

## Late Precambrian microfossils from Deoban Limestone Formation, Lesser Himalaya, India

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A well-preserved microbiota consisting of filamentous Cyanobacteria, viz., *Oscillatorioopsis*, *Cyanonema*, *Siphonophycus*, *Eomycetopsis*, *Gunflintia* and *Animikiea*; spheroidal unicells, viz., *Glenobotrydion*, *Globophycus*, *Sphaerophycus* and *Myxococoides*; Eubacteria, viz., *Archaeotrichion*, *Biocatenoides*; and acritarch (?plankton) *Kildinosphaera*, is described from petrographic thin sections of cherts from the Deoban Formation, Garhwal Lesser Himalaya. The assemblage has been compared with other authentic Proterozoic records. The palaeomicrobial community is interpreted to have inhabited protected shallow intertidal environment.

**Key-words**—Palaeoecology, Cyanobacteria, Spheroidal unicells, Eubacteria, Lesser Himalaya, Precambrian (India).

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### सारांश

लेसर हिमालय (भारत) में देववन चूनाश्म शैल-समूह से अनंतिम कॅम्ब्रिय-पूर्व सूक्ष्मजीवाश्म

मनोज शुकला वी सी तिवारी एवं विनोद कुमार यादव

गढ़वाल लेसर हिमालय में देववन शैल-समूह में एकत्रित गममेकाशमों की शैलकीय पतली काटों में सूक्ष्मत्व मियेनोजीवाण अथवा ऑमिलेटोरिऑगिस, मियेनोनीमा, माइफोनोफाइकस, इओमार्डमिटीगिस, गनेपिलिशिया एवं एनिमीकिया; गोलाभ एकलकोशायें अथवा ग्लीनोबोट्रीडियन ग्लोबोफाइकस, स्फेरोफाइकस एवं मिक्सोकॉइडिस; यबैक्टीरिया अथवा आर्कियोट्राइकिऑन, बायोकेटिनार्याडिस तथा एक एक्रिटार्च (?प्लंकटन) किल्डिनोस्फेरा में यवन एक सर्पारगंधत सूक्ष्मजीवित्ता का वर्णन किया गया है। इस समूह की तुलना अन्य ग्रामाणिक आद्यजीवी अभिलेखों में की गई है। उक्त उपखण्ड परासूक्ष्मजीविक समुदाय संरक्षित छिछले अतगज्वारीय वातावरण में विद्यमान था।

LATE Proterozoic microbiota is known from over 150 localities establishing considerable biological diversity and ecological variability. Fossiliferous Proterozoic formations are known from Australia, Canada, Africa, Greenland, India, USA, USSR and China, which contain authentic biota both as carbonised remains from shales and permineralised from cherts. The chert biotas are three dimensionally preserved in fine grained chert matrix permitting an indepth study of the morphology and complexities achieved by the organism. The symsedimentary nature is established by evaluation of the relationship between mineral matrix and microbiota in petrographic thin sections

while the acid resistant biotic remains known from shales do not have any direct evidence of their being symsedimentary in nature, however, the relationships is only implied.

The present paper deals with three dimensionally preserved carbonaceous remains from stratified and lensoid black chert in Deoban Limestone near Chakrata area. This sedimentary sequence exposed in the inner sedimentary belt of Lesser Himalaya is characterised by siliciclastic-carbonate sequence with profuse development of columnar stromatolites.

Kumar and Singh (1979a) recorded microbiota from this area in petrographic thin sections. They

have reported three forms namely *Glenobotrydion majorinum* Schopf & Blacic, *Huronispora* sp. Awramik & Barghoorn and *Eomycetopsis filiformis* Schopf. However, detailed descriptions of these forms are lacking. A detailed systematic analysis of morphological types present in these cherts, their affinities and comparison with other microbiota and palaeoecological analysis have been attempted in this paper.

