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MICROFOSSILS FROM THE NEOPROTEROZOIC BUXA DOLOMITE, WEST SIANG DISTRICT, ARUNACHAL LESSER HIMALAYA, INDIA AND THEIR SIGNIFICANCE

*MANOJ SHUKLA[1], V. C. TEWARI[@], *RUPENDRA BABU and AMBIKA SHARMA[@]

*BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY, 53 UNIVERSITY ROAD, LUCKNOW - 226007
[@]WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN - 248001, UTTARANCHAL, INDIA

ABSTRACT

A diversified assemblage of organic-walled microfossils comprising 31 benthic and planktic forms (cyanobacteria and acritarchs) has been recovered in petrographc thin sections from the lenses and the bedded chert belonging to the Buxa Dolomite exposed near Igo Bridge, Daring-Basar road in West Siang District of Arunachal Pradesh. In this assemblage, 17 taxa of cyanobacterial remains belonging to Chroococcaceae, Nostocaceae and Oscillatoriaceae, 14 forms of acritarchs belonging to Sphaeromorphida, Scaphomorphida and Sphaerohystrichomorphida subgroups are present. The cyanobacterial remains are *Huroniospora psilata*; *Eosynechococcus moorei*; *Paratetraphycus giganteus*; *Glenobotrydion aenigmatis*; *Myxococcoides minor*; *Palaeoanacystis suketensis*; *Oscillatoriopsis breviconvexa*, *O. robusta*, *Partitiofilum yakshinii*, *Palaeolyngbya contenata*; *Siphonophycus typicum*, *S. rugosum*; *Polythrychoides lineatus*; *Obruchevella parva*; *O. valdaica*; *Veteronostocale amoenum* and *Veteronostocale* sp. The 14 taxa of acritarchs are *Margominuscula rugosa*; *Granomarginata vetula*; *Lophosphaeridium rarum*, *L. jansoniusii*; *Trachysphaeridium robustum*; *Micrhystridium lanatum*, *M. ampliatum*; *Baltisphaeridium cerinum*; *Archaeohystrichosphaeridium semireticulatum*, A. *cellulare*; *Vandalosphaeridium reticulatum*; *Gorgonisphaeridium pindyium*; *Meghystrichosphaerium perfectum*; and *Navifusa bacillaris*.

The present microbiota compares well with the known assemblages from the Late Neoproterozoic (Vendian) sediments of Northwest and Central Lesser Himalaya, India and its equivalent sediments in other parts of the world. The presence of both benthic and plantonic forms in the assemblage indicates deposition in lagoonal tidal flat condition whereas contact with open sea was occasionally available.

Key words: Microfossils, Neoproterozoic, Buxa Dolomite, West Siang, Arunachal, Lesser Himalaya

INTRODUCTION

The geology of the northeast Lesser Himalaya has been described by Gansser (1964), Acharyya (1974), Bhushan *et al.* (1991), Kumar and Singh (1974), Kumar (1997), Srinivasan (1999) and Srinivasan (2001). Earlier workers have suggested a Mesoproterozoic age for these beds belonging to Bomdila Group exposed in Arunachal Pradesh, NE Lesser Himalaya. The Terminal Proterozoic-Early Cambrian succession is well exposed in several windows in Arunachal Pradesh (Tewari, 1998, 2001, 2002, 2003). The stromatolitic cherty dolomites are similar to the Buxa Dolomite in the present area and represent its western extension. The ministromatolites, stromatolites, cyanobacterial remains and sponge spicules have been recently reported from the Menga Limestone in Subansiri and Chillipam Dolomite in Kameng areas of the Arunachal Lesser Himalaya (Tewari, 2001, 2003, 2004) and correlated with the Late Proterozoic sediments of InfraKrol-Krol Formation on the basis of stromatolites, sedimentological facies and carbon isotopic ratios (Tewari, 2003). The palaeobiological remains of late Proterozoic age are already known from the northwestern and central part of lesser Himalaya (Kumar *et al.*, 1984; Maithy *et al.*, 1988; Acharyya *et al.*, 1989; Venkatachala *et al.*, 1990; Prasad *et al.*, 1990; Tiwari and Knoll, 1994; Maithy *et al.*, 1995, Tiwari *et al.*, 2000; Tiwari and Pant, 2004; and Shukla *et al*, 2005). The present study aims at understanding the implication of the palaeobiological remains on age and palaeoenvironment of the Buxa sediments in Arunachal Pradesh. It is an essential tool as thus far no absolute dates are available for the sediments of this area.

MATERIAL AND METHODS

The collection of the samples of black-bedded chert and chert nodules belonging to the Buxa Dolomites, Arunachal Lesser Himalaya India were done by two of the authors (V. C. Tewari and A. Sharma) Wadia Institute of Himalayan Geology, Dehradun, Uttaranchal. The palynological analysis was carried out at the Birbal Sahni Institute of Palaeobotany, Lucknow under a collaborative programme. All taxa described below are preserved in petrographic thin sections. Petrographic thin sections were prepared both along and perpendicular to the bedding planes of rocks. The preservation of the microfossils is variable from section to section and depends upon the angle at which samples were cut. The specimens are well preserved. The slides have been examined and photographed at 40 X and 100 X (under immersion oil) in transmitted light in an Olympus BH2 microscope. All the slides are deposited at the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow, India (Statement no. 1116).

GEOLOGICAL SETTING OF THE AREA

The Buxa Group is subdivided into three units in Buxa-Duars and adjoining Bhutan Himalaya namely Sinchula Quartzite, Jainti Quartzite and Buxa Dolomite (Gansser, 1964). Acharyya (1974) subdivided the Buxa Group of type area into two units, the lower Sinchula Formation and the upper Jainti Formation. The Buxa Dolomite in the type area comprises dolomite, orthoquartzite and variegated slates. In Arunachal Pradesh, the Miri Quartzite of Subansiri and Siang district overly the Buxa Dolomite (Figs. 1 and 2). The age of the Miri Quartzite conformably overlying the Buxa Dolomite is assigned Lower Cambrian on the basis of the presence of well-preserved ichnofossils (Lasker, 1972; Roy Chowdhury, 1975 in Lasker and Chowdhury, 1977; Tandon *et al.*, 1979; Tewari, 2003).

Dolomites, limestones, cherty stromatolitic dolomite, oolitic-intraclastic dolomite and calcareous quartzite represent the Buxa Group in the Arunachal Lesser Himalaya. The detailed geology and stratigraphic position of various sedimentary formations of NE Lesser Himalaya has been discussed in the recent literature (Bhushan *et al.*, 1991; Kumar, 1997; Srinivasan,

[1]E-mail: manoj_shukla_1999@yahoo.com

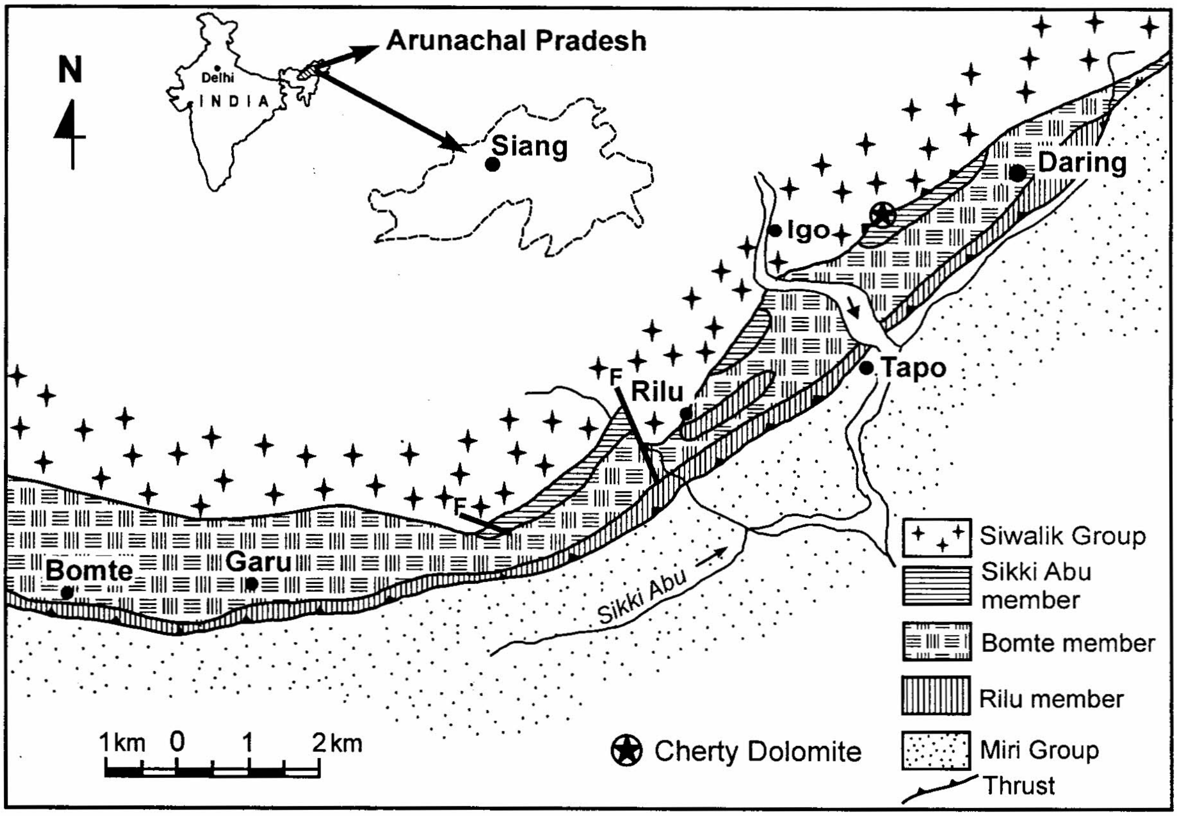

Fig. 1. Geological map of the Daring -Igo area, West Siang, Arunachal Pradesh after Kumar and Singh (1974). 1. Miri Group, 2. Rilu Member, 3. Bomte Member, 4. Sikki Abu Member and 5. Siwalik Group.

1999; Srinivasan, 2001; Tewari, 1998, 2001, 2002, 2003). In the present area, Kumar and Singh (1974) have classified marine Permian rocks and diamictite beds of the Siang area as the Garu Formation with three members viz. Rilu, Bomte and Sikki Abu (Fig. 1; Table1). The Buxa-Miri sediments (Terminal Neoproterozoic – Lower Cambrian) in the area have a thrust contact with the underlying Lower Permian Gondwana Group (Bomte Member of the Garu Formation). The generalized lithostratigraphic succession of the area is given below in Table 1.

FOSSIL LOCALITY

The thin band of the Buxa Dolomite is exposed along Basar-Daring road near Igo Bridge (Fig. 1) in the restricted zone in Arunachal Lesser Himalaya. The cherty dolomite is 25 m. thick (Fig. 3). The microbiota-bearing cherty intraclastic dolomite is about 3 meter in thickness (Fig. 2). The chert lenses are 8-12 mm in size. The light gray cherty intraclastic dolomite, overlying the digitate stromatolitic dolomite, is brecciated. Fenestral fabric (birds's eye) structures are also preserved in the light gray dolomite indicating supratidal depositional environment. The bedded chert bands are 4 to 5 cm thick. Dark black cherty bands underlie thinly laminated chert and gray carbonate bands.

The detailed litholog of the microbiota yielding Buxa Dolomite is given in the Fig. 3. The olive-green phyllites,

EXPLANATION OF PLATE I

(Single line scale Bar = 10μm, double line scale Bar = 20μm and wrinkle line scale Bar = 40μm)

1. Showing main mat builder form ***Siphonophycus*** BSIP Slide No., 13005.
2,3. Showing at places dominant genus, *i.e.* ***Paratetraphycus*** and ***Eosynechococcus.*** BSIP Slide Nos., 13005, 13006.
4. ***Partitiofilum yakshinii*** Sergeev *et al.*, BSIP Slide No., 13005.
5. ***Paratetraphycus*** **and** ***Eosynechococcus*** evenly distributed in the mat formed by ***Siphonophycus,*** BSIP Slide Nos., 13005,
6. ***Veteronostocale amoenum*** (Schopf and Blacic) Xu and Awramik, BSIP Slide No., 13005.
7. ***Palaeoanacystis suketensis,*** Maithy and Shukla, BSIP Slide No., 13005.
8, 9. ***Paratetraphycus giganteus*** Zhang, BSIP Slide Nos., 13005, 13006.
10. ***Veteronostocale*** sp., BSIP Slide No., 13005.
11 ***Palaeolyngbya cantenata,*** Hermann, BSIP Slide No., 13005.
12. ***Siphonophycus rugosum*** (Maithy) Hofmann & Jackson, BSIP Slide No., 13005.
13. ***Oscillatoriopsis robusta,*** Horodyski & Donaldson, BSIP Slide No., 13005.
14. ***Siphonophycus typicum*** (Hermann) Butterfield *et al.*, BSIP Slide No., 13005.
15. ***Glenobotrydion aenigmatis,*** Schopf, BSIP Slide No., 13005.
16 ***Huroniospora psilata*** Barghoorn, BSIP Slide No., 13005.
17. ***Myxococcoides minor*** Schopf, BSIP Slide No., 13005.
18. ***Eosynechococcus moorei*** Hofmann, BSIP Slide No., 13005.
19. ***Obruchevella valdaica*** Jankauskas, BSIP Slide No., 13005.
20 ***Oscillatoriopsis breviconvexa*** Schopf and Blacic, BSIP Slide No., 13005.

