Precambrian and Lower Cambrian stromatolites of the Lesser Himalaya, India*

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In the lesser Himalayan carbonate formations all known stromatolite assemblages with Lower, Middle. Upper Riphean, Vendian and Lower Cambrian (Tommotian and Lenian) affinities are present. The Lesser Himalaya show spectacular assemblages of Riphean taxa. The Upper Proterozoic (Riphean) carbonate formations can be traced from the north-western (Jammu) to the north-eastern (Arunachal) end of the Lesser Himalaya and are designated by various groups and formations exposed in tectonic windows. The Terminal Proterozoic (Vendian/Ediacaran) and Lower Cambrian (Tommotian and Lenian) stromatolites, carbonates and phosphorites are more or less restricted to the Central sector of the Lesser Himalaya (Krol Belt) in Kumaun, Garhwal and Himachal Pradesh. The Precambrian-Cambrian stratigraphy of the lesser Himalaya has become more interesting since the discovery of the Ediacaran metaphytes (Vendotaenids) and metazoans from the Krol Formation to understand the possible links between the evolution of the metaphytes and metazoans and the decline of the stromatolites across the Precambrian-Cambrian boundary in the Indian subcontinent.

Key-words—Precambrian, stromatolites, Lesser Himalaya, Krol Belt, Ediacaran, Vendotaenids, Precambrian-Cambrian boundary.

INTRODUCTION

TEWARI (1988a; 1989) has made an attempt to assess the biostratigraphic usefulness of stromatolite taxa in Upper Proterozoic and Lower Cambrian carbonates of the Lesser or Lower Himalaya (Text-fig.1) with special reference to Proterozoic-Cambrian boundary. The distribution of stromatolite taxa in time and space across the Proterozoic-Cambrian boundary suggests that only Lower Riphean to Lower Cambrian (Lenian Stage) taxa are found in the Lesser Himalaya (Table 1, Text-fig.2). The Lower Proterozoic (Aphebian/Pre Riphean) stromatolites have not been recorded so far. The Upper Proterozoic (Riphean) stromatolite taxa are widely distributed in the carbonates of the inner Lesser Himalaya. The Terminal Proterozoic (Vendian) and Precambrian-Cambrian boundary stromatolite taxa are found in the Upper Krol and Lower Tal Formations of Mussoorie, Korgai, Niglidhar and Nainital synclines. The Lower Cambrian (Tmmotian to Lenian) taxa are restricted to the Tal Formation of Mussoorie and Korgai synclines. Recently, Ediacaran metaphytes, metazoans and trace fossils have been recorded from the Krol Formation of the Lesser Himalaya (Tewari, 1988b, 1989, 1991c, 1992a; Shankar & Mathur, 1991). The available data on the stromatolites from the Precambrian and Cambrian Lesser Himalaya and Peninsular Indian basins have been reviewed by Kumar (1980, 1984), Tewari (1984b, 1989), Valdiya (1989) and Raha and Das (1989). In the present paper, an attempt has also been made to establish the possible link between the decline of the Riphean stromatolites and the appearances of the Vendian (Ediacaran) metaphytes and metazoans in the Lesser Himalaya.

RIPHEAN STROMATOLITES

The Upper Proterozoic (Riphean) in the north-western Jammu and Kashmir Himalaya is represented by a thick sequence of carbonates known as the Jammu Limestone (Great Limestone) or Vaisnodevi Limestone. For a long time it was considered to be Late Palaeozoic in age (Wadia, 1928). However, the presence of Riphean stromatolites (Singh & Vimal, 1972; Raha, 1980; Tewari, 1984b, 1989) proved it to be Upper Proterozoic. From numerous stromatolite discoveries, Raha (1980), demonstrated that the entire sequence of the Great

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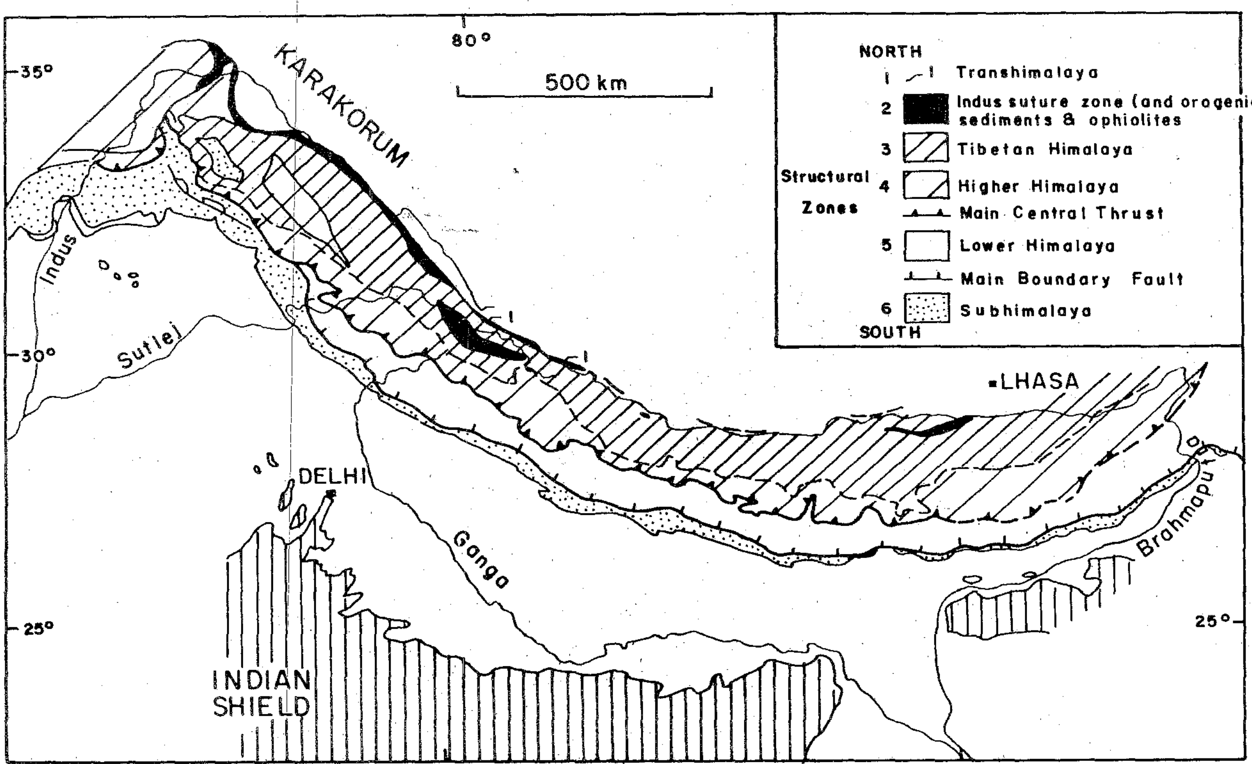


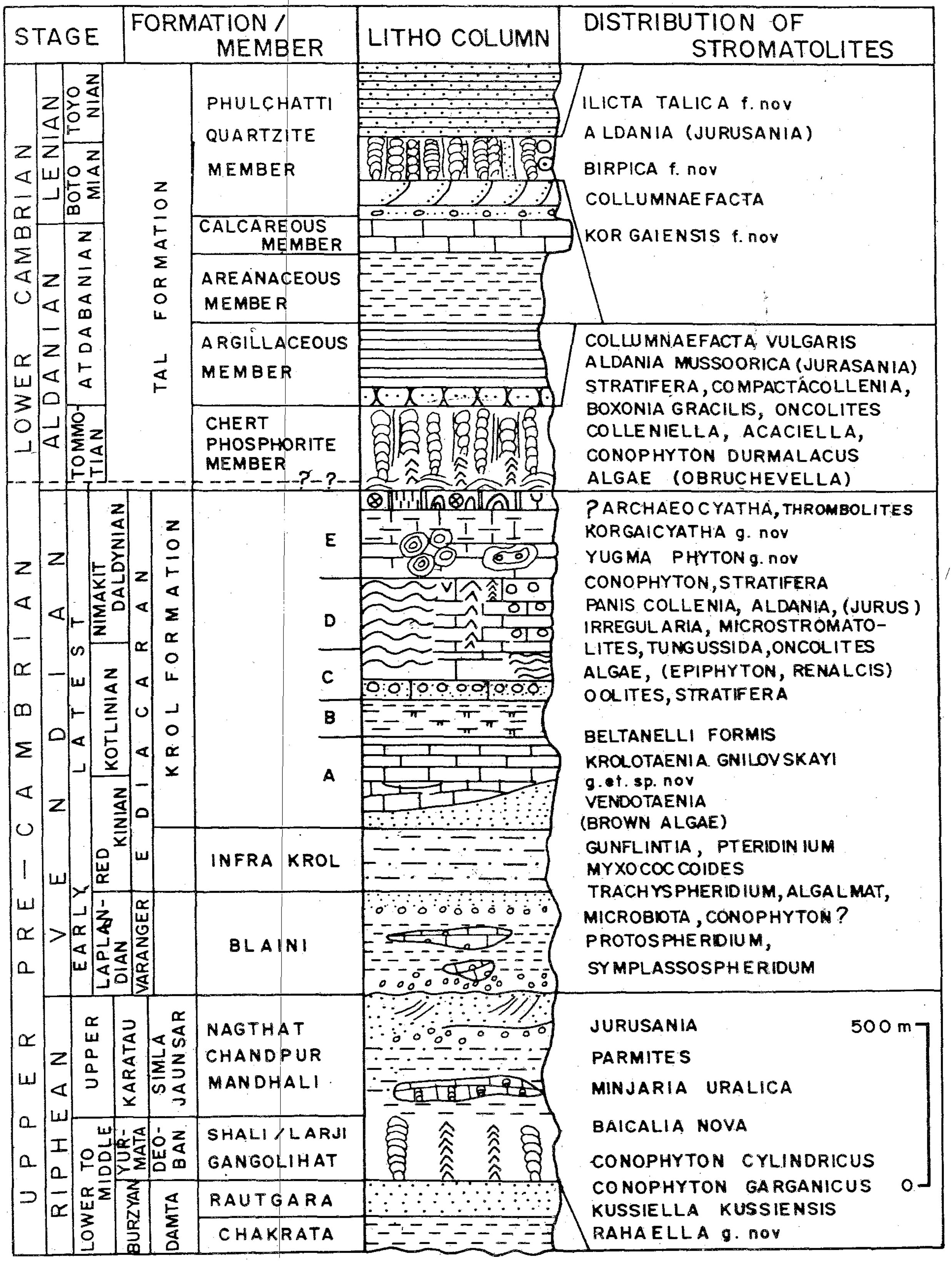
Text-figure 1. Geological map of the Himalaya (after Gansser, 1974). The stromatolites are abundantly found in the Lesser/Lower Himalaya (5).

