criticism is untenable with regard to the Gunflint assemblage. First, the material thought to be morphologically

similar to certain existing organisms is, without any question, within the rock as demonstrated by thin section analysis. In addition, this material is very profuse, a fact which makes detailed, systematic work very time consuming, and which would be impossible to explain by contamination. Further, microscopic investigation of cellulose acetate peels obtained from a polished section etched in hydrofluoric acid and using acetone as a bond between the cellulose acetate and the section, reveal that the organic material is part of the chert. And finally, the silicic matrix can be dissolved in hydrofluoric acid, and the insoluble members of the assemblage can be concentrated in the residue, washed free of acid, pipetted onto microscope slides and examined directly, free of the mineral matrix.

## ORGANIC NATURE OF THE ASSEMBLAGE

In addition to the view sometimes advanced that some reported micro-fossils are not indigenous to the material from which they are reported, the other important criticism often leveled against unusual discoveries of this sort is that the reported microfossils are not biogenic in nature. Thus, it is important to establish that the micro-forms extracted from the Gunflint are, in actuality, of organic origin. The most obvious way of establishing the biogenic nature of the forms reported is that of considering their morphology. The morphology of several of the forms discovered can be compared to members of existing genera, and the ecological affinities of the existing organisms to which they may be compared coincide with the environment of the Gunflint suggested above. Further, the complexity of the organisms suggested is not unreasonable in terms of evolutionary considerations. However, although morphology is perhaps the easiest and most available method of establishing — that the material is of biogenic nature, it is not as convincing as are the biochemical analyses done on the material. After washing about 27 grams

of the chart in benzene and alcohol, to remove possible surface organic
residue, the material was heated to 110°C to drive off any free water.
Following weighing, the material was emersed in hydrofluoric acid, to dissolve
the silicic matrix. The remaining residue was concentrated, washed free of
acid, and again weighed after drying in a phosphorus pentoxide desiccator.
The same procedure was followed after emersing the remaining material in hot
concentrated hydrochloric acid to dissolve the carbonates, hematite and magnetite.
After prolonged drying (72 hours), the residue was weighed directly prior
to combustion in a platinum crucible at approximately 1000°C. Final weighing
indicated that about 0.01% of the material was combustible, a fact strongly
suggestive that this percentage of the original material was of organic
nature. After final weighing a small amount of non-combustible material
remained in the crucible. Treatment with nitric acid removed much of this
material, and thus it is theorized that some of the remaining material was
pyrite. The material remaining after nitric acid treatment may be insoluble
fluorite, formed by the reaction of hydrofluoric acid with calcium carbonate.
See Chart 1 for further details.

## CHART 1

| Mineral | Formula | Solubility |
|---|---|---|
| Chalcedony | $SiO_2$ | Soluble in HF |
| Greenalite | iron-magnesium-silicate | Soluble in HF |
| Calcite | $CaCO_3$ | Soluble in HCl |
| Dolomite | $CaMg(CO_3)_2$ | Soluble in conc. HCl |
| Hematite | $Fe_2O_3$ | Soluble in conc. HCl |
| Magnetite | $Fe_3O_4$ | Soluble in HCl |
| Pyrite | $FeS_2$ | Soluble in conc. $HNO_3$ |
| Fluorite (may be formed by: $2HF + CaCO_3 = CaF_2 + H_2CO_3$) | $CaF_2$ | Insoluble |

Weight of original material: 27.4582 gm.　　Percent of HF-soluble minerals: 99.8839%

Weight after HF treatment: 0.0319 gm.　　Percent of HCl-soluble minerals: 0.0065%

Weight after HCl treatment: 0.0301 gm.　　Percent of combustible material: 0.0961%

Weight after combustion: 0.0037 gm.
Weight after $HNO_3$ treatment: 0.0027 gm.　　Percent of $HNO_3$-soluble minerals: 0.0027%

(non-combustible, insoluble material)　　Percent of non-combustible, insoluble material: 0.0098%

In addition, the writer has discovered that the floral microfossils
of the assemblage, extracted from the silicic matrix with hydrofluoric acid,
which constitute the major part of the combustible residue mentioned above,
will absorb a Safranin-O stain, a stain used on modern and ancient pollen
and thought to be absorbed only by organic matter. Further, much biochemical
analysis of the Gunflint micro-organism-bearing material has been done by the
Jersey Oil Company. The results of this work, reported by Tyler, Barghoorn and
Barrett, may be summarized as follows:

1) Various extractive and chromatographic techniques demonstrate the presence
of strongly pigmented organic compounds.

2) Organic extractives show strong fluorescence in ultraviolet light, solublity
in both acid and base solutions, color change with pH change, relatively
featureless absorption spectra in the visible and ultraviolet light, and high
thermal stability.

3) The extractives are soluble in organic solvents, and unable to diffuse through
a dialyzing membrane.

4) Absorption spectrophotometric measurements in both visible and ultraviolet
light indicate the presence of porphyrin or metallo-porphyrin complexes.
                                        (Tyler, et. al., 1957).

It should be noted that although the results summarized above are taken from
work dealing with an anthracitic coal from a Precambrian shale deposit in
northern Michigan, it is stated in the article that substances "exhibiting
similar properties, though present in smaller amounts," have been secured
from the algal cherts of the Gunflint formation (Tyler, et. al., 1957, p. 1303).
In addition, Barghoorn reports that degassing of Gunflint material yields
methane and aromatic hydrocarbons (Barghoorn, personal communication, April, 1963).

