Occurrence of endosporulating cyanobacteria in the Lower Bhander Limestone Formation, Bhander Group exposed around Narsingharh, Madhya Pradesh

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Endosporulating cyanobacterium *Sphaerocongregus* is reported for the first time from the cherty band of the Lower Bhander Limestone Formation, Bhander Group exposed around Narsingharh in Damoh District, Madhya Pradesh. Individual colonies are globose and contain closely packed globular cells. The cells get arranged in the form of a loose colony after the dissolution of the encircling organic sheath. Globular colonies and the encircled cells can be distinctly discriminated into two distinct groups due to their distinct sizes. Globular colonies are clumped together to form either globose mass or linear chain. It is suggested that endosporulation of the algae was due to stressed habitat.

Key-words—Cyanobacteria, Endosporulation, *Sphaerocongregus*, Lower Bhander Limestone, Bhander Group, Vendian (India).

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साराँश

मध्य प्रदेश में नरसिंहगृह के आस-पास अनावरित भंडेर समूह के अधरि भंडेर चूनापत्थर शैल-समूह में अन्तःबीजाणुकजनक सियेनोजीवाणुओं की उपस्थिति

प्रभात कुमार माइती एवं रूपेन्द्र बाबू

मध्य प्रदेश में दमोह जनपद में नरसिंहगृह के आस-पास अनावरित भंडेर समूह में अधरि भंडेर चूनापत्थर शैल-समूह की रामसैकाश्मी पट्टी से पहली बार ***स्फ़ेयरोकौंग्रीगस*** नामक अन्तःबीजाणुकजनक सियेनोजीवाणु उपलब्ध हुआ है। प्रत्येक कॉलोनी गोलाकार है तथा इसमें विद्यमान गोलाकार कोशायें आपस में पर्याप्त सटी हुई हैं। चारों ओर विद्यमान कार्बनिक आच्छद के विलोडन के पश्चात् सभी कोशायें एक कॉलोनी के रूप में विन्यस्त हो जाती हैं। गोलाकार कॉलोनी एवं परिवृत्तीय कोशायें अपने विभिन्न आकार के कारण दो अलग-अलग समूहों में विभाजित की जा सकती हैं। गोलाकार कॉलोनी आपस में मिलकर या तो गोलाकार पिण्डक बनाती हैं अथवा रेखीय श्रंखला का निर्माण करती हैं। यह प्रस्तावित किया गया है कि शैवालों का अन्तःबीजाणुकजनन संघर्षमय परिस्थितियों में हुआ था।

OCCURRENCE of cyanobacterial remains are well documented from the entire Indian Proterozoic succession (Maithy, 1992), but the cyanobacterial remains showing endosporulation were not known. This paper records well-preserved remains of the endosporulating cyanobacteria from the silicified rocks belonging to the Lower Bhander Limestone Formation exposed near Narsingharh in Madhya Pradesh.

GENERAL GEOLOGY

Around Damoh-Narsingharh area, the rocks of the Bhander Group are well exposed which form small hillocks. The stratigraphic succession is as under:

	Formation
	Upper Bhander Sandstone
	Sirbu Shale
Bhander Group	Lower Bhander Sandstone
	Lower Bhander Limestone
	Ganurgarh Shale

The Ganurgarh shale is the oldest formation of the Bhander Group and constitutes a marked stratigraphic horizon. The shales are brick-red to purplish-red and often contain snow-white translucent calcite stringers. The shales at some places, intercalated with creamy or dirty-white limestone and fine grained reddish sandstone. The dirty-white limestone bands intercalated with the Ganurgarh shales are different from the succeeding Lower Bhander Limestone, which are predominantly bluish-grey in colour. The Ganurgarh Shale Formation occupies

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low grounds and valleys with scarce outcrops on account of the softness of the included rocks.

Succeeding the Ganurgarh shale, the Lower Bhander Limestone has been tracèd for a distance of about 24 km along E N E-W S W trend. The width of the outcrop is about 4 km. It occurs as lenticular mass intercalated with shales and sandstones. The thickness of limestone bands varies from about 3 to 6 metres. These limestones usually show a dip of 5° to 20° due to S SE.

The limestone also shows a peculiar violet tinge and contains specks of galena with a little pyrite in the joint planes having N 35° WS 35° E trend. It also contains a fairly large amount of fibrous clove brown variety of calcite.