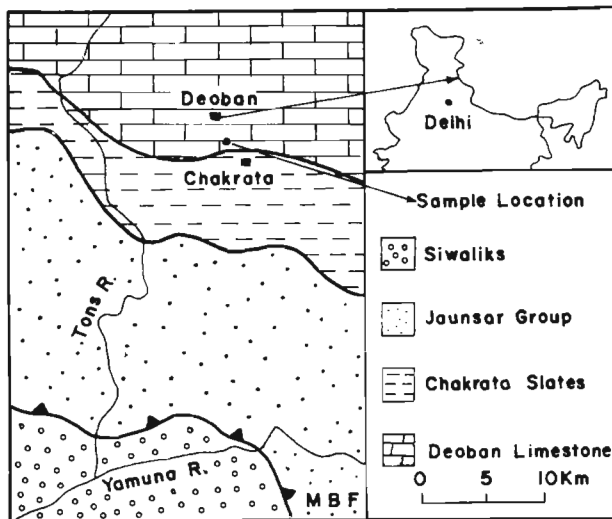
**GEOLOGICAL SETTING AND AGE**

Deoban Limestone Formation is extensively developed in Deoban mountain (30°45' : 77°54'), north of Chakrata (Text-fig. 1) in Garhwal Lesser Himalaya. It was first designated by Oldham (1883) for a sequence of pale-grey dolomitic limestone with cherty concretions occurring north of Chakrata. It comprises thick succession of stromatolitic dolomite, dolomitic limestone, cherty limestone, oolitic intraclastic limestone and slates (Text-fig. 2). The Deoban Limestone overlies the Atal Quartzite in Tons Valley and is overlain by Mandhali Slate and Limestone and the contact is normal gradational. However, Prashra (1977) marked a thrust contact in Tons area where the Subathus (nummulites) and Simla Slate are found along the thrust plane. The Deoban Group in the area, north of Deoban belt, is unconformably succeeded by the Mandhali Formation of Jaunsar Group.

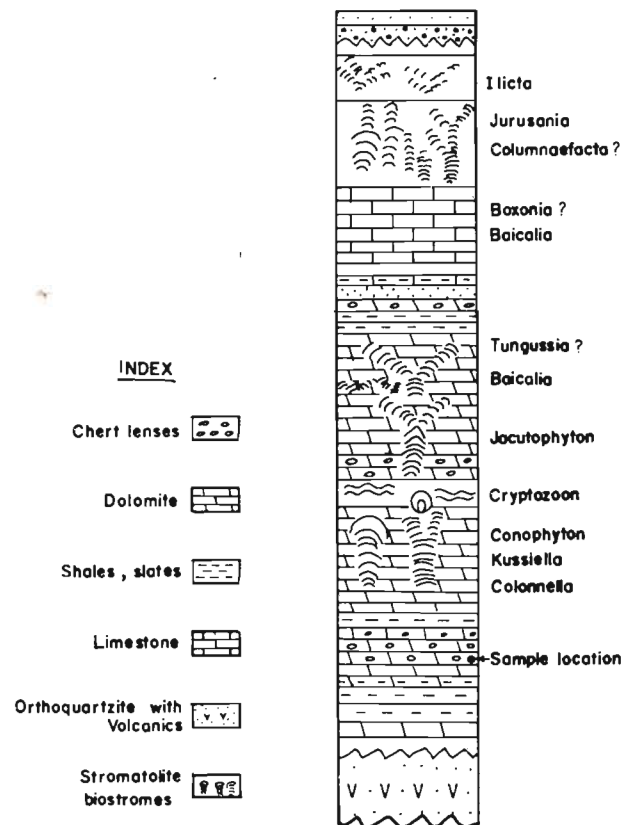
Thin layers and lenses of black chert, which have yielded microfossils, occur in the limestone bed showing development of stromatolites (Text-fig. 2). The thickness of the chert layers varies from 1 mm to 10 cm. The limestone show prolific development of columnar stromatolites. The extension of Deoban Limestone in south-eastern

Kumaon was designated as the Gangolihat Dolomite by Valdiya (1969). Detail geology of the area is discussed by Prashra (1977), Valdiya (1980) and Srikantia and Bhargava (1982). Valdiya (1969) on the basis of specific forms of stromatolites and lithological similarities correlated Deoban Limestone with Gangolihat Dolomite, Shali Formation of Satluj Valley, Dharamkot Limestone of Dharamsala area and Jammu Limestone of Riasi area in the Lesser Himalaya.

No direct radiometric date is available for Deoban Limestone Formation. However, Valdiya (1986) assigned approximately 1,000 Ma age to these beds on the basis of correlation with Jammu Limestone. Raha *et al.* (1978) gave Pb/U dates based on Galena of 967 Ma for the Jammu Limestone. Late Precambrian columnar stromatolites in Deoban Limestone have been recorded by Valdiya (1969), Prashra (1977) and Kumar and Singh (1979b). However, Sinha and Raaben (1981) recorded Lower Cambrian stromatolites from this area. Tewari (1983, 1984) in a detailed systematic study of stromatolites from Kumaon Himalaya has assigned Lower-Middle Riphean age to Deoban Limestone Formation based on *Kussiella-Conophyton-Baicalia* Assemblage (Text-fig. 2).



**Text-figure 1**—Geological map of Deoban area showing the locality.



**Text-figure 2**—Simplified lithology of Deoban Limestone showing distribution of stromatolites and sample location of chert lenses yielding microbiota (after Tewari, 1983).