## MICROFOSSIL ASSEMBLAGE

The assignment of phylogenic relationships to any new found material is a
formidable task, but it becomes much more difficult when the material is of
such antiquity as is the Gunflint assemblage. This difficulty arises from the
fact that the most reliable method of determining such relationships is to compare

the fossil forms with similar modern forms in order to arrive at a reasonable conclusion regarding the affinities of the fossil material. However, 1900 million years is an extremely long period of time in which to have the mechanisms of evolution at work, and it would be remarkable, indeed, if any of the Gunflint organisms could be placed with certainty in any existing genera or perhaps families. In addition, although the preservation is unusually distinct, enough of the fine detail has been lost, perhaps because of the dehydration-contraction of the matrix, to make detailed comparison between the ancient and related modern forms very difficult. Hence, comparison of this type is limited to only the grossest of morphological detail. Since this method is not entirely satisfactory, a comparison of the new-found forms with identified fossil material of the same age would be desirable. Unfortunately, however, only seven photomicrographs of members of the Gunflint assemblage have been published (Rutten, 1962, p. 83-89), and these include only two types of organisms which the writer has discovered. Examination of Barghoorn's unpublished plates has added three more types, making a total of five forms about which the writer can rely on the judgement of a well-versed scientist. Consultation with other workers acquainted with organisms of the type found has added helpful suggestions and much interest, but nothing in a concrete nature in terms of possible affinities. In addition to other difficulties encountered, and perhaps more importantly, the writer's own lack of previous experience in the assignment of phylogenic relationships to fossil material has served as a severe handicap. Thus, as was stated at the outset, the conclusions which are to be drawn concerning the affinities of the fossil assemblage are necessarily tentative and are subject to alteration at a later date.

Bearing the above observations in mind, then, the writer would tentatively suggest that the following types of organisms are present in the Gunflint

material studied:

In the Plant Kingdom;

1) One member of the Cyanophyta, member of the Oscillatoriaceae, perhaps comparable to certain members of the existing genera Oscillatoria or Lyngbya.

2) Two types of aquatic fungi (fungal type "A" and fungal type "B"), having structural features comparable to those found in certain existing Phycomycetes.

3) Numerous free spore-like bodies, both sporangia and spores, probably of fungal origin.

In the Animal Kingdom;

1) One, possibly two types of radiolarians, planktonic protozoans usually with an opaline siliceous skeleton.

2) One, possibly two types of coelenterates, which may be related to the Octocorallia.

3) One form possibly similar to the existing genus Discoaster, a group of planktonic calcareous marine flagellates of uncertain systematic position, probably related to the Coccolithophorides (Tyler and Barghoorn, 1954).

4) One form which may be related to the hystrichospheres, a group of spherical organisms exhibiting numerous hooked hollow spines radiating from the central sphere. The hystrichospheres have at various times been considered radiolarians and desmid spores, and at present are usually considered to be the resting cyst-like stage of unicellular dinoflagellates (Downie, 1960, p. 198). It is noted that this microform bears spines which appear similar to those present on some existing chitinozoans.

In addition, numerous individuals of unknown possible affinity, grouped under the morphological term "asteroids," and clumps of humic matter of organized but undefined morphology, are present.

## DISCUSSION OF FLORA

The floral assemblage consists of algal, fungal, and isolated spore-like members (Plate II, 1-3). The algal member is described by Tyler and Barghoorn as consisting of "free, unbranched filaments, devoid of heterocysts and spores, with filaments approximately 1.5 microns in diameter" and is thought by them to be comparable to "certain species of the existing genera Lyngbya or Oscillatoria" (Tyler and Barghoorn, 1954). All filaments identified by

the writer as belonging to this group exhibit a characteristic uneven clumping of the material within the filament which the writer believes may be due to the coagulation of internal humic material in an analogous manner to the way in which microscope slide preparations of modern algae sometimes exhibit a clumping due to cytoplasmic coagulation (Plate II, 4-8). The fungal members are of two types, differentiated by the mode of attachment of the spore-like bodies, and less definitively, by the diameter of the hyphae. Fungal type "A" is considered to be similar to the fungal type described by Tyler and Barghoorn as consisting of "many-branched hyphae, apparently non-septate, bearing small laterally attached spores," and is thought by them to exhibit structural features "comparable to those found in certain existing Phycomycetes" (Tyler and Barghoorn, 1954). Although from the writer's investigation the hyphae appear to branch only rarely (Plate II, 9-10), the lateral attachment of small, sessile, reticulate spores which may exhibit horizontal and vertical suture lines, is well documented (Plate III, 1-7). The hyphae of fungal type "A" are approximately 2.5 microns in diameter. The reticulate or rugose spore-like bodies of fungal type "B" are attached to the hyphae by short ringed stalks (Plate III, 3-10) and are thus probably sporangia rather than spores. The hyphae of this fungal type are approximately 2 microns in diameter. A thin hypha attached to a terminal reticulate spore-like body has been discovered and is interpreted to be a germinating sporangiospore (Plate III, 11-14), possibly related to fungal type "B". Numerous small, isolated spores and sporangia, with well defined reticulate structure and probably of fungal origin, have been noted in all thin sections of the chert studied (Plate III, 15-19). Usually these bodies are ruptured, indicating either their place of attachment to the hypha or their mode of spore dispersal.

## DISCUSSION OF FAUNA

The faunal members of the assemblage consist of one or two types of radiolarians, one or two types of coelenterates, one micro-form thought to be similar to members of the existing genus Discoaster, and one individual thought to be related to the hystrichospheres. The micro-form thought with most assurance to/ the Radiolaria exhibits a perforated central sphere from [be related to] which radiate segmented spines (Plate V, 1-8). Also visible is the suggestion of an outer capsule. Although the smallest paleozoic radiolarian is approximately 60 microns in the diameter of the central sphere (Foreman, H. P., personal communication, May, 1963), and the central sphere of this form is approximately 5 microns in diameter, it does not seem inconceivable to the writer that forms of this size could have been in existence at the time of Gunflint deposition. The second form tentatively identified as a radiolarian consists of a spinous body with biradial or pentrametal symmetry (Plate IV, 1-4). The spines, which appear to be sheath-enclosed as they emerge from the body, radiate from a central ring which may be the equivalent of the radiolarian's central sphere. It should be noted that although many radiolarians exhibit radial symmetry, spherical and bilateral members are also known (Campbell, 1954).

