Upper Proterozoic microfossils from the Infra Krol sediments, Nainital Synform, Kumaon Himalaya, India

B. S. Venkatachala, Manoj Shukla, Rajendra Bansal & S. K. Acharyya

Venkatachala, B. S., Shukla, Manoj, Bansal, Rajendra & Acharyya, S. K. 1990. Upper Proterozoic microfossils from the Infra Krol sediments, Nainital Synform, Kumaon Himalaya, India. *In* : Jain, K. P. & Tiwari, R. S. (eds)—*Proc Symp. 'Vistas in Indian Palaeobotany', Palaeobotanist* **38** : 29-38.

Thin sections of cherty nodules, occurring within the dark grey to black carbonaceous slates of Infra Krol sediments from Nainital Synform of Kumaon Himalaya, India show abundant microfossils. These are attributed to *Gunflintia minuta, Eomycetopsis robusta, Palaeolyngbya barghoorniana, Siphonophycus kestron. Animikiea septata, Myxococcoides minor, Palaeoanacystis vulgaris, Huroniospora psilata, Eosphaera* sp., *Sphaeranasillos irregularis, Melanocyrillium* sp. (vase-shaped microfossils) and associated unnamed Form "A" They are distributed randomly in the matrix containing a large amount of dispersed organic matter which imparts brown to dark brown colour to the chert matrix. The fossiliferous nodules may have been transported and redeposited along with the Infra Krol slates. The vase-shaped microfossils indicate possibility of Upper Riphean-Lower Vendian age for this assemblage. The age of Infra Krol sediments may be younger.

Key-words—Microfossils, Infra Krol, Lesser Himalaya, Upper Proterozoic (India).

B. S. Venkatachala, Manoj Shukla & Rajendra Bansal, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

S. K. Acharyya, Geological Survey of India, 27 Jawaharlal Nehru Road, Calcutta 700 013, India.

सारॉंश

कुमायुं हिमालय (भारत) में नैनीताल अभिनत रूप के निम्न क्रोल अवसादों से उपरि प्राग्जीवी सूक्ष्म-जीवाश्म

बेंगलूर श्रीनिवासा वेंकटाचाला, मनोज शुक्ला, राजेन्द्र बन्सल एवं ऍस० के० आचार्य

भारत में कुमायुं हिमालय के नैनीताल अभिनत रूप से निम्न क्रोल अवसादों के गहरे भूरे अथवा काले कार्बनी स्लेटों में मिलने वाले रामसैकाश्मों की पतली काटों में सूक्ष्मजीवाश्म प्रचुर मात्रा में मिले हैं। इन्हें **गनफ्लिंशिआ माइन्यूटा, ईओमाइसिटॉप्सिस रोबस्टा, पेलियोलिंगबिआ बार्घूनियाना, साइफ़ोनोफ़ाइकस केस्ट्रॉन, एनिमिकिया सैप्टेटा, मिक्सोकोकॉयडिस माइनर, पेलियोऐनासिस्टिस वुल्गेरिस, ह्यूरोनिओस्पोरा साइलेटा, ईओस्फ़ेयरा** जाति, **स्फ़ेयरानासिलॉस इर्रेगुलेरिस, मिलेनोसाइरिल्लियम** जाति एवं सहयुक्त प्ररूप ए० नाम दिये गये हैं। ये विकीरित कार्बनिक पदार्थ में अविन्यस्त बिखरे हुए मिलते हैं, जिसके कारण रामसैकाश्मों का रंग भूरे से गहरे भूरे रंग का हो गया है। उक्त जीवाश्ममय ग्रंथिकायें अन्य स्थान से आकर निम्न क्रोल स्लेटों के साथ पुनःनिक्षेपित हो गई हैं। ये जीवाश्म इस समुच्चय की सम्भवतया उपरि रिफियन-अधरि वेन्डियन आयु इंगित करते हैं। निम्न क्रोल की आयु और कम हो सकती है।

KROL BELT is a 3,000 meter thick sedimentary sequence of limestones, dolomites, shales, slates and nodular cherts on the southern margin of Lesser Himalaya. The age of this sequence has been controversial. A Palaeozoic-Mesozoic age for the Blaini-Infra Krol-Krol-Tal sequence was initially assigned on the basis of correlation of Blaini conglomerate with the Late Palaeozoic basal Gondwana conglomerate (=Talchir Boulder Bed) (Oldham, 1888). The occurrence of Late Mesozoic fossiliferous bed at the top of Tal Formation (Shrivastava, 1972; Bhatia, 1980), the records of Late Palaeozoic microflora (Sitholey *et al.*, 1954; Lakhanpal *et al.*, 1958; Sah *et al.*, 1968; Tewari & Singh, 1979) and a solitary Permian brachiopod, *Linoproductus* (Valdiya, 1980) from the Krol Formation lent further support to this view. However, recent palaeobiological evidences, viz., well-preserved microfossils from Blaini (Tewari, 1988a) indicate an Upper Riphean age