(Jammu) Limestone is characterised by several levels of Riphean stromatolite taxa. He established a sequence of three assemblages, namely, (I) *Colonnella-Kussiella* assemblage zone, (II) *Colonnella-Conophyton* assemblage zone and (III) *Baicalia* assemblage zone. The two lower zones (I and II) are considered by Raha (1980) to be Lower Riphean in age and third zone as Middle Riphean. Additional studies by the present author (Tewari, 1984b, c, 1989) and Raaben and Tewari (1987) have confirmed the age suggested by Raha (1980).

The Stromatolite assemblage (I) comprises *Kussiella kussiensis* Krylov, *Kussiella* fm. indet., *Omachtenia granesis* Raha, *Platella talwarensis* Raha and also four taxa of *Colonnella* Komar, namely, *Colonnella elongata* Raha, *Colonnella katraensis* Raha, *Colonnella* cf. *C. laminata* Komar, *Colonnella* cf. *C. discreta* Komar.

Table 1. Stromatolite biozonation of Lesser Himalaya, north India (Tewari, 1989)

No.	Biozone	Stromatolite Assemblage	Age
VII	*Ilicta*	*Ilicta talica*. f. nov., *Collumnaefacta korgaiensis* f. nov., *Aldania birpica* f. nov.	LENIAN/TOYONIAN (Lower Cambrian)
VI	*Collumnaefacta-Boxonia*	*Collumnaefacta vulgaris*, *Boxonia gracilis*, *Aldania mussoorica*, *Colleniella*, *Acaciella*, *Compacto-collenia*, *Conophyton durmalacus*, *Conophyton* msp.	TOMMOTIAN (Precambrian - Cambrian (PC/C) Boundary)
V	*Yugmaphyton*	*Yugmaphyton* g. nov., *Minicolumellae*, *Stratifera*, *Conophyton*, *Tungussia* msp.	LATE VENDIAN
IV	*Jurusania-Parmites*	*Jurusania* msp. *Jurusania himalayika*, *Parmites*, *Tungussia*, *Poludia*	UPPER RIPHEAN TO EARLY VENDIAN
III	*Baicalia*	*Baicalia nova*, *Baicalia* *Chandakia* f.nov., *Minjaria uralica*, *Jacutophyton*	MIDDLE RIPHEAN
II	*Conophyton*	*Conophyton cylindricus*, *Conophyton garganicus*, *Colonnella columnaris*	LOWER RIPHEAN
I	*Rahaella-Kussiella*	*Rahaella* g. nov., *Rahaella elongata*, *Rahaella katraensis*, *Kussiella kussiensis*, *Kussiella vittata*	LOWER RIPHEAN



Text-figure 2. Lithocolumn showing the distribution of Precambrian (Riphean, Vendian) and Lower Cambrian stromatolites, algae and Ediacaran biota.

Although the four taxa named above have been assigned to *Colonnella* Komar, they do not, in fact, have any of the basic characteristics of that group (Komar, 1966) and has been revised by the author (Tewari, 1989).

The four taxa were examined by Dr. V.A. Komar in USSR who has confirmed (V.A. Komar, personal communication, 1986) the opinion of the author that they do not belong to *Colonnella* (Komar, 1966). Tewari (1989) has described these taxa under a new group (form genera), *Rahaella*.

The lowermost part of stromatolite assemblage I biostrome (the *Colonnella-Kussiella* assemblage zone of Raha, 1980) is established here as those beds with *Rahaella* (P1 1; Text-fig. 3). The association also includes *Omachtenia granensis* Raha, which is the smallest size form amongst the group *Omachtenia* Nuzhnov. All these forms are restricted to the lower part of the beds. Above the *Rahaella* assemblage, locally distinctive beds can be recognized and are characterised by the stromatolite *Platella talwarensis* which is specific to this horizon. *P. talwarensis* has affinity with other Riphean taxa of *Platella* Komar, but it also resembles some forms of *Parallelophyton* from the Lower Proterozoic of Karelia, USSR. *P. talwarensis* does not appear in the upper part of the section.

The uppermost part of the first biostrome is characterised by beds of *Kussiella kussiensis* and may be considered as a distinct unit. *K. kussiensis* is the dominant form and other indeterminate forms of *Kussiella* are also present in this biostrome (Text-fig. 3). Slightly higher in the section, separate beds with well developed laminated stromatolites of the supergroup Thyssagetacea Vlasov are found. This supergroup, together with *Kussiella* is characteristic of the Satka asssemblage of the Lower Riphean of the Urals, USSR.

A second biostrome is exposed higher in the section. The horizon is more correctly described as biohermal. As indicated by Raha (1980), the bioherm is characterised by *Conophyton* sp. and *Colonnella* sp., *Conophyton cylindricus* Maslov forms spectacular structures having more than 50 cm in diameter and up to several meters in height (Text-fig. 3). Large *Colonnella* sp. structures, described as *Colonnella riasiensis* Raha, are also present. Some of these stromatolites indeed belong to the group *Colonnella* Komar, but other having inverted conical and cylindric columns are identified as *Conusella regularis* Golovanov and correspond to the diagnosis of *Conusella* Golovanov. A characteristic feature of this association is that the big columns of *Colonnella* sp., *Conophyton* sp. and *Conusella* sp. occur in high dome shaped bioherms. It is also important to note that such bioherms are either found in the same bed or in adjoining beds together with *Gaya* sp. and with large forms of *Paniscollenia* sp.The general aspect of the association of

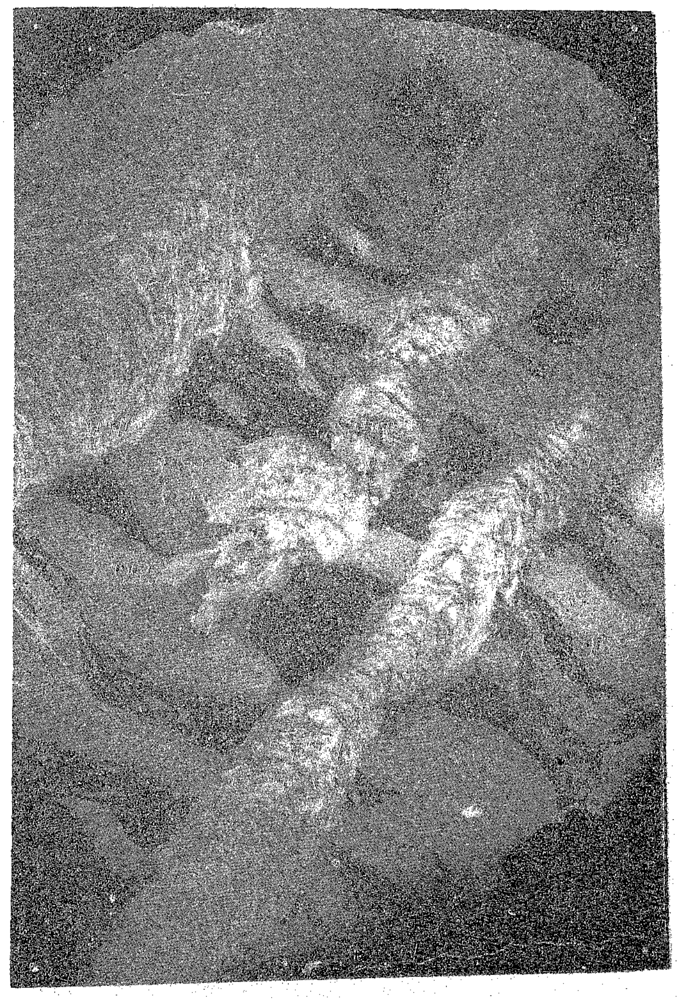


Plate 1

1. Lower Riphean form *Rahaella elongata* Tewari 1989 from Lower Shali Limestone, Lesser Himalaya showing nature of columns, laminae and microstructure etc. (WIF/A-1360)