The coelenterate member is similar to forms tentatively identified by Barghoorn as being members of the Coelenterata, and photomicrographs of well defined individuals will appear in his forthcoming article. Figure 2 is a drawing made from his photographs and shows the salient characteristics of this form. The form consists of a reticulate capsule connected by a filamentous strand to a membranous body with tetrametal symmetry. Well defined radiating projections are visible, and it is thought by Barghoorn that these may be radial canals. The prevalent eight-fold symmetry of the membranous body and the shape of the capsule suggest that if this form is a coelenterate it

Figure 2

Organism identified by Dr. Barghoorn as probably belonging
to the Coelenterata. Note reticulate capsule connected
by a filamentous strand to a membranous body with tetrametal
symmetry. Dotted lines indicate position of well defined
radiating projections, thought to be radial canals. This
micro-form may be related to the Octocorallia. However,
small size and reticulate nature of the capsule suggest to
the writer that it may be related to the fungal members of
the Gunflint assemblage. (See Plate V, 9-17, for photo-
micrographs of similar organisms.)
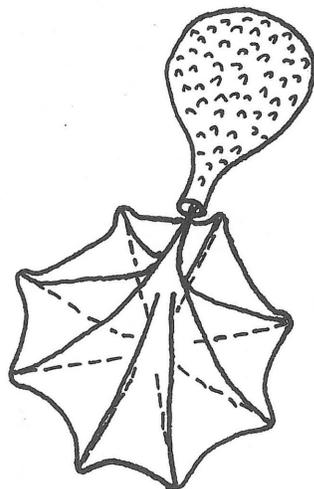
0    10   20   30  40   50
microns

may be related to the Octocorallia. The individuals discovered by the writer demonstrate all defining characteristics of Barghoorn's prototype, although the tetrametal symmetry of one individual seems to have been destroyed in diagenesis (Plate V, 9-17). The fact that the two members of this group discovered by the writer differ markedly in size is suggestive, although far from conclusive, that they may be two different types of coelenterates. However, the small size of the organisms, as well as the shape and reticulate nature of the capsule, lead the writer to wonder if this form may have closer affinities to the fungal members described above than to the Coelenterata.

Two individuals, thought possibly to be related to Discoaster are present in the assemblage (Plate IV, 15-23). Both individuals demonstrate characteristics common to the genus which are as follows: a discoidal body, between 2 and 30 microns in diameter, with variable symmetry determined by the number of projections usually radiating from a central ring. It should be noted that one individual pictured (Plate IV, 15-19) is connected to clumped organic material of undefined morphology, and it is possible that this material may be the remains of the capsule mentioned above as being characteristic of the coelenterate member of the assemblage. Thus, this individual may possibly belong to the coelenterate group rather than be related to members of the genus Discoaster.

Hystrichospheres may be characterized as exhibiting a spheroidal smooth body, usually 40-60 microns in diameter, from which emerge numerous hooked, hollow spines. It is somewhat questionable whether the individual termed "Hystrichosphere (?)" in the assemblage is a member of this group, but possible affinities to other groups appear even more remote. The individual discovered exhibits a spheroidal reticulate body through which paired, segmented projections,

having knobby or curled-back ends, emerge via raised openings (Plate IV, 5-14).
It has been suggested to the writer that the curled ends of the paired
projections is a feature similar to that exhibited by certain existing chitinozoans,
although the body is dissimilar to known forms (Cross, A., personal communication,
May, 1963).

## DISCUSSION OF PROBLEMATICA

In addition to those members of the assemblage for which affinities
have been suggested, several forms have been noted for which possible affinities
are unknown. The most numerous of these are those forms which may be grouped
under the morphological term "asteroids." In general, these "asteroids"
exhibit segmented filaments of variable number radiating irregularly from
a central structure of undefined morphology(Plate V, 18-25). From a consideration
of the size and structure of the filaments it seems most probable that
these forms may be related to the floral members of the assemblage. In addition,
large clumps of humic material which appear to be organized, as evidenced
by their reticulate nature, but which exhibit undefined morphology, are
present in the assemblage (Plate V, 26-27).

## SUMMARY AND CONCLUSIONS

Although the discovery of nearly two-billion-year-old, structurally
preserved micro-organisms occurring in the Gunflint formation of southern
Ontario was made in 1952, a limited amount of data has been published dealing
with the paleontological aspects of this unusual deposit. This paper summarizes
the results of a preliminary and somewhat cursory investigation into several
related problems associated with this Precambrian microfossil assemblage.
Converging arguments suggest that the algal and fungal members of the
assemblage grew in thimble shaped masses in a shallow, marine environment
which constituted the extended arm of the Animikie sea. Acidic, silicic
material, probably derived from volcanic activity and carried in a finely

divided colloidal state, permeated the interstices of the floral mats, encasing them in micro-crystalline quartz which, upon lithification, became a thin chert layer. It is well established that the micro-forms reported to be present in the material are, in fact, indigenous to the deposit. Further, from biochemical analyses and an ash determination, there can be little doubt that organic matter is present in the chert. In addition, the fact that the floral members of the assemblage absorb Safranin-O stain is strongly suggestive that they are biogenic in nature. Morphology strongly suggests that a variety of faunal members are present. Further work must be done, not only to discover a greater number and variety of micro-organisms in the deposit, but to establish, perhaps with the aid of the petrographic microscope, the nature of the skeletal material present by which possible affinities of the faunal members of the assemblage may be more strongly inferred.

PLATES

I-V


All photographs taken of material in thin section

with transmitted light.

PLATE   I

1-2        Section through spherite-filled cavities showing downward bend
           of mycelial mats on sides of cavities.  See Figure 1 and text
           for discussion of interpretation.
           1,     Edge of cavity meeting mycelial mats;  X  35.
           2,     Bottom of cavity with mycelial mats crossing cavity;  X  35.


3          Spherite with greenalite core surrounded by alternating concentric
           layers of hematite, magnetite, and/or chalcedony;  dehydration-
           contraction crack visible in core;  X  125.