Table 1—Fossil log of Krol Belt

FORMATION	MEMBER	MICRO - AND MACROBIOTA		LEBENSPURREN	AGE	REFERENCE
		PLANTAE	ANIMALIA			
TAL	PHULCHATTI QUARTZITE MEMBER		BRACHIOPOD		LENIAN	Tripathi et al. 1984
	CALCAREOUS MEMBER		BRACHIOPOD GASTROPOD HYOLITHS CHANCELLORIIDS	TAPHRHELMINTHOPSIS	ATDABANIAN	Kumar et al., 1983 1987
	ARENACEOUS MEMBER		CHANCELLORIIDS POLYMERID TRILOBITE	SKOLITHOS PLAGIOGMUS PHYCODES		Singh & Rai 1983 Rai & Singh, 1983 Singh et al. 1984 Kumar et al., 1987
	ARGILLACEOUS MEMBER			SMALL VERTICAL BURROWS		
	CHERT - PHOSPHORITE MEMBER		CONODONTS & SMALL SHELLY FOSSILS		TOMMOTIAN	Azmi et al. 1981 Azmi et al., 1983 Bhatt et al., 1983, 1985
KROL	E	EPIPHYTON RENALCIS	? ARCHAEOCYATHA KORGAICYATHA		UPPER VENDIAN	Singh & Rai, 1983 Singh & Rai, 1984 Tewari & Ghosh, 1986
	D			PHOSPHATIC TUBES & ROUND FORMS		Singh & Rai, 1983
	C			SMALL VERTICAL BURROWS WORM TUBES		Singh & Rai, 1983
	B	CALCAREOUS ALGAE			MIDDLE VENDIAN	Gansser, 1974
	A	VENDOTAENIDES (BROWN ALGAE)				Tewari, 1988b
INFRAKROL		GUNFLINTIA EOMYCETOPSIS PALAEOLYNGBYA SIPHONOPHYCUS ANIMIKIEA MYXOCOCCOIDES PALAEOANACYSTIS EOSPHAERA VSMs	PROBLEMATICA		LOWER VENDIAN	Acharyya et al., 1989 Venkatachala et al., 1988 (This ms)
BLAINI		TRACHYSPHAERIDIUM ALGAL MAT PROTOSPHAERIDIUM SYMPLASSOSPHAERIDIUM			UPPERMOST RIPHEAN TO LOWER VENDIAN	Tewari, 1988 a
NAGTHAT FORMATION						

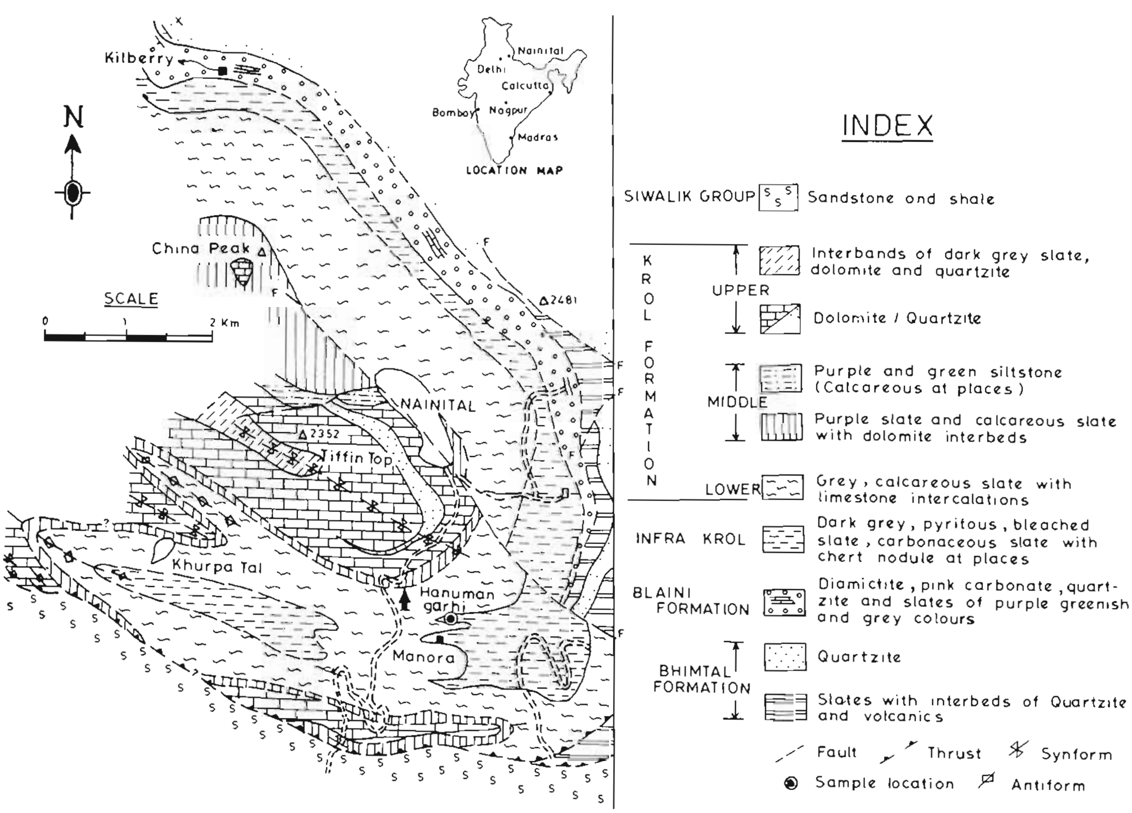
Vendotaenides (Tewari, 1988b) from the Lower Krol Formation, Archaeocyatha (Singh & Rai, 1984) and ediacaran fossils (Mathur & Shankar, 1989) from the Upper Krol Formation show Vendian age for the Krol Formation. The presence of shelly Tommotian fauna (Azmi, 1983; Azmi *et al.*, 1981; Bhatt *et al.*, 1983, 1985) and stromatolites (Tewari, 1984) from the Chert-Phosphorite Member, Trilobites (Rai & Singh, 1983; Joshi *et al.*, 1989) and brachiopods (Mathur & Joshi, 1989) from the Arenaceous Member, stromatolites (Tewari *et al.*, 1988) and brachiopods (Tripathi *et al.*, 1984) in the Phulchatti Quartzite Member indicates a Lower Cambrian age for the Tal Formation (Table 1). The palaeobiological evidences from the Infra Krol sequence are important to afford logical support to date the lower limit of the Krol Formation.

