ORGANIC REMAINS FROM DHARWAR SEDIMENTS*

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ABSTRACT

Microfossils are recovered from Dharwar-Shimoga Schist belt of the Archaean complex of Mysore State. The fossils are assigned to 13 genera and 21 species of microfossils grouped under Cyanophyceae, Chlorophyceae and Sphaeromorphitae. Unidentifiable organic plates perhaps of animal origin are also recorded. A detailed comparison with the available Precambrian records in the literature is made. It is concluded that the Dharwar microbiota is more advanced than the Early Pre-cambrian and more primitive than the Late Precambrian microbiota. Thus a Middle Precambrian to Early Late Precambrian age is assigned.

INTRODUCTION

THE Archaean complex of South India embraces geologic formations of diverse types and is one of the most important complex stratigraphic entities. Being economically important, it has formed the subject of study by numerous workers for well over a hundred years, yet the stratigraphic sequence, the *inter-se* relationship, in space and time, of the various constituent units and their structural framework have been a subject of much speculation and protracted controversy.

The finding of an interesting assemblage of microfossils from the Dharwar-Shimoga schist belt by Venkatachala & Rawat was reported in the O.N.G.C. Reporter (*Anon.* 1971). The present paper summarizes the results of these studies.

SAMPLE LOCALITIES

A number of samples were collected from Dharwar outcrops marked in Fig. 1 and processed for their fossil contents; all of them come from what is known as the Dharwar-Shimoga band of Bruce Foote (1888) or the West Central Group of Rama Rao (1936).

GEOLOGY

The Dharwar sequence has been subdivided by Rama Rao (1936) into a Lower igneous division and the mainly sedimentary Middle and Upper divisions. Nautiyal (1967), on the other hand, has proposed a different classification in which there is a lower Dharwar metasedimentary and metavolcanic division and the mainly metasedimentary Middle and Upper Dharwar divisions all of which, he contends, have been thrust over the Archaeans.

The authors have not tried to go into the relative merits of these and earlier stratigraphic classifications but rest content with stating that their samples come from the Dharwar without indicating the localities. They would, however, like to point out that the samples analysed are from two different localities (near Dharwar city and near Chikmagalur) but that these are from the same Schist belt (hitherto generally regarded as stratigraphic equivalents). The samples belong to widely differing lithologic types (viz., clays/shales of Dharwar area and Schists of Chikmagalur area). This could perhaps be due to the fact that in a regional sense the metamorphism of the Dharwar rocks increases south and southeast within Mysore State, starting from the type area around Dharwar City (Rama Rao, 1936; Pichamuthu, 1962). It seems to the authors that the samples from the vicinity of Dharwar city are younger than those from the Chikmagalur area especially in view of the fact that the Schist belt is the remnant of a great anticlinorium plunging NNW (Pichamuthu, 1962).

A long standing controversy centred round whether the Dharwar Schists and some of the associated rocks were crystalline or sedimentary. Early workers like Bruce Foote (1888) made the important observation that the Dharwars were the remains of a 'great sedimentary series' and that these were different from the surrounding and possibly older gnessic formation. Later systematic work by the Mysore Geological Department during the first two decades of the present century led its head, W. F. Smeeth, and his coworkers (with few ex-

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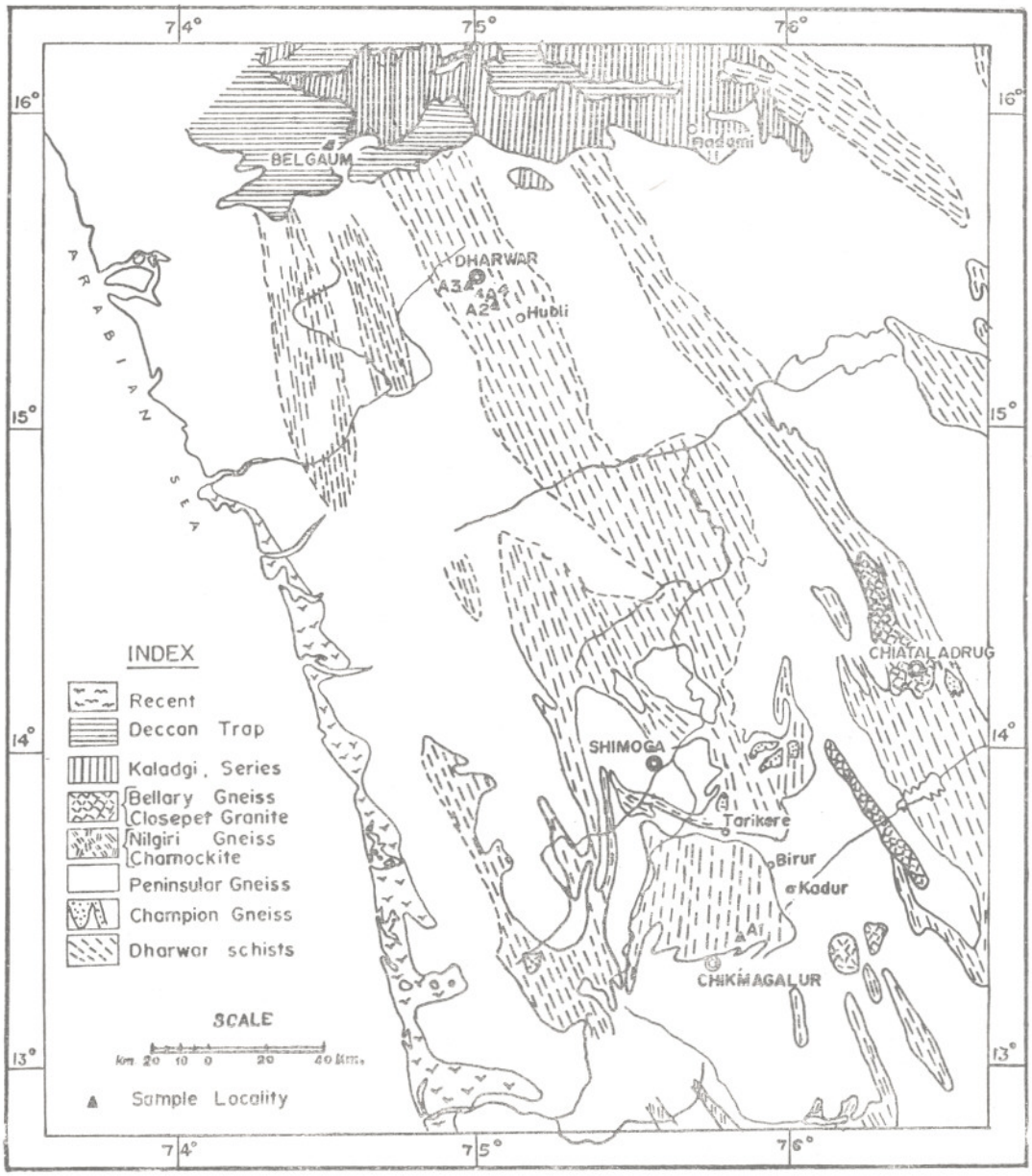