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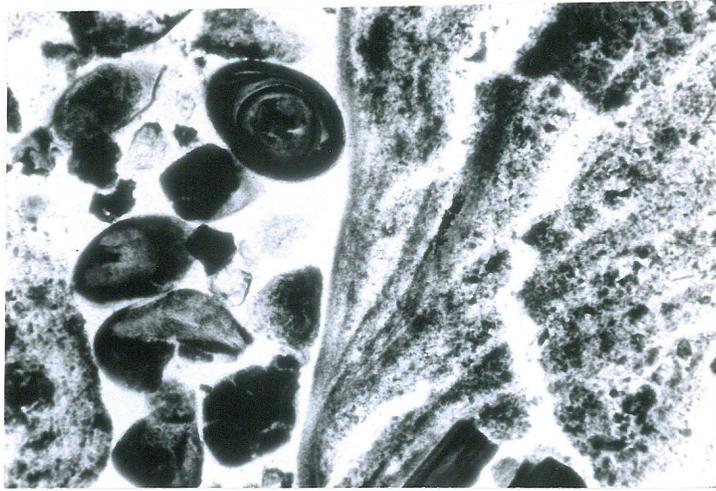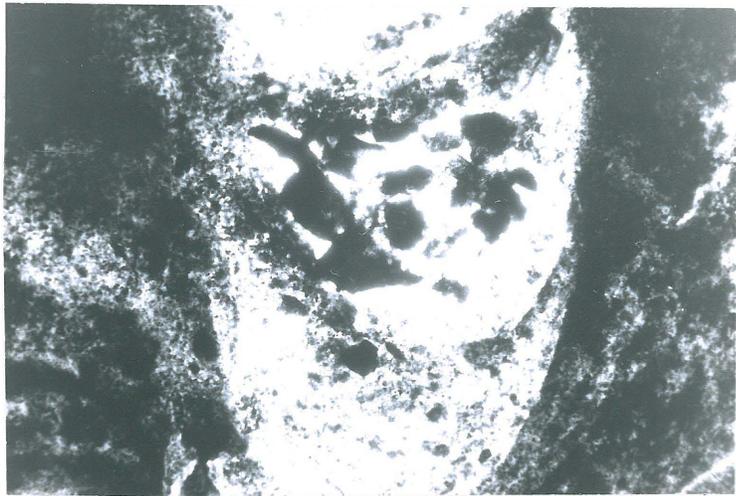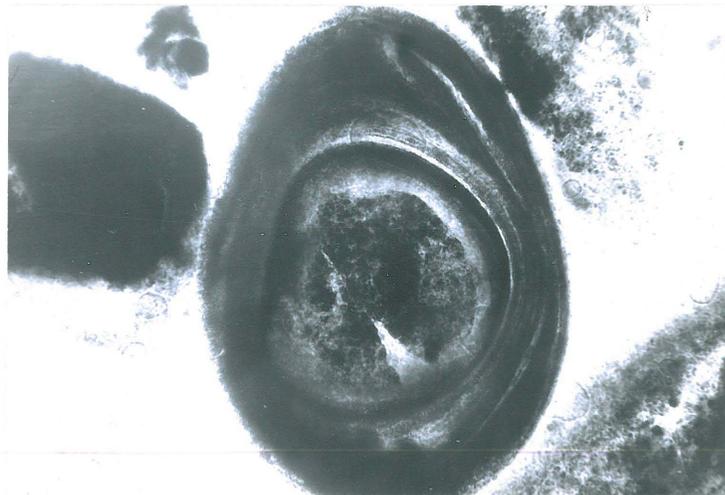
PLATE I

PLATE   II

1-2    General view of floral assemblage; algal, fungal, and spore-
      like bodies visible;  both, X  280.


3     Same as 1 at higher magnification; spore in early stage of germination
      is visible in upper right-hand quadrant;  X  440


4-8    Free, unbranched filaments of algae, devoid of heterocysts and
      spores, thought to be similar to species of the existing genera
      Oscillatoria or Lyngbya.
      4,5  Clumping of material within filament is thought to be
          due to coagulation of humic material;  X  1175.
  PLATE  II (cont.)
      6,7  Same filaments as in 4 shown at lower magnification;
          X  1080.
      8,   Algal filaments are shown;  X  1080.


9-10    Branched, apparently non-septate hyphae of the type bearing small
      sessile laterally attached spores (fungal type "A") thought
      to be similar to certain existing Phycomycetes;  both, X  1080.