## SYSTEMATICS

The fossil taxa described here have been recorded through the study of petrographic thin sections of black cherts under transmitted light. Morphologically they can be classified into filaments, coccoids, tubular sheaths and fine thread-like forms. The forms are grouped here under the existing fossil taxa to facilitate comparison with other known Proterozoic microbiota. The affinity of these forms have been discussed separately. The type and figured specimens are deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

**Genus—*Eomycetopsis* Schopf 1968**

*Eomycetopsis robusta* Schopf 1968 emend. Knoll & Golubic 1979

Pl. 1, figs 10, 11, 17, 20

*Description*—Nonseptate, unbranched, partially flattened tubular sheaths with circular to elliptical cross section, 2.5–5  $\mu\text{m}$  in diameter and 120  $\mu\text{m}$  in length. Surface texture coarsely granular.

**Genus—*Siphonophycus* Schopf 1968**

*Siphonophycus kestron* Schopf 1968

Pl. 1, figs 8, 14

*Description*—Nonseptate, unbranched, tubular or cylindrical sheaths, 8–18  $\mu\text{m}$  wide and up to 140  $\mu\text{m}$  long (incomplete specimen). Straight to slightly bent, surface texture rugose.

**Genus—*Oscillatoriopsis* Schopf 1968**

*Oscillatoriopsis media* Mendelson & Schopf 1982

Pl. 1, figs 1, 22

*Description*—Multicellular, uniseriate, unbranched trichomes 8–12  $\mu\text{m}$  wide slightly tapering towards apices, generally not constricted at septa, cross walls distinct, somewhat granular, disc-shaped, cells more closely spaced near apices than in medial portion 3–4  $\mu\text{m}$  in diameter. Sheath absent. Poorly preserved with smaller cells in apical part.

**Genus—*Cyanonema* Schopf 1965**

*Cyanonema* sp.

Pl. 1, fig. 18

*Description*—Sharply curved, up to 120  $\mu\text{m}$  long (incomplete specimen) multicellular, uniseriate, unbranched, trichomes not at all constricted at septa, cross walls distinct, sheath absent. Trichome not capitate, solitary, or in mesh-like mass. Cells commonly as long as wide (2.8–3.5  $\mu\text{m}$ ). Apical cells are considerably smaller than medial cells. Reproductive structures unknown.

**Genus—*Gunflintia* Barghoorn 1965**

*Gunflintia minuta* Barghoorn 1965

Pl. 1, figs 2, 3, 4, 5, 6, 9, 12, 13, 15

*Description*—Unbranched, uniseriate, straight or curved filaments up to 350  $\mu\text{m}$  long and 1 to 4  $\mu\text{m}$  in diameter. Transverse septa and reproductive structures are not recognisable.

**Genus—*Animikiea* Barghoorn 1965**

*Animikiea septata* Barghoorn 1965

Pl. 1, fig. 21

*Description*—Multicellular unbranched filaments up to 120  $\mu\text{m}$  long and 8–12  $\mu\text{m}$  wide, straight or curved, with closely spaced transverse septae. Individual cells much wider than long. Enclosing sheath distinct, surface texture granular.

**Genus—*Myxococcoides* Schopf 1968**

*Myxococcoides minor* Schopf 1968

Pl. 2, fig. 8

*Description*—Spheroidal or ellipsoidal cells 8 to 12  $\mu\text{m}$  in diameter, occasionally distorted and flattened due to mutual compression, solitary or clumped in globular colonies. Number of cells differ in colonies. Surface texture varies from psilate to reticulate. Cell wall distinct and about 0.5  $\mu\text{m}$  thick.

**Genus—*Sphaerophycus* Schopf 1968**

*Sphaerophycus parvum* Schopf 1968

Pl. 2, figs 11–18

*Description*—Spheroidal or ellipsoidal cells with 2–4.2  $\mu\text{m}$  in diameter, commonly solitary or sometime in groups of three, four, eight or more, surface texture commonly psilate, occasionally granular. Sheaths encompassing cells occasionally present. Reproduction apparently by fission, followed by separation of resulting daughter cells.

**Genus—*Melasmatosphaera* Hofmann 1976**

*Melasmatosphaera media* Hofmann 1976

Pl. 2, figs 2, 3

*Description*—Cells spheroidal, solitary, occasionally double-walled, diameter 15–20  $\mu\text{m}$ , containing numerous scattered or clustered submicron to micron sized granules.

**Genus—*Glenobotrydion* Schopf 1968**

*Glenobotrydion aenigmatis* Schopf 1968

Pl. 2, figs 1, 19, 20

*Description*—Spheroidal or ellipsoidal cells, in loosely associated groups, distorted by mutual compression. Ranging from 8–10  $\mu\text{m}$  in diameter. A small circular organic structure eccentrically placed on inner surface of cell wall; amber to black

coloured intracellular body, 0.5 to 2.0  $\mu\text{m}$  in diameter.