TEXT-FIG. 1 — Geological map of Dharwar schist belt and adjoining areas

ceptions) to the view that Dharwar Schists were the oldest formations in Mysore and that some of the apparently sedimentary rock types were of non-sedimentary origin. Still later, however, by the middle 1930's the official view of the Mysore Geological Deptt. veered (albeit haltingly) towards a truly sedimentary origin for the conglomerates, quartzites, shales and limestones which form such a large part of the Dharwar sequence. The sedimentary origin of the greater part of the Dharwars came to be

well established after the writings of Rama Rao (1936) and Pichamuthu (1947).

It, therefore, follows that earlier an obsession with the igneous/metamorphic nature of the Dharwars and later perhaps with their great antiquity did not constitute an incentive to fossil hunters. This was unfortunate, especially in view of some very significant comments of Pichamuthu (1947) concerning the occurrence in the Dharwars of graphite schists, true limestones (associated with current bedded quartzites), banded ferruginous quartzites — all pointing towards possibility of life during the Dharwar times — and lastly those concerning the occurrence of algal structures (? *Haplosiphon*) in some cherts of the Chitaldrug schist belt. Gowda and Sreenivasa (1969) reported fossil Acritarchs from the Guddadaranganahalli Formation of the Chitaldrug Schist belt.

Crawford (1969) gives the radiometric ages of some of the lavas in the Chitaldrug Schist belt as 2345 ± 60 m.y. This is very close to the age reported by Holmes (1955) for a galena from the same area (2450 ± 120 m.y.). No radiometric age from the Dharwar-Shimoga schist belt has so far been reported.

SYSTEMATIC DESCRIPTION OF FOSSILS

In the present study, 12 genera and 20 species of microfossils are recognized and described. 2 genera and 14 species are newly proposed. Detailed descriptive analysis and differential diagnosis are given to exemplify the new taxa.

Group — *Acritarcha* Evitt, 1963
Sub-group — *Leiosphaeritae* Eisenack, 1954

(Leiosphaeridae Eisenack, 1954) (Sphaeromorphitae Downie, Evitt & Sarjeant, 1963)

General Remarks — Downie & Sarjeant (1963) in a critical review of the smooth walled and ornate vesicles classed under leiospheres, have expressed an opinion " that *Protoleiosphaeridium* should be treated as a synonym of *Leiosphaeridia* and rejected, and that its species should be reattributed to the later genus ". Staplin *et al.* (1965) in a subsequent study discuss this point at length and retain *Protoleiosphaeridium sensu* Timofeev (1959 & 1960). The genus was validated by Timofeev (1960) by designation of *P. coglutinatum* as the type species. The vesicles referred to here to *Protoleiosphaeridium* distinguish from *Leiosphaeridia* in possessing a firm wall, smaller size (up to 30 μ) and ornamentation.

The views expressed by Staplin *et al.* (*l.c.*) to retain this genus is considered practicable in the study of very ancient leiospheres where additional characters are not developed which can form a basis for differentiation into different groups or genera. Size is, thus the only criterion which can help classify these fossils. The authors are of the opinion that vesicle ornamentation also should be used in generic distinction. It will be worth the while to re-examine the other genera proposed by Timofeev (1959). *Vavosphaeridium, Orycmatosphaeridium, Lophosphaeridium* and *Trachysphaeridium* may be useful groupings in the study of Precambrian-Cambrian fossils. A re-examination of types of all these genera is necessary. As suggested by Downie & Sarjeant (1963), the " other genera *Zonosphaeridium* (thick walls), *Trematosphaeridium* (Perforate test) and *Symplassosphaeridium* (Clusters of vesicles) seem either to be products of accidents of preservation or to be quite different kinds of structure from the typical leiospheres. . . . ". In the Dharwar sediments various types of preservations are present and all the above genera can be recognized in one group of fossil vesicles. The following groupings are recognized in this study:

1. Vesicle smooth walled, faint or no ornamentation, wall thickness 1-2 μ, not firm, often folded, 18-60 μ: *Leiosphaeridia* (Timofeev, 1959, 1960; Eisenack, 1958); Downie & Sarjeant, 1963.
2. Vesicle smooth walled, ornamentation scanty, wall up to 2 μ thick, firm, not folded, less than 25 μ: *Protoleiosphaeridium* (Timofeev, 1959, 1960).
3. Vesicle granulose, grana closely spaced, wall up to 2 μ thick, firm, folds rare, 25-30 μ: *Granomarginata* (Naumova, 1961).
4. Vesicle conate, coni distinct, wall firm up to 2 μ thick, 25 μ: *Lophosphaeridium* (Timofeev, 1959).

Hizhnyakov and Shepeleva (1964) have described comparable sphaeromorphs under *Asperatopsophaera, Leiopsophosphaera, Acanthopsophosphaera* and *Brochopsophosphaera.* These genera have to be reexamined from nomenclatural point of view and compared

with generic names already in use and valid according to the International Code of Botanical Nomenclature.