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PLATE    II

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PLATE II (cont.)
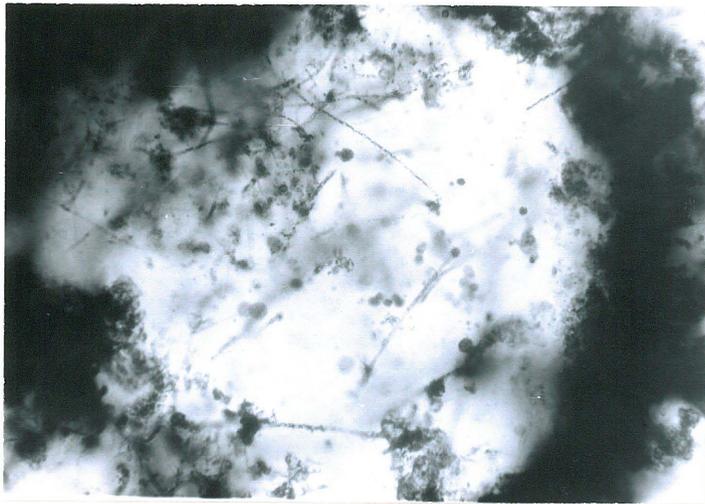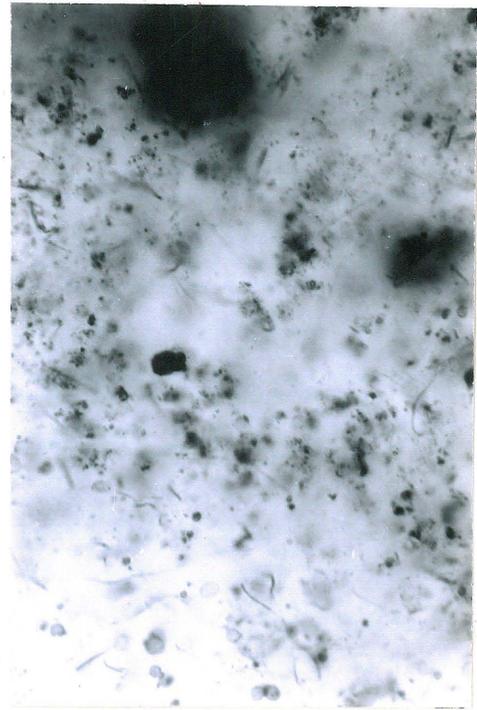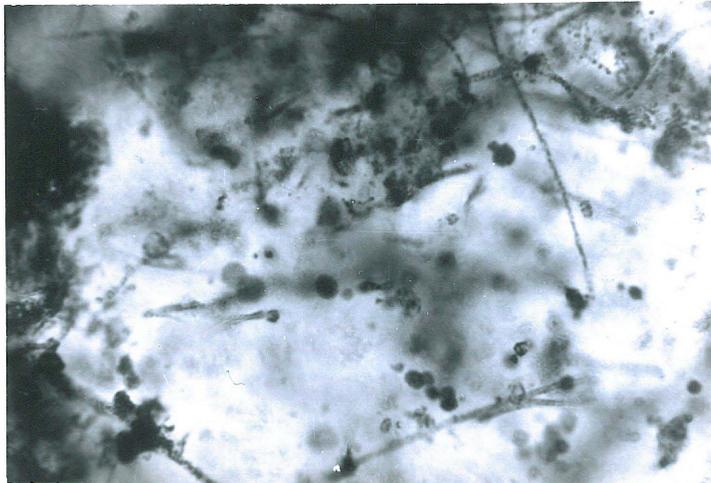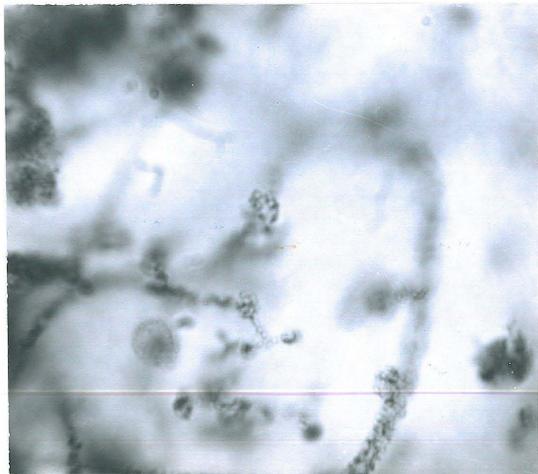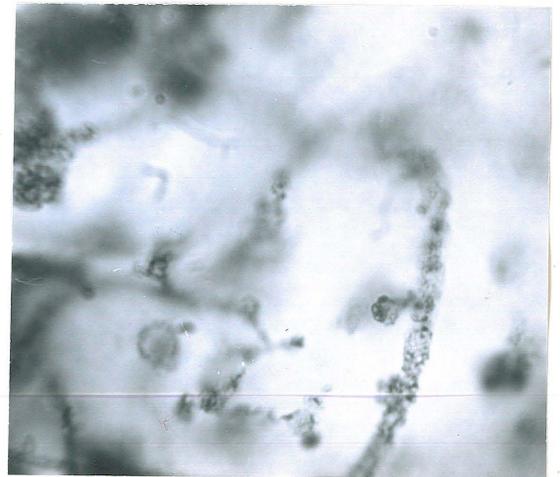
PLATE   III

1-2      Hypha of fungal type "A" with attached sessile spore; vertical
         and horizontal suture(?) lines visible on the reticulate spore;
         both,  X  1080.


3-7      Hypha and laterally attached sessile spore of fungal type "A", and
         hypha and stalked sporangium of fungal type "B".
         3,      Detail of fungal type "B" hypha is shown;  X  1080.
         4,      Reticulate nature of fungal type "B" sporangium is shown;  X 1080.
         5,      Rugose nature of fungal type "B" sporangium and stalk of
                 sporangium are shown;  X  1080.
         6,      Stalk of fungal type "B" sporangium and reticulate nature of
                 fungal type "A" sessile spore are shown;  X 1080.
         7,      Detail of fungal type "B" sporangium stalk and hypha, and
                 reticulate nature of fungal type "A" sessile spore are shown;
                 X 1175.

      PLATE III (cont.)

8-9      New Form.  Stalked sporangium and hypha of fungal type "B".
         8,      Reticulate nature of sporangium is shown;  X  1080.
         9,      Section through sporangium showing cross-section of
                 stalk;  X  1080.


10-13    New Form.  Germinating fungal sporangiospore and hypha.
         10,     Thin hypha and finely reticulate spore are shown;  X  1080.
         11,     Same hypha and spore as pictured in 11 at slightly deeper
                 focus;  X  1080.
         12,     Cross-section through spore showing attachment to thin hypha;
                 X  1080.
         13,     Thicker area of spore (part of mother sporangium?) visible
                 on underside of spore;  X  1080.


14-18    Free, reticulate spore-like body,
         14,     Reticulate nature of ruptures spore-like body is shown; X 1175.
         15,     Cross-section through same body as in 14 is shown;  X  1175.
         16,     Reticulate nature of underside of same body as in 14 is shown;
                 X  1175.
         17,     Same as 14, at lower magnification;  X  1080.
         18.     Same as 16, at lower magnification;  X  1080.