*Glenobotrydion majorinum* Schopf 1971

Pl. 2, figs 6, 7

*Description*—Solitary spheroidal, undistorted cells, 20–35  $\mu\text{m}$  in diameter, sheath not present, circular organic body with 3–4  $\mu\text{m}$  diameter present on inner surface of cell wall, or near centre.

**Genus—*Globophycus* Schopf 1968**

*Globophycus* sp.

Pl. 2, figs 4, 9, 10, 21

*Description*—Large, spheroidal, solitary, light coloured, thin-walled cells ranging in diameter from 18–20  $\mu\text{m}$ , encapsulating darker, thick-walled spheroids with 5–7  $\mu\text{m}$  in diameter. Inner spheroids detached from the outer spheroid and has more irregular configuration. Reproductive structure unknown.

**Genus—*Archaeotrichion* Schopf 1968**

*Archaeotrichion* sp.

Pl. 1, fig. 7

*Description*—Solitary or irregularly entangled, narrow, sinuous, nonseptate, unbranched, flexed, twisted and compressed tubes, up to 150  $\mu\text{m}$  long, 2–4  $\mu\text{m}$  wide and about 1/2  $\mu\text{m}$  thick.

**Genus—*Biocatenoides* Schopf 1968**

*Biocatenoides* sp.

Pl. 1, figs 16, 19

*Description*—Slender, chain-like, unbranched filamentous colonies, composed of rod-shaped or coccoid cells, uniseriate, less than 0.5–2  $\mu\text{m}$  broad, colonies thread-like, often sinuous or recurved, up to 150  $\mu\text{m}$  long. Reproductive structures unknown.

**Genus—*Kildinosphaera* Shepeleva & Timofeev 1963  
emend. Vidal 1963**

*Kildinosphaera* sp.

Pl. 2, fig. 5

*Description*—Spheroidal vesicles up to 260  $\mu\text{m}$  in diameter, thick-walled, wall psilate and characteristically folded and wrinkled.

## MICROBIOTA—COMPARISON AND AFFINITIES

### Comparison

The microbiota comprises multicellular septate trichomes, tubular remnants, spheroidal coccoids with or without eccentrically placed intracellular dark bodies; narrow thread-like filaments and ?plankton associated with dark brown to black organic residue disseminated in the rock matrix. Spheroidal structures are dominantly present in bedded cherts while filaments dominate the chert lenses. Table 1 gives a comparative account of the Deoban microbiota with other records.

Microbiota of Deoban cherts and Bitter Springs Formation (Barghoorn & Schopf, 1965; Schopf 1968; Schopf & Blacic, 1971) of Central Australia are remarkably similar. Both deposits contain well preserved filamentous and spheroidal unicells. Ten Deoban taxa are morphologically comparable to the ones recorded from the Bitter Springs Formation. Four of these genera are filamentous cyanobacteria, viz., *Oscillatoriopsis*, *Cyanonema*, *Siphonophycus* and *Eomycetopsis* and four genera of spheroidal unicells, viz., *Glenobotrydion*, *Globophycus*, *Sphaerophycus* and *Myxococcoides*. Two genera of Eubacteria, viz., *Archaeotrichion* and *Biocatenoides* are common to both. However, the Bitter Springs microbiota is dominated by septate filamentous trichomes, which in Deoban is represented only by *Oscillatoriopsis media* and *Cyanonema* sp. The Deoban microbiota is dominated by coccoid and nonseptate filamentous forms.

*Eomycetopsis*, an abundant and cosmopolitan component of the Proterozoic microbiota, is recorded from most of the Proterozoic deposits of the world (see Mendelson & Schopf, 1982). In India, this genus is recorded from Kheinjua Formation (Kumar, 1978; McMenamin *et al.*, 1983), Suket Shale (Maithy & Shukla, 1977) of Lower Vindhyan and

## PLATE 1

Filamentous microfossils from thin sections of Deoban cherts.

- |         |  |             |  |
|---------|--|-------------|--|
| 1, 22.  | <i>Oscillatoriopsis media</i> , Slide no. BSIP 9628. $\times 500$ .      | 2-6, 9,     | <i>Gunflintia minuta</i> , Slide nos. BSIP 9628, 9629,                 |
| 21      | <i>Animikiea septata</i> , Slide no. BSIP 9629 $\times 1000$ .           | 12, 13, 15. | figs 2, 3, 4, 13, 15. $\times 500$ , figs 5, 6, 9, 12. $\times 1000$ . |
| 18.     | <i>Cyanonema</i> sp., Slide no. BSIP 9629 $\times 1000$ .                | 8, 14.      | <i>Siphonophycus kestron</i> , possible empty sheath of                |
| 10, 11, | <i>Eomycetopsis robusta</i> , filamentous colony of <i>E.</i>            |             | <i>Oscillatoriopsis media</i> . Slide no. BSIP 9628. $\times 500$ .    |
| 17, 20. | <i>robusta</i> , note three dimensionally preserved tubular              | 7.          | <i>Archaeotrichion contortum</i> , possible bacteria or                |
|         | filament (fig. 10) having circular opening. Slide nos.                   |             | flattened " <i>Eomycetopsis filiformis</i> ", Slide no. BSIP           |
|         | BSIP 9628, 9629, 9630; fig. 10 $\times 1000$ ; figs 11, 17, 20. $\times$ |             | 9628. $\times 1000$ .  |
|         | 500.   | 16, 19.     | <i>Biocatenoides</i> sp., Slide nos. BSIP 9628, 9629. $\times 1000$ .  |