***Leiosphaeridia* (Eisenack, 1958) Downie & Sarjeant, 1963**

Syn. — *Leiosphaeridium* Timofeev, 1959
Leiosphaeridium Timofeev, 1959 ex Staplin, 1961

Type species — *Leiosphaeridia baltica* Eisenack, 1958.

Leiosphaeridia raoi sp. nov.

Pl. 1, figs. 1, 2

Holotype — Pl. 1, fig. 2.

Type locality — Dharwar exposures near Dharwar city.

Derivation of name — Named after Late Prof. B. Rama Rao who pioneered the idea of the sedimentary nature of the Dharwars.

Description — Vesicles spherical, often folded, 40-60 μ, without pylome, wall smooth, firm, up to 2 μ thick.

Comparison — *L. baltica* Eisenack (1958) is from the Silurian rocks and has a faint ornamentation. *L. pellucida* Salujha *et al.* (1971) is smaller in size and according to the authors is punctate. *L. tenella* Salujha *et al.* (*l.c.*) is also small, up to 22 μ and is granulose. The specimens recorded here from the Dharwar sediments are smooth spheres without any recognizable pylome.

Remarks — Specimen figured in Pl. 1, Fig. 1 is corroded and hence appears granulose in the photograph; the areas which are clear show the smooth exine.

Leiopsophosphaera spp. described by Hizhnyakov and Shepeleva (1964) are closest in comparison to the fossils recorded here. *Leiosphaeridia* is a valid genus and widely used and as such is used in this study.

Leiosphaeridia aglutinata sp. nov.

Pl. 1, figs. 3, 9, 10, 12, 16 & 23

Holotype — Pl. 1, fig. 3.

Description — Vesicle spheroidal, 35-45 μ, holotype 45 μ. Wall thin, folded variously, smooth.

Remarks — Granulose organic debris collects in and around the vesicles giving an ornamented appearance. Similar agglutinated fine organic debris perhaps mixed with mineral particles are also found in several vesicles attributed to this species as well as in the filaments (Pl. 2, figs. 42, 43 & 44) described elsewhere in this report. It is also observed in vesicles described as *L. dharwariana* (Pl. 1, figs. 7, 8, 11 & 15). It is probable that ornamented vesicles attributed to *Granomarginata* by several authors may also belong to this group of thin walled *Leiosphaeridia*.

Comparison — *Leiosphaeridia pellucida* (Salujha *et al.*, 1971) have a thicker vesicle wall and according to the authors are punctate. The punctation is also an artifact and the vesicles are smooth walled. *L. tenella* (Salujha *et al.*, 1971) are smaller in size. The other species recorded are all characterized by thicker vesicle walls and do not give a granulose appearance due to agglutination of organic and mineral debris.

L. Raoi described in this study has a thick firm wall and hence distinguished from this species.

Leiosphaeridia dharwariana sp. nov.

Pl. 1, figs. 7, 8, 11 & 15

Holotype — Pl. 1, fig. 11.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Vesicle spherical, folded, 18-25 μ; holotype 18 μ. Pylome not present, wall less than 1 μ thick, often folded.

Remarks — Agglutinated organic debris in the vesicles and surrounding them are commonly seen (see also remarks of *L. aglutinata*).

Comparison — Both *L. Raoi* and *L. aglutinata* are larger in size. *L. aglutinata* is comparable in the nature of the vesicle wall.

***Protoleiosphaeridium* Timofeev (1959) 1960**

Type species — *Protoleiosphaeridium conglutinatum* Timofeev, 1959.

Protoleiosphaeridium problematicum sp. nov.

Pl. 1, fig. 5 & 6

Holotype — Pl. 1, fig. 6.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description— Vesicles spherical, ellipsoidal, bean shaped or acquiring any other shape due to fusion of two or more vesicles. Each vesicle 15-30 μ; wall up to 2 μ thick, smooth or faintly granulose.

Comparison & Remarks — *Protoleiosphaeridium* as designated by Timofeev (*l.c.*) as well as those described by Staplin *et al.* (*l.c.*) are spheroidal vesicles with smooth or granulose ornamented walls. Combaz (1967) in an extensive review and study of the leiospheres has illustrated and described a number of forms with two or more vesicles joined together from the Lower Cambrian of Australia, Wenlockien and Ludlowien of Libya. The Dharwar specimens are very closely comparable to those figured by Combaz (*l.c.*).

Acanthodiacrodium angustum (Downie) Defl. & Defl.-Reg., 1962; Combaz, 1967 described by Combaz (*l.c.*) from the Tremadocien of the Hassi-Messaoud in Africa has a superficial resemblance to *Protoleiosphaeridium problematicum* described here. The genera included under *Trachydiacrodidae*, a family proposed by Deflandre and Deflandre, Rigaud (1962) are bipolar with ornamentation restricted to the polar zones. Some types of vesicles included under this group may have a globular or ellipsoidal outline. The comparison with these is also superficial.

Schopf (1968) and Schopf and Barghoorn (1969) have illustrated and described a number of chroococcalean algae which are comparable to the Dharwar specimens described here. *Sphaerophycus* Schopf (*l.c.*) is small, the unicells are only up to 3·6 μ and the cells enclosed in a sheath. The specimens illustrated by Schopf are distinguishing and do not need any explanation. *Myxococcoides* Schopf (1968) are reticulate, unicells or colonies.

In view of the above discussion, it is difficult to ascertain if the specimens figured here are chroococcalean unicells which have lost the sheath or sphaeromorphs belonging to *Protoleiosphaeridium* comparable to the ones described by Combaz (*l.c.*). The specimen figured here as well as the others studied from the Dharwars do not show any sheath and as such are described under *Protoleiosphaeridium.*

Protoleiosphaeridium sp.