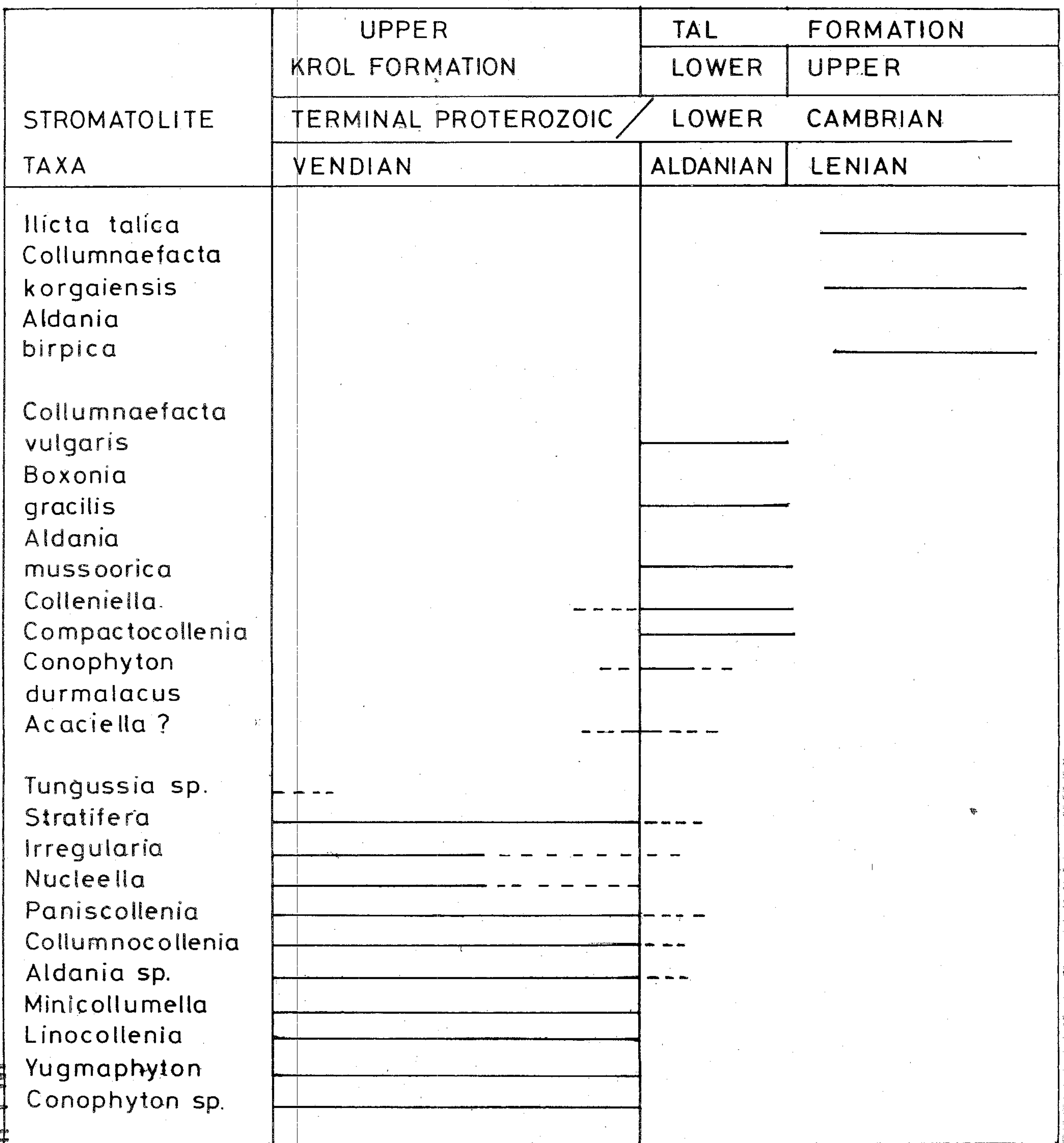
Table 2. Riphean stromatolite time range chart for the Lesser Himalaya (Jammu-Dharamkot-Shali including Shimla and Sataun, Larji-Deoban-Gangolighat Ta Jem Belt)

STROMATOLITE TAXA	PALAEO PROTEROZOIC/ PRE-RIPHEAN/ APHEBIAN FORMS NOT FOUND	MESOPROTEROZOIC		NEOPROTEROZOIC	
		R I P H E A N			
		LOWER	MIDDLE	UPPER	
		BURZYANIAN 1650±50–1350	YURMATANIAN 1350±50–1000±50	KARATAVIAN 1000±50–680 Ma	KUDASHIAN 680–650 Ma
Kussiella kussiensis		——			
Kussiella vittata		——			
Kussiella msp.		——			
Rahaella elongata		——			
Rahaella katraensis		——			
Colonnella msp.		——			
Colonnella columnaris		——			
Colonnella riasiensis		——			
Omachtaenia granensis		——			
Omachtaenia msp.		——			
Platella msp		——	- - -		
Platella talwarensis		——			
Poludia msp		——			
Conophyton cylindricus		——	- - -		
Conophyton garganicus		——	- - -		
Conophyton misrai		——			
Baicalia msp.			——		
Baicalia chandakia			——		
Baicalia nova			——		
Baicalia prima			——		
Jacutophyton msp.			——		
Svetliella msp.			——		
Minjaria uralica			——		
Masloviella columnaris			——		
Plicatina antiqua		- - -	—— - - -		
Nucleella msp.		- -	——	- - -	
Gongylina differentiata		——	- - -	- -	
Paniscollenia msp.			——	——	- - -
Stratifera undata		——	—— - - -	- - -	
Conusella msp.		——			
Parmites concrescens				——	
Cryptophyton msp.		——			
Jurusania himalayika				——	- - -

the second biostrome is very similar to the Lower Riphean Baikalian association of the southern Urals, Russia.

Biostrome III (*Baicalia* assemblage zone) includes stromatolites of the group Baicalia in its lower part, originally described by Raha (1980) as *Baicalia baicalica* (Text-fig. 3). However, this form species has been now revised by Krylov and Shapovalova (in Raaben & Komar, 1982) as *Baicalia nova*. The revision demonstrated that several forms have been described in the former USSR under the name *Baicalia capricornia* Water 1972. *Baicalia* sp. from Jammu Limestone and *Baicalia nova* from Russia are not identical to *Baicalia capricornia* described from Bangemall Group (Middle Riphean) of Western Australia but are closely comparable. *Baicalia* cf. *B. baicalica* and *Baicalia* f. described from assemblage 4, Jixian system of Sinian suberathem of China

Table 3. Vendian and Lower Cambrian (Krol-Tal) stromatolite time range chart for the Lesser Himalaya



(Zhu Shixing, 1982) is identical to *Baicalia* sp. from Jammu Limestone. *Baicalia* sp. from the Jammu Limestone is similar to *Baicalia nova* Krylov and Schapovalova, described from the Avzyan Series of the southern Ural and *Baicalia prima* Semikhatov from Middle Riphean of Siberia, but does not resemble the type form *Baicalia baicalica* from the Prebaikal region. *Baicalia burra* Preiss described from the Burra Group of Australia resembles *Baicalia* sp. from Jammu Limestone.

The stromatolites from the Jammu Limestone have a very simple microstructure and their gross morphology and branching pattern are very simple and are not bush

Table 4. Tentative divisions of Terminal Proterozoic System in the Lesser Himalaya (Tewari, 1991c).

Lower Cambrian	Lenian	Toyonian Botomian	
	Aldanian	Atdabanian, Talian Tommotian/Meischunian	
Terminal Proterozoic System	Vendian Period	Ediacaran Varanger	*Krolian* Blainian
	Riphean		Deobanian

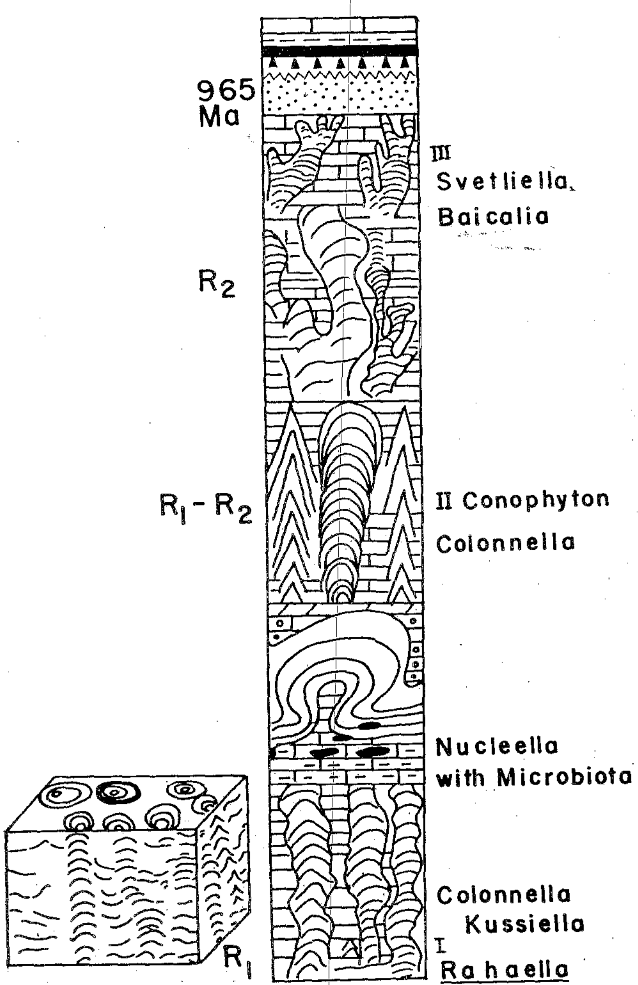
like. The structure is roughly turbinate and forms only 2-3 new columns.

Higher in the section., multiple dome shaped stromatolites of the group *Paniscollenia* Korolyuk and some *Cryptophyton* structures are found. *Cryptophyton* Raaben and Komar is characteristic of the Middle Riphean Avzyan Series of the southern Urals, Russia. Also in the upper part of the sequence, Raha (1980) described *Anabaria* Komar. However, the reconstruction of the form suggests that it possibly belongs to the group *Svetliella* Schapovalova (Text-figs 3, 4).