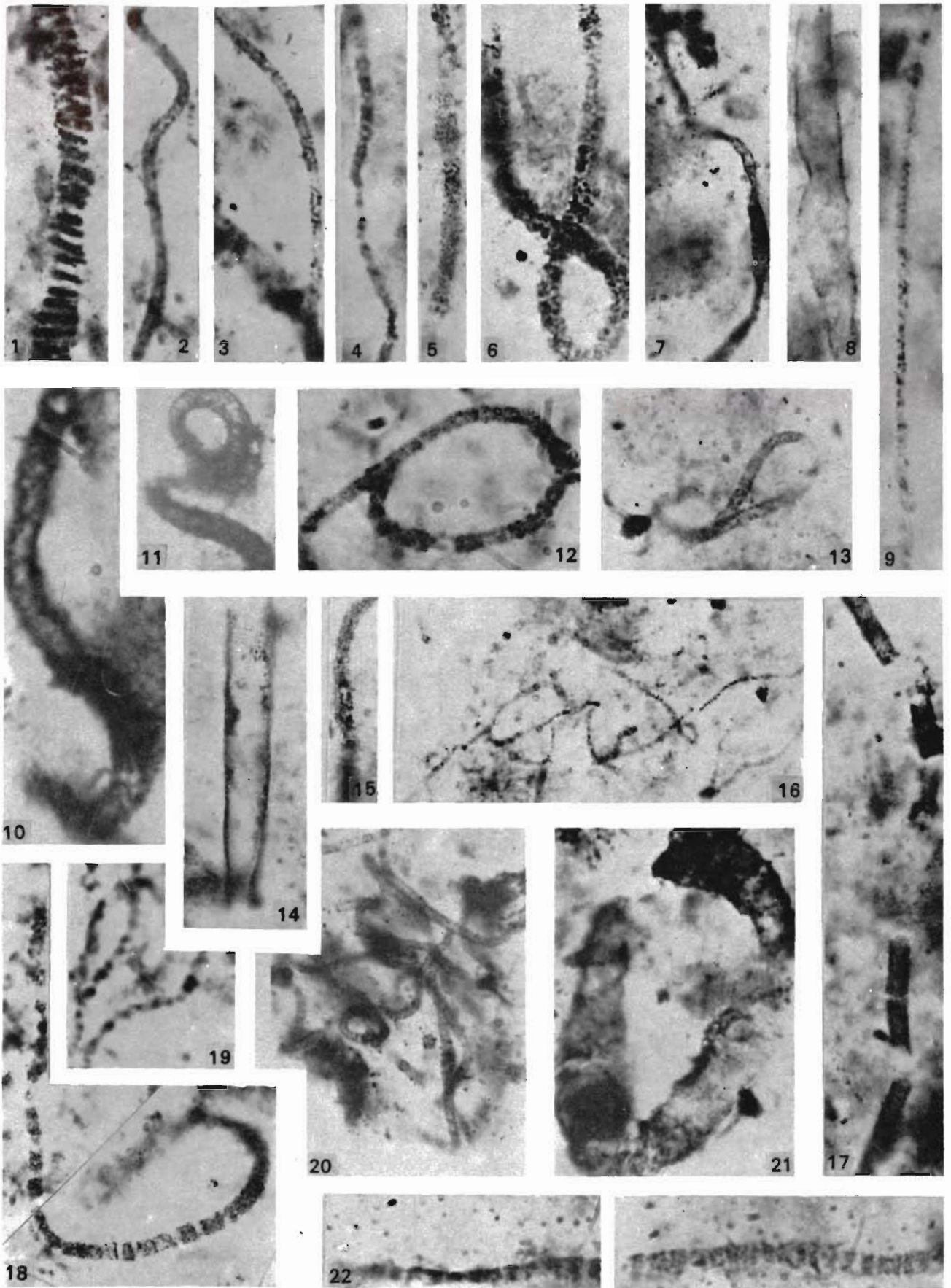


PLATE 1

Gangolihat Dolomites (Nautiyal, 1978 a, b, c, 1980). The authenticity of *Eomycetopsis* from Gangolihat Dolomite has been questioned by Mendelson and Schopf (1982). Banerjee (1973) recorded a single specimen of *Eomycetopsis* (20-25  $\mu\text{m}$  across) from Aravalli Supergroup. This specimen does not fall within the size range of *E. robusta* described from the Deoban Limestone.