Pl. 1, figs. 4

Description — Vesicle folded, appear to be spheroidal, 28 μ; wall firm less than 2 μ thick, smooth. Germinal aperture not present.

Granomarginata Naumova, 1961

Type species— *Granomarginata prima* Naumova, 1961.

Granomarginata clara sp. nov.

Pl. 1, fig. 14

Holotype — Pl. 1, fig. 14.

Type locality — 8 miles short of Dharwar.

Description — Vesicle spherical, 27 μ; wall up to 2 μ thick, granulose, grana less than 1 μ wide and closely set, discernible in the equatorial outline.

Comparison — *Granomarginata clara* is distinguished by true grana as opposed to the organic agglutination observed in many species of *Leiosphaeridia* described here. *G. primitiva* Salujha *et al.*, is smaller in size.

Lophosphaeridium Timofeev, 1959

Type species — *Lophosphaeridium rarum* Timofeev, 1959.

Lophosphaeridium conatum sp. nov.

Pl. 2, figs. 36 & 40

Holotype — Pl. 1, fig. 40.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Vesicle spherical, 10-12 μ, holotype 10 μ, wall thick occasionally folded, beset with sharp tipped up to 1 μ long coni.

Comparison — The specimens ascribed to this genus by Salujha *et al.* (1971), show a thicker wall and closely set ornamentation.

Lophosphaeridium sp.

Pl. 2, fig. 30

Description — Vesicles spherical, 22 μ; wall thick beset with sharp tipped coni, coni less than 1 μ wide.

Comparison — This species differentiates from the ones described by Salujha *et al.* (*l.c.*) in a sparse ornamentation.

Rugocystis Gen.Nov.

Type species — *Rugocystis velaris* sp. nov.

Description — Spherical vesicles or unicells, wall rugose, with branching, anastomosing or free muri, covered by an outer

organic sheath. Sheath hyaline, smooth to granulose.

Comparison — *Globophycus* (Schopf, 1968) is much smaller in size and not as prominently ornamented as the cells of *Rugocystis*.

Rugocystis velaris sp. nov.

Pl. 2, figs. 24-27 & 37

Holotype — Pl. 2, fig. 27.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Spheroidal unicells or vesicles, 50-60 μ. Wall with distinct muri, muri low, anastomosing or free, rarely forming meshes, sheath hyaline membranous, smooth-granulose.

Remarks — Pl. 2, fig. 26 illustrates a specimen which is partially broken, showing the irregular muri. Pl. 2, fig. 25 is a overmacerated specimen showing coarse surface structure and the hyaline sheath partially attached to the body.

Trachysphaeridium Timofeev, 1959

Type species —*Trachysphaeridium patellare* Timofeev, 1959.

Trachysphaeridium decorum sp. nov.

Pl. 2, fig. 29

Holotype — Pl. 2, fig. 29.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Vesicle spheroidal, 11 μ. Wall up to 1 μ thick, granulose, grana uniformly distributed, closely set forming a network in lower focii. Pylome present.

Comparison — *Trachysphaeridium* sp. 2 illustrated by Combaz (1967) is closely comparable.

Trachysphaeridium sp.

Pl. 2, figs. 31 & 41

Description — Vesicles spherical, 15-18 μ, thick walled, up to 2 μ thick, granulose, grana closely set. Pylome circular up to 2 μ wide.

Comparison — *T. decorum* is smaller in size and has a coarse ornamentation.

Sub-group — *Herkomorphitae* Downie ,Evitt & Sarjeant, 1963

***Concentrites* gen nov**

Type species — *Concentrites muricatus* sp. nov.

Description — Vesicles spheroidal, wall thick, ornamented with concentric muri.

Concentrites muricatus sp. nov.

Pl. 2, figs. 32 & 33

Holotype — Pl. 2, fig. 33.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Spheroidal, 25-30 μ. Wall up to 2 μ thick, ornamented with concentric ridges and furrows.

Comparison & remarks — *Chemotriletes* described by Naumova (1953) and other specimen referred to this genus by Staplin (1961) are comparable. As no trilete or any other haplotypic mark is observable on the specimens they are considered as algal cysts.

Sub-group — *Leiofusidae* Eisenack, 1938 (*Netromorphitae* Downie, Evitt & Sarjeant, 1963).

***Navifusa* Combaz 1967**

Type species — *Navifusa navis* (Eisenack, 1938) Combaz, 1967.

Navifusa purana sp. nov.

Pl. 1, fig. 22

Holotype — Pl. 1, fig. 22.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Ellipsoidal, up to 70 μ long and 20 μ broad, elongated, wall thin, faintly granulose, grana fine, less than 0·5 μ broad, aligned longitudinally giving a pseudo-striate surface pattern in lower focii.

Comparison— *Quisquilites* Wilson & Urban (1963) described from the Devonian of Oklahoma, USA, are bean shaped, oval with a hyaline wall and are larger in size. The other species of *Navifusa* listed by Combaz (*l.c.*) are not comparable. The species described here distinguishes in possessing characteristic granulose ornamentation.

ALGAE

CYANOPHYTA

Class — CYANOPHYCEAE
Order — CHROOCOCCALES
Family — CHROOCOCCACEAE Naegeli, 1849
Genus — MYXOCOCCOIDES Schopf, 1968

Type species— Myxococcoides minor Schopf, 1968.

Myxococcoides indicus sp. nov.

Pl. 1, figs. 17, 18 & 19

Holotype — Pl. 1, fig. 17.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Ellipsoidal colonies containing few to 40 cells may be more in larger colonies, the number of cells depending on the size of the colony. Cells, circular, oblong or angular due to close approximation of neighbouring cells, 7-10 μ wide, cell walls thin. The colony enveloped by a sheath. Sheath not ornamented appearing granulose due to agglutination of organic mineral debris.

Comparison — *M. minor* Schopf (*l.c.*) is closely comparable to the present species, but differs in possessing a thicker sheath as compared to the thin filmy sheath in *M. indicus*. *M. reticulata* Schopf (1968) has loosely arranged cells and punctate to reticulate ornamentation. *M. inornata* Schopf (1968) has larger cells measuring up to 18 μ. Thus both these species are not comparable.