Plate I

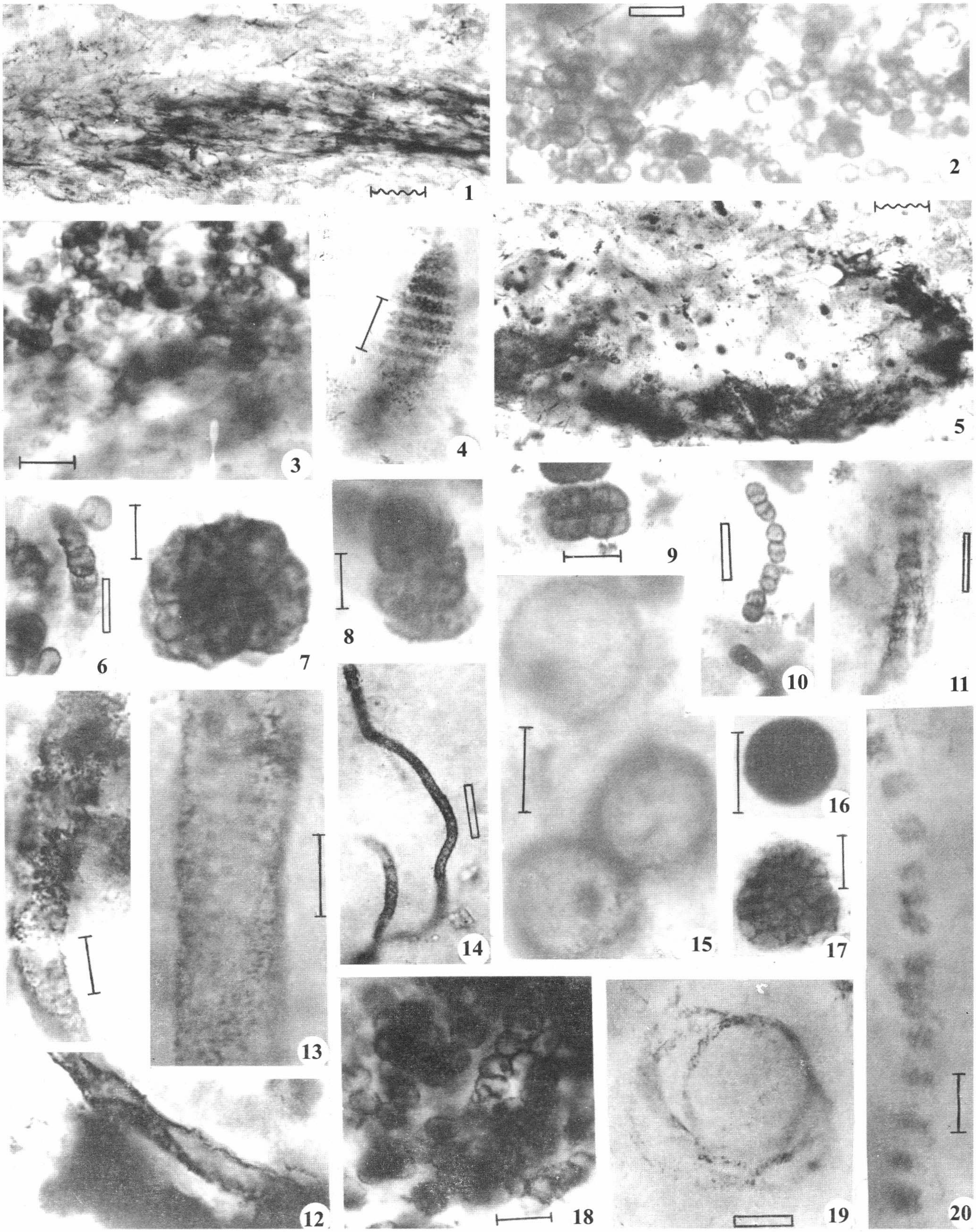

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Table 1: Generlised Lithotectonic Succession of the Area

BOMDILA GROUP	Phyllites, Quartzites, Schists, Mylonites, Gneisses
^^^^^^^^^^^^^^^^^^^^^^^^ Thrust	^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
Miri Quartzite (Lower Cambrian)	Conglomerate, pebbly quartzite, variegated quartzite with slates and phyllites
Buxa Dolomite (Vendian)	Cherty stromatolitic limestone / dolomite, intraclastic, oolitic dolomite
^^^^^^^^^^^^^^^^^^^^^^^^ Thrust	^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
	(Sikki-Abu Member)
	Middle Clastic Facies
(Garu Formation)	(Bomte Member)
Lower Permian	Lower Diamictites
	(Rilu Member)
^^^^^^^^^^^^^^^^^^^^^^^^ Thrust	^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
Siwalik Group	Sandstone, siltstone, coal beds

quartzites and metavolcanics of the Miri Quartzites overlie the Buxa Dolomite along the Igo river section, the Igo - Basar and the Igo-Garu road sections in West Siang District. The primary sedimentary structures like large scale cross laminations, ripple marks and herringbone structures are well preserved in the Miri Quartzite and indicate shallow marine (intertidal) depositional environment. The position of the thin cherty dolomite on the geological map of the area by Kumar and Singh (1974) is shown in Fig.1 by the present authors. The stromatolitic- cherty dolomite of Subansiri area (Menga Limestone) and the Kameng area (Chillipam Dolomite) are identical to the Buxa Dolomite in the present area and represent the western extension (Tewari, 2003). All the slides and micro photonegatives are deposited at the museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATIC DESCRIPTION

Cyanobacterial Remains

Kingdom **Eubacteria** Woese & Fox, 1977
Phyllum **Cyanophyta** Stanier *et al.*, 1978
Class **Coccocogoneae** Thuret, 1875
Order **Chroococcales** Wettstein, 1924
Family **Chroococcaceae** Nägeli, 1849
Genus ***Huroniospora*** Barghoorn, 1965
(Type species: ***Huroniospora microreticulata*** Barghoorn, 1965)
Huroniospora psilata Barghoorn, 1965
(Pl. I, fig.16)

Description: Cells solitary, spherical to sub circular in outline, 8-14 μm, exine thin, surface and margin smooth, mucilaginous sheath present but not clearly visible. Five specimens recorded.

Distribution: This form has been recorded from the sediments ranging from 2000 Ma to 650 Ma exposed in different parts of the world, viz. Gunflint Iron Formation of Ontario, Canada (Barghoorn, 1965); Vindhyan Supergroup (McMenamin *et al.*, 1983; Maithy and Gupta, 1983), Gangolihat Limestone (Nautiyal, 1989), Infra-Krol Formation (Venkatachala *et al.*, 1990; Tiwari and Azmi, 1992) of India.

Genus ***Eosynechococcus*** Hofmann, 1976
(Type species: ***Eosynechococus moorei*** Hofmann, 1976)
Eosynechococcus moorei Hofmann, 1976
(Pl. I, fig. 18)

Description: Loose to closed aggregation in clumping manner, individual cells 4-6 μm in size, rounded to oblong, sheath absent around the cells, cell wall thin, surface laevigate and cells contain dark inclusions. Seven specimens recorded.

Distribution: The present form is known from the 1.9 Ga old chert of the Belcher Island (Hofmann, 1976) and from the latest Precambrian sediments of the Tindir Group, Canada (Allison and Awramik, 1989) and Russia (Sergeev *et al.*, 1997).

Genus ***Paratetraphycus*** *Zhang*, 1984
(Type species: ***Paratetraphycus giganteus*** *Zhang*, 1984)
Paratetraphycus giganteus Zhang, 1984
(Pl. I, figs. 8, 9)

Description: Group of dyad and cross tetrads cells forming rounded to tetrahedral shaped colony due to mutual compression. These closely arranged cells are mostly in a common mucilaginous sheath; each clump length is 15-30μm and width 10-15μm. Sheath around individual cells absent, & width of individual cell 5-7 μm, wall thin, psilate in nature and cell inclusions absent. Four specimens recorded.

Distribution: This form has been recorded from the Late Sinian chert of Western Hubei Province and Guizhou Province of the China (Zhang, 1984; Zhang *et al.*, 1998 and Yuan and Hofmann, 1998) and Vendian sediments of the Scotia Group, Svalbard (Knoll, 1992).

Genus ***Glenobotrydion*** Schopf, 1968
(Type species: ***Glenobotrydion aenigmatis*** Schopf, 1968)
Glenobotrydion aenigmatis Schopf, 1968
(Pl. I, fig.15)

Description: Irregular aggregates of spherical to sub circular cells, occasionally also occur in solitary state, individual cells 7-18μm in size, wall smooth to fine granular, cells generally contain a small internal circular body of an organic matter ranging in size 2-4μm and wall of cells often distorted due to mutual compression of adjacent cells. Four specimens recorded.

Distribution: This form has been recorded from the Bitter Springs Formation, Australia (Schopf, 1968), Svalbard (Knoll and Calder, 1983), and from the sediments of Peninsular and Extra peninsular, India (Shukla *et al.*, 1987; Kumar and Srivastava, 1992, 1995).

Genus ***Myxococcoides*** *minor* Schopf, 1968
(Type species: ***Myxococcoides minor*** Schopf, 1968)
Myxococcoides minor Schopf, 1968
(Pl. I, fig. 17)

Description: Cluster of upto 30 spherical to sub circular cells surrounded by a common mucilaginous sheath measuring 20-30 μm in size, mucilaginous sheath indistinct around the individual cell measuring upto 5.0 μm, wall 1.0 μm thick, surface and margin smooth. Six specimens recorded.

Distribution: This form has been recorded from the 2000 Ma to 550 Ma old sediments of Bitter Springs Formation, Australia (Schopf, 1968), Belcher Islands of Canada (Hofmann, 1976), Tianzhushan member, Western Hubei, China (Yin *et al.*, 2003), Svalbard (Knoll and Calder, 1983), Spitsbergen (Knoll *et al.*, 1991), Kazakhstan, Central Asia and Siberia (Sergeev, 1989, 2001; Sergeev *et al.*, 1997), Deoban Formation, Lesser Himalaya (Kumar and Srivastava, 1992), and Vindhyan Supergroup, India (Maithy and Shukla, 1977; Kumar and Srivastava, 1995) and Infra Krol sediments of Nainital, Uttaranchal, India (Venkatachala *et al.*, 1990, Shukla *et al.*, 1987, Shukla *et al.*, 2005).

Genus ***Palaeoanacystis*** Schopf, 1968
(Type species: ***Palaeoanacystis vulgaris*** Schopf, 1968)
Palaeoanacystis suketensis Maithy and Shukla, 1977
(Pl. I, fig.7)

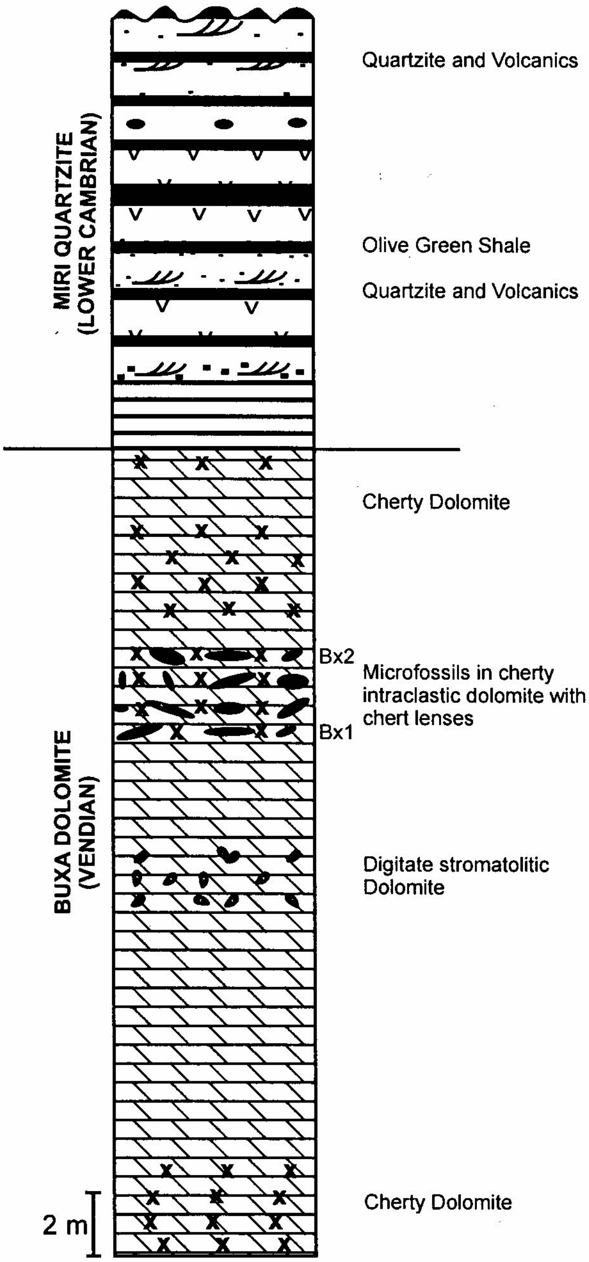

Fig. 2. Generalised litholog of the Buxa Dolomite and Miri Quartzite showing microbiota-yielding lithology in West Siang district, Arunachal Pradesh.