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PLATE III

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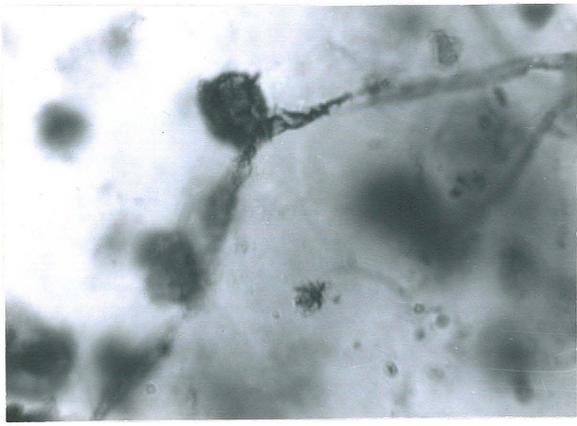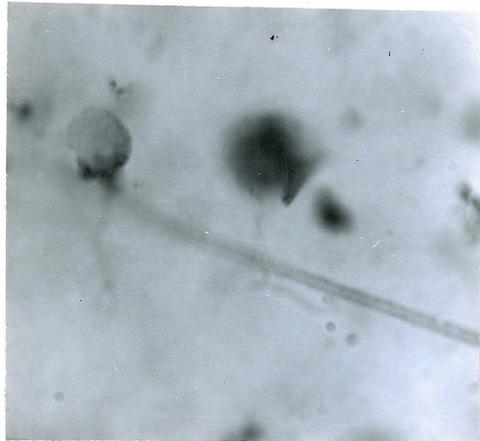


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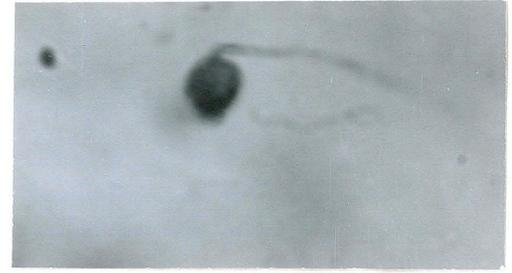


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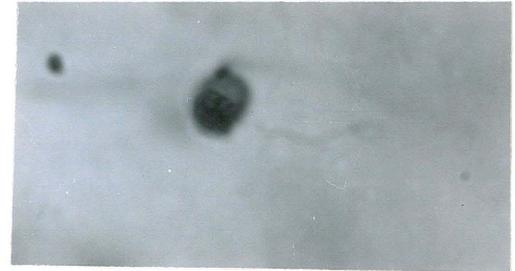


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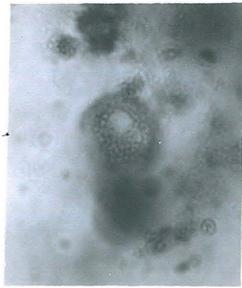


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PLATE   III   (cont.)
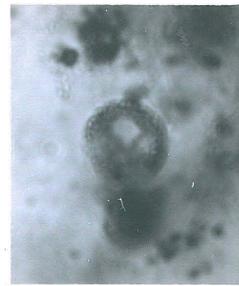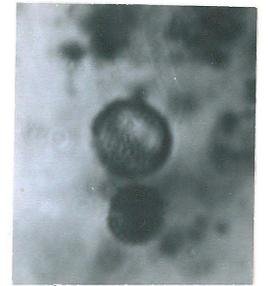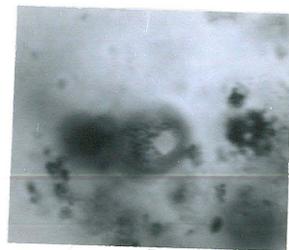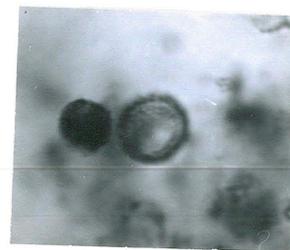
PLATE  IV

1-4    New Form.  Radiolarian (?), Hystrichosphere (?).  Spinous body
       with biradial, pentrametal symmetry.  Note: "filament" which
       appears to be attached to spinous body is an artifact of preparation.
       1,     Spines radiating from body are shown; biradial symmetry is
              suggested;  X  1175.
       2,     Detail of spines radiating from sides of body is shown;
              spines appear to be sheath-enclosed as they leave body;
              X  1175.
       3,     Spines radiating from body are shown;  X  1175.
       4,     Detail of the central area showing projections radiating
              from central ring suggesting pentrametal symmetry; X 1175.


5-14   New Form.  Hystrichosphere (?), Chitinozoan (?).  Spheroidal
       reticulate body with paired projections having knobby or curled
       ends emerging from body through raised openings.
       5,9    Six pairs of projecting spines are visible at varying depths
              on the spheroid; 5 X 1175; 9 X 1080.
       6,10   Segmented projections with knobby ends, one pair of which are
              well curled back from one another, are visible;  6  X  1175;
              10  X  1080.
       11,    Reticulate nature of spheroid is visible on raised opening;
              X  1080.
       7,12   Detail of segmented paired projections with knobby ends is
              shown;  7  X  1175;  12  X  1080.
       8,13,14    Reticulate nature of spheroid is shown;  8  X  1175;
                  13, 14,  X  1080.

    PLATE  IV (cont.)

15-19  Discoaster (?), Coelenterate (?).  See text for defining characteristics.
       Discoidal body with radiating projections connected to organic
       clumped material.
       15,    Discoidal form shown;  X  1175.
       16,    Two radiating projections and connection to organic clumped
              material visible;  X  1175.
       17,18  Same as 16, shown at deeper focal depths;  X  1175.
       19,    Five radiating projections shown;  X  1175.