Myxococcoides elongatus sp. nov.

Pl. 2, figs. 34 & 39

Holotype — Pl. 2, fig. 34.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description— Cells spheroidal, or acquiring derived shapes due to compression, aggregated in a linear filamentous fashion, 4-5 cells observed. Individual cells covered in a granulose amorphous organic matrix, agglutinated with organic debris.

Comparison — The specimens, figured and included here show a filamentous habit. This may be due to chance approximation of a number of cells. *M. inornata* is comparable in characters of the cell as well as the organic cover but has larger individual cells.

?*Myxococcoides* sp.

Pl. 2, fig. 38

Description — 3 celled specimen, cells spheroidal, 18-22×22-26 μ. Wall smooth. Sheath thin and opaque.

Comparison — This fossil cannot be compared with *Myxococcoides* recorded by Schopf (*l.c.*) as well as from Dharwars.

***Palaeoanacystis* Schopf, 1968**

Type species — *Palaeoanacystis vulgaris* Schopf, 1968.

Palaeoanacystis puratanum sp. nov.

Pl. 2, fig. 28

Holotype — Pl. 2, fig. 28.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Colonial, cells spheroidal to elliptical angular or derived shapes due to approximation of individual cells, 4-5 μ-6-8 μ. Cell wall less than 1 μ thick, smooth. Individual sheaths not present, entire colony of nearly 100-200 cells encompassed by organic matrix.

Comparison — *P. vulgaris* lacks well pronounced organic sheath as in *P. puratanum* described here.

Phylum — CHLOROPHYTA
Class — CHLOROPHYCEAE
Order — (?) CHLOROCOCCALES

***Glenobotrydion* Schopf, 1968**

Type species — *Glenobotrydion aenigmatis* Schopf, 1968.

cf. *Glenobotrydion* sp. 1

Pl. 1, fig. 20

Description — Cells spherical (spheroidal), longish oval (ellipsoidal). Wall thick up to 1 μ, in groups of 3-4 appearing pseudofilamentous. Individual cells 15 μ broad and up to 17 μ long. Sheath of organic matrix not observed.

Comparison — *G. aenigmatis* described by Schopf (1968) is a colony of large number of circular cells and is distinctly different. Not many specimens have been studied/ recovered by us and as such are compared with *Glenobotrydion* only.

cf. *Glenobotrydion* sp. 2

Pl. 1, fig. 21

Description— Spheroidal unicell, 21×19 μ. Wall thick, distinct, fairly ornamented.

Comparison — This specimen is comparable to a single cell of *G.* sp. 1.

Globophycus Schopf, 1968

Type species — *Globophycus rugosum* Schopf, 1968.

Globophycus circularis sp. nov.

Pl. 1, fig. 13

Holotype — Pl. 1, fig. 13.

Type locality— Dharwar exposures, 8 miles short of Dharwar city.

Description — Spheroidal, 25-30 μ. Wall covered by sheath. Sheath folded closely giving a pseudoreticulate appearance, agglutination of organic debris common.

Comparison — *G. rugosum* has a larger sheath.

TRILETE SPORE

Spore Type

Pl. 2, fig. 35

Occurrence — Dharwar exposures, 3½ miles from Dharwar city on the Halyal road.

Description — ? spore roundly triangular, 13 μ. Wall up to 1 μ thick, apiculate, apiculae closely spaced, rounded, less than 1 μ long and as wide. A faint trilete mark observed, arms reaching 2/3 radius. Y-rays not open.

Remarks — The mark observed is very faint and may represent only a tetragonal compression mark. The specimen is distinct and may represent a spore of a land plant. The occurrence of a tetrad scar, though not functional points out to their adherence in tetrads, thus leaving a tetrad scar. Only one specimen has so far been recorded.

Incertae Sedis

Algal filament type 1

Pl. 2, figs. 42 & 43

Description — Filament cylindrical, 8-10 μ in diameter, unbranched, non-septate appearing granulose due to agglutination of organic debris.

Comparison— *Siphonophycus* Schopf (1968) has capitate apices. The specimens studied by us are small, tubular filaments with a hoisted apices.

Algal filament type 2

Pl. 2, fig. 44

Description — Filamentous specimen, broken; filament long, cylindrical, about 7-9 μ in diam., probably non-septate, branched. Wall thin, ill-defined, about 0·5 μ.

Organic Plates

Type — 1

Pl. 2, fig. 45

Description — Fragmentary, elongated plate with simple, alternately arranged, circular to lenticular, perforations, 2-4 μ in diam.

FOSSIL ASSEMBLAGE

The assemblage consists of a rich variety of fossils grouped under cyanophyceae, chlorophyceae and sphaeromorphitae. The cyanophycean and chlorophycean algal remains are mostly unicellular with a well preserved sheath enclosing the unicell. Several sphaeromorphs are present in the assemblage, the most dominant of them are those classed under *Leiosphaeridia*. Other vesicles include *Protoleiosphaeridium, Granomarginata, Lophosphaeridium, Concentrites* and *Trachysphaeridium*. The sphaeromorphs do not show any distinct characters on the basis of which the forms can be classified. Ornamentation and size are used in differentiating different genera. The cyanophycean algal fossils are mostly unicellular or colonial chroococcalean forms and no distinct filamentous form has been recovered. *Palaeo-*

TABLE 1

Sample studied	Lithology, locality & other details
A_1	Greyish green Schist, 13 k.m. from Chikmagalur on the Chikmagalur-Kadur road.
A_2 (3 samples)	Red ferruginous sandstone overlain by fissile, soft; red shale 8 miles short of Dharwar on the Habli-Dharwar road.
A_3 (5 samples)	Buff, purple, reddish-brown and white shale, at times sandy; 5.5 k.m. from Dharwar on the Dharwar-Halyal road (a quarry about 100 m. west of the road).
A_4 (4 samples)	Dark grey, fine-grained, hard greywacke with dark grey shales which weather buff on surface; shales are fissile; 2 k.m. from Dharwar on Dharwar Kalgatki road (near building stone quarry).

anacystis, *Myxococcoides* are common in the assemblage.