Several of the stromatolite beds mentioned above are also found in other parts of the Himalaya in Himachal, Garhwal and Kumaon. East of the Riasi window, *Kussiella* sp. bearing beds occur in the Dharamkot Limestone (Tewari, 1985b). In the Simla Himalaya, *Kussiella* sp. and *K. kussiensis* beds are well represented in the Shali window near Tattapani in the Satluj Valley (Valdiya, 1969; Tewari 1981, 1984b, 1989), in carbonate beds of the Lower Shali Limestone. In the underlying beds in the Satluj Valley, *Rahaella elongata* (P1. 1) has been observed (Tewari, 1989). Beds with *Kussiella* sp. have been recorded in the Aut Dolomite of the Larji window, Kulu area and are correlated with the Lower Shali Limestone (Tewari, 1981, 1984b, 1985b, 1989). The lower part of the Deoban Limestone shows prolific development of *Kussiella* sp. and *K. kussiensis* (Prashra, 1977; ewari, 1981, 1984b, 1989). *Kussiella* sp. is also present in the Lower Deoban Limestone of the eastern Garhwal and Kumaon region (Tewari, 1981, 1984b, 1989). The *Kussiella* sp. and *K. kussiensis* assemblage of Aut Dolomite, Lower Shali Limestone and Deoban Limestone is identical to the Assemblage 2 of Nankou System of China.

Recently, Shukla *et al.* (1986) have recorded a very rich microbiota from petrographic thin sections of black chert lenses in the lower part of the Deoban Limestone. The palaeomicrobial community includes *Oscillatoriopsis*, *Cyanonema*, *Siphnophycus*, *Eomycetopsis*, *Gunflintia*, *Anemikia*, *Glenobotrydion*, *Globophycus*, *Sphaerophycus*, *Myxococcoides*, *Archaeotrichion*, *Biocatenoides and Kildinosphaera*. The assemblage of Deoban chert is dominated by filamentous cyanobacteria and coccoid microfossils and has been compared with other known Proterozoic microbiota of the world (Tewari *et al.*, 1984b, 1989; Shukla 1986). Vase–shaped microfossils Chitinozoans?/megă acritarchs), Acanthomorphs, Obruchevella algae and a few other forms of uncertain affinities (possibly the ancestors of the first metazoans of the *Ediacara fauna)* have been recorded from Deoban Limestone (Shukla & Tewari, 1989). *Conophyton cylindricus,* a characteristic form of the Jammu Limestone, is also found here. *Colonnella columnaris* (Text-fig. 4) and *C. garganicus* are best developed in the Kathpuria Chhina and adjoining areas in Sarju Valley and Gangolihat area (P1. 2, fig. 8; P1. 4, fig. 8; P1. 5, fig. 6) and overlying beds contain the laminated stromatolites *Gongylina differentiata* Komar, *G. mixata* (P1. 2, fig. 2) and *Stratifera hearnica* (P1. 2, fig. 3), *Stratifera undata* Komar, linked *Conophyton (Conophyton misrai* Kumar & Tewari, 1977) and *Plicatina antiqua* Raaben (Tewari, 1983) (Text-figs 4, 5; Pl. 2, fig. 5). *Plicatina antiqua* has been described from the lower horizons of the Upper Proterozoic Anti Atlas section of Morocco (Raaben, 1980a). *Conophyton garganicus* from Gangolihat Dolomite is identical to *C. garganicum australe* Walter described from Bangemall Group of Australia (Walter, 1972) and *C. garganicum* from Nankou System of China (Zhu Shixing, 1982). On the basis of presence of *Baicalia-Conophyton garganicus,* Kumar and Tewari (1978) and Tewari (1989) correlated the Gangolihat Dolomite with Bangemall Group (1100 Ma) of Bangemall Basin, Australia and Callanna Beds of Adelaide Geosyncline, Australia.

The *Conophyton cylindricus* beds also occur in the Dharamkot Limestone, Aut Dolomite and Shali Limestone of the Himachal Himalaya (Tewari, 1984b, 1985b; Sinha, 1977). *C. cylindricus* bioherms overlie beds with multiple *Kussiella* sp., structures. In the Aut Dolomite, *C.cylindricus* is accompanied by *Conusella regularis,* and large structure of *Paniscollenia* sp., *Conophyton* sp. form of Aut Dolomite is not exactly identical to *C. ressoti* described from Mauritania (Bertrand-Sarfati, 1972) but has similar axial zone and small columns around *Con-*



Text-figure 3. Distribution of stromatolites in the Jammu Limestone, J & K (modified after Raha, 1980).

ophyton trunks. Large *Conophyton* forms described by Donaldson (1976) from Dismal Lakes Group (Helikian) and Rae Group (Hadraynian) of Canada are comparable to *Conophyton* sp. form Jammu, Shali and Gangolihat Dolomite of the Lesser Himalayan region. *Conophyton cf. C. cylindricum* is also recorded from Upper Proterozoic Fyn Dolomite of Greenland (Walter, 1976, p. 365). In the Dharamkot Limestone, *Conusella* sp. is associated with *C. cylindricus* and lies directly above a bed of *Kussiella sp.* Thus it is evident that in Riasi window as well as in other regions of the Lesser Himalaya, similar bioherms are developed and persist over a long distance. The uppermost stromatolite beds of the Jammu Limestone with *Baicalia* ex gr. *prima* may be correlated with *Baicalia* sp. containing Upper Deoban Limestone. The smaller phosphatic branching stromatolites from upper part of the Gangolihat Dolomite belong to the Group Baicalia Krylov (P1.2, fig.3).

The Upper Riphean stromatolites have not been found in the Jammu Limestone. Valdiya (1989) has mentioned the occurrence of *Minjaria* sp. and *Jurusania* sp. from the Upper Shali, Upper Deoban and Thalkedar Limestone. Tewari (1989) reported the occurrence of *Minjaria uralica* from Upper Gangolihat Formation (Text-fig. 4).

In the Simla Himalaya the Upper Riphean taxa *Parmites concrescens, Jurusania himalayika* and *Jurusania* sp. (Text-fig. 4) are present in limestone lenses within the Simla Group (Sinha, 1977; Tewari , 1984b, 1989). *Jurusania himalayika* has some affinities to *J.sibirica* and *J. tumuldurica* found in the uppermost Judomian of Western Siberia. *J. derbalensis* Raaben recorded from Taoudeni Basin (Upper Proterozoic), Western Africa differs from *J. himalayika* in microstructure. Riphean stromatolite time range chart for the Lesser Himalaya is shown in Table 2.

VENDIAN STROMATOLITES

The Upper Krol Formation (Late Vendian/Ediacaran) is basically a microbial-stromatolitic sedimentation facies. It is characterised by microbial-laminites, fenestral fabric, oncolites, calcareous algae, microstromatolites (P1. 2, figs 4, 7; Pl. 5, figs 1, 2, 3, 4). The other domal, stratified, columnar and conical forms recorded from Mussoorie, Nainital and Himachal Pradesh include *Stratifera, Irregularia, Nucleella, Panis collenia, Linocollenia Conophyton* msp. *Yugmaphyton* (linked *Conophyton), Tungussia* sp., *Aldania* sp., *Colleniella, Conistratifera* (conical stratified forms) (Pl. 3,

→

Plate 2

1. *Collumnaefacta vulgaris* (Tommotian) from Chert Phosphorite Member of Lower Tal Formation, Durmala phosphorite mine, Mussoorie Syncline. (WIF/A 1350).
2. Microphotograph of *Gongylina mixata*, X 2, Gangolihat Dolomite, Almora district, U.P.
3. *Stratifera hearnica* Semikhatov from Gangolihat Dolomite, Pithoragarh.
4. Microphotograph of fenestral texture (microbial) in Upper Krol (D) Dolomite, Mussoorie Syncline.
5. Microphotograph of *Plicatina antiqua*, X 3, from Gangolihat Dolomite, Kathpuria Chhina, Almora District.
6. Stromatolite microstructure showing carbonate (inorganic) and phosphatic (organic laminae) in *Baicalia* from Pithoragarh.
7. *Conophyton* Maslov, from Upper Krol (D) Dolomite, Chamasari, Mussooorie Syncline. (WIF/A-1351).
8. Microstructure of axial zone of *Conophyton garganicus* from Gangolihat Dolomite, Kathpuria Chhina. Almora District.