The present paper concerns with thin-section studies detailing the morphology, taxonomy and affinities of the biota. An attempt has also been made to compare Infra Krol assemblage with well documented assemblages of the world and to infer the age of the Infra Krol sequence.

GEOLOGY OF THE AREA

The Blaini-Infra Krol-Krol-Tal sequence forms a persistent litho-stratigraphic unit in the Krol Belt of Himalaya. In the Nainital area (29°25′ : 75°28′), an undisturbed stratigraphic succession from Infra Krol to Upper Krol succession is present from Manora to Tiffin Top section. According to Acharyya *et al.* (1989), the stratigraphic contact between the Blaini and Infra Krol sequence is not clear owing to structural complications. The Infra Krol sequence is constituted of bleached pyritiferous slates. It conformably grades upwards into Lower Krol succession constituted by marl, calcareous slates and limestones. The contact between the Lower Krol and overlying Middle Krol sequence is gradational; middle Krol consists of purple-green and grey slates and calcareous siltstones with dolomite beds and conformably grades upwards into the Upper Krol carbonate near Hanumangarhi. In Kailakhan area and on the Manora-Hanumangarhi mule-track, bleached pyritiferous slates of the Infra Krol thicken in outcrop. On this mule-track a thin bed of black slate with black chert nodules is exposed which form material for the present study. They have been collected by one of us (SKA) from about 250 m north of Manora Village towards Hanumangarhi. The black slates are exposed in a narrow wedge of about 3 m width at this point (Text-fig. 1).

The fossiliferous chert nodules form a minor constituent of the bulk lithology which is made up of black slates. The nodules measure about 2-3 cm in thickness and are slightly compressed along the plane of bed, though they themselves do not form any bedding. Their surface is polished and shows concoidal fractures. It is apparent that these nodules may have been transported and redeposited with black slates of Infra Krol sediments which have been attributed to shallow lagoonal environment (Bhargava & Singh, 1981; Singh, 1981). Microbiota and few broken parts of algal mats are seen randomly distributed in the cryptocrystalline to amorphous matrix. The dispersed organic matter imparts a brown to dark brown colour to the chert



Text-figure 1—Geological map of the area around Nainital, Uttar Pradesh.

matrix. However, Acharyya *et al.* (1989) have observed well-preserved mat structures with preferred orientation in thin sections of these chert nodules. This has led them to conclude that the area mainly represents progressive trapping of superficial microorganisms in abiogenic shales and these microfossils must have been later replaced by silica.

TAXONOMIC AFFINITIES

The microfossils are organically preserved They have been studied in petrographic thin-sections. The highly diagenised nature imposes some limitations on assigning taxonomic affinities. The assemblage is dominated by hollow sheaths and cell envelopes.

The slides have been deposited in the Museum of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Genus—*Gunflintia* Barghoorn & Tyler 1965

Gunflintia minuta Barghoorn & Tyler 1965
Pl, 1, fig. 6

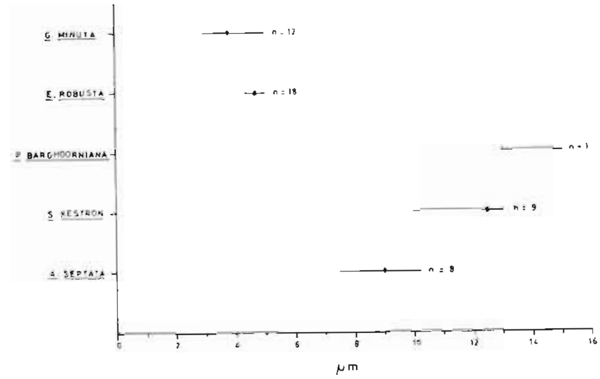
Description—Filaments multicellular, unbranched, uniseriate, straight or slightly curved, septa indistinct and occasionally variably spaced. Surface texture granular. Filament width 3 to 5 μm, $\tilde{g}$ = 3.8 μm (n = 12, see Text-fig. 2). Maximum filament length observed 120 μm (incomplete filament).

Remarks—Few forms with ill-defined septa and variable cell lengths have also been included here. They may be diagenetically altered forms.

Genus—*Eomycetopsis* Schopf 1968

Eomycetopsis robusta Schopf 1968
Pl. 1, figs 1, 2

Description—Filaments unbranched, tubular, non-septate, occasionally in entangled mesh (Pl. 1, fig. 1), surface texture granular. Filament width 4.4 to 5.0 μm, $\tilde{g}$ = 4.7 (n = 18, see Text-fig. 2). Maximum



Text-figure 2—Comparative graph of size variation of filamentous cyanobacteria.

filament length observed 80 μm (incomplete filament).

Remarks—The Infra Krol microfossils have larger width.

Genus—*Palaeolyngbya* Schopf 1968

Palaeolyngbya barghoorniana Schopf 1968
Pl. 1, fig. 4

Description—Filament solitary, multicellular, unbranched, uniseriate, constricted at septa, apex rounded, cross walls distinct, evenly spaced, surface texture granular. Cells discoid, 4.5 to 5.0 μm long and 13.00 to 15.00 μm wide (only one specimen observed).

Remarks—The solitary filament described here is comparable to *P. barghoorniana* Schopf 1968 in overall morphology. However, the specimen is larger in size and the sheath is not preserved.