The Lower Bhander Sandstone is overlain by an arenaceous horizon. It is with a persistent horizon but occurs as an intercalation in the Lower Bhander Limestone and Sirbu Shale, sometimes forming isolated mounds of hillocks owing to their relative hardness. Sandstones are brownish to reddish brown in colour and medium to coarse grained in texture. They are invariably intercalated with shales and vary in composition from orthoquartzites to protoquartzites.

MATERIAL

The material was collected from the outcrops exposed along the north bank of Sunar River, about 800 m northeast of Narsingharh Inspection Bunglow (24° 00′ : 79° 24′; Text-figure 1). The greyish-white chert band, nearly 10 cm in thickness is intercalated in between the siliceous grey limestone bands.

The organic-walled microfossils, generally preserved golden yellow to brown in colour, show moderate degree of organic metamorphism and often details of the structures are obscured by black granular organic matter in the rock. Biogenicity can be distinctly proved by the presence of enveloping sheath and dark spot in cells.

AGE OF LOWER BHANDER LIMESTONE

Uptil now no physical data on the age of this bed is available. The underlying bed, i.e., Lower Bhander Sandstone containing glauconite exposed around Karauli, north-east Rajasthan has been dated ±625 Ma by Fission Track method (Srivastava & Rajagopalan, 1990).

Genus—*Sphaerocongregus* Moorman 1974

Sphaerocongregus variabilis Moorman 1974

Pl 1, figs 1-29

Synonymy—For synonymy list see Zang and Walter, 1992, p. 311

Description—Rock sections preserve globose structures, solidly packed with isodiametric coccoidal subunits, often preserved as structureless with dark brown opaque walls. Generally, a number of globose structures are clumped together into a globular mass (Pl. 1, figs 5, 10; Text-figure 2A). Sometimes these structures are also clumped together laterally and form linear chain (Pl. 1, figs 20, 21; Text-figure 2B). Some of the individual globose structures show thick wall enclosing shrinked content in the centre (Pl. 1, fig. 15) or placed laterally (Pl. 1, figs 16, 23) indicating endosporulation stage. In cases, these globose structures are translucent with thick lamellated wall (Pl. 1, fig. 17). They are of two sizes, one small sized measuring

PLATE 1 →

All photographs are × 2000: Position of specimen in each slide is indicated by England Finder

1 Empty mucilaginous sheath after releasing globular cells: Slide no. 10963, × 35.

2,3,13. Endosporulation stage showing globular structures arranged into linear chain: Slide nos. 10964. Q 26/1, K44 and 10962. J46/3.

4. Endosporulation stage showing subglobular structures arranged in linear chain with a dark spot; Slide no. 10963, W40.

5,10 Globose structures clumped together into globular masses: Slide nos. 10963, U 38 and 10964, F28/1.

6,7,27 Large sized globular cells arranged in a globular colony surrounded by indistinct mucilaginous sheath; Slide nos. 10962, L29, H53/1 and 10963, S30.

8,9. Small sized globular cells released after the dissolution of wall: Slide nos. 10962, M43 and 10963, X37/4.

11 Large sized individual cell, in some showing condensed centric dark spot; Slide no. 10962, J45/3.

12,22. Small sized globular cells arranged in a globular colony surrounded by indistinct mucilaginous sheath; Slide no. 10962, M34/2, H53.

14,26,28. Variation in sizes of globose structures and cells, their overlapping ranges: Slide nos. 10962, M40/1, M52 and 10964, Q43.

15,16,23. Endosporulation showing large globular structures with dark coloured condensed protoplast: Slide nos. 10964, J48 and 10962, K45/2, G35/3.

17 Large globular structure showing dispersed protoplast with in the thick lamellated wall; Slide no. 10962, H51/4.

18,19,25. Large sized globular cells released after dissolution of wall, Slide nos. 10962, J46/1; 10964, Q44/1 and 10962, L 39/1.

20. Empty mucilaginous sheath of globose structures of globular small sized cells; Slide no. 10963, W30.

21 Linear arranged globose structures of tiny subunits within the mucilaginous sheath; Slide no. 10963, Q 35/3.

24,29. Globose structures clumped into dumble-shaped small-sized cells after dissolution of wall; Slide no. 10962, N50, N50/3.