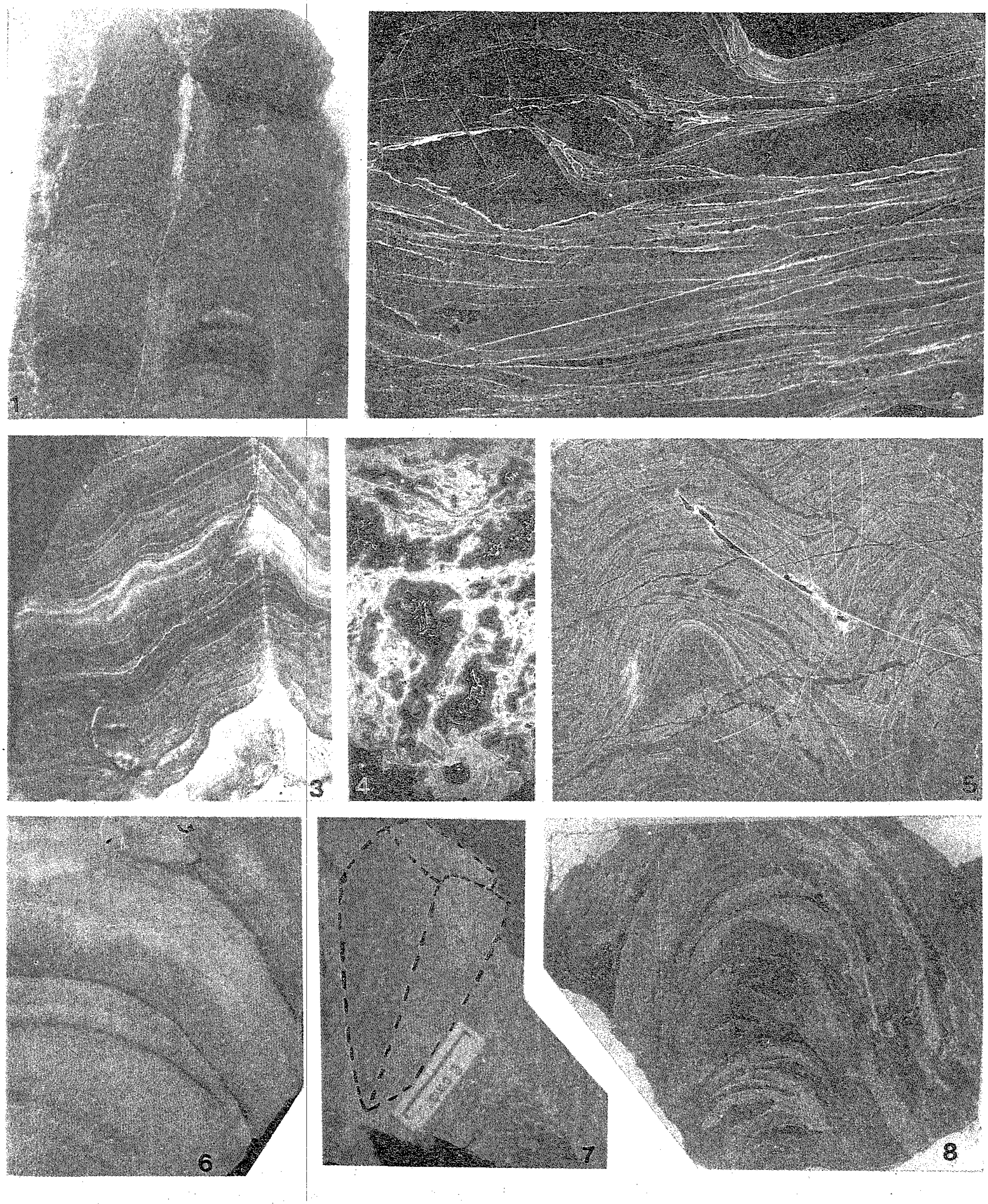
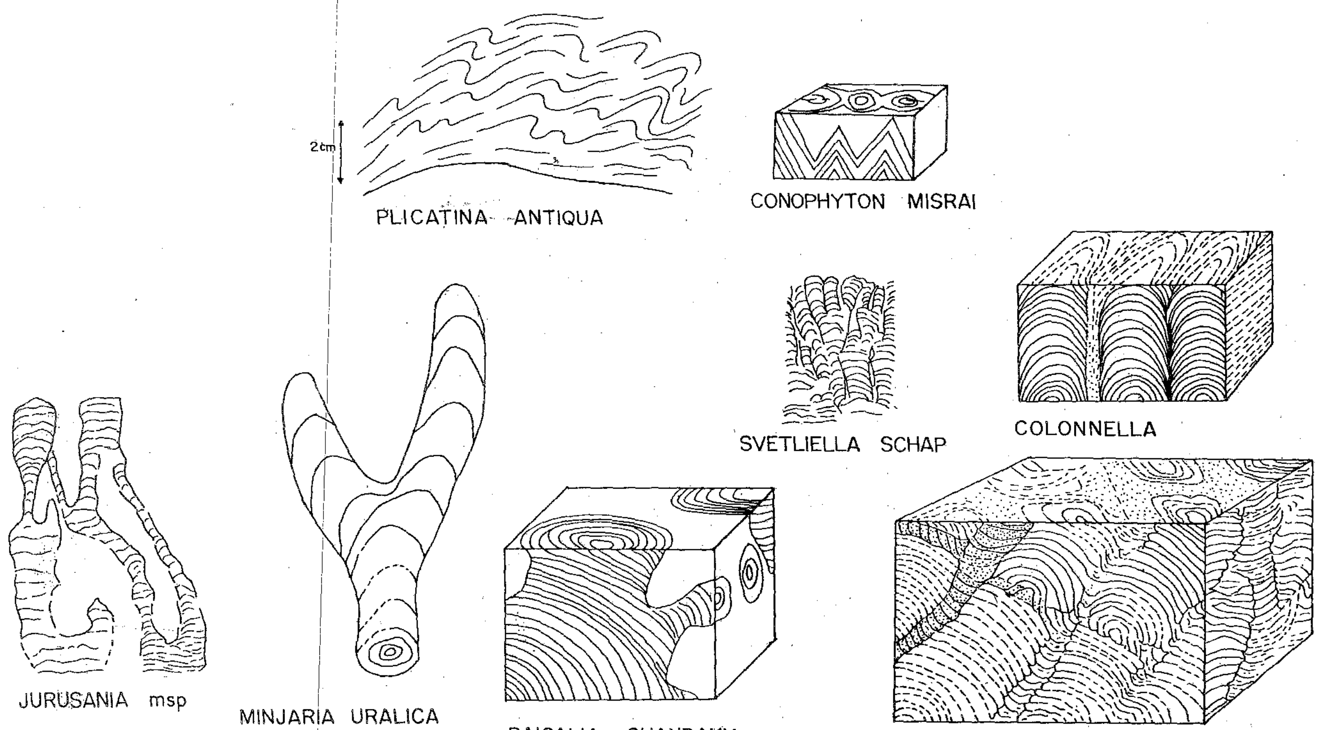


Plate 2



Text-figure 4. Three dimensional reconstructions of the Upper Proterozoic (Riphean, Vendian) stromatolites from Lesser Himalaya.

figs 1,2; pl. 4, figs 1, 2, 3, 4, 5).

The microstromatolites (*microstromatite*) of the Upper Krol Formation (Krol D Member) are columnar microstromatolites and may be included in the group (form genus) *Minicolumellae* Raaben (Pl. 5, figs 1,3). The presence of these microstromatolites also suggests a Late Vendian (Yudomian) age to the Krol D Member of Krol Formation. Joshi (1992) and Tewari and Joshi (1993) have studied the Vermiform microstructure found in Krol stromatolites for the first time in detail.

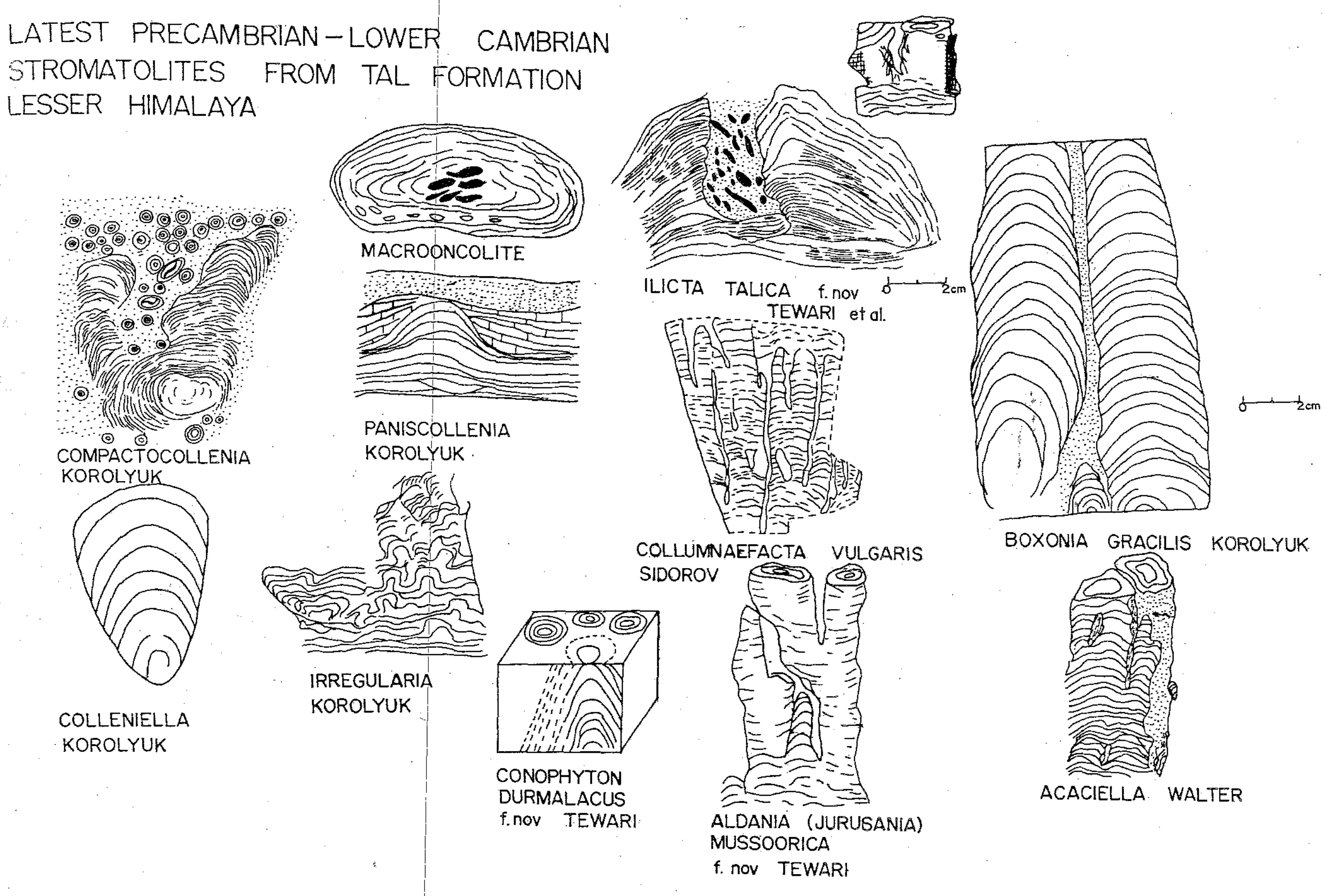
Raaben (1980b) proposed a separate taxon *Microstromatite* for the microstromatolites that consists of microscopic to quasimicroscopic stromatoids (columns, nodules). The microstromatolites represent various morphological features but the most characteristic feature is the very small dimension of the elementary stromatoids which varies from one tenths (1/10 mm) to a few mm and the length of the columns varies from few decimeters upto 2-3 cm (Pl 5, fig.1). A new group (form genus) *Minicolumelle* was established by Raaben (1980) for the columnar microstromatolites which consists of the columns with average diameter not exceeding 1-2 mm. Tewari (1987) has done detailed work on the microstromatolites from the Krol Formation.