Glenobotrydion & Globophycus both genera erected by Schopf (1968) and classed under chlorophyceae (? Chlorocoaccales) are common in the assemblage. The assemblage is mostly characterized by these algal remains and sphaeromorphs. The sphaeromorphs may represent cysts or reproductive bodies of fossil algae or may themselves be algal bodies. No conclusion is drawn or differentiations made except on external morphology.

A spore-like form is recovered from the Dharwar sediments, exposed near Dharwar city on the Halyal road. This triangular fossil bears a faint triradiate mark. The affinity or relationship of this fossil is not known (see discussion in Syst. Palynology).

A number of organic plates (perhaps of animal origin) are also found.

DISCUSSION

Early Precambrian microbiota recorded from the Onverwacht Series (>3200 m.y.), Fig Tree Formation (3200 m.y.) of Swaziland system near Barberton, South Africa (Engel *et al.*, 1968; Barghoorn & Schopf, 1966; Schopf & Barghoorn, 1966, 1967; Pflug 1966, 1967) and Soudan Iron Formation (2800 m.y.) of Minnesota (Grunner, 1925; Clound & Licari, 1968) comprises unicellular, spheroidal algal microfossils

TABLE 2 — DISTRIBUTION OF FOSSILS IN THE DIFFERENT SAMPLES STUDIED

Fossil	Sample Nos.			
	A-1	A-2	A-3	A-4
Sphaeromorphitae				
Leiosphaeridia	+	+	+	+
Protoleiosphaeridium	+	+	+	+
Granomarginata		+	+	
Lophosphaeridium		+	+	
Trachysphaeridium		+		+
Concentrites		+		
Rugocystis		+		
Navifusa			+	
Cyanophyceae (Chroococcales)				
Palaeocanacystis		+		
Myxococcoides		+		
Chlorophyceae (Chlorococcales ?)				
Glenobotrydion		+		
Globophycus		+		
Spore type			+	
Algal Filaments		+	+	
Indeterminable organic matter	+	+	+	+

(*Archaeosphaeroids barbertonensis*) similar to modern blue green algae (Chroococcales), globular bodies resembling cysts of flagellates, filamentous forms assigned to nostocalean blue-green algae and organically preserved bacterium-like rod-shaped microfossils (*Eobacterium isolatum*) of eubacterial affinity along with larger remnants of partially organized organic matter.

Early Precambrian biota as recorded above are not comparable with Dharwar assemblage. The Dharwar assemblage contains morphologically complex algal unicells (*Globophycus, Glenobotrydion*) of Chlorococcales and colonial forms (*Palaeoanacystis, Myxococcoides*) of chroococcalean affinity.

The Gunflint (2000 m.y.) and Lower Belcher (1700 m.y.) assemblages comprise the best documented Middle Precambrian microbiota. The microbiota is predominantly composed of filamentous and spheroidal procaryotic microorganisms referable to cyanophycean families (Chroococcaceae, Oscillatoriaceae, Nostocaceae) and a variety of chemosynthetic bacteria (Barghoorn & Tyler, 1963, 1965; Cloud, 1965; Cloud & Hagen, 1965; Schopf *et al.*, 1965; Hofmann & Jackson, 1969). The Dharwar assemblage consists of a rich variety of fossils grouped under Cyanophyceae, Chlorophyceae and Sphaeromorphitae. The cyanophycean algal fossils are mostly unicellular or colonial chroococcalean forms and very few ill-defined filamentous forms have been recorded.

Although the Middle Precambrian and Dharwar assemblages are characterized by the abundance of photosynthetic procaryotic plants of cyanophycean affinity, the comparison between well documented Middle Precambrian and Dharwar biotas appears to be difficult at this stage of our knowledge of the Dharwar biota.

Structurally and organically well-preserved microorganisms have been discovered and described in many Late Precambrian sedimentary units of Central, Northern and Southern Australia, Montana, Michigan, South California, Poland and China. The best preserved and diverse assemblage is recorded from the Black Cherts of the Bitter Spring Formation of Central Australia, dated as approximately 1000 m.y. in age (Barghoorn & Schopf, 1965; Schopf, 1968, 1970) and offers some comparison with the Dharwar microfloral assemblage in having the following common constituents. The common constituent genera are: *Palaeoanacystis, Myxococcoides* (Chroococcaceae); *Glenobotrydion, Globophycus* (Chlorococcales).

The Bitter Spring microbiota contains well-preserved procaryotic filamentous (Oscillatoriaceae, Nostocaceae and Rivulariacea) blue-green alga, spheroidal green algae (*Caryosphaeroides*) assigned to Chlorellaceae and organic filaments probably related to modern filamentous fungi (Eumycophyta ?). The eucaryotic (Nucleate) nature of Dharwar assemblage is evidenced by the presence of *Globophycus, Glenobotrydion*, and a doubtful trilete spore, also a significant feature of the Bitter Spring microflora. The Dharwar assemblage essentially lacks the filamentous fossils typical of the Bitter Spring assemblage, and thus indicates a major compositional dissimilarity between the two assemblages.

A comparison of the Dharwar assemblage with the well-dated assemblages of Precambrian sediments reveals that Dharwar assemblage is more advanced than the Early Precambrian microbiota, as the latter is characterized by the procaryotic microorganisms consisting of coccoid and filamentous blue-green algae and rod-shaped bacteria and as such the two assemblages are not comparable.