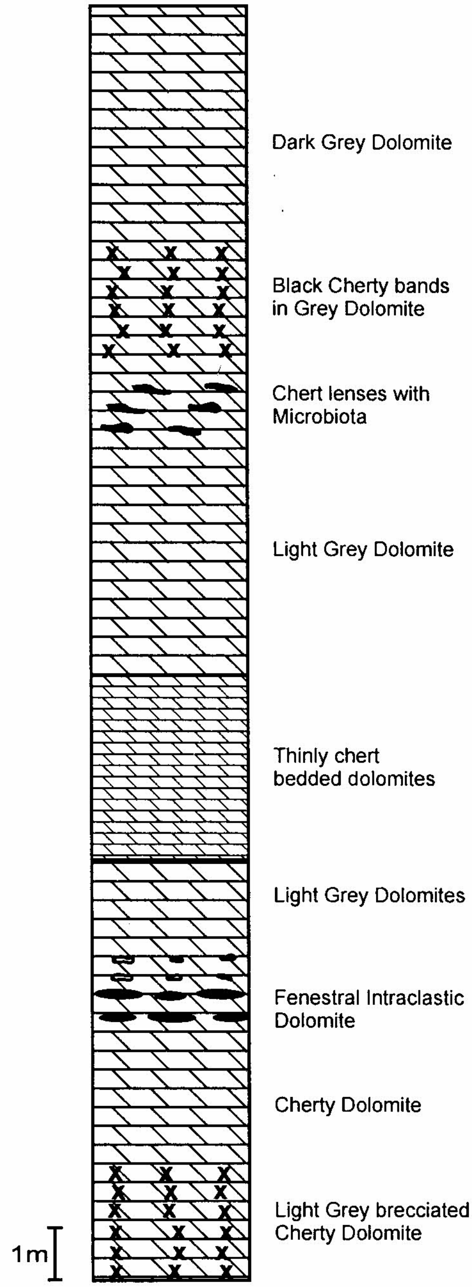

Fig. 3. Detailed litholog of the Buxa Dolomite showing microbiota-yielding bed in Igo-Daring road section, West Siang district, Arunachal Pradesh.

Description: Spherical to sub circular aggregate of cells, 26-40 μm in size, surrounded by a common mucilaginous sheath, cells counted 50. Individual cells are 5-11 μm in size, spheroidal to polygonal in shape due to mutual compression, exine thin, surface and margin smooth. Three specimens recorded.

Distribution: This form has been recorded from the Late Precambrian sediments (1200-900 Ma) belonging to Suket Shale Formation, Vindhyan Supergroup, India (Maithy and Shukla, 1977; Nautiyal, 1983).

Class **Hormogoneae** Thuret, 1875
Order **Nostocales** Wettstein, 1924
Family **Oscillatoriaceae** (SF Grey) Dumortier ex Kirchner, 1898
Genus ***Oscillatoriopsis*** (Schopf) Butterfield *et al.*,1994

(Type species: ***Oscillatoriopsis obtusa*** Schopf, 1968)

Oscillatoriopsis breviconvexa Schopf and Blacic, 1971
(Pl. I, fig. 20)

Description: Trichome multicellular, incomplete, uniseriate, unbranched, straight to curved, 85-130 μm long, individual cell 2-4μm long, 4-6 μm broad and trichome constricted near septation, Nine specimens recorded.

Distribution: This form has been recorded from the 1000 to 550 Ma old sediments of the Bitter Springs Formation, Amadeus Basin, Australia and Kazakhstan, central Asia and India (Schopf and Blacic, 1971; Sergeev, 1989; Kumar and Srivastava, 1992, 1995).

Oscillatoriopsis robusta Horodyski and Donaldson, 1980
(Pl. I, fig. 13)

Description: Trichome multicellular, solitary, uniseriate, unbranched, straight to slightly curved incomplete, length ranges from 70-100μm, maximum width 16 μm, mucilaginous sheath indistinct, cross wall present, trichome cells capsule shaped, cross walls may become double concave, cell size 4-6μm, surface granulate. Three specimens recorded.

Distribution: This form has been recorded from the middle Proterozoic sediments of the Dismal Lakes Group, Canada (Horodyski and Donaldson, 1980, 1983).

Remark: The present forms are larger in size than the forms reported from the middle Proterozoic chert of Dismal Lakes Group, Canada. (Horodyski and Donaldson, 1980, 1983) but they are morphologically similar to them and hence placed in the same species.

Genus ***Partitiofilum*** (Schopf and Blacic) Sergeev *et al.*, 1995

(Type species: ***Partitiofilum gonguloides*** Schopf and Blacic, 1971)

Partitiofilum yakshinii Sergeev *et al.*, 1995

(Pl. I, fig. 4)

Description: Solitary nonconstricted, oblong (convex) shaped trichome (single specimen) with psilate to granulate margins, terminal cells (ends) subrounded to conical, thin walled, length to width ratio 3:1, 32 μm long and 11.0 μm broad, trichome divided into a numbers of rectangular chambers or segments by transverse striations or grooves, 11 partitions counted.

Distribution: The present form morphologically resembles with the known form from Late Mesoproterozoic to Neoproterozoic sediments of Billykh Group, Anabar uplift, northern Siberia (Sergeev *et al.*, 1995).

Remarks: The length of present specimen is lesser than earlier described *Partitiofilum yakshinii* Sergeev *et al.*, 1995. The form has thin wall without any covering and looks like a broken trichome (Mendelson and Schopf, 1982; Sergeev, 2001). This form may be hormogonia or early life stage /juvenile stage of the filament belonging to the family Oscillatoriaceae.

Genus ***Palaeolyngbya***, Schopf; 1968

(Type species: ***Palaeolyngbya barghoorniana***, Schopf, 1968)

Palaeolyngbya cantenata (Hermann) Butterfield *et al.*, 1994

(Pl. I, fig. 11)

Description: Trichome incomplete, uniseriate, unbranched, straight to slightly curved, 85-125 μm long, 22 μm broad, mucilaginous sheath present, prominent cross wall may or may not be present, trichome cells disc shaped, 6.0 μm long and 12.0 μm wide cell. Three specimens recorded.

Distribution: This form has been recorded from the Meso-Neoproterozoic sediments of the Russian Platform (Hermann, 1974); Spitsbergen (Butterfield *et al.*, 1994) and Lesser Himalaya, India (Srivastava and Kumar, 2003).

Genus ***Siphonophycus*** (Schopf) Knoll, Swett and Mark, 1991

(Type species: ***Siphonophycus kestron*** Schopf, 1968)

Siphonophycus typicum (Hermann) Butterfield *et al.*, 1994

(Pl. I, fig. 14)

Description: Trichome, incomplete, unbranched, entangled, 95-130μm long, 4-6 μm wide, wall psilate to finely granular, 1.0 μm thick, septation 2.0 μm thick, not clear at places. Three specimens recorded.

Distribution: This form has been recorded from the uppermost Mesoproterozoic-Vendian sediments of Spitsbergen (Butterfield *et al.*, 1994; Knoll *et al.*, 1991), Sukhaya Tunguska, Shorikha and Burovaya formations of northeastern Siberia (Sergeev *et al.*, 1997 and Sergeev, 2001), Doushantuo Formation, China (Zhou *et al.*, 2002), Canada (Samuelsson and Butterfield, 2001) and Australia (Cotter, 1997).

Siphonophycus rugosum (Maithy) Hofmann and Jackson, 1994

(Pl. I, fig. 12)

Description: Trichomes solitary, incomplete, cylindrical, unbranched, non-septate, 80-140μm long, 8-11 μm wide, surface appears granulate which may be due to diagenetic condition. Eight specimens recorded.

Distribution: This form has been recorded from the Meso-Proterozoic – Sinian shales and chert of Spitsbergen (Hofmann and Jackson, 1994), China (Yuan and Hofmann, 1998), Bushimay Zaire, Africa (Maithy, 1975) and Peninsular/Extrapeninsular India (Prasad and Asher, 2001; Shukla *et al.*, 2005).

Genus ***Polythricoides*** (Hermann) Hermann, 1976

(Type species: ***Polythricoides lineatus*** (Hermann) Hermann, in Timofeev *et al.*, 1976)

Polythricoides lineatus (Hermann) Knoll *et al.*, 1976

(Pl. II, figs. 2-3)

Description: Aseptate tubular filaments, 80-130μm in long, aggregation of upto 10 entangled trichomes in a common sheath, width of the bundle ranging 15-20 μm, diameter of the trichomes 2-4μm. Two specimens recorded.

Distribution: This form has been recorded from the Late Proterozoic – Early Paleozoic sediments of Russian platform

EXPLANATION OF PLATE II

(Single line scale Bar = 10μm, double line scale Bar = 20μm and wrinkle line scale Bar = 40μm)

1, 20. ***Obruchevella parva*** Reitlinger, BSIP Slide No., 13005.

2, 3. ***Polythricoides lineatus*** (German) Timofeev *et al.*, BSIP Slide No., 13005.

4. ***Meghystrichosphaeridium perfectum*** (Kolosova) Zhang *et al.*, BSIP Slide No., 13005

5,7. ***Margominuscula rugosa*** Naumova, BSIP Slide No., 13005.

6. ***Micrhystridium ampliatum***, Wang BSIP Slide No., 13005.

8,13. ***Archaeohystrichosphaeridium semireticulatum*** Timofeev, BSIP Slide No., 13005.

9,11. ***Granomarginata vetula*** Salujha *et al.*, 1972, BSIP Slide No., 13005.

10. ***Micrhystridium lanatum*** Volkova, BSIP Slide No., 13006.

12,14. ***Archaeohystrichosphaeridium cellulare*** Timofeev, BSIP Slide No. 13005.

15 ***Navifusa bacillaris*** (German) Hofmann and Jackson, BSIP Slide No., 13005

16. ***Vandalosphaeridium reticulatum*** (Vidal.) Vidal, BSIP Slide No., 13005.

17. ***Lophosphaeridium jansoniusii*** Salujha *et al.*, BSIP Slide No., 13006.

18. ***Baltisphaeridium cerinum*** Volkova, BSIP Slide No., 13007.

19. ***Trachysphaeridium robustum*** Yin and Li, BSIP Slide No., 13005.

21. ***Lophosphaeridium rarum*** Timofeev, BSIP Slide No., 13005.

22. ***Gorgonisphaeridium pindyium*** Zang, BSIP Slide No., 13005.

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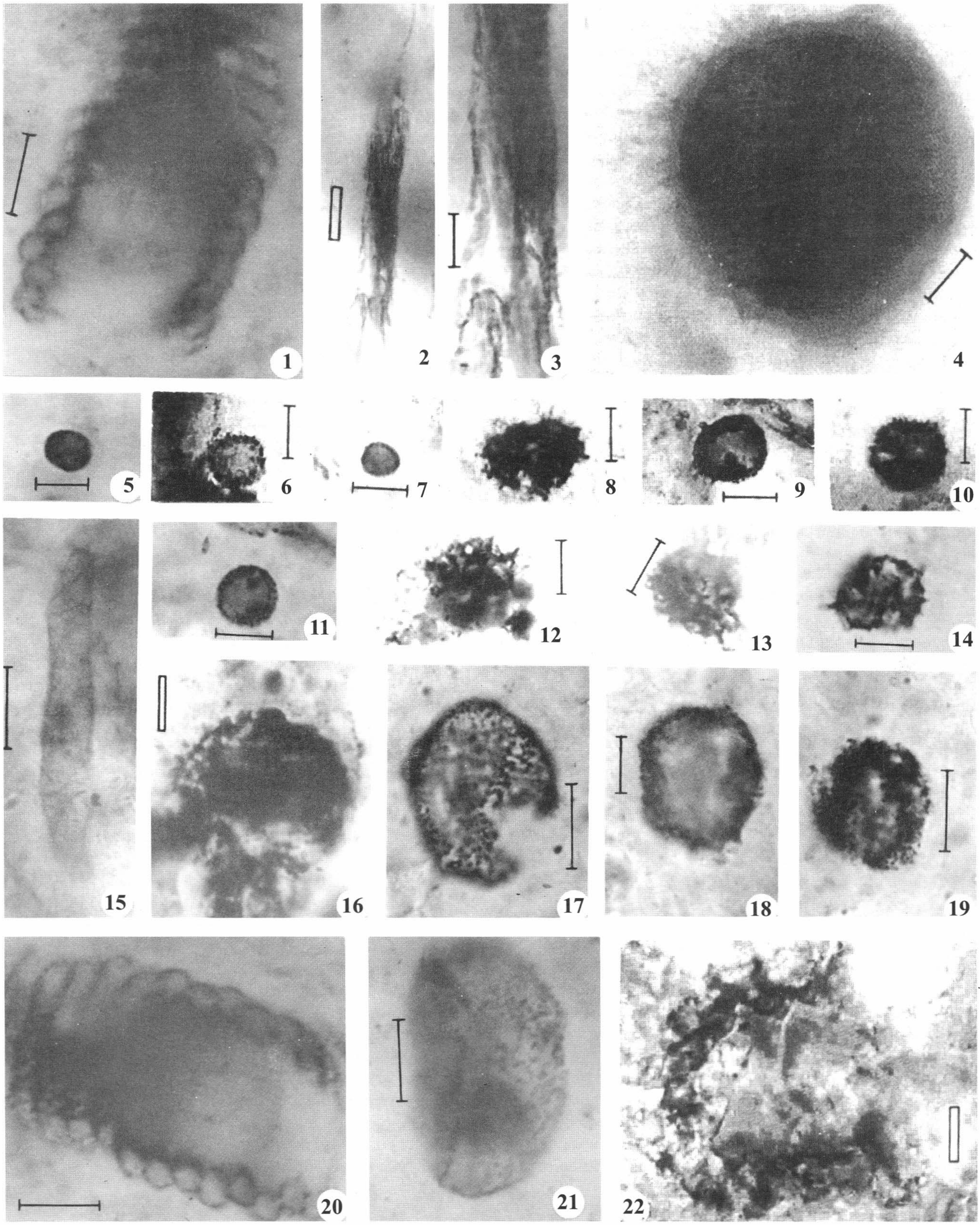
Plate II



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(Hermann, 1974; Timofeev *et al.*, 1976; Ragozina and Shivertseva, 1990); Svalbard (Knoll, 1992); Spitsbergen (Knoll *et al.*, 1991; Knoll *et al.*, 1995); Canada, (Hofmann and Jackson, 1994); China (Zang and Walter, 1992; Yin and Sun,1994 and Yin and Yuan, 2003) and Bhander Group, India (Maithy and Babu, 1993) and Deoban Limestone, Lesser Himalaya (Srivastava and Kumar, 2003).