The Krol stromatolites from the Lesser Himalaya are comparable to that of the Vendian from Russia (Tewari, 1987, 1989). The Late Vendian stromatolites of Siberian platform are characterised by the dominance of domal and stratified stromatolite forms *Paniscollenia* Korolyuk, *Irregularia* Korolyuk (Text-fig. 5), *Stratifera, Linocollenia, Colleniella singularis* Korolyuk and *Boxonia* (?) *granulosa* Korolyuk. The less abundant stromatolites present in the Late Vendian carbonates (Yudomian) are linked with *Conophyton (Conophyton goubitza* Krylov) and microstromatolites. Some columnar-stratified stromatolite taxa like *Collumnaefacta* Korolyuk. *Patomia* Krylov, *Aldania* Krylov, *Jurusania aldanica* Shenfil have also appeared in the latest Vendian, just near or below the Precambrian-Cambrian boundary and are considered very significant for Precambrian-Cambrian transition (Krylov *et al.*, 1981). However, they are widespread and abundantly found in the lower most Cambrian deposits (Tommotian Stage) of the Siberian platform, USSR (Korolyuk, 1966) (Text-fig. 5).

The stromatolite time range chart for the Vendian taxa of the Lesser Himalaya is shown in Table 3.

LOWER CAMBRIAN STROMATOLITES

The Lower Cambrian stromatolites are very typical in their morphology, texture and microstructure and can easily be distinguished from Vendian or Pre-Vendian (Riphean) stromatolites. The most characteristic features of the Lower Cambrian stromatolites are the presence of a well developed wall, patchy texture, banded and



Text-figure 5. Three dimensional reconstructions of the latest Precambrian (Precambrian-Cambrian Boundary) and Lower Cambrian stromatolites from the Tal Formation of the Lesser Himalaya.

grumous microstructure, (Joshi, 1992; Tewari & Joshi. 1993) and the combination of the stratiform and columnar morphologies with or without coalescence (Text-fig.5; Pl. 2, fig. 1; Pl.5, fig. 5). The most important taxa which are recorded from the Pestrotsvet Formation (Sidorov in Raaben, 1981), Lena River section in USSR (Tommotian Stage/Earliest Cambrian), Siberia are *Collumnaefacta vulgaris* Sidorov, *Ilicta composita* Sidorov, *Aldania sibirica* Yakovlev, *Tunicata nochtuica* Sidorov, *Sacculia zonalis* Korolyuk and *Compactocollenia* Korolyuk (Text-fig. 5).

The earliest Cambrian (Tommotian Stage) stromatolite form *Collumnaefacta vulgaris* Sidorov was discovered by Tewari (1983, 1984a, b) from Chert Phosphorite Member of Lower Tal Formation from PPCL Phosphorite Mine located at Durmala near Mussoorie in Dehra Dun District (Pl. 2, fig. 1; Text-fig. 5). *Collumnaefacta vulgaris* is found in the surface outcrops (Adit No. 1A/RL 1800) along with *Aldania (Jurusania mussoorica* Tewari and *Compactocollenia* Korolyuk in Durmala area (Pl. 2, fig.1; Text-fig. 5).

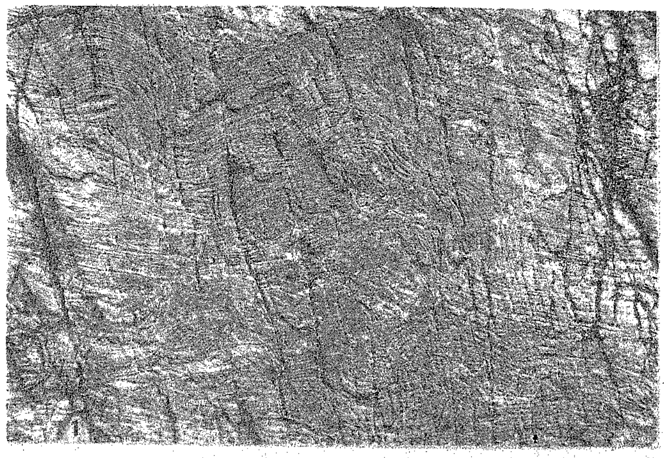
Recently, an assemblage of latest Precambrian-early Cambrian stromatolite taxa has been recorded from the PPCL underground mine at Durmala (Tewari, 1989). The 40 cm thick stromatolitic bed (biostrome bioherm series) is persistent in the Chert Phosphorite Member and now can be used as a marker horizon for the correlation of the Precambrian-Cambrian boundary interval beds in the Lower Tal Formation since it has been also located in Surkhet block in Maldeota area. The assemblage recorded include *Conophyton* msp., *Conophyton durmalacus* f. nov., *Boxonia gracilis* Korolyuk, *Colleniella* Korolyuk and ? *Acaciella* msp. (Text-fig. 5). This stromatolite assemblage is found in the typical association of phosphorite, pyrite and oncolites in the underground mine (Adit 4/RL 1650), presently the lowest level (Adit 2 A/RL 1746) and surface outcrops (at RL 1795 and Adit 1 A/RL 1800).

The occurrence of *Conophyton* msp. in the Chert Phosphorite Member is quite significant since this group is restricted to the Precambrian/latest Precambrian all over the world and not recorded from anywhere in the Phanerozoic beds. A new form *Conophyton durmalacus* is being recorded and named after the locality Durmala, about 10 km S70 E of Mussoorie. *Boxonia gracilis* Korolyuk and *Colleniella* Korolyuk are characteristic forms of Lower Cambrian (Aldanian) beds of Bokson Suite, Eastern Sayans and Pre-Baikal regions of Eastern Siberian Platform (Korolyuk, 1966). The group *Acaciella* Walter is found in the Adelaidean to Early Cambrian of Bitter Springs Formation, Central Australia (Preiss, 1972). Tewari (1983, 1984 a, b) suggested that the Precambrian-Cambrian boundary (Tommotian Stage) lies in the Krol-Tal contact, based on the occurrence of *Collumnaefacta vulgaris* and *Aldania (Jurusania) mussoorica* from Chert Phosphorite Member of Lower Tal Formation and the *Conophyton* Maslov, *Stratifera irregularis,* microstromatolites (now identified as Group Minicolumella Raaben, 1980), linked *Conophyton (Yugmaphyton* gen. nov. Tewari, 1989) and *Oncolites* from Krol D Member of Mussoorie Syncline. A late Vendian (Nemakit Daldynian) age has been assigned to the Upper Krol Formation (Tewari, 1987, 1988, 1989, 1991). The time range chart for the Krol-Tal (Vendian-Lower Cambrian) stromatolites from the Lesser Himalaya has been prepared and is shown in Table 3.

The Lower Cambrian (Lenian Stage) stromatolite taxa have been described from the Phulchatti Member of the Upper Tal Formation, Himachal Pradesh, Lesser Himalaya. The stromatolite and macrooncolite bioherm is profusely developed about 600 meter S.E. of village Birpa (30° 34'50" : 77°39'15") in Korgai Syncline. Tewari *et al.* (1988) and Tewari (1989) have indentified three new forms of Lower Cambrian stromatolites, namely, *Ilicta talica, Collumnaefacta korgaiensis* and *Aldania birpica* (Text-fig.5) and compared them with known Siberian forms from U.S.S.R. The biostratigraphic significance of these Lenian stromatolites in fixing the upper age limit of the Tal Formation is quite significant since this horizon represents the uppermost part of the Tal Formation and there is no other evidence of additional life in the beds overlying the stromatolite bearing horizon. The systematics of the stromatolites is being published elsewhere.

DISCUSSION AND CONCLUSION

The biostratigraphic usefulness of the stromatolite taxa in the Precambrian and Lower Cambrian carbonates of the Lesser Himalaya has been assessed with special reference to the Precambrian-Cambrian boundary. The distribution of stromatolite taxa in time and space across the Precambrian-Cambrian boundary suggests that only Lower Riphean to Lower Cambrian taxa are found in the Lesser Himalaya. The early Precambrian (Pre Riphean or Aphebian) stromatolites are completely absent (Tables 2, 3). Late Precambrian (Riphean) stromatolite taxa are widely distributed in the carbonates of the inner Lesser Himalaya (Table 2). The Terminal Precambrian (Vendian) and the Precambrian-Cambrian boundary stromatolite



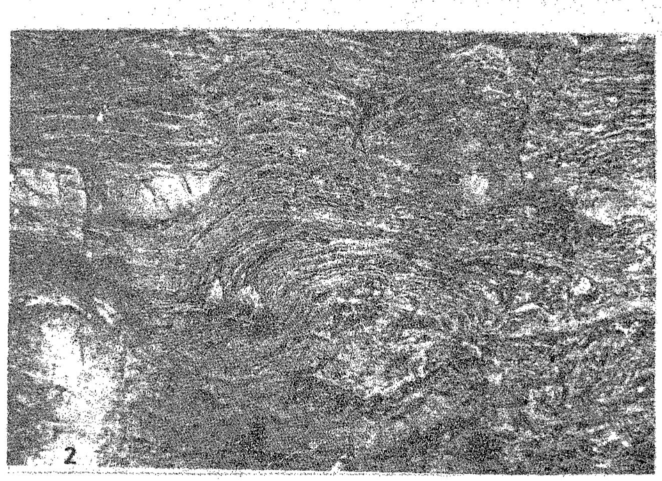


Plate 3

1. Nucleella along with *Stratifera* sp. in the Upper Krol Formation, Near All Saints' College, Nainital.
2. *Irregularia* type stromatolites developed in Upper Krol near All Saints' College, Nainital.