Comparing the fairly well known Late Precambrian Bitter Spring microbiota with the Dharwar assemblage, it becomes apparent that although the two have few common genera viz., *Myxococcoides, Palaeoanacystis* of Cyanophyceae, *Globophycus, Glenobotrydion* of Chlorophyceae; their overall comparison shows a clear distinction between the two. The above common coccoid members exhibit dissimilarity at the specific level. An abundance of filamentous fossils referred to the oscillatoriaceae, Nostocaceae and Fungi (? Eumycophyta) in Late Precambrian sediments is marked. *Palaeolyngbya Barghoorniana* Schopf, *Cephalophytarion grande* described by Schopf (*l.c.*) and other fossils which exhibit evolved cyanophycean features as rounded, attenuated or dilated terminal cells, disc or barrel-shaped middle cells and encompassing organic sheaths and organic filaments (*Eomycetopsis robusta, E. filiformis*) closely comparable to modern filamentous fungi (?) characterize the late Precambrian microbiota. The Dharwar assemblage consists of unicellular and colonial algal remains forming the major constituents of the flora. This comparison affords to suggest that the Dharwar assemblage is less evolved in

complexity as compared to the Late Precambrian microbiota.

Thus it is probable that Dharwar Microbiota is more advanced than the Early Precambrian assemblage and more primitive than the Late Precambrian one, ranging between Middle Precambrian to Early late Precambrian in age.

The presence of eucaryotic microfossils *Glenobotrydion*, *Globophycus*, and a doubtful trilete spore in the Dharwar assemblage reveals that the eucaryotic microorganisms of algal affinity were represented during the Dharwar times. The available evidence recorded up till now from the well-documented Precambrian microbiota, suggests that this higher level of biological organization originated during the period between 1800 and 2200 m.y. ago (Schopf, 1967, 1968; Cloud, 1968; Margulis, 1968). Thus the age of the Dharwar microbiota according to comparisons made as above is younger in aspect than the approximate radiometric age of 2400 m.y. (Pichamuthu, 1971).

Gowda and Sreenivasa (1969) have recorded Dharwar fossils from the Guddadarangayanhalli Formation (G.R. Formation) of the Chitaldrug Schist Belt. The organic fossils come from an age group of 2000-1400 m.y. and referred to Sphaeromorphitae and Netromorphitae of the Group Acritarcha and cuticular remains to *Spongiophyton*, Kraüsel. An abundance of Sphaeromorphitae in G.R. Formation and Dharwar assemblage described here exhibits a similarity between the two. Detailed comparison between these two biotas is not made due to poor preservation and lack of details of the morphology of fossils of the G.R. Formation.

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EXPLANATION OF PLATES

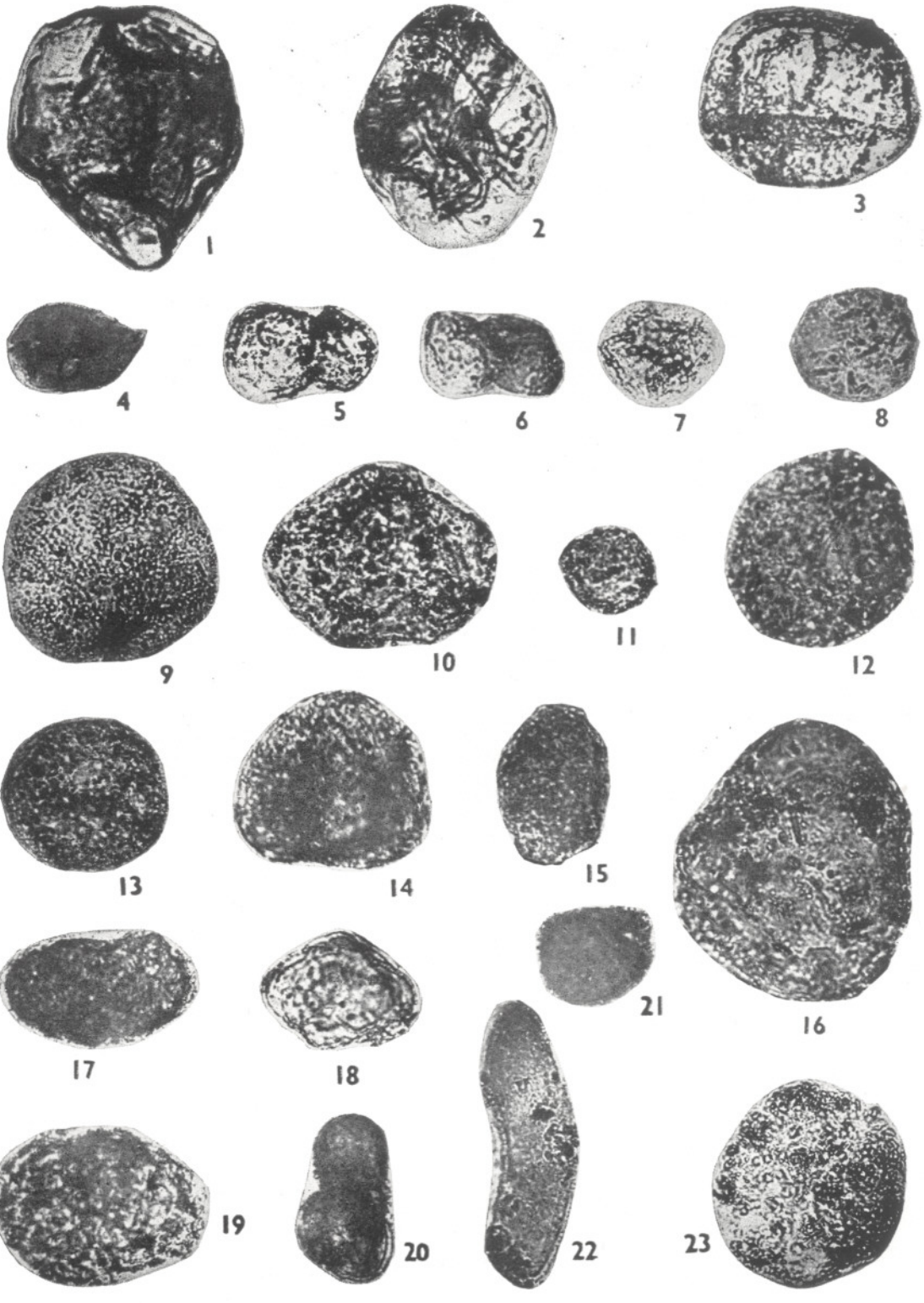
(All photomicrographs magnified — × 750, except Pl. 1, Figs. 14, 15, 16 & Pl. 2, Figs. 7, 13, 17 which are —× 1000)