Genus ***Obruchevella*** (Reitilinger) emend.
Yakshin and Luchinina, 1981
(Type species: ***Obruchevella delicata*** Reitilinger, 1948)
Obruchevella parva Reitlinger, 1959
(Pl. II., figs. 1, 20)

Description: Hollow cylindrical tube, non septate, bound into regular helix with no whorl expansion and constant rate of whorl transition along the coiling axis, adjacent turns at coil in contact with each other, cross-sectional diameter of tube 2-4μm, outer dimension of the coil 20-35 μm and length of helix 45-54 μm, septation distance 2-3 μm. Three specimens recorded.

Distribution: This form has been recorded from the sediments ranging between Upper Riphean–early Cambrian from the Siberian platform (Reitlinger, 1959; Yakshin and Luchinina, 1981; Kolosova, 1982; Yakshin, 1989; Golovenok and Belova, 1983; Sergeev,1989); Svalbard (Knoll and Ohta, 1988; Knoll, 1992); Canada (Mankiewicz, 1992); Greenland (Peel,1988); Arabian Shield (Cloud *et al.*, 1979); Northeast China (Wang, *et al.*, 1983; Song, 1984; Yin *et al.*, 1993; Yin *et al.*, 2003) and India (Tiwari and Azmi, 1992; Maithy and Babu,1997; Srivastava and Kumar, 2003).

Obruchevella valdaica (Shepeleva, ex Aseeva, 1974)
Jankauskas, 1989
(Pl. I, fig. 19)

Description: Trichome forms irregular whorls, whorl width 70-80μm, solitary, unicellular, incomplete, unbranched, non-septate, 2-6 μm wide, wall thin, surface smooth to finely granulate, cross wall like structures appear on the surface of trichome due to tight folds and compression. Four specimens recorded.

Distribution: This form has been recorded from the Vendian sediments of Russian platform (Aseeva, 1974; Hermann, 1990 and Jankauskas *et al.*, 1989), Canada (Mankiewicz, 1992 and Hofmann and Jackson, 1994); Greenland (Samuelsson and Vidal, 1999) and also India (Prasad and Asher, 2001).

Family **Nostocaceae** Nageli, 1849
Genus ***Veteronostocale*** (Schopf and Blacic)
Xu and Awramik, 2001
(Type Species: ***Veteronostocale amoenum***
(Schopf & Blacic) Xu and Awramik, 2001)
Veteronostocale amoenum (Schopf and Blacic)
Xu and Awramik, 2001
(Pl. I, fig.6)

Description: Trichome (chain like aggregation of sphaeroidal to subsphaeroidal cells), straight to slightly curved, uniseriate, unbranched, incomplete, size 50-80μm long, 6-10μm wide and upto 8.0μm long cells overlap each other, usually 8 in number, margin thin, surface laevigate, Ten specimens recorded.

Distribution: This form has been recorded from the 1500-1000 Ma old cherts of the Australia (Schopf and Blacic, 1971) and China (Xu and Awramik, 2001).

Veteronostocale sp
(Pl. I, fig.10)

Description: Trichomes incomplete, ranging 30-60 μm long, uniseriate, unbranched straight to slightly curved, made-up of chain like 7-10μm long and 4-6μm wide aggregation, sphaeroidal to dumble shaped cells, cell margin thin and surface laevigate. Three specimens recorded.

Comparison: The present form in the assemblage differs from the other species viz. *Veteronostocale amoenum*, (Xu and Awramik, 2001), *V. moniliforme* (Xu and Gao, 1991), and *V. vaginata* (Xu and Awramik, 2001) and *Cyanonema disjuncta* Ogurtsova and Sergeev, 1987 from Kazakhstan in shape and arrangement of the cells *Palaeoanacystis plumbii* (Muir, 1976) and looks similar in having mucilaginous sheath around the colony.

Acritarchs (Forms of unknown Affinities)

Group **Acritarcha** Downie,
Evitt and Sarjeant, 1963
Subgroup **Sphaeromorphida** Timofeev, 1966
Genus ***Margominuscula*** Naumova, 1960
(Type species: ***Margominuscula rugosa*** Naumova, 1960)
Margominuscula rugosa Naumova, 1960
(Pl. II, figs. 5, 7)

Description: Vesicles subspherical, solitary, size 5-7 μm, with distinct narrow margin, exine baculate, bacula less than 1.0 μm in size, central area psilate to granulose, thin walled. Five specimens recorded.

Distribution: This form has been recorded from the Tovidonian to Sinian sediments of Scotland (Naumova, 1960) and China (Jinbiao *et al.*, 1980).

Genus ***Granomarginata*** Naumova, 1960
(Type species: ***Granomarginata prima*** Naumova, 1960)
Granomarginata vetula Salujha, Rehman and Arora, 1972
(Pl. II, figs. 9,11)

Description: Vesicles circular to oval in outline, 10-14μm in size, exine 3 μm thick, surface granulates and grana arranged at a distance of 1-2 μm. Four specimens recorded.

Distribution: This form has been recorded from the Late Proterozoic (1200-900 Ma) sediments of the Kurnool Group (Salujha *et al.*, 1972), Semri Group (Nautiyal, 1983) and Ganga Basin (Prasad and Asher, 2001).

Genus ***Lophosphaeridium*** (Timofeev) Lister, 1970
(Type species: ***Lophosphaeridium rarum***
(Timofeev) Downie, 1963)
Lophosphaeridium rarum Timofeev, 1959
(Pl. II, fig. 21)

Description: Vesicle subcircular, 30-35 μm, thin walled, margin inwardly folded and 2.0μm large baculae sparsely distributed on the entire surface. Two specimens recorded.

Distribution: This form has been recorded from the Late Proterozoic to Sinian sediments of the Baltic Series of Russia (Timofeev, 1959), Doushantou Formation of China (Zhang *et al.*, 1998), Vindhyan (Nautiyal, 1983) and Ganga Basin of India (Prasad and Asher, 2001).

Lophosphaeridium jansoniusii Salujha *et al.*, 1971b
(Pl. II, fig.17)

Description: Vesicle subcircular, 15-26 μm, margin thin and baculae densely distributed on the entire surface, ± 2.0μm in size. Three specimens recorded.

Distribution: This form has been recorded from the Meso–Neoproterozoic sediments of Vindhyan Supergroup (Salujha *et al.*, 1971b) and Ganga Basin (Prasad and Asher, 2001) in India.

Genus ***Trachysphaeridium*** Timofeev (1966) 1969

Table 2: Comparative chart of O.W.M. (cyanobacterial remains, acritatrchs and vsm) in present assemblage belonging to neoproterozoic sediments of the world.

				Cyanobacteria						Acritarch			VSM
COUNTRY	Authors	Lithology	Formation/Group	⭘	✹	∞	&	Y	§	●	✹	◆	Ω
INDIA	Shukla *et al.* **Present studies**	Sh+C	Buxa Dolomite	+	–	+	+	+	+	+	+	+	
	Venkatachala *et al.*, 1990	Nl+C+ Sh	Infra-Krol	+	–	+	+	–	+	–	–	–	+
	Tiwari & Pant, 2004	Nl+C	Infra Krol	+	+	–	+	–	+	+	+	–	+
	Maithy & Babu, 1997	Sh+C	Bhander Gr.	+	+	–	+	+	+	+	+	+	+
	Shukla *et al.*, 2005	Sh+C	Infra Krol	+	–	–	–		+	+	+	–	+
CANADA	Butterfield & Rainbird, 1998	Sh	Wynniat	–	–	–	+	–	+	+	+	–	–
CHINA	Wang *et al.*, 1983	Ph+C	Dengying & Meishucun	+	–	+	+	–	+	+	+	+	–
	Zang & Walter, 1992	Sh+Slt.	Huanian Gr	+	–	+	+	–	–	+	+	+	–
	Yin *et al.*, 1993	Sh+Slt+C	Shuijigtuo	+	+	+	+	+	+	+	+	–	–
	Yin & Gao, 1995	C	Dengying	+	–	–	+	+	–	+	+	–	–
	Zhang *et al.*, 1998	Nl+C+Ph	Doushantuo	+	+	+	+	+	+	+	+	+	–
	Yin *et al.*, 2003.	Slt+C	Doushantuo	+	–	+	–	–	+	+	+	–	–
GREENLAND	Knoll *et al.*, 1987	Sh+Sst	Polarisbreen Gr	–	+	–	–	–	–	+	+	–	–
	Strother *et al.*, 1983	Slt+Sh	Narssarssuk	+	+	+	+	–	–	+	+	–	–
SPITSBERGEN	Knoll, 1982	Silici-clastic	Draken Conglte	+	+	–	–	+	–	+	+	+	–
	Knoll & Swett, 1985	Sh+Slt	Veteranen Gr.	+	+		+	–	+	+	+	–	–
	Knoll *et al.*, 1991	Siliĉi Carbonate	Conglte	+	–	–	+	–	–	+	+	-	+
	Butterfield *et al.*, 1994	Sh+C	Svanbergfellet	+	+	+	+		+	+	+	+	–
SVALBARD	Knoll *et al.*, 1981	Sh+ slt	Mineral Fork, Utah	+	–	–	+	–	–	+	+	–	+
	Knoll & Ohta, 1988	Sh+D	P. K. F.	–	–	–	+	–	+	+	+	–	–
	Vidal and *Neustan,* 1990a	Sh+Sst+ Conglte	Hedmark Gr	+	–	–	+	–	–	+	+	+	–
	Knoll, 1992	C	Backlundtoppen	+	–	–	+	–	–	+	+	–	–
FINLAND	Tynni and Donner, 1980	Slt+Sh	Muhos	–	–	+	+	–	–	+	+	–	–
AFRICA	Maithy, 1975	Sh	Kanshi, Zaire	+	–	+	+	–	–	+	+	–	–
RUSSIA	Pykova, 1973	Sh	South Urals Siberia	–	–	–	+	–	–	+	+	–	–
	Timofeev, 1973	Sh	Siberia	–	+	–	+	–	+	+	+	+	–
	Lo, 1980	C+ Lst	Lr. Yudoma Suite	+	+	–	+	+	–	+	+	–	–

	Sergeev, 1989	Silis+ C+D	Maly-Karatau Ridge, Kazakhstan	+	+	+	+	–	+	+	+	+	
	Weiss, 1989	C	Judoma Majurgian	+	+	+	+	–	–	+	+	–	–
	Jankauskas, 1990	Sh+Slt+C	South and CIS Urals	–	–	–	+	–	–	+	+	–	–
	Pyatiletov & Rudavskaya, 1990	Sh+Slt+C	Siberian Platform	–	–	–	+	–	–	+	+	–	–
	Ragozina and Sivertseva, 1990	Sh+ Slt+C	Valdai Series	–	–	–	+	–	–	+	+	–	–
	Yakshin, 1989	Sh+ C	East European	+	+	+	+		+	+	+	+	–
	Yakshin, 1990	Sh+ Slt+C	Tinnovka	–	–	–	+		+	+	+	–	–
	Volkova, 1990	Sh+Slt+C	Regions of E. Europe	–	–	–	+	–	–	+	+	–	–
AUSTRALIA	Damassa and Knoll, 1986	Sh	Arcoona Quartzite	–	–	–	+	–	–	+	–	–	–
	Zang & Walter, 1992	Sh+C	Pertataka Fm	+	+	+	+	+	+	+	+	–	–
	Zang, 1995	C+Sh+Slt	Alinya Fm	+	–	+	+	+		+	+	+	–
	Cotter, 1997	Siliceous + C	Madley & Browne Fms	+	–	-	+	-		+	+	-	–

D = Dolomite, Ph =Phosphate, Nl = Nodular, C = Chert, Sh = Shale, Slt = Siltstone, Sst = Sandstone, Lst.= Limestone, Conglte = Conglomerate
○ = Chroococcaceae, ✱= Pleurocapsaceae, ∞ = Nostocaceae, &ℨ = Oscillatoriaceae, Y=Branched filaments, § = Coiled sheath
● = Sphaeromorphida, ✱ = Sphaerohystrichomorphida, ◆ = Scaphomorphida, Ω = VSM, + = Present, – = Absent

(Type species: ***Trachysphaeridium attenuatum*** Timofeev (1966) 1969)

Trachysphaeridium robustum Yin and Li, 1978
(Pl. II, fig. 19)

Description: Vesicles circular to oval, 15-25 μm, irregularly microfolded, exine thin, surface granulate and grana densely arranged, ±2 μm in size. Two specimens recorded.

Distribution: This form has been recorded from the late Precambrian sediments of China (Yin and Li, 1978; Yin, 1987).