20-23  Discoaster (?).  Discoidal body with radiating projections.
       20,21  Discoidal form and four poorly defined projections shown;
              both, X  1175.
       22,    Four projections radiating from central area of disc are shown;
              X  1080.
       23,    Four projections radiating from central area and reticulate
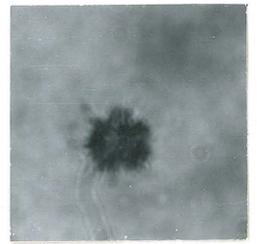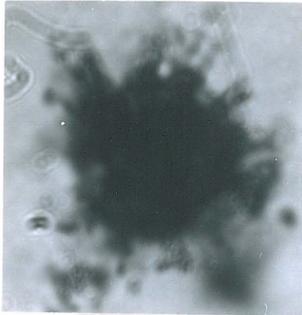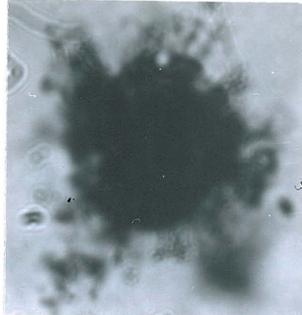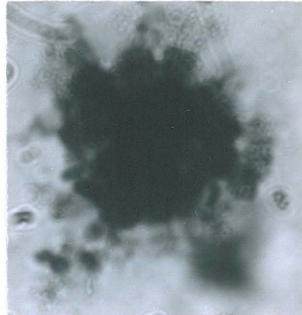              "webbing" between two projections are shown;  X  1080.

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PLATE   IV
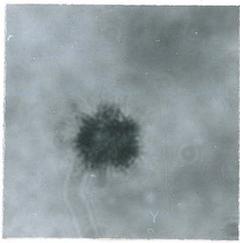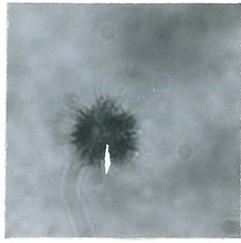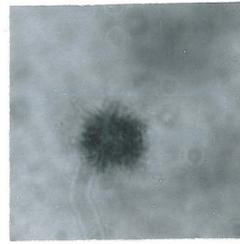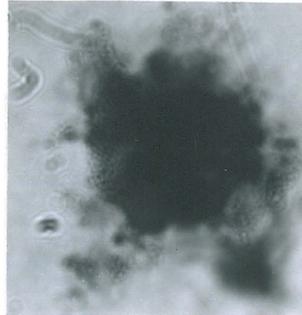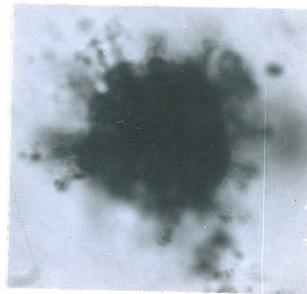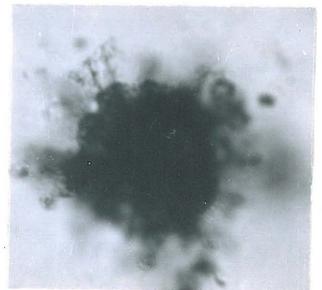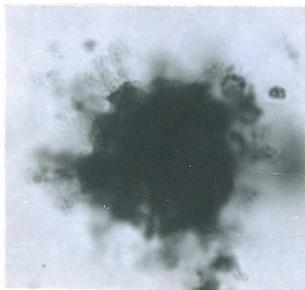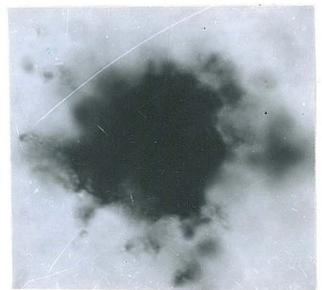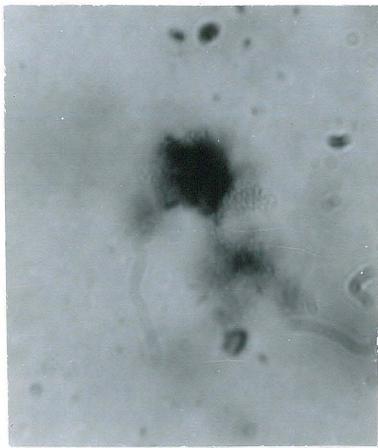
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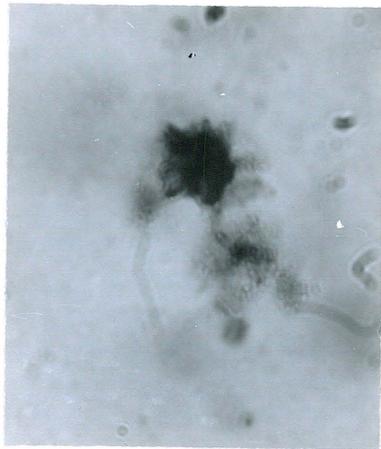
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PLATE IV (cont.)
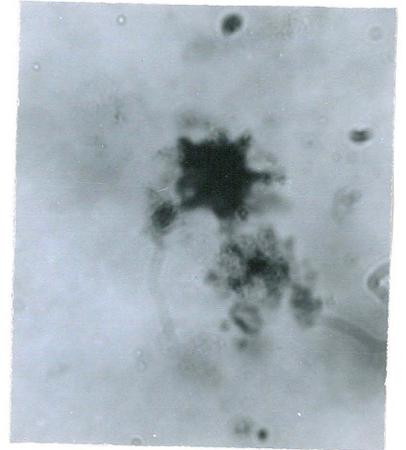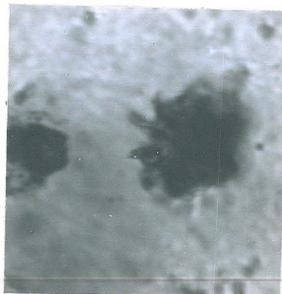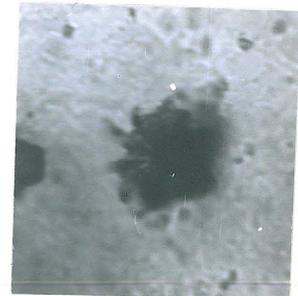
PLATE   V

1-8          New Form.  Radiolarian (?).  Radially symmetrical body with
perforated central sphere, radiating segmented spines and the
suggestion of an outer capsule.
      1,       Radial symmetry is shown;  X  1080.
      2-6,     Perforated central sphere and suggestion of outer capsule
              visible; X  1080.
      7,8     Detail of segmented, radiating spines shown;  X  1080.