Genus—*Siphonophycus* Schopf 1968

Siphonophycus kestron Schopf 1968
Pl. 1, fig. 3

Description—Solitary, unbranched, tubular, non-septate, tapers towards rounded apex. Surface texture granular. Filament width 10-13 μm, $\tilde{g}$ = 12.5

→

PLATE 1

Bar = 10 μm

1, 2. *Eomycetopsis robusta*, Slide no. BSIP 10260.
3. *Siphonophycus kestron*, Slide no. BSIP 10258.
4. *Palaeolyngbya barghoorniana*, Slide no. BSIP 10261.
5, 12, 14. *Incertae sedis*, Unnamed Form 'A', Slide no. BSIP 10258.
6. *Gunflintia minuta*, Slide no. BSIP 10260.
7 *Melanocyrillium* sp., Slide no. BSIP 10261.
8. *Animikiea septata*, Slide no. BSIP 10258.
9. *Huroniospora psilata*, Slide no. BSIP 10258.
10. *Eosphaera* sp., Slide no. BSIP 10258.
11 *Myxococcoides minor*, Slide no. BSIP 10261.
13. *Palaeoanacystis vulgaris*, Slide no. BSIP 10258.
15, 16. *Sphaeranasillos irregularis*, Slide nos. BSIP 10259, 10261.

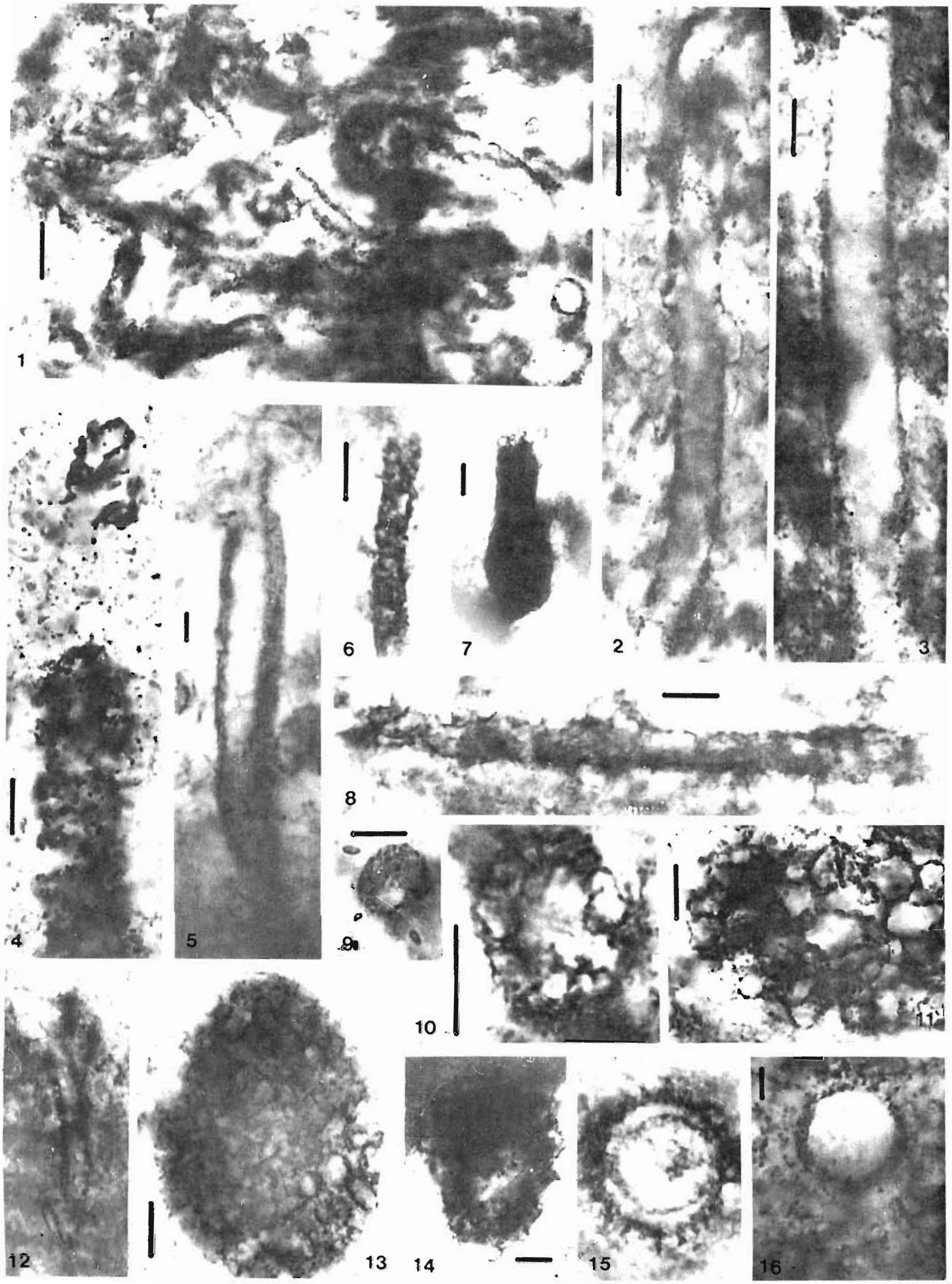


PLATE 1

μm (n = 9, see Text-fig. 2). Maximum length observed 90 μm (incomplete specimen).

Remarks—The microfossils described here have smaller average width and granular surface texture. The granular texture may be due to diagenetic alteration.

Genus—*Animikiea* Barghoorn & Tyler 1965

Animikiea septata Barghoorn & Tyler 1965
Pl. 1, fig. 8

Description—Filaments unbranched, straight or slightly curved, multicellular with indistinct septa. Filament diameter 7.5 to 10.2 μm wide, $\tilde{g}$ = 9.0 μm (n = 8, see Text-fig. 2).

Remarks—These microfossils do not show distinct septa due to diagenesis.