*Gunflintia minuta* and *Animikea septata*, first described from 2,000 Ma old Gunflint Iron Formation (Barghoorn & Tyler, 1965), are also recorded from the Deoban cherts. Probably due to post depositional diagenesis of organic matter septae are not clearly visible. Morphotype similar to *Gunflintia minuta* have also been recorded from Kheinjua Formation of Lower Vindhyan (McMenamin *et al.*, 1983). Chroococcacean spheroidal unicells,

*Myxococcoides* and *Sphaerophycus* without intracellular organelles-like bodies are present in Bitter Springs (Schopf, 1968; Schopf & Blacic, 1971), Balbirni Dolomite (Muir, 1974, 1976), HYC Pyrite Member (Oehler, 1977), Amelia Dolomite, Australia (Oehler, 1978) and Belcher Supergroup (Hofmann, 1976), Canada. Narrow thread-like filamentous *Biocatenoides* are comparable to similar forms recorded from Bitter Springs (Schopf, 1968; Schopf & Blacic, 1971) and Belcher Supergroup (Hofmann, 1976). *Biocatenoides* and *Archaeotrichion* recorded from HYC Pyrite Member of McArthur Group; Sukhaya Tunguska, Shorikha and Yudoma Formation of Siberian Platform, forms significant components of the Deoban biota (for detailed comparison see Table 1).

Table 1

Deoban cherts	Bitter Springs Formation	Siberian platform	Balbirni Dolomite McArthur Group	HYC—Pyritic Shale Member	Amelia Dolomite	Belcher Super Group	Gunflint Iron Formation
	1	2	3	4	5	6	7
<i>Archaeotrichion contortum</i>	S	G				G	
<i>Biocatenoides</i> sp.	G			G		G	
<i>Myxococcoides minor</i>	S		G	G	G	S	
<i>Sphaerophycus parvum</i>	S		S	S	S	S	G
<i>Melasmatosphaera media</i>						S	
<i>Glenobotrydion aenigmatis</i>	S					G	S
<i>G. majorinum</i>	S					S	
<i>Globophycus</i> sp.	G			G		G	
<i>Oscillatorioopsis media</i>	G	S		G			
<i>Siphonophycus kestron</i>	S		G				
<i>Cyanonema</i> sp.	G			G	G		
<i>Eomycetopsis robusta</i>	S	S	G	G		G	
<i>Gunflintia minuta</i>					S		S
<i>Animikea septata</i>							S

G = Genus present; S = Species present

## PLATE 2

- Spheroidal microfossils from thin sections of Deoban cherts.
- 11-18. *Sphaerophycus parvum*, showing probably cell division. Note cells in pair (fig. 11 and in tetrad fig. 16), Slide no. BSIP 9628.  $\times 1000$ .
- 1, 19, 20. *Glenobotrydion aenigmatis*, Note eccentrically placed, black pyrenoid-like intracellular bodies at the bottom of fig. 1 ellipsoidal cell has larger dimension of pyrenoid-like intracellular body. Slide no. BSIP 9628.  $\times 1000$ .
- 4, 9, *Globophycus*. arrow in fig. 9 points possible thread-like bacteria, Slide nos. BSIP 9628, 9629; figs 9, 10, 21.  $\times$  fig. 4.  $\times 500$ .
- 2, 3. *Melasmatosphaera media*, Note double-walled cell (fig. 2), Slide no. BSIP 9628.  $\times 1000$ .
5. *Kildinosphaera*, a planktonic body. Note the robust and folded cell wall, Slide no. BSIP 9628.  $\times 250$ .
- 6, 7. *Glenobotrydion majorinum*, Slide no. BSIP 9628.  $\times 1000$ .
8. *Myxococcoides minor*, Slide no. BSIP 9628.  $\times 1000$ .