9-15         Coelenterate (?).  Reticulate capsule connected by filamentous
strand to membranous body of tetrametal (?) symmetry.  See text
and Figure 2 for discussion of Coelenterate characteristics.
      9,12   Reticulate capsule, connected by filamentous strand to
              membranous body, is shown;  9  X  1175;  12  X  1080.
      10,13   Reticulate nature of capsule is shown;  10  X  1175;  13 X  1080.
      11,14,15    Irregular symmetry of membranous body is shown;
              apparently in digenesis the tetrametal symmetry
              has been destroyed;  11, X  1175;  14,15  X  1080.

16-17       Coelenterate (?).  Reticulate capsule connected by filamentous
strand to membranous body with tetrametal symmetry.
      16,     Reticulate nature of capsule and connection to membranous
              body are shown;  X  1080.
      17,     Tetrametal symmetry of membranous body shown;  X  1080.

PLATE    V (cont.)

18-25       New Form.  "Asteroid"  A morphological group of unknown affinity;
segmented filaments of variable number radiating irregularly from
central structure of undefined morphology.
      18-23, Varying focal depths of the same "asteroid" showing segmented
              irregularly radiating filaments;  18-20, X  1080;  21-23, X 1175.
      24,     "Asteroid" similar to the individual pictured in 18-23;
              segmented nature of the filaments, however, is less clearly
              defined; X  1175.
      25,     "Asteroid" similar to that pictured in 24, but of smaller
              size;  X  1080.

26-27       New Form.  Large clump of humic material of organized but undefined
morphology.
      26,     Undefined morphology shown;  X  1080.
      27,     Organized, reticulate nature of material shown;  X  1175.
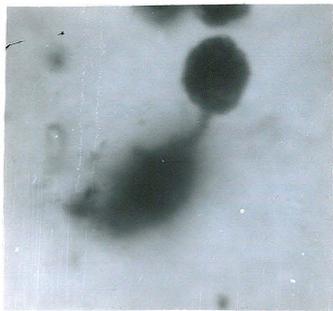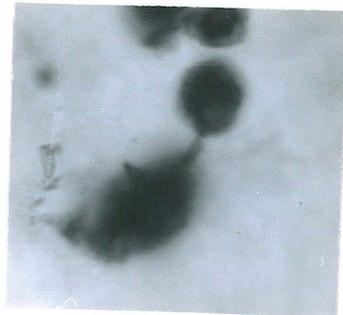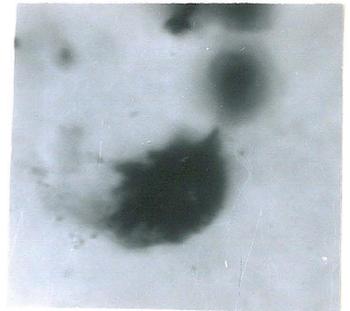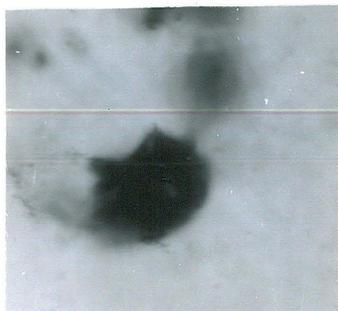
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PLATE    V

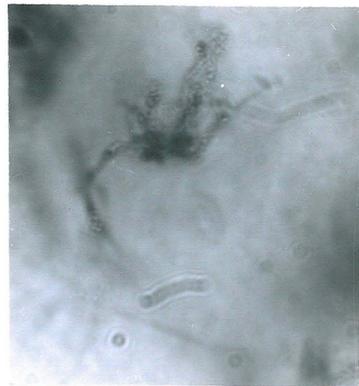18                    19                    20

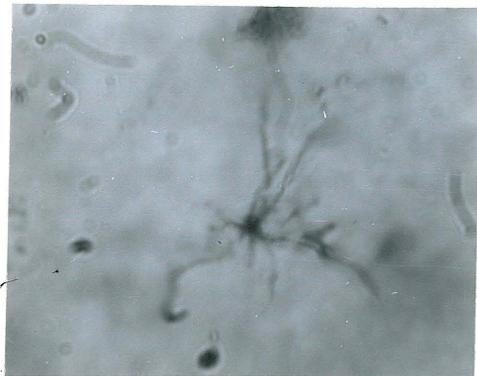21                    22                    23

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PLATE  V (cont.)
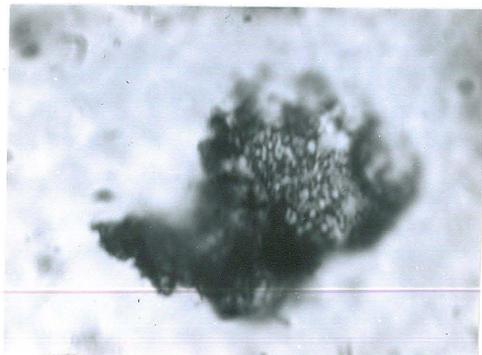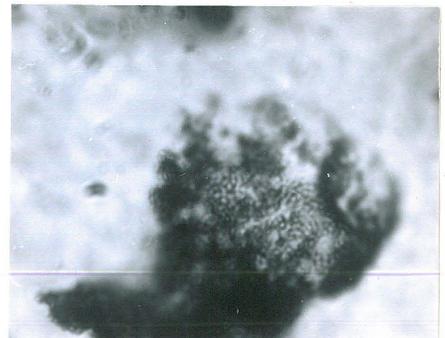
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