Genus—*Myxococcoides* Schopf 1968

Myxococcoides minor Schopf 1968
Pl. 1, fig. 11

Description—Cells spherical or ellipsoidal, clumped in globular colonies composed of few to many cells, occasionally distorted due to mutual compression. Surface texture psilate to finely granular. Sheaths around individual cells absent. Individual cell diameter 9.0 to 12.0 μm, $\tilde{g}$ = 11.0 μm (n = 178, see Text-fig. 3).

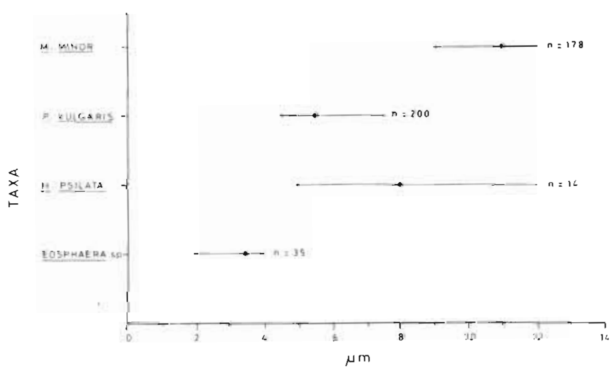
Remarks—The microfossils here have larger individual cells. They are distorted perhaps due to diagenetic alteration.

Genus—*Palaeoanacystis* Schopf 1968

Palaeoanacystis vulgaris Schopf 1968
Pl. 1, fig. 13

Description—Cells spheroidal, clumped in spherical to oval colonies, composed of 100 to 125 cells. Surface texture psilate, cells distorted due to mutual compression. Cell diameter 4.5 to 7.5 μm, $\tilde{g}$ = 5.5 μm (n = 200, see Text-fig. 3).

Remarks—The colonies have smaller number of cells which are larger in size as compared to similar forms from Bitter Springs Formation (Schopf, 1968).



Text-figure 3—Comparative graph of size variation of coccoidal cyanobacteria.

Genus—*Huroniospora* Barghoorn & Tyler 1965

Huroniospora psilata Barghoorn & Tyler 1965
Pl. 1, fig. 9

Description—Cells solitary, spherical to oval, psilate, cell size 5 to 12 μm, $\tilde{g}$ = 8 μm (n = 14 see Text-fig. 3).

Genus—*Eosphaera* Barghoorn & Tyler 1965

Eosphaera tyleri Barghoorn & Tyler 1965
Eosphaera sp. Barghoorn & Tyler 1965
Pl. 1, fig. 10

Description—Hollow sphaeroidal colony with outer ring formed by granular cells. Diameter of inner sphere 8-10 μm and outer 15 to 18 μm. Individual cells 2 to 4 μm, $\tilde{g}$ = 3.5 μm (n = 35, see Text-fig. 3).

Remarks—These microfossils are distorted due to diagenetic alterations, but morphologically resemble hollow globular colonies of the chroococcacean cyanophytes.

Genus—*Sphaeranasillos* Allison & Awramik 1989

Sphaeranasillos irregularis Allison & Awramik 1989
Pl. 1, figs 15, 16

Description—Round, solitary, cell-like body, surface double-walled, walls distinct with spinose or pyramidal projections. Surface projections irregularly distributed. Texture granular. Size 28-30 μm in diameter. Projections 4-8 μm in height.

Remarks—The forms described here morphologically compare with the form from the earliest Cambrian or latest Proterozoic Tindir Group, Yukon Territory, Canada (Allison & Awramik, 1989). However, the forms described are larger in size.

Genus—*Melanocyrillium* Bloeser 1985

Melanocyrillium sp. Bloeser 1985
Pl. 1, fig. 7

Description—Greyish black to black, flask or vase-shaped vesicles, base rounded, body tapers towards apex, wall apparently rigid permitting undistorted preservation of shape. Size 45 to 80 μm long. Maximum cross sectional diameter 20 to 35 μm.

Remarks—These forms morphologically compare with the vase-shaped microfossils from Kwagunt Formation, Chuar Group, Arizona (Bloeser, 1985). However, they do not show the characteristic excystment pore (pylome) mostly seen in SEM studies.

INCERTAE SEDIS

Unnamed Form 'A'

Pl. 1, figs 5, 12, 14

Description—Solitary, unbranched, hollow cylindrical, straight or slightly curved, tubular, tapering towards apices. With single or multichambered (?cellular) margin, texture microgranular. Microfossils 120 to 180 μm long and 20 to 40 μm broad, marginal cells 3 to 5 μm in size.

Remarks—On the basis of morphology the form depicted in Pl. 1, fig. 14 resembles *Eosphaera* sp., a hollow globular colonial form. However, on change of focus, the circular arrangement of cells project unidirectionally in a linear manner. It perhaps represents cross section of the horizontally inclined tubular sheath (Pl. 1, figs 5, 12) with thick margins.

DISCUSSION

Forms attributed to *Gunflintia* and *Eomycetopsis* have more or less overlapping size ranges and hence it is probable that the *Eomycetopsis* sheaths are envelopes left by *Gunflintia* like trichome (see Comparative graph for size-variation of filaments: Text-fig. 2). *Gunflintia* like trichomes and *Eomycetopsis* type of sheaths are morphologically comparable to extant cyanobacteria belonging to the Family Oscillatoriaceae (Hofmann, 1976; Knoll & Golubic, 1979). *Animikiea* is morphologically comparable to *Oscillatoria* and *Lyngbya* (Barghoorn & Tyler, 1965). A solitary specimen of *Palaeolyngbya* recorded here and sheaths attributed to *Siphonophycus* apparently represent fossilised trichomes and sheath of *Oscillatoria* and *Lyngbya* respectively (Schopf, 1968). They also show overlapping size ranges in the Infra Krol assemblage. The coccoid unicells referred here as *Huroniospora* has cell sizes comparable to both *Palaeoanacystis* and *Myxococcoides* (see Comparative graph for size variation of coccoids: Text-fig. 3), and may represent detached cells from crushed colonies. Hollow spherical colonies of *Eosphaera* have been compared with extant genera *Gomphosphaeria* and *Coelosphaerium* (Golubic & Barghoorn, 1977). *Myxococcoides* and *Palaeoanacystis* are the two colonial forms which occur as solid globular colonies and have been compared with extant chroococcacean genus *Anacystis* (Golubic & Barghoorn, 1977).