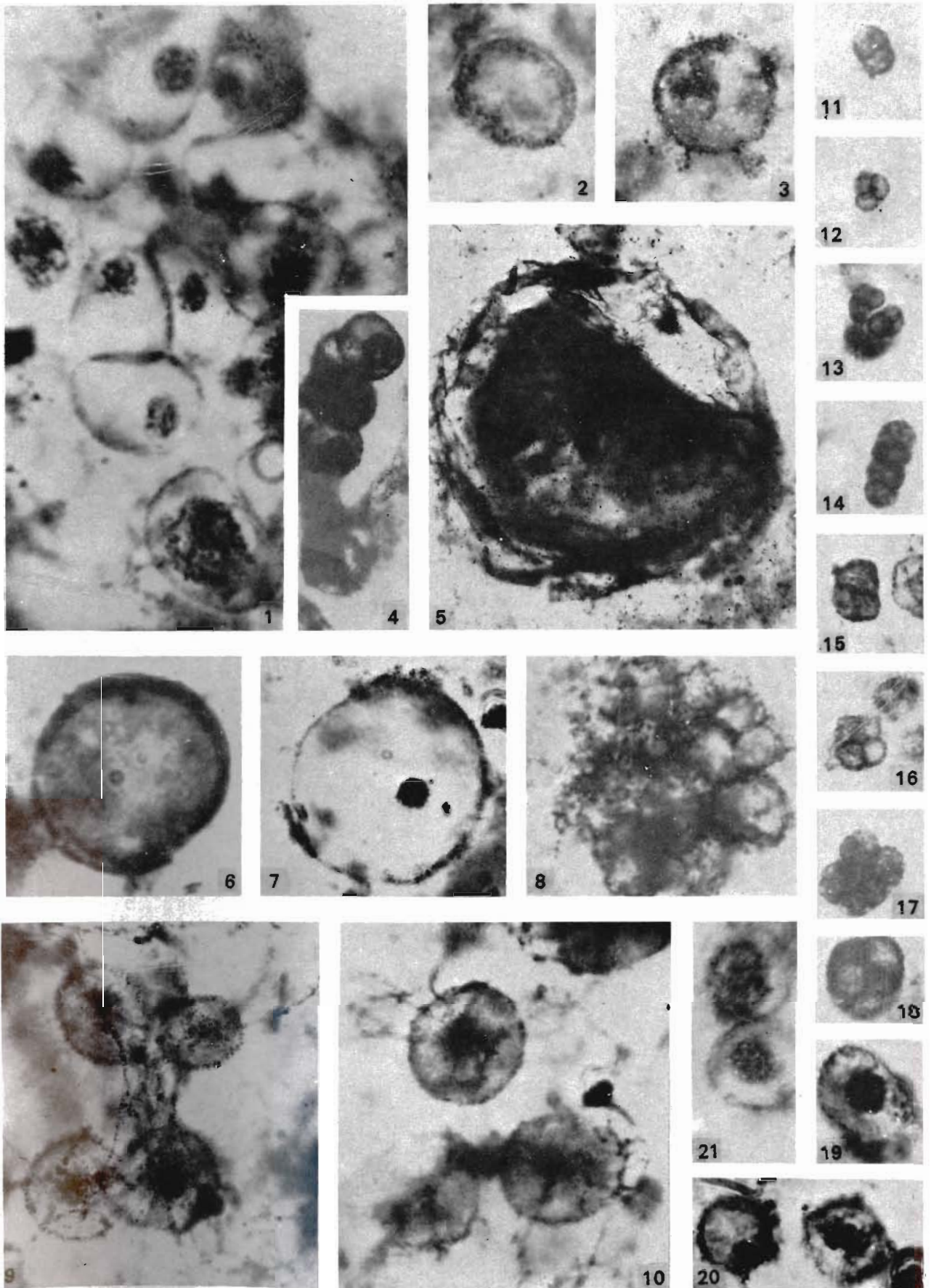


PLATE 2

### Affinities

Septate filamentous forms in Deoban Limestone are represented by *Oscillatorioopsis media*, *Cyanonema*, *Animikea septata* and *Gunflintia minuta*. These taxa are morphologically comparable with modern Cyanobacteria belonging to Oscillatoriaceae.

Schopf (1968) interpreted tubular remnants of *Eomycetopsis robusta* as possibly belonging to fungi (*Eumycophyta*). Hofmann (1976) and Knoll and Golubic (1979) re-examined the type material and suggested that the tubules responding to *Eomycetopsis* are sheaths of either *Phormidium* type of Cyanobacteria or *Leptothrix* type of filamentous bacteria. *Siphonophycus kestron* Schopf (1968) apparently represents empty mucilaginous sheath of *Oscillatoria-Lyngbya*-like Cyanobacteria (Schopf, 1968).

Cocoid microfossils are of mainly two types, i.e. one with eccentrically placed, intracellular, dark, pyrenoid-like bodies and the other lacking in these dark bodies. Spheroidal unicells without pyrenoid-like dark bodies are represented by *Myxococoides* and *Sphaerophycus*.

*Myxococoides minor* Schopf shows colonial habit and is comparable to *Anacystis* a genus of the family Chroococcaceae. *Sphaerophycus parvum* Schopf is apparently a product of asexual reproduction. Cells are not only present in pairs but in group of three, four and more cells (Pl. 2, figs 11-18). These cells probably represent cell division by fission.