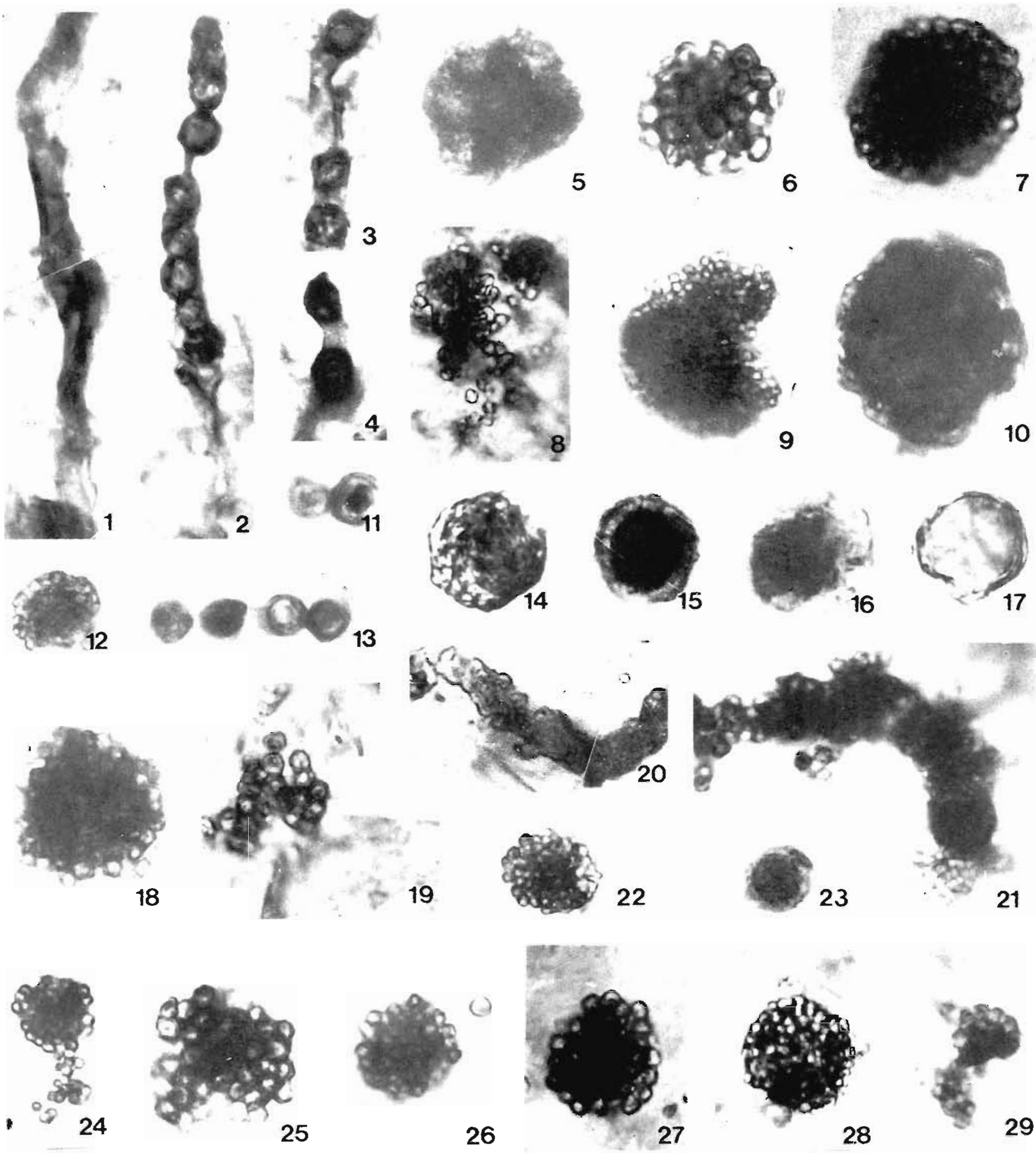
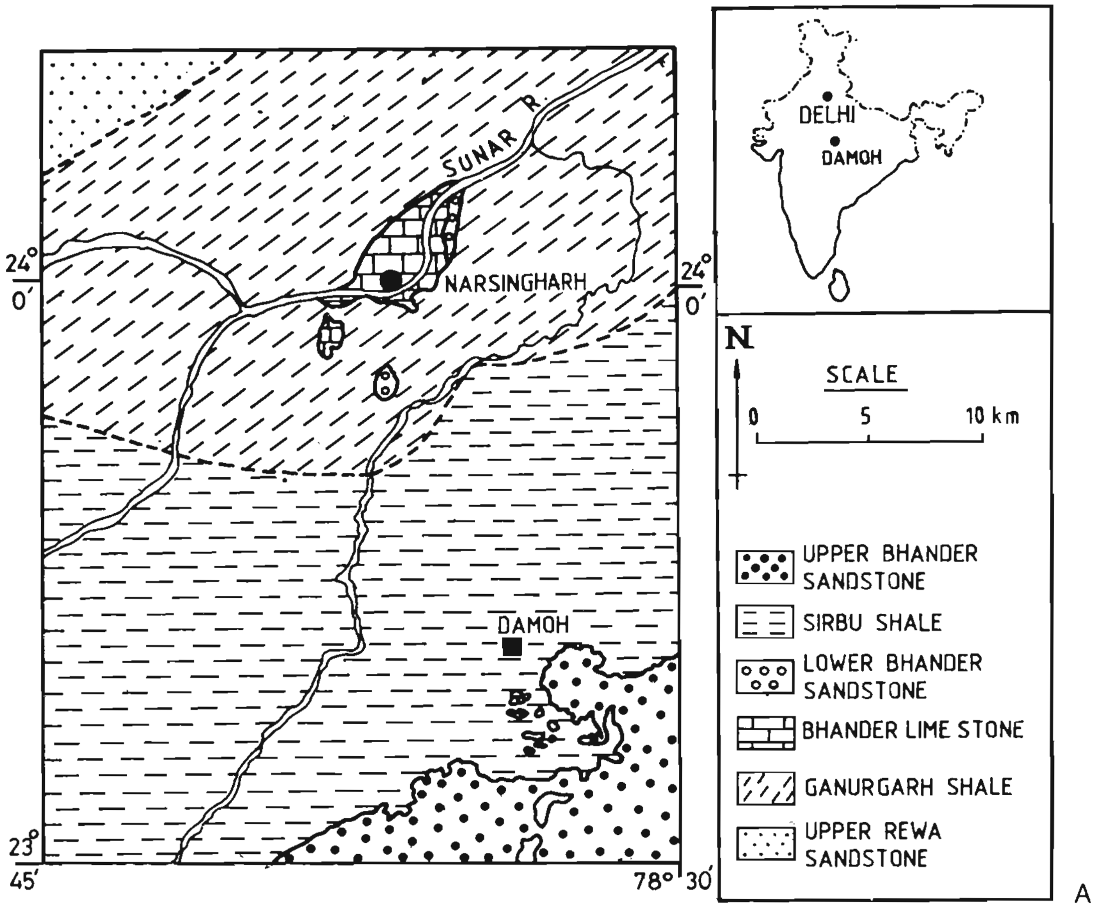
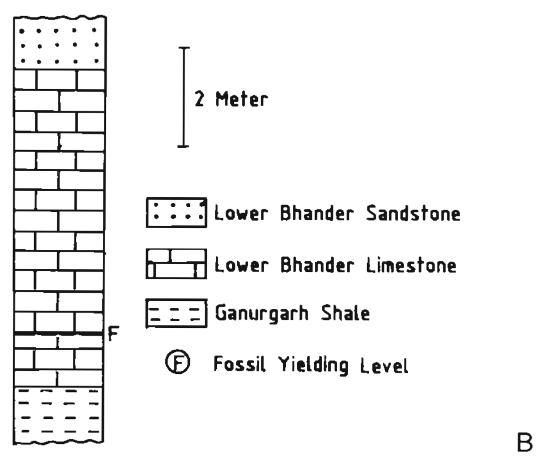