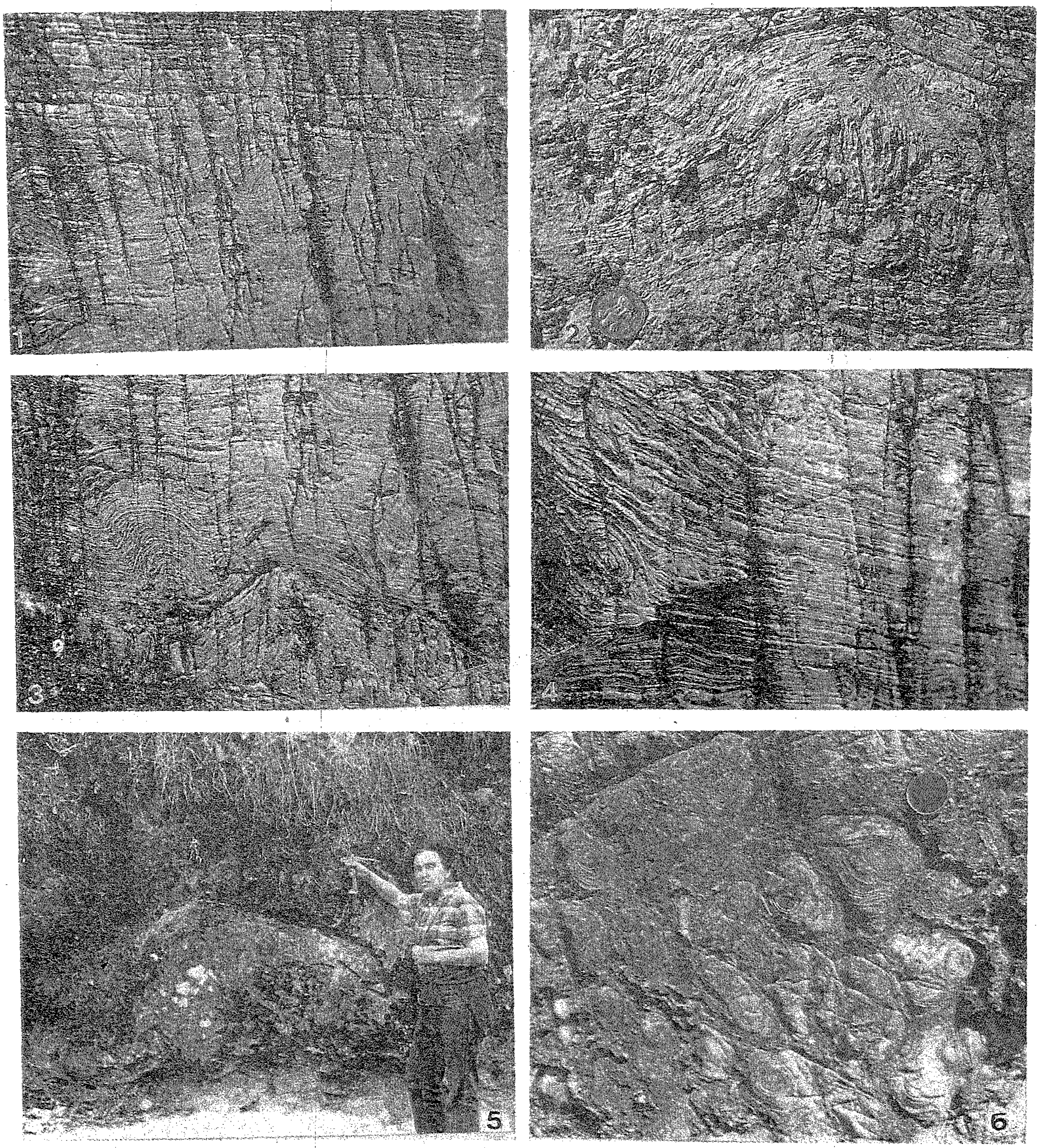


Plate 4

1, 3, 4. *Nucleella, Stratifera* and finely laminated Microbiallamites in Upper Krol Formation developed near All Saints' College, Nainital.

2. Conical and domal type stromatolite from Upper Krol Formation developd near All Saints' College, Nainital.

5. *Paniscollenia* sp. from Upper Krol Formation developed near Sherwood College, Nainital.

6. Transverse section of *Conophyton garganicus*, Gangolihat Dolomite.

taxa are found in the Upper Krol and Lower Tal Formation (Table 2). The Lower Cambrian (Botomian) taxa are restricted to only Tal Formation, which is the youngest stratigraphic lithounit in the revised time stratigraphy of the Lesser Himalaya (Tewari 1984a, b, 1988, 1989, 1991 a, b, c; Table 4).

The Upper Precambrian and Lower Cambrian succession of the Lesser Himalaya has been subdivided on the basis of the stromatolite assemblages and the Precambrian-Cambrian boundary has been established in the Krol-Tal sequence as discussed below (Text-fig. 2; Table 1).

The Lower Riphean (R1) Stromatolite assemblage (Biostrome I) comprises *Kussiella kussiensis* Krylov, *Omachtenia* Nuzhnov, *Omachtenia granensis* Raha, *Platella talwarensis* Raha, *Thyssagetacea* Vlasov and a new group *Rahaella* and form *Rahaella elongata* Tewari in the Great (Jammu) Limestone. This assemblage is also found in the lower part of all the other inner Lesser Himalayan carbonates (Dharamkot, Aut/Larji, Shali, Deoban, Gangolihat, Tejam, Kapkot belt) (Pl. 1).

The middle part (Biostrome II) of these carbonates is characterised by the taxa *Conophyton cylindricus* Maslov, *Conophyton garganicus* Korolyuk, *Conophyton* msp., *Colonnella* msp., *Conusella* msp., and *Conusella regularis* Golovanov. There is a large bioherm of dome shaped and stratified stromatolites just above the Biostrome II and consists of *Gaya* msp., *Paniscollenia* msp., *Gongylina differentiata* Komar, *Stratifera undata* Komar, *Stratifera hearnica* Semikhatov *Plicatina antiqua* Raaben and *Conophyton misrai* Kumar and Tewari. The Middle Riphean (R 2) assemblage includes the stromatolite group *Baicalia nova* Krylov and Shapovalova (Biostrome III) in the lower part and *Paniscollenia* Korolyuk, *Cryptophyton* Raaben and Komar and *Svetliella* Schapovalova, higher in the section in Jammu Limestone (Text-fig. 3). In other lesser Himalayan carbonates this biostrome is recognized by the presence of *Baicalia* msp. in the upper part of the sequence. The phosphatic *Baicalia chandakia* Tewari and Shukla (1988) and *Minjaria uralica* is found in the Gangolihat Dolomite (Tewari, 1989).

The Upper Riphean (R 3) stromatolite taxa *Jurusania* msp., *Jurusania himalayika* and *Parmites concrescens* are found in the Naldera and Kakarhatti carbonate lenses in Simla Group, Himachal Pradesh, which conformably overlies the Middle Riphean (R 2) Upper Shali Limestone. The Upper Riphean assemblage *Tungussia* msp., *Poludia* msp., *Parmites* msp., *Gymnosolen* msp. and *Jurusania* msp. is also present in the isolated carbonate lenses within the Tertiary rocks (Subathus) at Tundapathar and Sataun. The Mandhali Limestone of Jaunsar Group also contains the Upper Riphean taxa? *Jurusania* msp. The pink limestone of Blaini Formation is microbial in nature and only smooth and crenulated microbial laminites have been recorded. The Riphean-Vendian acritarch group *Symplassosphaeridium* Timofeev *and Protosphaeridium* Timofeev is present in the microbial limestone of Blaini Formation and it is interpreted that Riphean-Vendian boundary possibly lies in the Nagthat (Simla) Blaini transition and the Blaini Formation is of Lower Vendian (Varanger) age. This is also supported by the C isotope data from Blaini Formation (Tewari, 1991a). Blaini Formation is put at the base of the Terminal Proterozoic System (TPS) or Neoproterozoic III.

The Lower Krol (Krol A) is essentially a sequence of thinly laminated shales and limestones with wave dominated shallow marine sedimentary structures like wavy bedding, ripple marks, lenticular and flaser bedding and climbing ripple laminations. The impressions of Ediacaran metazoan *Beltanelliformis* sp. and metaphyte (Vendotaenides) *Vendotaenia*, *Vendotaenia antiqua, Krolotaenia* Tewari and *Krolotaenia gnilovskayi* Tewari (Pl. 6, figs 1, 2, 7) have been recently recorded from Korgai, Nigalidhar, Garhwal and Nainital synclines (Tewari, 1988c, 1989, 1991 b, c). Recently some enigmatic *Problematica* has been recorded from Krol B Member from Nainital Syncline (Pl. 6, fig. 8).

The Upper Krol stromatolite assemblage of Mus-

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Plate 5

1. Microstromatolite *(Minicolumella* Raaben) from the Upper Krol (D Member) Formation, Jharipani-Barlow Ganj, Mussoorie Syncline.
2. Microbial oncolites and fenestral (Popcorn) fabric in Upper Krol (D Member), Mussoorie Syncline, x 1.3.
3. Photomicrograph of microstromatolitic microstructure in the Krol Formation, tiny column showing dark and light laminae partly replaced by sparry carbonate. Large quartz grains are found surrounding the microcolumn. Crossed nicol, x 80. (Photo M. Joshi). Mussoorie Syncline.
4. Microstructure of a composite microbial micropopcorn micrite showing an outer layer of fibrous crystals, an fibrous fringe and a central mosaic of crystals. (Photo M. Joshi), Nainital Syncline.
5. Photomicrograph of patchy banded microstructure in *Aldania mussoorica*, Lower Tal Formation, patches of sparry carbonate occur within dark banded phosphatic material (Photo M. Joshi), Mussoorie Syncline.
6. Photomicrograph of banded microstructure in *Conophyton garganicus*, Deoban Formation, showing alternate dark and light laminae made up of sparry carbonate ordinary light, 80. (Photo M. Joshi).