PLATE 1

1, 2. *Leiosphaeridia raci* sp. nov. (Slide No. A2/1).
3. *Leiosphaeridia aglutinata* sp. nov. (Slide No. A2/2).
4. *Protoleiosphaeridium* sp. [Slide No. A2(2)/2].
5, 6. *Protoleiosphaeridium problematicum* sp. no. (Slide No. A2/1).
7,8. *Leiosphaeridia dharwariana* sp. nov. [Slide No. A2/1, A2(2)/3].
9, 10. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2(1)/12, A2(1)/3].
11. *Leiosphaeridia dharwariana* sp. nov. [Slide No. A2(1)/8].
12. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2/2, A1/2].
13. *Globophycus circularis* sp. nov. [Slide No. A2(1)/3].
14. *Granomarginata clara* sp. nov. [Slide No. A2/2].
15. *Leiosphaeridia dharwariana* sp. nov. [Slide No. A3(2)/1].
16. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2(1)/8].
17, 18, 19. *Myxococcoides indicus* sp. nov. [Slide No. A2/1, A2(1)/8, A2(1)/6]
20. Cf. *Glenobotrydion* sp. 1 [Slide No. A2(1)/12].
21. Cf. *Glenobotrydion* sp. 2 [Slide No. A2(1)/8].
22. *Navifusa purana* sp. nov. [Slide No. A3(2)/1].
23. *Leiosphaeridia aglutinata* sp. nov. [Slide No. A2(1)/12].

PLATE 2

24-27. *Rugocystis velaris* Gen. et sp. nov. [Slide No. A2/1, A2(2)/3, A2(1)/4, A2/2].
28. *Palaeoanacystis puratanum* sp. nov. [Slide A2(1)/6].
29. *Trachysphaeridium decorum* sp. nov. [Slide A2(1)/3].
30. *Lophosphaeridium* sp. [Slide No. A2(1)/12].
31. *Trachysphaeridium* sp. [Slide No. A4(2)/1].
32, 33. *Concentrites muricatus* Gen. et. sp. nov. (Slide No. A2/1, A2/2).
34. *Myxococcoides elongatus* sp. nov. [Slide No. A2(1)/11].
35. Spore type-1 [Slide No. A3(2)/1].
36. *Lophosphaeridium conatum* sp. nov. [Slide No. A2(1)/8].
37. *Rugocystis velaris* Gen. et sp. nov. [Slide No. A2(1)/3].
38. ? *Myxococcoides* sp. [Slide No. A2(1)/6].
39. *Myxococcoides elongatus* sp. nov. [Slide No. A3(2)/1].
40. *Lophosphaeridium conatum* sp. nov. [Slide No. A2(1)/12].
41. *Trachysphaeridium* sp. (Slide No. A4/2).
42, 43. Algal filament type-1 [Slide No. A2(1)/8].
44. Algal filament type-2 [Slide No. A2(1)/3].
45. Organic plate [Slide No. A2(1)/10].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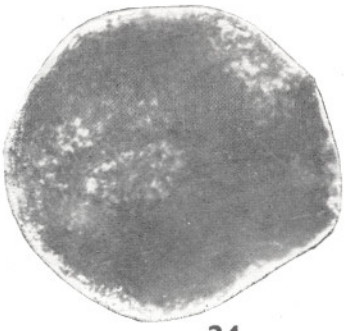
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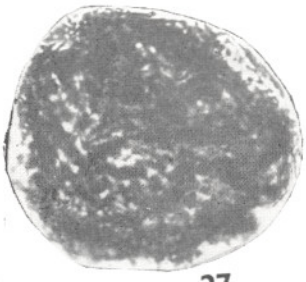
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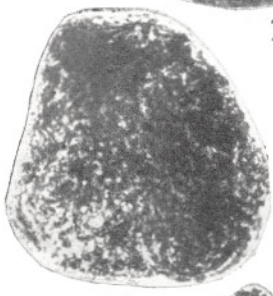
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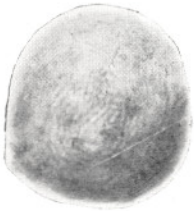
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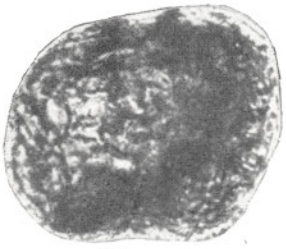
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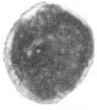
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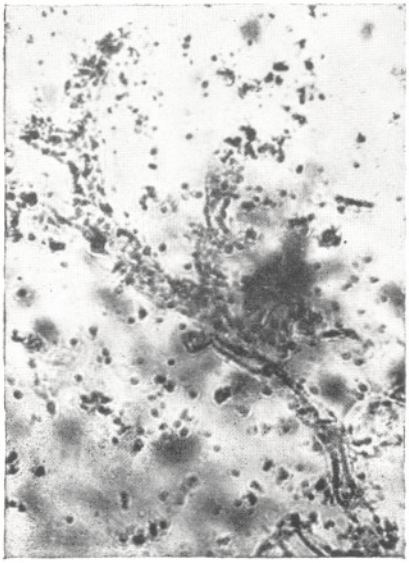
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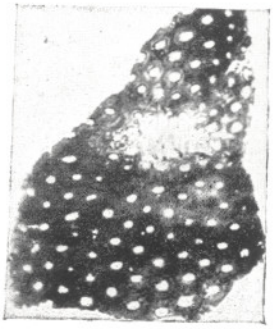
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