Cocoid microfossils with amber to black coloured, eccentrically placed intracellular pyrenoid or organelles-like bodies are represented by *Glenobotrydion aenigmatis*, *G. majorinum* and *Globophycus* sp. These dark intracellular bodies in *Glenobotrydion* and other similar Proterozoic fossil taxa have been considered the product of cytoplasmic degradation (Awramik *et al.*, 1972; Knoll & Barghoorn, 1975; Hofmann, 1976; Golubic & Hofmann, 1976; Peat *et al.*, 1978; Knoll & Golubic 1979; Zhang, 1980). However, others (Schopf, 1968, 1974; Schopf & Blacic, 1971; Schopf & Oehler, 1976; Oehler, 1976, 1977a, b; Licari, 1978) consider them to be remnants of delicate cell organelles-like pyrenoid and nucleus. They opined that consistency in size, shape and distribution among members of each species establishes that they are original intracellular organelles rather than shrunk or coalesced cytoplasm. Oehler (1977a) studied these structures in *Glenobotrydion aenigmatis* and suggested that they are similar to pyrenoids and nuclei. Some species of *G. aenigmatis* probably represent cocoid green algae. Thus *Glenobotrydion aenigmatis* and *Glenobotrydion majorinum* in

Deoban cherts apparently represent eukaryotic green algae.

Thin sections of Deoban cherts have also yielded large (260  $\mu\text{m}$  across), characteristically folded, thin-walled acritarchs. These acritarchs of uncertain origin could be a cyst, or comparatively sturdy outer membrane formed by a unicellular plankton during resting stage in its life cycle.

Long narrow thread-like filaments referred to *Archaeotrichion contortum* and *Biocatenoides* are abundant in Deoban cherts. Schopf (1968) considered them ?Eubacteria. Hofmann (1976) compared *Archaeotrichion* sp. with *Leptothrix* and *Spirophyllum*-like Iron Bacteria. He further opined that they could be collapsed or deflated nonseptate filaments of *Eomycetopsis filiformis*. However, it is difficult to precisely assign taxonomic position to these forms.

### PALAEOECOLOGY

Sedimentological studies indicate that the Deoban Limestone is a product of deposition in carbonate tidal flats. The primary sedimentary structure like parallel laminations, wavy laminations and ripple bedding are well preserved in the limestone containing bedded black cherts and the chert lenses yielding microbiota. The presence of oolites and intraclasts in the Deoban Limestone indicates high energy condition in intertidal zone.

The microbiota assemblage present in Deoban cherts represent not only benthic cyanobacterial communities but also plankton. Shallow benthic communities were represented by both motile and nonmotile prokaryotic micro-organisms. The mat building filaments belong to the family Oscillatoriaceae of Cyanobacteria and are much like the modern mat forming Cyanobacteria *Phormidium-Lyngbya-Oscillatoria plexus*. These microfossils indicate restricted coastal intertidal environment. However, according to Knoll (1985) filamentous microfossils corresponding to the extant genera *Oscillatoria*, *Lyngbya*, *Phormidium* and *Microcoleus* occur as mat builders in a wide variety of environments and also as nonmat forming microbenthos and allochthonous (transported) elements in shelf sediments. The presence of plankton indicates open sea environment. It is interpreted that these were transported and preserved in shallow marine locales. Extensive development of columnar stromatolites in Deoban Limestone indicates that they were formed in shallow water environment protected from stronger current activity where flat laminated mats form columnar stromatolites.

Presence of *Siphonophycus kestron* representing the original mucilaginous, empty sheath of



*Oscillatoria-Lyngbya*-like Cyanobacteria and unsheathed trichomes recorded here are indicators of gliding motility of these micro-organisms. Trichomes are well known to glide towards light source leaving behind empty sheaths. Thus, this population of filamentous Cyanobacteria were phototactic and mat builders as are extant *Oscillatoriaceae*.

### CONCLUSION

Palaeomicrobial community found in Deoban Limestone Formation consists of *Oscillatoria*-like Cyanobacteria, eukaryotic green algae and *Leptothrix/Spirophyllum*-like filamentous Eubacteria. Phytoplanktons are rare.

Forms like *Glenobotrydion aenigmatis* and *G. majorinum* present in Deoban cherts are similar to forms described from Bitter Springs Formation and apparently represent eukaryotic green algae.

The Deoban biota (1,000 Ma) consists of mostly spheroid and nonseptate filaments while the Bitter Springs is distinguished by septate filamentous biota. This perhaps reflects that the Bitter Springs biota shows distinctive advancement over the Deoban biota. The microbiota shows evidence of development in shallow restricted coastal intertidal environment.

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