The round cell-like forms with spinose projections have been assigned to *Sphaeranasillos irregularis* of unknown affinity. The vase-shaped organic structures here refered to *Melanocyrillium* have been compared with Palaeozoic chitinozoans (Bloeser *et al.*, 1977) and chitinozoan-like microfossils (Vidal, 1979; Binda & Bokhari, 1980). Another more plausible comparison has been given by Fairchild *et al.* (1978), who considers these as unequivocal evidence of heterotrophic protists, a group about which very little is known.

The Unnamed Form 'A', with single to multichambered (?cellular) margin resembles the diploblastic stage in the ontogenic phase of the cnidarians. The Cnidarians are the most primitive and presumably the oldest of all the metazoan phyla. They are generally triploblastic but they pass through a diploblastic stage in their ontogenic development. It is quite possible that this diploblastic stage, sometimes in the evolutionary history of that phylum, could have been a free living form. Diploblastic forms refered to as Unnamed Form 'A' could represent precursors of Cnidarians.

The Infra Krol assemblage is predominantly constituted by filamentous and coccoid cyanophytes which are not helpful as specific age indicators. However, the presence of vase-shaped microfossils help tentatively to deduce the age of the Infra Krol microbiota. These vase-shaped organic structures are recorded to appear at the end of Riphean and extend into Vendian.

The present microfossil assemblage from the Infra Krol also compares well with the records from Suket Shale Formation (Maithy & Shukla, 1977), Gangolihat Dolomite (Nautiyal, 1980), Ujhani Deep Well, Ganga Basin (Maithy *et al.*, 1983), Kheinjua Formation (McMenamin *et al.*, 1983), Deoban Formation (Shukla *et al.*, 1987), Rohtas Formation (Venkatachala *et al.*, in press) of India; Doushantuo Formation, China (Zhang, 1985), Yudoma Suite, USSR (Lo, 1980), Bitter Springs Formation (Schopf, 1968), Amelia Dolomite (Muir, 1976), H.Y.C. Pyritic Shale (Oehler, 1977), Balbirini Dolomite (Oehler, 1978) of Australia, Hecla Hoek Sequence, Svalbard (Knoll, 1982a), Draken Conglomerate (Knoll, 1982b) of Europe and Tindir Group (Allison & Awramik, 1989) of Canada. But many other genera of both coccoid and filamentous cyanobacteria as well as Acritarchs recorded in these assemblages are not found in the Infra Krol assemblage (see Table 2). The assemblage recorded from Dismal Lakes Group, Canada (Horodyski & Donaldson, 1980), Hailuoto

Table 2—Comparison of Infra Krol microfossils with other assemblages of the world

Infra Krol genera / Other Areas	*Gunflintia*	*Eomycetopsis*	*Palaeolyngbya*	*Siphonophycus*	*Animikiea*	*Myxococcoides*	*Palaeoanacystis*	*Huroniospora*	*Eosphaera*	*Sphaeranasillos*	V.S.M.'s
Deoban Formation, India	+	+		+	+	+					+
Rohtas Formation, India		+		+		+	+	+			
Kheinjua Formation, India	+	+				+					
Gangolihat Dolomite, India		+		+		+					
Suket Shale, India		+				+	+				
Ujhani deep well, Ganga Basin, India	+					+	+				
Hecla Hoek sequence, Svalbard		+		+		+					+
Visingso[3] beds, Sweden											+
Draken conglomerate, Svalbard		+		+		+					
Hailuoto Area, Finland			+								
Amelia Dolomite, Australia	+					+	+	+			
Bitter Springs Formation, Australia		+	+	+		+	+				
Dismal lakes group, Canada						+					
Balbirini Dolomite, Australia		+	+	+		+	+				
HYC pyritic shale, Australia	+					+		+			
Yudoma suite, USSR		+				+			+		
Doushantuo Formation, China	+	+	+	+		+		+			
Tindir Group, Canada		+	+	+		+	+			+	

area, Finland (Tynni & Donner, 1980) and Visingsö beds, Sweden (Knoll & Vidal, 1980) differs from the Infra Krol assemblage in the absence of all Infra Krol genera except for *Myxococcoides* in Dismal Lakes Group, *Palaeolyngbya* in Hailuoto area and the vase-shaped microfossils in Visingso beds (see Table 2). The available palaeobiological evidences from the Krol Formation (see Table 1) suggest a Vendian age for the Lower Krol sediments, thus implying a pre-Vendian or Upper Riphean-Lower Vendian age to the Infra Krol sequence. This conclusion is further substantiated by the occurrence of vase-shaped microfossils, viz., *Melanocyrillium*. Thus even if the nodules were deposited in some other environment and transported later, there must not have been a considerable time lag between their deposition, erosion and redeposition in the lagoonal site of the Infra Krol sediments.

ACKNOWLEDGEMENTS

The authors are thankful to Mr Mukund Sharma for useful discussion. They are also thankful to Mr P. C. Roy for assistance in photography and Mr Madhukar Arvind for secretarial assistance.

REFERENCES

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

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

Azmi, R. J. 1983. Microfauna and age of the Lower Tal Phosphorite of Mussoorie Syncline, Garhwal Lesser Himalaya, India. *Himalayan Geol.* **11** : 373-409.