Subgroup ***Scaphomorphida*** Timofeev, 1966

Genus ***Navifusa*** Combz, Lange and Pansart, 1967

(Type species: ***Navifusa navis*** Eisenack, 1938)

Navifusa bacillaris (Hermann) Hofmann and Jackson, 1994
(Pl. II, fig. 15)

Description: Vesicle single, longitudinally elongate, 40 μm long and 6.0 μm wide, stretched, both ends sub-rounded, vesicle psilate and margin thin. Two specimens recorded.

Distribution: This form has been recorded from the Late Meso–Neoproterozoic sediments of the Russian Platform (Hermann, 1981), Canada (Hofmann and Jackson, 1994) and India (Prasad and Asher, 2001).

Subgroup **Sphaerohystrichomorphida** Timofeev, 1966

Genus ***Micrhystridium*** (Deflandre) Lister, 1970

(Type species: ***Micrhystridium inconspicum*** (Deflandre) Deflandre, 1937)

Micrhystridium lanatum Volkova, 1969
(Pl. II, fig.10)

Description: Vesicles spherical, thin-walled, 10-12 μm in size, micro folds present on the surface, surface covered with sharp tipped, dense 2-3 μm long spines. Three specimens recorded.

Distribution: This form has been recorded from the Late Precambrian sediments of Northwest Russian platform (Volkova, 1969) and Kazakhstan (Sergeev, 1989).

Micrhystridium ampliatum Wang, 1985
(Pl. II, fig. 6)

Description: Vesicles spherical, 8-10 μm, thin-walled, surface covered with small sized unbroken spines arranged at regular intervals, spine 2-3 μm long and up to 2.0 m broad at the base. Four specimens recorded.

Distribution: This form has been recorded from the Middle-Upper Proterozoic sediments of China (Wang, 1985; Yin *et al.*, 2003).

Genus ***Baltisphaeridium*** Eisenack, 1958

(Type species: ***Baltisphaeridium longispinosum*** Eisenack, 1958)

Baltisphaeridium cerinum Volkova, 1968
(Pl. II, fig. 18)

Description: Vesicle sub-spherical to ovate, size 20-24μm, spines counted 23 around the periphery, sharp to blunt on the margin, 2-3 μm long and ± 3 μm broad, margin slightly thickened and sometimes folds present around the periphery. Two specimens recorded.

Distribution: This form has been recorded from the Vendian to Lower Cambrian sediments of Estonia (Volkova, 1968), East European and Siberian platform (Pyatiletov and Rudavskaya, 1990) and Kazakhstan (Sergeev, 1989).

Genus ***Archaeohystrichosphaeridium*** Timofeev, 1959

(Type species: ***Archaeohystrichosphaeridium vologdense*** Timofeev, 1959)

Archaeohystrichosphaeridium semireticulatum Timofeev, 1959
(Pl. II, figs. 8, 13)

Description: Vesicles sub spherical, size 15-20 μm, polygonal folds present on the surface form pseudo-reticulation, spines 3μm long and sharp to blunt having >2 μm wide base. Four specimens recorded.

Remark: The present specimen is morphologically similar, but smaller in size, than earlier reported form from the Baltic Region of the Russian Platform (Timofeev, 1959) and Lesser Himalaya, India (Shukla, *et al.*, 2005).

Distribution: This form has been recorded from the Late Proterozoic sediments of the Russian Platform (Timofeev, 1959) and Lesser Himalaya, India (Shukla, *et al.*, 2005).

Archaeohystrichosphaeridium cellulare Timofeev, 1959
(Pl. II , figs. 12,14)

Description: Vesicles subspherical, size 16-20 μm, thin walled, irregular folds present, surface covered with small sized spines, 2-4 μm long, sharp to blunt, having >2 μm wide base and polygonal chambering/ reticulation formed by small sized spines. Two specimens recorded.

Distribution: This form has been recorded from the Late Proterozoic sediments of the Russian Platform (Timofeev, 1959) and Lesser Himalaya, India (Shukla *et al.*, 2005).

Genus ***Vandalosphaeridium*** Vidal, 1981
(Type species: ***Vandalosphaeridium reticulatum*** (Vidal) Vidal, 1981)

Vandalosphaeridium reticulatum (Vidal) Vidal, 1981
(Pl. II, fig. 16)

Description: Vesicles circular to subcircular in outline, 60-80 μm in size, wall moderately thick, irregular micro folds in exine form false reticulation, exine thin, surface covered with spines like structures, spine tip subrounded, size 6-16 μm long and 4-6 μm broad processes at the base. Two specimens recorded.

Comment: The present form contains more spines around the margin and on the surface than the forms reported from the Alinya Formation, eastern part of Officer Basin of the Australia (Zang, 1995).

Distribution: This form has been known from the Meso-Neo Proterozoic sediments of Sweden, East Greenland (Vidal, 1976, 1981), Australia (Zang, 1995) and India (Prasad and Asher, 2001).

Genus ***Gorgonisphaeridium*** Staplin, Jansonius, and Pocock, 1965
(Type species: ***Gorgonisphaeridium winslowii*** Staplin, Jansonius and Pocock, 1965)

Gorgonisphaeridium pindyium Zang, 1995
(Pl. II, fig. 22)

Description: Single vesicle, circular to irregular in outline, 80-125 μm, wall thin $\pm$ 2 μm, flexible, commonly folded, bears 12 or more un-branched spines around the margin, angular to rounded tips, spines 8-12 μm long and 5-8 μm wide at the base.

Distribution: The present species has also been reported from the early Neoproterozoic chert of Alinya Formation, eastern part of Officer Basin, South Australia (Zang, 1995).

Genus ***Meghystrichosphaeridium*** Zhang, Yin, Xio and Knoll, 1998
(Type species: ***Meghystrichosphaeridium chadianensis*** (Chen and Liu) Zhang *et al.*, 1998)

Meghystrichosphaeridium perfectum (Kolosova) Zhang *et al.*, 1998
(Pl. II, fig. 4)

Description: Vesicle, subspherical to spheroidal in outline, size 40-58 μm, bears numerous regularly spaced processes of variable length ranging 6-13 μm in length, spine sharp to blunt on the margin. Two specimens recorded.

Distribution: This form is reported from the Vendian and Sinian sediments of the Siberia (Kolosova, 1990) and China (Zhang *et al.*, 1998).

DISCUSSION AND CONCLUSION

The recovered organic-walled microfossils comprise of 31 taxa of cyanobacteria, and acritarchs from the bedded chert belonging to Buxa Group exposed in West Siang district, Arunachal Pradesh, India. Cyanobacterial remains (17) belong to Chroococcaceae, Nostocaceae and Oscillatoriaceae, while acritarchs (14) belong to Sphaeromorphida, Scaphomorphida and Sphaerohystrichomorphida subgroups. The recovered assemblage compares well with the known late Neoproterozoic assemblages from other parts of the world (see Table 2).

The cyanobacteria is the most tolerant and primitive group and has remained morphologically unchanged since Archaean to recent (Knoll and Bauld, 1989). The similar filamentous and coccoidal forms described here; have been reported from the Archaean to Neoproterozoic sediments exposed in other part of the world (see distribution part in the systematics of present paper. The similar cyanobacterial remains belonging to different ages are reported from the Precambrian cherts in other parts of the world (Reitlinger, 1959; Barghoorn, 1965, Schopf, 1968; Schopf and Blacic, 1968; Muir, 1976; Hofmann, 1976; Horodyski and Donaldson, 1980, 1983; Mc Menamin *et al.*, 1983; Allison and Awramik, 1989; Knoll and Sergeev, 1995; Green *et al.*, 1988; Srivastava and Kumar, 2003 and Rai and Singh, 2004). Thus, these forms do not have any stratigraphic significance. However, the helically coiled morphology, as shown by *Obruchevella* has widespread occurrence in upper Riphean – early Cambrian sediments (Reitlinger 1959; Cloud, *et al.*, 1979; Yakshin and Luchinina, 1981; Golovenok and Belova, 1983; Wang *et al.*, 1983; Sergeev 1989; Peel, 1988; Knoll and Ohta, 1988; Yakshin, 1989; Knoll, 1992; Tiwari and Azmi, 1992; Yin *et al.*, 1993; Maithy and Babu, 1997; Yin *et al.*, 2003;). The *Obruchevella* is generally considered marker for Vendian. However, there are stray records of *Obruchevella* from the older sediments (Hofmann and Jackson, 1994; Prasad and Asher, 2001; Srivastava and Kumar, 2003 and Rai and Singh, 2004).

The acritarchs show morphological changes through time and hence have been used worldwide for stratigraphic purpose especially in absence of dating material (Timofeev, 1959; 1966; Downie, 1984; Traverse, 1988; Fensome *et al.*, 1990; Vidal and Ford, 1985; Weiss, 1989; Moczydlowska, 1991; Zang and Walter, 1992; Jenkins *et al.*, 1992; Knoll, 1996; Burzin, 1996 and Prasad and Asher, 2001). The large size acanthomorphic acritarchs along with leiosphaerids are present in the early Vendian and these large forms disappear near the advent of the Ediacara fauna (Knoll, 1992; Zang and Walter, 1989 and Burzin, 1996). The size of the acanthomorphs reduces in younger sediments till we get dominance of small forms in the late Vendian (Volkova, 1968; Germs, 1995; Germs *et al.*, 1986 and Jankauskas, 1989). The acanthomorphs in the present assemblage, which include *Trachysphaeridium; Micrhystridium; Baltisphaeridium; Archaeohystrichosphaeridium; Vandalosphaeridium; Gorgonisphaeridium; Meghystrichosphaeridium* and *Navifusa,* are generally of small to medium size indicating Late Neoproterozoic affinity. The present acritarch assemblage compares with known assemblages of late Neoproterozoic sediments (shales, siltstone and cherts) in other part of the world (see distribution part of systematics in the present paper). This assemblage has close resemblance with chert facies acritarchs assemblage reported from the equivalent sediments of world (Vidal, 1976, 1981; Yin and Li, 1978; Wang *et al.*, 1983; Vidal and Ford, 1985; Yin, 1987, 1997; Green *et al.*, 1988; Kolosova, 1990; and Pyatiletov and Rudavskaya, 1990).

The commonly occurring taxa of Cyanobacterial remains and acritarchs in the present assemblage are also know from the equivalent late Neoproterozoic sediments exposed in other parts of world (Jinbiao *et al.*,, 1980; Wang *et al.*, 1983, Green *et al.*, 1987; Sergeev 1989; Yakshin, 1989; Jankauskas, 1989; Venkatachala *et al.*, 1990; Hofmann and Jackson, 1991; Knoll *et al.*, 1991; Knoll, 1992; Yin *et al.*, 1993; Butterfield *et al.*, 1994; Maithy and Babu, 1997; Yuan and Hofmann, 1998; Zhang *et al.*, 1998; Yin *et al.*, 2003 and Shukla, *et al.*, 2005). Thus, the overall analysis (quantity and quantity) of the recovered assemblage indicates late Neoproterozoic age for Buxa Dolomites.

The present assemblage consists of coccoidal and filamentous cyanobacterial remains including helically coiled forms, planktons, viz. leiosphaerids and small sized acanthomorphs. The nature of morphology, especially quantity of the coccoids and filaments may be due to ecological condition hence cyanobacteria are assumed the best indicator of the ecology during that period. The significance of cyanobacterial remains has been used in determining the ecological condition (Hofmann, 1976; Horodyski *et al.*, 1977; Green *et al*, 1987; Knoll, *et al.*, 1989; Vidal and Nystuen, 1990a,b; Yin,1991; Hofmann and Jackson, 1991; Knoll *et al*, 1991; Veis and Petrov, 1994a and Petrov, 1995).

The present assemblage consists of interwoven meshes (Pseudo-reticulation) of mat builders with mat dweller, plankters and some open sea plankton. The presence of mat building forms and plankton depends upon the environment (Round, 1981; Zhang, 1985; Allison and Awramik, 1989; Knoll and Bauld, 1989 and Javaux, *et al.* 2001). The dominant genus *Siphonophycus* is seen to form interwoven cyanobacterial meshes and represents the main mat builder in this assemblage (Pl. I, fig. 1). The next dominant genera are *Eosynechococcus*; *Paratetraphycus* that are evenly distributed in the mat formed by *Siphonophycus* (Pl. I, fig. 5) and at places becomes the dominant genus in the mat (Pl. I, figs. 2,3) The other mat building forms viz. *Palaeolyngbya* and *Oscillatoriopsis* in the assemblage are allochthonous and did not play a role informing the mat. These allochthonous forms are found in solitary state and show degradation of cytoplasmic content. . The forms viz. *Myxococcoides*, *Glenobotrydion* and *Palaeoanacystis* in the assemblage represent the plankters, and are distributed randomly in the matrix. The open sea planktons viz. *Trachysphaeridium; Micrhystridium; Baltisphaeridium; Archaeohystrichosphaeridium; Vandalosphaeridium; Gorgonisphaeridium; Meghystrichosphaeridium* and *Navifusa* are also distributed randomly in this assemblage. The forms i.e. *Polythricoides, Palaeolyngbya* and *Myxococcoides* that have common mucilaginous sheath indicate desiccating condition in the depositional environment (Knoll *et al.*, 1981, Mansuy and Vidal, 1983, Seong *et al.*, 1999 and Kah and Knoll, 1996). The *Glenobotrydion,* which has dark body, indicates shrinkage of cytoplasm including cell organelles due to plasmolysis condition, which indicates drier (harsh nest) environment such as hypersaline pool at the time of deposition (Golubic, 1976, Golubic and Hofmann, 1976 and Bauld, 1984). The blooming nature of *Obruchevella* (Mankiewicz, 1992) is also indicative of harsh condition due to seasonal changes of environmental condition. The analysis of the recovered OWM assemblage indicate that the deposition of this assemblage took place either in upper intertidal or supratidal region and it had occasional contact with open sea, which is indicated/supported by the presence of open sea planktons (Knoll, 1984; Knoll *et al.*, 1991; Sergeev, 1992,1994 and Burzin, 1996).