PLATE 1

5-12 μm (Pl. 1, figs 12, 22) and the other large, measuring 10-20 μm (Pl. 1, figs 6, 7, 27) in dimension. In both, isodiametric coccoidal subunits are solidly packed; however, their arrangement is not clear. In the smaller globose structure there appears to be a tendency of smaller masses to be composed of tiny subunits measuring less than 1 μm (Pl. 1, figs 12, 22). The tiny subunits get released from the enveloping unit by the enlargements of the globose structure into a dumble shaped (Pl. 1, figs 24, 29) structure and ultimately the dissolution of wall. Cells after release form irregular flat mats (Pl. 1, figs 8, 9).

The large globose units are packed with cells measuring ±2 μm having thickened cell wall with a small

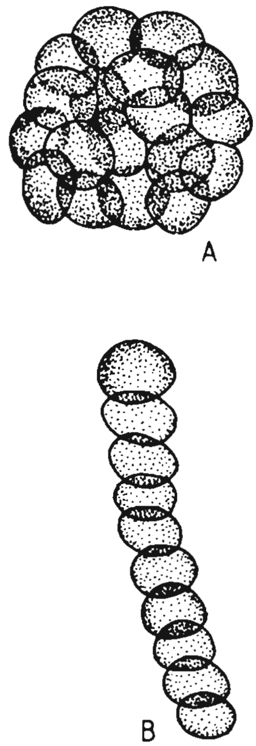




Text-figure 1—**A**, Map showing the fossil locality; **B**, lithocolumn.

dense spot in the centre (Pl. 1, fig. 11). Individual cells are circular or polyhedral and on release form colonies of irregular shape (Pl. 1, figs 18, 19, 25). Cell units within show the presence of opaque dark bodies which are spheroidal to ellipsoidal, polyhedral and irregular in shape measuring 0.2 to 0.5 µm. These opaque bodies occur near the centre or periphery of the cell units (Pl. 1, fig. 13); in several units they are absent. Occasionally, the globose cells with spots are enveloped in a gelatinous sheath and form a linear chain (Pl.. 1, figs 1-4).

Different opinions have been expressed in the past regarding the nature of these opaque bodies. Study of the degraded modern coccoid cyanophytes (Golubic & Hofmann, 1976; Francis, Margulis & Barghoorn, 1978) demonstrates that some of these Precambrian intracellular structures represent shrunken and degraded protoplast of coccoid cyanophytes, while others (Oehler, 1977; Schopf & Oehler, 1976) are of the opinion that the intracellular granules probably represent preserved organelles, most likely pyrenoids or nuclei of eukaryotic



Text-figure 2—Diagrammatic figures showing arrangements of endosporulation cell in resting stage; **A.** Globularly arranged; **B.** Linear arranged.

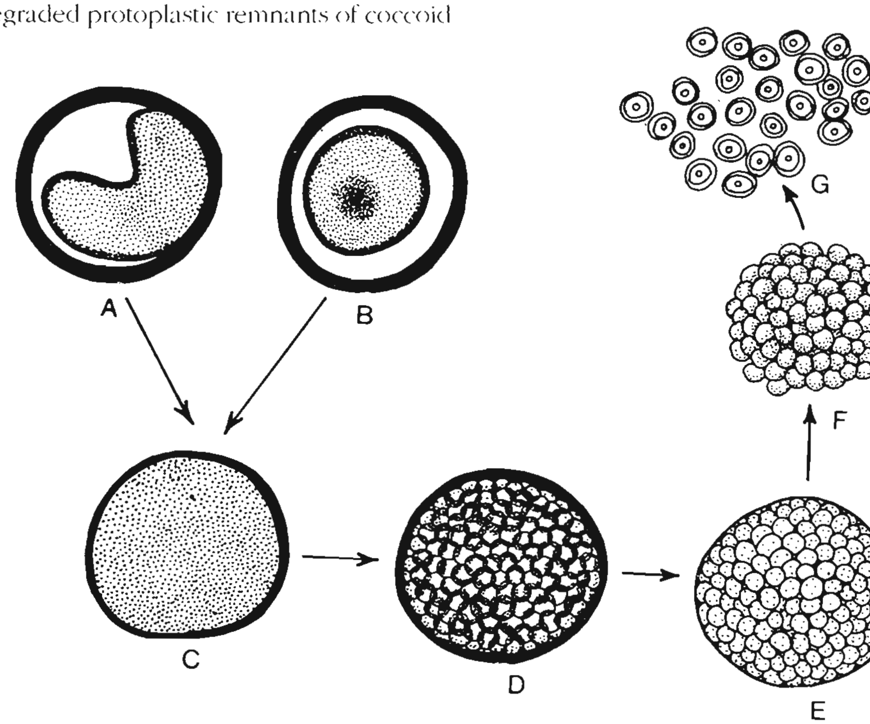
algae. We are also of the same view that these opauqe bodies are the degraded protoplastic remnants of coccoid cyanophytes as the sizes of the individual cells are less than 20 µm.

The cycle showing cell formation of endospores and their release after wall dissolution and liberation of individual cells to form colonies has been detailed in Text-figure 3. The resting stage is represented by globose structures with thick walls enclosing shrinked protoplasm (Text-figure 3A, B). On return of favourable conditions, the shrinked protoplasm gets activated, expands and spreads out in the total area of the globose resting stage. Subsequently, the division of protoplasm starts to form individual cells (Text-figure 3D) by cytokinesis. Individual cells remain closely adpressed to one another (Text-figure 3D, E) and get released on the dissolution of endospore walls (Text-figure 3F, G). This process gets reversed for the formation of endospores during adverse conditions.

Variation in the size of globose structures and cells and their overlapping (Pl. 1, figs 14, 26, 28) indicate that they belong to one species. The variation in sizes must be due to ecological factors affecting the growth of colonies.