Azmi, R. J., Joshi, M. N. & Juyal, K. P. 1981 Discovery of Cambro-Ordovician conodonts from the Mussoorie Tal Phosphorite : its significance in correlation of Lesser Himalaya. *In*: Sinha, A. K. (Ed.)—*Contemp. Geoscient. Res. Himalaya* **1** : 245-250.

Barghoorn, E. S. & Tyler, S. A. 1965. Microorganisms from the Gunflint chert. *Science* **147** : 563-577

Bhargava, A. K. & Singh, I. B. 1981 Some palaeoenvironmental observations on the Infra Krol Formation, Lesser Himalaya. *J. Palaeont. Soc. India* **25** : 26-32.

Bhatia, S. B. 1980. The Tal tangle. *In*: *Stratigraphy and correlations of Lesser Himalayan formations*, pp. 79-96. Hindustan Publ. Corp. (India), Delhi.

Bhatt, D. K., Mamgain, V. D., Misra, R. S. & Srivastava, J. P. 1983. Shelly microfossils of Tommotian age (Lower Cambrian) from Chert-Phosphorite Member of Lower Tal Formation, Dehradun District, Uttar Pradesh. *Geophytology* **13** : 116-123.

Bhatt, D. K., Mamgain, V D. & Misra, R. S. 1985. Small shelly fossils of Early Cambrian (Tommotian) age from Chert-

Phosphorite Member, Tal Formation, Mussoorie Syncline, Lesser Himalaya, India and their chronostratigraphic evaluation. *J. Palaeont. Soc. India* **30** : 92-102.

Binda, P. L. & Bokhari, M. M. 1980. Chitinozoan-like microfossils in a late Precambrian dolostone from Saudi Arabia. *Geology* **8** : 70-71

Bloeser, B., Schopf, J. W., Horodyski, R. & Breed, W. J. 1977. Chitinozoans from the Late Precambrian Chuar Group of the Grand Canyon, Arizona. *Science* **195** : 676-679.

Fairchild, T R., Barbour, A. P. & Haralyi, N. L. E. 1978. Microfossils in the "Eopalaeozoic" Jacadigo Group at Urucum, Mato Grosso, southwest Brazil. *Bol. IG. Inst. Geosci. Univ. Sao Paulo* **9** : 74-79.

Gansser, A. 1974. The Himalayan Tethys. *In*: *Riv. Ital. de Paleont. Stratigr. Mem.* **14** : 393-411.

Golubic, S. & Barghoorn, E. S. 1977. Interpretation of microbial fossils with special reference to the Precambrian. *In*: Flugel, E. (Ed.)—*Fossil algae.* : 1-14. Springer, Berlin.

Hofmann, H. J. 1976. Precambrian microflora, Belcher Islands, Canada : significance and systematics. *J. Palaeont.* **50** : 1040-1073.

Horodyski, R. J. & Donaldson, J. A. 1980. Microfossils from the middle Proterozoic Dismal Lakes Group, Arctic Canada. *Precambrian Res.* **11** : 125-159.

Joshi, A., Mathur, V. K. & Bhatt, D. K. 1989. Discovery of Redlichid Trilobites from the Arenaceous Member of the Tal Formation, Garhwal Syncline, Lesser Himalaya, India. *J. geol. Soc. India* **33**(6) : 538-546.

Knoll, A. H. & Golubic, S. 1979. Anatomy and taphonomy of a Precambrian algal stromatolite. *Precambrian Res.* **10** : 115-151

Knoll, A. H. & Vidal, G. 1980. Late Proterozoic vase-shaped microfossils from the Visingso beds, Sweden. *Geologiska Förenin gens i Stockholm Forhandlingar* **102**(3) : 207-211

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

Knoll, A. H. 1982b. Microfossils from the Late Precambrian Draken Conglomerate, Ny Friesland, Spitsbergen. *J. Palaeont.* **56** : 755-790.

Kumar, G., Raina, B. K., Bhatt, D. K. & Jangpangi, S. 1983. Lower Cambrian body and trace-fossils from the Tal Formation, Garhwal Synform, Uttar Pradesh, India. *J. Palaeont. Soc. India* **28** : 106-111.

Kumar, G., Bhatt, D. K. & Raina, B. K. 1987. Skeletal microfauna of Meishucunian and Qiongzhusian (Precambrian-Cambrian boundary) age from the Ganga Valley, Lesser Himalaya, India. *Geol. Mag.* **124** : 167-171.

Lakhanpal, R. N., Sah, S. C. D. & Dubey, S. N. 1958. Further observation on plant microfossils from a Carboniferous shale (Krols) near Nainital with a discussion on the age of the bed. *Palaeobotanist* **7** : 111-120.

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

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

Maithy, P. K., Venkatachala, B. S. & Lele, K. M. 1983. Microbiota from subsurface of Ganga Basin. *Geophytology* **13**(2) : 190-194.

Mathur, V. K. & Joshi, A. 1989. Record of inarticulate brachiopods from the arenaceous member of the Tal Formation, Garhwal Syncline, Lesser Himalaya, India. *Curr. Sci.* **58**(8) : 446-448.

Mathur, V. K. & Shankar, R. 1989. First record of Ediacaran fossils from the Krol Formation of Naini Tal syncline. *J. geol. Soc. India* **34**(3) : 245-254.

McMenamin, D. S., Kumar, S. & Awramik. S. M. 1983. Microbial fossils from the Kheinjua Formation, middle Proterozoic, Semri Group (Lower Vindhyan), Son Valley area, central India. *Precambrian Res.* **21** : 247-271

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

Nautiyal, A. C. 1980. Cyanophycean algal remains and palaeoecology of the Precambrian Gangolihat Dolomite Formation of the Kumaon Himalaya. *Indian J. Earth Sci.* **7**(1) : 1-11.