The carbon and oxygen isotopic ratios of the Buxa Dolomite from Subansiri, Chillipam and Dedza areas of the Arunachal Lesser Himalaya suggest that these signatures are of Neoproterozoic (Vendian) age and represent pristine marine environment (Tewari, 2002, 2003; Tewari and Sial in press). The carbon isotope ratios are significantly positive and quite consistent with δ^{13} C (carbonate carbon) values ranging from +3.7 to +5.4 ‰ (PDB). The Oxygen-isotope data also shows remarkable consistency with the δ^{18}O value fluctuating within a narrow range between −8.9 and −7.2 ‰ (PDB)(+24.6 to 25.9 ‰ SMOW). The Buxa Dolomite of the Arunachal Lesser Himalaya can be correlated with the Vendian Krol Formation of the Uttaranchal Lesser Himalaya on the basis of the very high positive carbon isotopic ratios and the present palaeobiological assemblage. The Doushantuo carbonates (Terminal Neoproterozoic) of the Yangtze Platform, South China also display very high carbon isotopic ratios identical to Krol- Buxa signatures of the Himalaya and were deposited after the global Neoproterozoic low latitude glacial event (Tewari, 2003, 2004 and Shen and Schidlowski, 2000).

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REFERENCES

Acharyya, S.K. 1974. Stratigraphy and sedimentation of the Buxa Group, Eastern Himalaya. Jour. *Him. Geol.* **4**: 102-116.

Acharyya, S.K., Raha, P.K., Das, D.P., Moitra, A.K., Shukla, M. and Bansal, R. 1989. Late Proterozoic microbiota from the Infra Krol rocks from Nainital Synform, U.P. Himalaya, India. *Indian Jour. Geol.* **61**(3): 137-147.

Allison, C.W. and Awramik, S.M. 1989. Organic-walled microfossils from earliest Cambrian or Latest Proterozoic Tindir Group rocks, northwest Canada. *Precamb. Res.* **43**: 253-294.

Aseeva, E.A. 1974. About spiral and ring-like structures in the upper Precambrian deposits of Podolima (In Russian). *Paleontol., Sbornik.* **11**(2): 95-98.

Barghoorn, E.S. and Tyler, S.A. 1965. Microorganisms from the Gunflint Chert. *Sci.* **147**: 563-577.

Bauld, J., 1984. Microbial mats in marginal marine environments: Shark Bay, Western Australia and spencer Gulf South Australia, p 39-58. In: *Microbial Mats : Stromatolites* (Eds. Cohen Y., Castenboltz, R.W. and Hashvonson, H.O.), New York, Allen Liss Inc.

Bhusan, S.K., Bindal, C.M. and Agarwal, R.K. 1991. Geology of Bomdila Group in Arunachal Pradesh. *Jour. Him. Geol.* **2**: 207-214.

Butterfield, N.J., Knoll, A.H. and Swett, K. 1994. Palaeobiology of the Neoproterozoic Svanbergfjellet Formation, Spitsbergen. *Fossils and Strata,* **34**: 1-84.

Butterfield, N.J. and Rainbird, R.H. 1998. Diverse Organic-walled microfossils, including possible 'Dinoflagellates' from the Early Neoproterozoic of Arctic Canada. *Geol.* **26**: 963-966.

Burzin, M.B. 1996. Late Vendian (Neoproterozoic III) microbial and algal communities of Russian Platform: models of facies-dependent distribution, evolution and reflection of basin development. *Rev. Ital. Paleontol. Stratigr.* **102**: 307-316.

Cloud, P., Awramik, S.M.. Morrison K. and Hadley, D.G. 1979. Earliest Phanerozoic or latest Proterozoic fossils from the Arabian Shield. *Precamb. Res.* **10**: 73-93.

Cotter, K. 1997. Neoproterozoic microfossils from the Officer Basin, Western Australia. *Alcheringa*, **21** (4): 247-270.

Damassa, S.P. and Knoll, A.H. 1986. Micropaleontology of the Late Proterozoic Arcoona Quartzite member of the Tent Hill Formation, Stuart Shelf, South Australia. *Alcheringa,* **10**: 69-74.

Downie, C., 1984. Acritarchs in British stratigraphy. *Geol. Soc. London, Special Report,* **17**, 1-27.

Fensome, R.A., Williams, G.L., Barss, M.S., Freeman, J.M. and Hill, J.M. 1990. Acritarchs and fossil Prasinophytes: An index to genera, Species and intraspecific taxa. *Am. Ass. Stratigr. Palynol. Contrib. Series,* **25**: 771.

Gansser, A. 1964. *Geology of Himalaya.* Intersciences Publishers, London.

Germs, G.J.B. 1995. The Neoproterozoic record of southwestern Africa, with emphasis on platform stratigraphy and palaeontology. *Precamb. Res.* **73**: 137-151.

Germs G.J.B., Knoll, A.H and Vidal, G. 1986. Latest Proterozoic microfossils from the Nama Group, Namibia (South West Africa). *Precamb. Res.* **32**: 45-62.

Golovenok, V.K. and Belova, M.Y. 1983. Nakhodki *Orbruchevella* v Rifee Patomskogo Nagorya I v vende Yuzhnogo Kazakhshstana (The finds of the microfossils genus *Orbruchevella* in the Riphean of the Patoma Uplift and Vendian of southern Kazakhstan) *Dok. Acad. Nauk SSSR,* **272**: 1462- 1465.

Golubic, S. 1976. Organisms that build stromatolites, p. 113-126. In: *Stromatolites Developments* in *Sedimentology* (Ed. Walter, M. R.) **20**.

Golubic, S. and Hofmann, H.J. 1976. Comparison of Holocene and Mid-Precambrian Eoentophysalidaceae (Cyanophyta) in stromatolitic algal mats: cell division and degradation. *Jour. Pal.* **50**: 1074-1082.

Green, J.W., Knoll, A.H., Golubic, S. and Swett, K. 1987. Palaeobiology of distinctive benthic microfossils from the Upper Proterozoic Limestone- dolomites"Series " Central East Greenland. *Amer. Jour. Botany*, **74**: 928-940.

Green, J.W.; Knoll, A.H.; Golubic, S. and Swett, K. 1988. Microfossils from Oolites and Pisolites of the Stromatolitic carbonates of the Upper Proterozoic limestone-dolomite 'Series' East Greenland. *Geol. Mag.* **126**(5): 567-585.

Hermann, T.N. 1974. Nakhodki Massovykh Skopleniyi Trikhomov v Rifeei, p. 6-10. In: *Mikrofossilii Proterozya i rannego Paleozoa SSSR* (Ed. Timofeev, B. V.), (Findings of mass accumulation of trichomes in Riphean), Nauka Moscow. (In Russian).

Hermann, T.N. 1981b. Nakhodi nitchaykh vodorosely vmiroyedikh Skay Suite Verkhnego do kembriya (Occurrence of filamentous algae from the Miroedikha Formation of Upper Precambrian) *Paleontol. Zhurnal,* **14**: 118-122 (English version, 1982), **10**: 111-116.

Hermann, T.N. 1990. Vendian filamentous algae, p. 173-178. In: *The Vendian System No. 1* (Eds. Sokolov, B. S. and Iwanoski, A. B.), Palaeontology, **1**.

Hofmann, H.J. 1976. Precambrian microflora, Belcher Islands, Canada: Significance and systematics. *Jour. Pal.* **50**: 1040-1074.

Hofmann, H.J. 1984. Organic-walled microfossils from the latest Proterozoic and earliest Cambrian of the Wernecke mountains, Yukon, p. 285-297. In: *Current Research Part 1B Geol. Surv. Canada,* **84**.

Hofmann, H.J. and Jackson, G.D. 1991. Shelf facies microfossils from the Uluksan Group (Proterozoic, Bylot Supergroup), Baffin Island, Canada. *Jour. Pal.* **65**: 361-382.

Hofmann, H.J. and Jackson, G.D. 1994. Shale facies microfossils from the Proterozoic, Bylot Supergroup, Baffin Island, Canada. *Mem. Pal. Soc Canada*, **37**: 1-35.

Hofmann, H.J. and Jackson, G.D. 1996. Notes on the geology and micropaleontology of the Proterozoic Thule Group, Ellesmere Island, Canada and northwest Greenland. *Geol. Surv. Canada, Bull.*: 1-26

Horodyski, R.J., Bloeser, B. and Vonder Haar, S. 1977. Laminated algal mats from a coastal lagoona, Laguna, Mormona, Baja, California, Mexico. *Jour. Sed. Petrol.* **47**: 68-96.

Horodyski, R.J. and Donaldson, I.A. 1980. Microfossils from the Middle Proterozoic Dismal Lakes Group, Arctic, Canada. *Precamb. Res.* **11**: 125-157

Horodyski, R.J. and Donaldson, I.A. 1983. Distribution and significance of microfossils in cherts of the Middle Proterozoic Dismal Lakes Group, District of Mackenzie, Northwest Territories, Canada. *Jour. Pal.* **57** (2) : 271-288.

Jankauskas, T.V. 1989. Mikrofossilli Dokembkriya SSSR (Precambrian microfossils of the USSR). *Trudy Inst. Geol. Geokhronologii SSSR Akad. Nauka Leningrad*, **1**, 188.pp (In Russian).

Jankauskas, T.V. 1990. Plant microfossils of the Urals, p. 171-172. In: *Vendian System* (Eds. Sokolov, B.S. and Iwanoski, A.B.). Akademika Nauka, SSSR, Moscow. Palaeontology, **1**.

Jankauskas, T.V. (Editor in Chief). Mikhailova, N.S. and German, T.N. 1989. Microfossilii dokembriya, SSSR (Precambrian microfossils of the USSR). *Trudy Inst. Geol. Geokhronologii Doked. SSSR Akad. i Nauka Leningrad*, 191.pp. (In Russian)

Javaux, A., Knoll, A.H. and Walter, M.R. 2001. Morphological and ecological complexity in early eukaryotic ecosystem. *Nature,* **412**: 66-69.

Jenkins, R.J., Mckirdy, D.M., Foster, C.B.O'leary, T. and Pell, S.D. 1992. The record and stratigraphic implications of organic-walled microfossils from the Ediacaran (Terminal Proterozoic) of South Australia. *Geol. Mag.* **129**: 401-410.

Jinbiao, C.; Zhang, H.M.; Zhu , S.; Zhao, Z. and Wang, Z. 1980. Research on Sinian Suberathem of Jixian Tianjin, p. 56-114. In: *Research on Precambrian Geology - The sinian Suberathem in China.* Science and Technology Press, Tianjin, (In Chinese).

Kah, L.C. and Knoll, A.H. 1996. Microbenthic distribution of Proterozoic tidal flats: Environmental and Taphonomic consideration. *Geol.* **24**: 79-82.

Knoll, A.H. 1982. Microfossils based biostratigraphy of the Precambrian Hecla Hock sequence, Nordaustlandet, Svalbard. *Geol. Mag.* **119** (3) : 269-279.

Knoll, A.H. 1982. Microfossils from the Late Precambrian Draken Conglomerate, Ny Friesland Spitsbergen. *Jour. Pal.* **56**(3): 755-790.

Knoll, A.H. 1984. Microbiotas of the late Precambrian Hunnberg Formation, Nordaustlandet, Svalbard. *Jour. Pal.* **58**(1): 131-162.

Knoll, A.H. 1992. Vendian microfossils in metasedimentary cherts of Scotia Group, Prins Karls Forland, western Svalbard. *Palaeont.* **35**(4): 751-774.

Knoll, A.H. 1996. Archeaen and Proterozoic Palaeontology, p. 51-80. In: *Palynology Principles and applications* (Eds. Jansonius, I. and Mc Gregor, D.C.), *Am. Ass. Stratigr. Palynol. Foundation,* **1**: 51-80.

Knoll, A.H. and Bauld, J. 1989. The evolution of ecological tolerance in prokaryotes. *Trans. Royal Soc. Edinburgh, Earth Sci.* **80**: 209-

223.

Knoll, A.H., Blick, N. and Awramik, S.M. 1981. Stratigraphic and ecological implications of Late Precambrian microfossils from Utah. *Am. Jour. Sci.* **281**: 247-263.

Knoll, A.H. and Calder, S. 1983. Microbiotas of the Late Precambrian Ryssö Formation Nordaustlandet, Svalbard. *Palaeont.* **26**: 467-496.

Knoll, A.H and Ohta, Y. 1988. Microfossils in metasediments from the Prins Karl Forland, Western Svalbard. *Polar Research*, **6**: 59-67.

Knoll, A.H. and Sergeev, V.N. 1995. Taphonomic and evolutionary changes across the Mesoproterozoic - Neoproterozoic Transition. *N. Jb Geol Paläonto. Abh.* **19**: 289-302.

Knoll, A.H. and Swett, K. 1985. Micropaleontology of the Late Proterozoic Veteranen Group. Spitsbergen. *Palaeont.* **28**(3): 451-473.