COMPARISON AND DISCUSSION

A perusal of recorded biota from the Late Proterozoic sequence indicates that the endosporulating cyanobacteria have earlier been refered to different names in the literature.



Text-figure 3—Diagrammatic figures showing cell cycle: **A, B.** resting stage showing protoplasm enclosed in a thick mucilaginous sheath; **C.** activities for division of protoplasm into endospores; **D, E.** formation of individual endospores; **F.** dissolution of mucilaginous sheath; and **G.** release of endospores containing a dark spot.

The present colonies in their outline and size compare to *Favosphaera* Burmann 1972. The large sized cells and their colony compares with *F. conglobata* Burman figure by Konzalova (1974, p. 43, pl. 3, figs 4, 5; pl. 4, figs 7, 8) and the small sized cells and their colony resemble *F. sola* Burmann figured by Konzalova (1974, p. 44, pl. 3, figs 1-3; pl. 4, figs 1-3). The figured specimens of Konzalova (1974) also demonstrate similar state of preservation as in the present material. Konzalova (1974, p. 43), while describing these forms from the Upper Proterozoic sequence of Bohemia, pointed out that the forms of *Favosphaera* are indistinguishable from the forms assigned to *Synsphaeridium* Eisenack, e.g., *S. sorediforme* (Timofeev) Downie & Sarjeant.

On the other hand, the present forms also compare with an acritarch form, *Bavlinella* Shepeleva 1962. The large-sized form encountered in the present study has been refered by the Russian workers to *Bavlinella faveolata* Shepeleva. It has also been attributed by them to be of chronostratigraphic value and marker of Vendian. However our observations support the view of Hofmann (1984, p. 289) as cited, "the current consensus among Precambrian palaeontologists seem to favour the view that they are related to planktonic endosporulating cyanobacteria; their great abundance at certain levels probably being attributable to explosive blooms in stressed habitat, such as glacially influenced marine environment".

The present form also resembles morphographically *Sphaerocongregus variabilis* Moorman (1974, p. 535) recorded from the uppermost Proterozoic, Hector Formation, southwestern Alberta, Canada. According to Moorman (1974), the forms are coccoidal, planktonic endospore forming blue-green algae. He also opined that the morphologic features of *Sphaerocongregus* are comparable with a modern epiphytic blue-green alga—*Pleurocapsa fuliginosa*? which reproduces by endosporulation and vegetative division. According to him this is a planktonic flora which settled into moderately deep intrageosynclinal basin or distal portion of the Cordilleran misgeosyncline. It is also interesting that the biota occurs very near to Proterozoic-Phanerozoic boundary, just before the appearance of a well defined record of multicellular animal life.

Vidal (1976) considered *Sphaerocongregus* cogeneric with *Bavlinella*. Recently, Zang and Walter (1992, p. 310) discussed in detail the generic status of similar looking forms under *Sphaerocongregus* Moorman, viz., *Pyritosphaera* Love, *Microconcentrica* Naumova and *Bavlinella* Shepeleva. They considered *Pyritosphaera* as a mineral modified specimen of unknown origin and synonymous to *Sphaerocongregus*. Vidal and Nystuen (1990) pointed out that the type specimen *Bavlinella* is pyrite framboids and therefore, they rejected the earlier proposed name and revalidated the later name *Sphaerocongregus* Moorman. We have therefore used the same name here for the present fossils belonging to Lower Bhander Limestone Formation

The present fossil is the significant marker of Late Proterozoic, particularly Vendian. *Sphaerocongregus* has previously been recorded from the Late Proterozoic Mineral Fork Formation near Salt Lake City, Utah (Knoll *et al.*, 1981); the Stappogiedde Formation, Mortensnes Tillite, Grasdal, Dakkovarre and Stangenes formations of East Finmark (Vidal, 1981); the Eleonore Bay and Tillite groups in East Greenland (Vidal, 1976); the Visingso beds (Vidal, 1976); uppermost Proterozoic Hector Formation, Alberta, Canada (Moorman, 1974); Uppermost Proterozoic of Bohemia (Konzalova, 1974); latest Proterozoic of the Wernecke Mountains, Yukon (Hofmann, 1984); Upper Sinian, Liulaobei Zhaowei and Shijia formations in northern Anhui, China (Zang & Walter, 1992).

It is currently conjectured that at certain levels the great abundance of the present planktonic endosporulating cyanobacteria seems to be due to stressed habitat.

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