Oehler, D. Z. 1978. Microflora of the Middle Proterozoic Balbirini Dolomite (McArthur Group) of Australia. *Alcheringa* **2** : 269-309.

Oehler, J. H. 1977 Microflora of the H. Y C. Pyritic Shale Member of the Barney Creek Formation (McArthur Group), middle Proterozoic of northern Australia. *Alcheringa* **1** : 315-349.

Oldham, R. D. 1888. The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas. *Rec. geol. Surv. India* **21** : 130-143.

Rai, V & Singh, I. B. 1983. Discovery of trilobite impressions in the Arenaceous Member of Tal Formation, Mussoorie area, India. *J. Palaeont. Soc. India* **28** : 114-117

Sah, S. C. D., Venkatachala, B. S. & Lakhanpal, R. N. 1968. Palynological evidences on the age of the Krol. *Centre Adv. Study Geol., Panjab Univ.* **5** : 115-120.

Schopf, J. W 1968. Microflora of the Bitter Springs formations, Late Precambrian, central Australia. *J. Palaeont.* **42**(3) : 651-688.

Shrivastava, R. N. 1972. Fossil lamellibranch from the Lower Tal shales of Mussoorie area, U. P. *Geol. Surv. India Misc. Publ.* **15** : 269-272.

Shukla, M., Tewari, V C. & Yadav, V K. 1987 Late Precambrian microfossils from Deoban Limestone Formation, Lesser Himalaya, India. *Palaeobotanist* **35**(3) : 347-356.

Singh, I. B. 1981. A critical review of the fossil records in the Krol belt succession and its implications on the biostratigraphy and palaeogeography of the Lesser Himalaya. *J. Palaeont. Soc. India* **25** : 148-168.

Singh, I. B. & Rai, V 1983. Fauna and biogenic structures in Krol Tal succession (Vendian-Early Cambrian), Lesser Himalaya: their biostratigraphic and palaeoecological significance. *J. Palaeont. Soc. India* **28** : 67-90.

Singh, I. B. & Rai, V. 1984. Discovery of *Archaeocyatha* in the Upper Krol carbonates, Mussoorie hills, Uttar Pradesh, India. *Curr Sci.* **53** : 243-246.

Singh, I. B., Shukla, V., Rai, V. & Kapoor, P. K. 1984. *Ichnogenus skolithos* in the Tal Formation of Mussoorie area. *J. geol. Soc. India* **25** : 102-107

Sitholey, S.V., Sah, S. C. D. & Dubey, S. N. 1954. Plant microfossils from carbonaceous shale (Krols) near Nainital. *J. scient. Ind. Res.* **13B**(6) : 450-451

Tewari, B. S. & Singh, R. Y 1979. The significance and occurrence of Late Palaeozoic plant remains in the Infrakrol sequence of Nainital, U.P. *Bull. Indian Geol. Assoc.* **12** : 263-266.

Tewari, V C. 1984. Discovery of Lower Cambrian stromatolite from the Mussoorie Tal Phosphorite, India. *Curr. Sci.* **53**(6) : 319-321

Tewari, V. C., 1988a. Stromatolites and the Precambrian-Cambrian boundary problem in the Lesser Himalaya, India. *In*: *Proc. natn. Sem. Stratigr boundary problems in India.* Department of Geology, Jammu Univ. (Abstr.) : 18-21.

Tewari, V. C. 1988b. Discovery of Vendotaenids from India. *Proc. Indo-Soviet Symp. on Stromatolites and stromatolitic deposits* (Abstr.) : 25-28. Wadia Institute of Himalayan Geology, Dehradun.

Tewari, V C. & Ghosh, S. K. 1986. On the discovery of Lower

Cambrian colonial *Archaeocyatha* from the Upper Krol carbonates, Korgai syncline, Himachal Pradesh. *6th Convention Indian Assoc. of sedimentol, Dehradun* (Abstr.) : 122.

Tewari, V C., Mathur, V. K. & Joshi, A. 1988. Discovery of Lower Cambrian (Lenian) stromatolites from Phulchatti Member (Tal Formation), Korgai syncline, Lesser Himalaya, India. *In*: *Proc. Indo-Soviet Symp. on Stromatolites and stromatolitic deposits* (Abstr.) : 28-29. Wadia Institute of Himalayan Geology, Dehradun.

Tripathi, C., Jangpangi, B. S., Bhatt, D. K., Kumar, G. & Raina, B. K. 1984. Early Cambrian brachiopods from "Upper Tal", Mussoorie syncline, Dehradun District, Uttar Pradesh, India. *Geophytology* **14**(2) : 221-227

Tynni, R. & Donner, J. 1980. A microfossil and sedimentation study of the Late Precambrian Formation of Hailuoto, Finland. *Bull. geol. Surv. Finland* **311** : 1-27.

Valdiya, K. S. 1980. Discovery of Late Palaeozoic brachiopod in the Upper Krol of the Nainital hills, Kumaon Himalaya. *J. geol. Soc. India* **21** : 97-101.

Venkatachala, B. S., Yadav, V K. & Shukla, M. (in press). Middle Proterozoic microfossils from Nauhatta Limestone Formation (Lower Vindhyan), Rohtasgarh, India.

Vidal, G. 1979. Acritarchs from the Upper Proterozoic and Lower Cambrian of East Greenland. *Bull. geol. Unders. Grønland* **134** : 1-55.

Zhang, Z. 1985. Coccoid microfossils from the Doushantuo Formation (Late Sinian) of South China. *Precambrian Res.* **28** : 163-173.