Knoll, A.H., Swett, K. and Burkhardt, E. 1989. Palaeoenvironment distribution of microfossils and stromatolites in Upper Proterozoic, Backlundtoppen Formation, Spitsbergen. *Jour. Pal.* **63**: 129-145.

Knoll, A.H., Swett, K. and Marks, J. 1991. Palaeobiology of a Neoproterozoic tidal flat/lagoonal complex in the Draken Conglomerate Formation, Spitsbergen. *Jour. Pal.* **65**: 531-570.

Knoll, A.H. and Walter, M.R. 1992. Latest Proterozoic stratigraphy and earth history. *Nature* **356**: 673-678.

Kolosova, S.P. 1982. *Verkhnedokembrijske paleoal' gologischeskie ostatki Sibirskoj platformy (Upper Precambrian Paeo-algal remains from the Siberian Platform). Nauka Moscow, (In Russian).*

Kolosova, S.P. 1990. Ancient acanthomorphs of eastern Siberian Platform. *Organic world and stratigraphy of deposits in oil gas and oil bearing regions of Siberia* **49947-B90**:7-45.

Kumar, G., Raina, B.K., Bhargava, O.N., Maithy, P.K. and Babu, R. 1984. Precambrian–Cambrian boundary problem and its prospects, Northeast Himalaya, India. *Geol. Mag.* **121** (3): 211-219.

Kumar, S. and Rai, V. 1992. Organic-walled microfossils from the bedded chert of the Krol Formation (Vendian) Solan, Himachal Pradesh, India. *Jour Geol. Soc. India,* **39**(3): 229-234.

Kumar, S. and Singh, T. 1974. Lithostatigraphy of the southern part of the Siang district, Arunachal Pradesh. *Him. Geol.* **4**: 648-656.

Kumar, S., and Srivastava, P. 1992. Middle to late proterozoic microbiota from the Deoban Limestone, Garhwal Lesser Himalaya, India. *Precamb. Res.* **56**: 291-318.

Kumar, S., and Srivastava, P. 1995. Microfossils from the Kheinjua Formation, Mesoproterozoic Semri Group, Newari Area, Central India. *Precamb. Res.* **74**: 91-117.

Lo, S.C. 1980. Microbial fossils from the Lower Yudoma Suite, earliest Phanerozoic eastern Siberia. *Precamb. Res.* **13**: 109-166.

Laskar, B. and Roychowudhary, J. 1977. Sedimentation Pattern along the margin of the Gondwanic Continent: Arunachal Pradesh, Northeastern India. *IV Int. Gondwana Symp., Calcutta.* Hindustan Publ. Co., New Delhi **2**: 581-587.

Lister, T.R. 1970. The acritarchs and chitinozoa from Wenlock and Ludlow Series of the Ludlow and Millichope areas, Shropshire. *Palaeontogr. Soc. Monographs*, **124**(1): 1-100

Maithy, P.K. 1975. Micro-organisms from Bushimay System (Late Precambrian) of Kanshi, Zaire. *Palaeobot.* **22**(2): 133-149.

Maithy, P.K. and Babu, R. 1993. Organic- Walled Microfossils from the Ganurgarh Shale Formation (Bhander Group) Vindhyan Supergroup, Hoshangabad, Madhya Pradesh, India. *Jour. Pal. Soc. India,* **38**: 43-49.

Maithy, P.K. and Babu, R., 1997. Upper Vindhyan biota and Precambrian / Cambrian Boundary. *Palaeobot.* **46** (1/2) : 1-6.

Maithy, P.K., Babu, R., Kumar, G. and Mathur, V.K. 1995. New cyanophycean remains from the Blaini Formation (Terminal Neoproterozoic Sequence) of Mussoorie Syncline, Lesser Himalaya, India. *Palaeobot.* **43** (1): 39-44.

Maithy, P.K., Babu, R., Raina, B.K. and Kumar, G. 1988. Proterozoic microfossils from Machhal and Lolab Formations of the Kashmir Himalaya, India, *N. Jb. . Geol. Paläontol. Abh.* **10:** 639-644.

Maithy, P.K. and Gupta, S. 1983. Microbiotic and organosedimentary structures from the Vindhyan Supergroup exposed around Chandrehi, Madhya Pradesh. *Palaeobot.* **42** (2): 101-107.

Maithy, P.K and Shukla, M. 1977. Microbiota from the Suket shales, Ramapura Vindhyan System (Late Precambrian) Madhya Pradesh. *Palaeobot.* **23** (3): 176-188.

Mankiewicz, C. 1992. *Obruchevella* and other microfossils in Burgess Shale: Preservation and Affinity. *Jour. Pal.* **66**(5) : 717-729.

Mansuy, C. and Vidal, G. 1983. Late Proterozoic Brioverian microfossils from France: taxonomic affinity and implications of plankton productivity. *Nature,* **302**: 606-607.

McMenamin, D. S., Kumar, S. and Awramik, S. M. 1983. Microfossils from the Kheinjua Formation, Middle Proterozoic Semri Group (Lower Vindhyan) Son Valley area, Central India. *Precamb. Res.* **21**: 247-272.

Mendelson, C.V. and Schopf, J.W. 1982. Proterozoic microfossils from Sukhaya Tunguska Shorikha and Yudoma formations of Siberian platform. *Jour. Pal.* **56**: 43-83.

Moczydlowska, M., 1991. Acritarch biostratigraphy of the lower Cambrian and the Precambrian-Cambrian Boundary in southeastern Poland. *Fossils and Strata* **29**: 1-127.

Moczydlowska, M., Vidal, G. and Rudavskaya, V. A. 1993. Neoproterozoic (Vendian) phytoplankton from the Siberian platform, Yakutia. *Palaeont.* **36**: 495-521.

Muir, M.D. 1976. Proterozoic microfossils from the Amelia Dolomite, McArthur Basin, Northern Territory. *Alcheringa* **1**: 143-158.

Naumova, S.N. 1960. Spore and pollen assemblages in the Riphean and lower Cambrian deposits of USSR, p. 109-117. In: 21Th *Intl. Geol. Cong. Session Papers presented by Soviet Geol.*, (Ed. Mezhdunar) **8**: (In Russian).

Nautiyal, A.C. 1983. Algonkian (Upper to Middle) micro-organisms from the Semri Group of Son Valley (Mirzapur Distt), India. *Geol. Sci. Jour.* **6** (2): 169-198.

Nautiyal, A.C. 1989. Biostratigraphic significance of microbial assemblages of Gangolihat Dolomites, Kumaun Lesser Himalaya. *Him. Geol.* **13**: 93-108.

Ogurtsova, R.N. and Sergeev, V.N. 1987. Microbiota Chichkanskoi svity verhnego Dokembria, Malogo Karatau (Ushnai Kazakhastan) *Paleontolgiocheskii Zhurnal*, **2**: 107-116 (Russian).

Peel, J.S. 1988. Spirellus and related helically coiled microfossils (cyanobacteria) from the lower Cambrian of north Greenland. *Rapot Gronlands geologiske Undersogelse,* **137**: 5-32.

Petrov, P. Yu. 1995. Depositional environments of the lower formations of the Russian sequence, northern part of the Turukhansk Uplift, Siberia. *Stratigr. Geol. Correlation*, **1**: 181-191.

Prasad, B. and Asher, R. 2001. Acritarch biostratigraphy and lithostratigraphic classification of Proterozoic and Lower Paleozoic sediments (Pre-Unconformity Sequence) of Ganga Basin, India. *Palaeontogr. Indica,* **5**: 1-153.

Prasad, B., Maithy, P.K., Kumar, G. and Raina, B.K. 1990. Precambrian-Cambrian acritarchs from the Blaini–Krol-Tal Sequence of Mussoorie Syncline, Garhwal Lesser Himalaya, India. *Mem. Geol. Soc. India,* **16**: 19-32.

Pyatiletov, V.G. and Rudavskaya, V.V. 1990. Acritarchs of the Yudoma complex, p. 179-187. In: *Vendian System,* (Eds. Sokolov, B.S. and

Iwanoski, A.B.), Akademika Nauka, SSSR. Moscow. Paleontology, 1.

Pykova, N.G. 1973. Acritarchs of Precambrian sections of southern Ural, Siberia, Eastern European Platform and their significance, p. 5-17. In: *Microfossils of the oldest deposits* (Eds. T. F. Vozzhennikova), Proceedings 3rd International Palynological Congress, Moscow, Nauka, (In Russian with English summary)

Ragozina, A.L. and Sivertseva, I.A. 1990. Microfossils of the Valdai Series in the Northwestern Arkhangelsk District, p. 165-170. In: *Vendian System* (Eds. Sokolov, B.S. and Iwanoski, A.B.), Akademika Nauka, SSSR., Moscow. Palaeont. **1**: 165-170,

Rai, V. and Singh, V.K. 2004. Discovery of *Obruchevella* Reitlinger, 1948 from the Late Palaeo-Proterozoic Lower Vindhyan succession and its significance. *Jour. Pal. Soc. India,* **49**: 189-196.

Reitlinger, E.A. 1959. Atlas of microscopic fossils and problematics of ancient strata of Siberia. *Izd. Akad. Nauk. SSSR Moscow*, **25**: 1-63 (In Russian).

Round, F.E. 1981. *The ecology of algae.* Cambridge University Press, Cambridge.

Roychowdhary, J. 1977. Sporomorphs in Abor Volcanics. *Geol. Surv. India, News,* **8**(6): 12.

Salujha, S.K., Rehman, K. and Arora, C.M. 1972. Early Palaeozoic microplankton from the Kurnools, Andhra Pradesh. *Jour. Palynol.* **3**: 123-131.

Salujha, S.K., Rehman, K. and Rawat, M.S. 1971b. Fossils palynomorphs from the Vindhyans of Rajasthan. *Rev. Palaeobot. Palynol.* **2**: 65-83.

Samuelsson, J.D.P.R. and Vidal, G. 1999. Organic walled microfossils from the Proterozoic Thule Supergroup, Northwest Greenland. *Precamb. Res.* **96**: 1-23.

Samuelsson, J.D.P.R. and Butterfield, N.J. 2001. Neoproterozoic fossils from the Franklin Mountains northwestern Canada: stratigraphic and palaeobiological implication. *Precamb. Res.* **107**: 235-251.

Schopf, J.W. 1968. Microflora of the Bitter Springs Formation, late Precambrian, Central Australia. *Jour. Pal.* **42**: 651-688.

Schopf, J.W. and Blacic, J.M. 1971. New microfossils from the Bitter Springss Formation (Late Precambrian) of north-central Amadeus Basin, Australia. *Jour. Pal.* **45**: 925-960.

Seong, J.L., Golubic, S. and Zhang, Y. 1999. Palaeoenvironmental distribution of silicified assemblage from Gaoyuzhuang Formation, north China. *Acta Micropaleontologica Sinica,* **16** (3): 237-258.

Sergeev, V.N. 1989. Microfossils from the transitional Precambrian-Phanerozoic strata of central Asia. *Him. Geol.* **13**: 269-278.

Sergeev, V.N. 1992. Okremnennye mikrofossilii Dokembrya I Kemrya Urala i Sredney Azii (Silicified microfossils from the Precambrian and Cambrian deposits of Southern Ural Mountains and Middle Asia). *Tr. Geol. Inst. Rossiiskoyi Akad. Nauka, Mosscow,* **434**: 134 pp.

Sergeev, V.N. 1994. Microfossils in cherts from the Middle Riphean (Mesoproterozoic) Avzyan Formation, Southern Ural Mountains, Russian Federation. *Precamb. Res.* **65**: 231-254.

Sergeev, V.N. 2001. Palaeobiology of Neoproterozoic (Upper Riphean), Shorikha and Burovaya silicified microbiotas, Turukhansk Uplift, Siberia. *Jour. Pal.* **75** (4): 427-448.

Sergeev, V.N., Knoll, A.H. and Grotzinger, J., 1995. Palaeobiology of the Mesoproterozoic-Billykh Group, Anabar Uplift, Northern Siberia. *Palaeontol. Soc. Mem.* **39**:1-37.

Sergeev, V.N., Knoll, A.H. and Petrov, P.Yu. 1997. Palaeobiology of the Mesoproterozoic-Neoproterozoic transition: The Suhkaya Tunguska Formation, Turukhansk Uplift, Siberia. *Precamb. Res.* **85**: 201- 239.

Shepeleva, E. D. 1974. Stratigraphic subdivision of Vendian deposits of the central Russian platform from acritarchs. *Trans. Akad. Nauka. SSSR Novosibirsk,* **81**: 13-23. (In Russian)

Song, X. 1984. *Obruchevella* from the Early Cambrian Meischucun stage of Meischucun Section, Jinning, Unnan, China. *Geol. Mag.* **121**: 179-183.

Shukla, M., Babu, R., Mathur, V.K. and Srivastava, D.K. 2005. Additional Terminal Proterozoic Organic-walled microfossils from the Infra Krol Formation, Nainital Syncline, Lesser Himalaya, Uttaranchal, India. *Jour. Geol. Soc. India,* **65**(2): 197-210.

Shukla, M., Tewari, V.C. and Yadav, V.K. 1987. Late Precambrian microfossils from Deoban Limestone Formation, Lesser Himalaya, India. *Palaeobot.* **35**: 347-356.

Srinivasan, V. 1999. Lithostratigrphy and structure of low-grade metasedimentaries in eastern part of Arunachal Pradesh. *Him. Geol.* **20** (2): 53-60.

Srinivasan, A. 2001. Stratigraphy and structure of low grade metasedimentaries in Eastern Bhutan and Western Arunachal Pradesh. *Him. Geol.* **22**: 83-89.

Srivastava, P. and Kumar, S. 2003. New microfossils from the Meso-Neoproterozoic Deoban Limestone, Garhwal lesser Himalaya, India. *Palaeobot.* **52**: 13-47.

Strother, P.K., Knoll, A.H. and Barghoorn, E. S. 1983. Micro-organisms from the Late Precambrian Narssarssuk Formation, Northwest Greenland. *Palaeont.* **26**: 1-32.

Tandon, S.K., Nanda, A.C. and Singh, T. 1979. The Miri rocks of the Eastern Himalaya–Stratigraphic and ichnological considerations, p. 85-99. In: *Metamorphic rock sequences of the Eastern Himalaya* (Ed. P.K. Verma), K.P. Bagchi and Co., Calcutta.

Tewari, V.C. 1998. Prospects of delineating Terminal Proterozoic and Precambrian–Cambrian boundary in the Northeastern Himalaya. *Geosci. Jour.* **19**(2): 109-114.

Tewari, V.C. 2001. Discovery and sedimentology of microstromatolites from Menga Limestone (Neoproterozoic/Vendian), Upper Subansiri district, Arunachal Pradesh, NE Himalaya, India. *Curr. Sci.* **80**(11): 1440-1444.

Tewari, V.C. 2002. Lesser Himalayan Stratigraphy, sedimentation and correlation from Uttaranchal to Arunachal, p. 63-88. In: *Aspects of Geology and Environment of the Himalaya, India,* (Eds. Pant C.C. and Sharma, A. K.), Gyanodaya Prakashan, Nainital.

Tewari, V.C. 2003. Sedimentology, Palaeobiology and stable isotope chemostratigraphy of the Terminal Proterozoic Buxa Dolomite, Arunachal Pradesh, NE Lesser Himalaya. *Him. Geol.* **24** (2): 1-18.

Tewari, V.C. 2004. Microbial diversity in Meso–Neoproterozoic formations, with particular reference to the Himalaya, p. 515-528. In: *Origins* (Ed. Seckbach, J.), Kluwer Academic Publishers, Printed in the Netherlands.

Tewari, V.C. and Sial, A.N. (in press). Neoproterozoic - Early Cambrian isotopic variation and chemostratigraphy of the Lesser Himalaya, India in Eastern Gondwana. *Chem. Geol.*

Timofeev, B.V. 1959. Ancient flora of Baltic Region and its stratigraphic significance. *Trudy Inst. All Union Scientific Invest. and prosp. Petrol. No.* **129**: 1-320 (In Russian).

Timofeev, B.V. 1966. *Microphytological investigations of ancient formations.* Acad. Sci. USSR, Laboratory of Precamb. Geol. Nauka Leningrad, (in Russian).

Timofeev, B.V. 1973. *Microphytofossils from the Precambrian of the Ukraine.* Inst. Precamb. Geol. Geochronol., Nauka, Leningrad, (in Russian).

Timofeev, B.V., Hermann, T.N. and Mikhailova, N.S. 1976. *Microphytofossils of the Precambrian, Cambrian and Ordovician.* Academy of Sciences, USSR, Inst. Geol. Geochronol. Precamb.

Nauka Leningrad: (In Russian).

Tiwari, M. and Azmi, R.J. 1992. Late Proterozoic Organic-walled microfossils from the Infra Krol of Solan, Himachal Lesser Himalaya: An additional age constraint in the Krol Belt Succession. *Palaeobot.* **39**: 387-394.

Tiwari, M. and Knoll, A.H. 1994. Large acanthomorphic acritarchs from the InfraKrol Formation of the Lesser Himalaya and their stratigraphic significance. *Him. Geol.* **5**(2): 193-201.

Tiwari, M., Pant, C.C. and Tewari, V.C. 2000. Neoproterozoic sponge spicules and organic walled microfossils from the Gangolihat Dolomite, Lesser Himalaya, India. *Curr. Sci.* **79**(5): 651-654.

Tiwari, M. and Pant, C.C. 2004. Neoproterozoic silicified microfossils in InfraKrol Formation, Lesser Himalaya, India. *Him. Geol.* **25**(1): 1-21.

Traverse, A. 1988. *Palynology, Palaeopalynology*. London-Boston Unwin, Hymen.

Tynni, R. and Donner, D. 1980. A microfossils and sedimentation study of the Late Precambrian Formation of Hailuoto, Finland. *Geol. Surv. Finland Bull. No.* **311**: 1-27.

Veis, A.F. and Petrov, P.Yu. 1994. Dependence of the Riphean organic-walled microfossils systematics diversity on conditions of their environment in Siberia. In: *(Ecosystem restructures and the evolution in biosphere), Moscow Fderal.*

Venkatachala, B.S., Shukla, M., Bansal, R. and Acharyya, S.K. 1990. Upper Proterozoic microfossils from the Infra-Krol sediments, Nainital Synform, Kumaon Himalaya, India, p. 29-38. In: *Proceeding Symposium "Vistas in Indian Palaeobotany;"* (Eds. Jain, K.P. & Tiwari, R.S.), *Palaeobot.* **38**.

Vidal, G., 1976a. Late Precambrian microfossils from the basal sandstone units of Visingsö Beds, Southern Sweden. *Fossils and Strata,* **9**: 1-57.

Vidal, G. 1981. Micropaleontology and biostratigraphy of the Upper Proterozoic and lower Cambrian Sequence in East Finmark, northern Norway. *Norges Geol. Un. Bull.* **362**: 1-53.

Vidal, G. and Ford, T.D. 1985. Microbiota from the Late Proterozoic Chuar Group (Northern Arizona) and Uinta Mountain Group (Utah) and their chronostratigraphic implications. *Precamb. Res.* **28** (3/4) : 349-391.

Vidal, G. and Moczydlowska, M. 1995. The Neoproterozoic of Baltica- Stratigraphy, Palaeobiology and general geological evolution. *Precamb. Res.* **37**: 197- 216.

Vidal, G. and Nystuen, J.P. 1990a. Lower Cambrian acritarchs and the Proterozoic - Cambrian boundary in Southern Norway. *Norsk Geol.Tid.* **70**, 191-222.

Vidal, G. and Nystuen, J.P. 1990b. Micropaleontology, depositional environment and biostratigraphy of Upper Proterozoic Hedmark Group, Southern Norway. *Am. Jour. Sci.* **290A**: 170-211.

Volkova, V.A. 1968. Acritarchs from Precambrian and lower Cambrian deposits of Estonia, p. 8-36. In: *Problematics of Riphean-Cambrian boundary layers of the Russian platform, Urals and Kazakhstan.* (Eds. B.M. Keller *et al.,*), *Academy Sciences , SSSR , Geol. Inst. Nauka Moscow,* **188**: (In Russian).

Volkova, N.A. 1969. Acritarchs of the north-west Russian platform, p. 224-235. In: *Tommotian stage and the Cambrian lower boundary problem* (Eds. Rozanov, *et al.,*), Academy Science, Nauka Moscow, 86-88. (Trans. Amer. Publ. Co. Pvt. Ltd., New Delhi, 1981), **206**.

Volkova, N.A. 1990. Middle and upper Cambrian acritarchs in the east European Platform, p. 155-164. In: *Vendian System.* (Eds. Sokolov, B.S. & Iwanoski, A.B.), Akademia Nauka, USSR, Moscow, Paleontology, **1**.

Wang, F.X. 1985. Middle-Upper Proterozoic and Lowest Phanerozoic microfossil assemblage from Southwest China and contiguous area. *Precamb. Res.* **29**: 33-43.

Wang, F., Xuanyang, Z. and Ruihuan, G. 1983. The Sinian microfossils from Jinning Yunnan, Southwest China. *Precamb. Res.* **23**: 133-175.

Weiss, A.F. 1989. Microfossils in Precambrian stratigraphy of USSR. *Him. Geol.* **13**: 279-289.

Xio, S. and Knoll, A.H. 1999. Fossil preservation in the Neoproterozoic Doushantuo Phosphorite, Lagerstätte, South China. *Lethaia,* **32**: 219-240.

Xu, Z-L. and Gao, J-P. 1991. A new stromatolitic mat builder discovered from the Late Precambrian in northern China. *Acta Bot. Sinica,* **33**: 757-762 (In Chinese with English abstarct).

Xu, Z.L. and Awramik, S.M. 2001. New microrganisms from the Gaoyuzhuang Formation of Northern Taihang Mountains China. *Acta Bot. Sinica*, **43**(3): 295-311.

Yakshin, M.S. 1989. Microbiota of Kotuikanskaya suite Lower Riphean of Anbar Massif. Himalayan Geology Proceeding Indo Soviet Symposium on stromatolites deposits. *Him. Geol.* **13**: 239-248.

Yakshin, M.S. 1990. Silicified Vendian algae of Southern Siberian Platform and Altai-Sayan area, p. 188-192. In: *Vendian System,* (Eds. Sokolov, B.S. & Iwanoski, A.B.), Akademia Nauka, USSR, Moscow, Paleontology, **1**.

Yakshin, M.S. and Luchinina, V.A. 1981. New data on fossil algae of family Oscillatoriaceae. *Acad. Nauk SSSR.* **475**: 28-34

Yin, C., Yue, Z., Gao, L. and Ding, Q. 1993. Microfossils from the chert in Lower Cambrian Shuijingtuo Formation at Miaohe, Zingui, Hubei Province. *Acta Geol. Sinica,* **6**(2): 223–233.

Yin, C. and Gao, L. 1995. The early evolution of acanthomorphic acritarchs in China and their biostratigraphic implications. *Acta Geol. Sinica,* **69**(4) : 636-671.

Yin, C., Gao, L.Z. and Xing, Yu. S. 2003. Silicified microfossils from Early Cambrian Tianzhushan member near Miaohe Village, Zingui, West Hubei, China. *Acta Palaeontol. Sinica,* **42**(1): 76-88.

Yin, L. 1987. Microbiotas of latest Precambrian sequence in China, p. 415-494. In: *Nanjing Institute of Geology and Paleontology, Academia Sinica, Stratigraphy and palaeontoloogy of Systematic Boundaries in China. Precambrian-Cambrian Boundary,* **1**.

Yin, L. 1991. Ecological history of Doushantuo period in Yangtze Gorge district South China, p. 1-10. In: *Paleoecology of China,* (Eds. Jiny, *et al.*), 1, Nanjing University Press, Nanjing.

Yin, L. 1997. Precambrian-Cambrian transitional acritarch biostratigraphy of the Yangtze Platform. *Bull. Nat. Mus. Nat Sci.* **10**: 217-231.

Yin, L. and Guan, B. 1999. Organic Walled microfossils of Neoproterozoic Dongjia Formation, Lushan, County Henan Province, North China. *Precamb. Res.* **94**: 121-137.

Yin, L. and Sun, W. 1994. Microbiota from the Neoproterozoic Liulaobei Formation in the Huainan Region, Northern Anhui, China *Precamb. Res.* **65**: 95-114.

Yin, L. and Yuan, X. 2003. Review o of the microfossils assemblage from the Late Mesoproterozoic Ruyang Group in Shanxi, China *Acta Micrplaeontol. Sinica.* **20** : 39-46.

Yin, M. and Li, Z.P. 1978. Precambrian microfloras of southwest China with reference to their stratigraphic significance. *Mem. Nanjing Inst. Geol. Palaeotol.* **10**: 41-102. (In Chinese with English abstract)

Yuan, X. and Hofmann, H.J. 1998. New microfossils from Neoproterozoic (Sinian) Doushantuo Formation, Wengan, Guizhou Province, Southwestern, China. *Alcheringa,* **22**: 189-222.

Zang, W. 1995. Early Neoproterozoic sequence stratigraphy and acritarchs, biostratigraphy, Eastern Officer Basin, South Australia. *Precamb. Res.* **74**: 119-175.

Zang, W. and Walter, M.R. 1989. Latest Proterozoic plankton from the Amadeus Basin in central Australia. *Nature,* **337**: 643-645.

Zang, W. and Walter, M.R. 1992. Late Proterozoic and Cambrian microfossils and biostratigarphy, Amadeus Basin, Central Australia. *Ass. Aust., Paleontol. Mem.* **12**: 1-132.

Zang, W. and Walter, M.R. 1992. Late Proterozoic and Early Cambrian microfossils and biostratigraphy, northern Anhui and Jiangsu, Central eastern China. *Precamb. Res.* **57**: 243-323.

Zhang, Y. 1985. Stromatolitic microbiota from the middle Proterozoic Wumishan Formation (Jixian Group) of the Ming Tombs Beijing, China. *Precamb. Res.* **30**: 277-302.

Zhang, Y., Yin, L., Xiao, S. and Knoll, A.H. 1998. Permineralised fossils from the Terminal Proterozoic Doushantuo Formation, South China. *Jour. Paleontol. Supplement Mem.* **50, 72** (4): 1-52.

Zhang, Z. 1984. Microfossil flora from the Late Sinian, Doushantuo Formation Hubei Province, China Intern. *Geological Proceedings Paper Coll., Geol. Publ. House, Beijing*: 129-137. (In Chinese)

Zhou, C.M., Chen, Zhe and Xue, Y.S. 2002. New microfossils from the Late Neoproterozoic Doushantuo Formation Chaoyang Phosphorite deposits in Jiangxi Province South China. *Acta Palaeontol. Sinica,* **41** (1): 178-192.

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