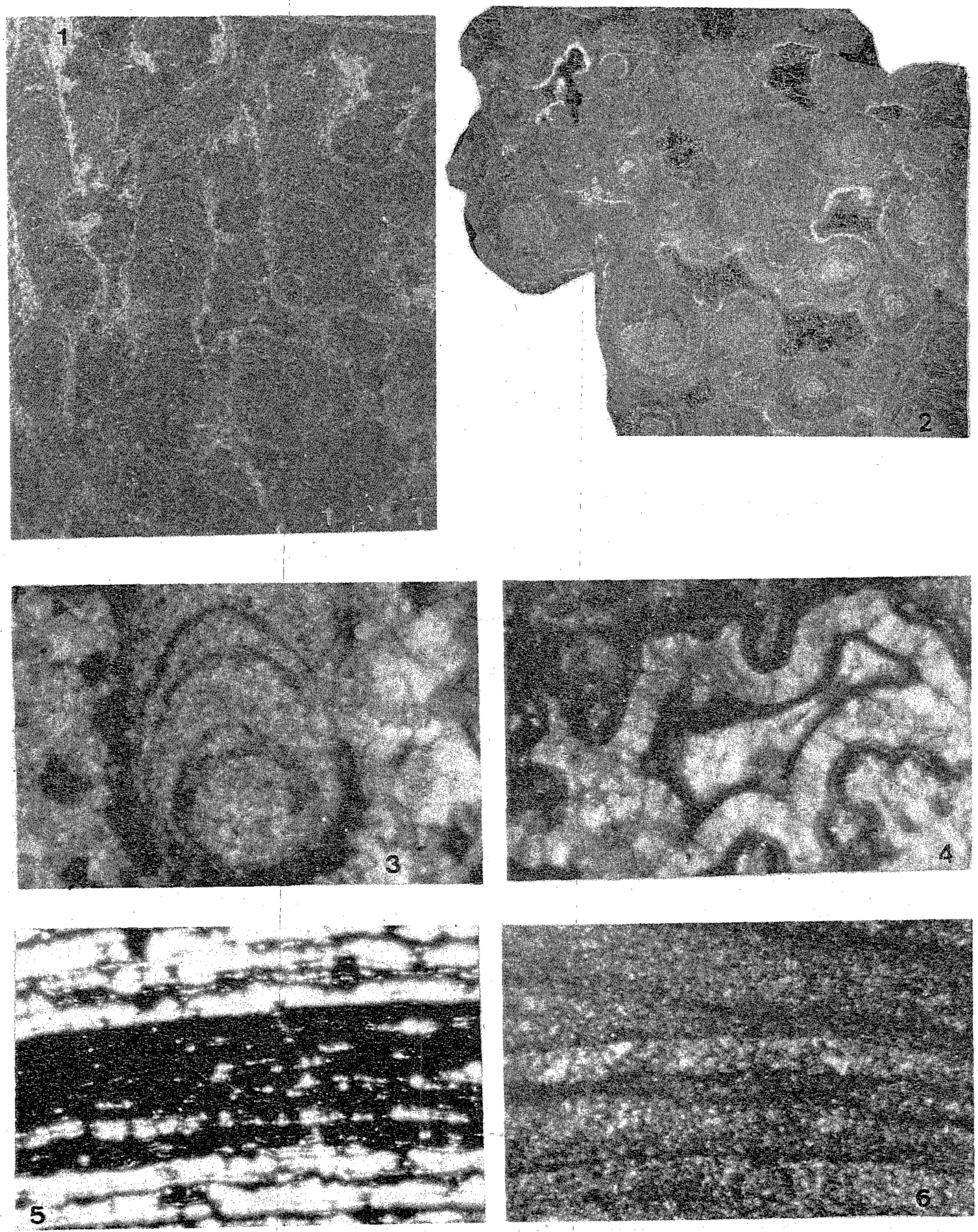

Plate 5

soorie and Nainital synclines include late Vendian taxa *Paniscollenia* Korolyuk, *Stratifera* Korolyuk, *Linocollenia* Korolyuk, *Irregularia* msp. tungussida, Conophyton Maslov, small linked *Conophyton (Yugmaphyton* Tewari), *Aldania* Krylov and the Microstromatolite Group (form genus) *Minicolumella* Raaben from Krol D Member of Mussoorie Syncline (Table 3). The oncolites and calcareous algae *Epiphyton* and *Renalcis* of late Vendian age are also present in the Upper Krol carbonates. The Krol stromatolite taxa and the Vermiform microstructure are very significant for demarcating Precambrian-Cambrian boundary since this asemblage is generally found just near or below the Precambrian-Cambrian boundary (Joshi, 1992; Tewari & Joshi, 1993; Tewari, 1992 b).

The Upper Krol (Krol E) shales, shaly dolomites and siltstones represent the topmost unit of the Krol sedimentary cycle. Recently, Ediacaran fossils *Beltanelliformis, Tirasiana, Charniodiscus, Charnia, Sekwia, Kimberella*, trace fossils, *Gordia* sp., *G. marina, G. meanderi* (Pl. 6, figs 4, 5, 6) and metaphyte *Tyrasotaenia* sp. (Pl.6, fig. 3) have been recorded from the Upper Krol Formation of the Nainital synform (Tewari 1991 c, 1992 a; Tewari, MS; Shankar & Mathur, 1991). The Ediacaran assemblage is being studied in detail.

The Tommotian stromatolite taxa *Collumnaefacta vulgaris* Korolyuk, *Aldania mussoorica* Tewari, *Compactocollenia* Korolyuk, *Boxonia gracilis, Colleniella, Conophyton durmalacus* Tewari, *Stratifera* and *Oncolites* have been recorded from the Chert Phosphorite Member of the Lower Tal Formation (Tewari, 1984a, b, 1988, 1989). This age is also confirmed by the presence of Tommotian shelly micro fauna assemblage in the Chert Phosphorite Member from Maldeota area (Brasier & Singh, 1987). The youngest stromatolitic carbonate beds are found within the Tal (Phulchatti) Quartzite of the Lesser Himalaya (Text-figs 2, 5). The stromatolite taxa recorded are *Collumnaefacta korgaiensis, Ilicta talica and Aldania birpica* (Tewari *et al.*, 1988; Tewari, 1989). They are compared with the Lower Cambrian assemblage from Russia (USSR). The age of the Tal Quartzite is Botomian (Lower Cambrian) on the basis of the recent record of trilobites and brachiopods from Mussoorie and Nigalidhar synclines.

A comparative study of Riphean to Lower Cambrian stromatolite taxa from Siberian platform, USSR and the Lesser Himalaya show remarkable similarity. The Upper Precambrian and Lower Cambrian sequences of Eurasia and Lesser Himalaya and Upper Precambrian successions of Peninsular India are correlatable (Tewari, 1989).

The characteristic forms of the Lower Riphean (I and II Biostromes) present in Jammu Limestone and other carbonates of inner Lesser Himalaya are similar to the Lower Riphean Satka and Baikalian assemblages of the southern Urals, USSR. The Middle Riphean (Biostrome III) of Lesser Himalaya is correlated with the Middle Riphean Avzyan Series of the southern Urals. The Upper Riphean characteristic taxa of stromatolites from Simla Group are similar to the Upper Riphean Karatau Series of the southern Urals (Raaben & Tewari, 1987; Tewari, 1989).

The microbiota assemblage *Oscillatoriopsis, Cyanonema, Siphnophycus, Eomycetopsis, Gunflintia, Anemikia, Glenobotrydion, Globophycus, Sphaerophycus, Myxococcoides, Archaeotrichion, Biocatenoides* and *Kildinella* recorded from the Deoban cherts of Lesser Himalaya are similar to the forms described from Sukhaya Tunguska cherts of Siberian platform (Shukla *et al.*, 1986).

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Plate 6

1. Impression of red brown macroalgae (Vendotaenides/metaphyte) *Krolotaenia gnilovskayi* Tewari from Lower Krol Formation, Korgai Syncline, Himachal Pradesh. (Holotype WIF/A-1301).
2. *Vendotaenia antiqua* Gnilovskaya from the Lower Krol Formation, Nainital-Kilbury road section, Nainital Syncline. (WIF/A-1302).
3. *Tyrasotaenia* sp. (twisted and crumpled ribbons) from Supper Krol Formation, Nainital Syncline. Barapathar-Kaladhungi road section (WIF/A-1303).
4. *Beltanelliformis* (spheroids) from Upper Krol Formation, Nainital Syncline. The spheroids are arranged in circular fashion. Barapathar-Land's End section(WIF/A-1304).
5. Trace fossil *Gordia* sp. from the Upper Krol Formation, Nainital Syncline. Barapathar-Land's End section. (WIF/A-1305)
6. Fronds of ? *Charniodiscus/Charnia* sp. from Upper Krol Formation, Nainital Syncline. Barapathar-Land's End section (WIF/A-1306)
7. Impression of red-brown macroalage *Vendotaenia* sp. from Lower Krol Formation. Korgai Syncline. Himachal Pradesh (WIF/A-1307).
8. Unidentified Cellular and septate *Problematica* from Middle Krol (B-Member) purple shales, Balia Nala, Nainital. (WIF/A-1308).
9. *Beltanelliformis* (spheroids/*Chuaria*)in th Lower Krol Formation of Nigalidhar Syncline, Himachal Pradesh. (WIF/A-1309).

The fossils are kept in the museum of the Wadia Institute of Himalayan Geology, Dehra Dun bearing nos. (WIF/a-1301 to 1309 and WIF/A-1350, 51 & 60).

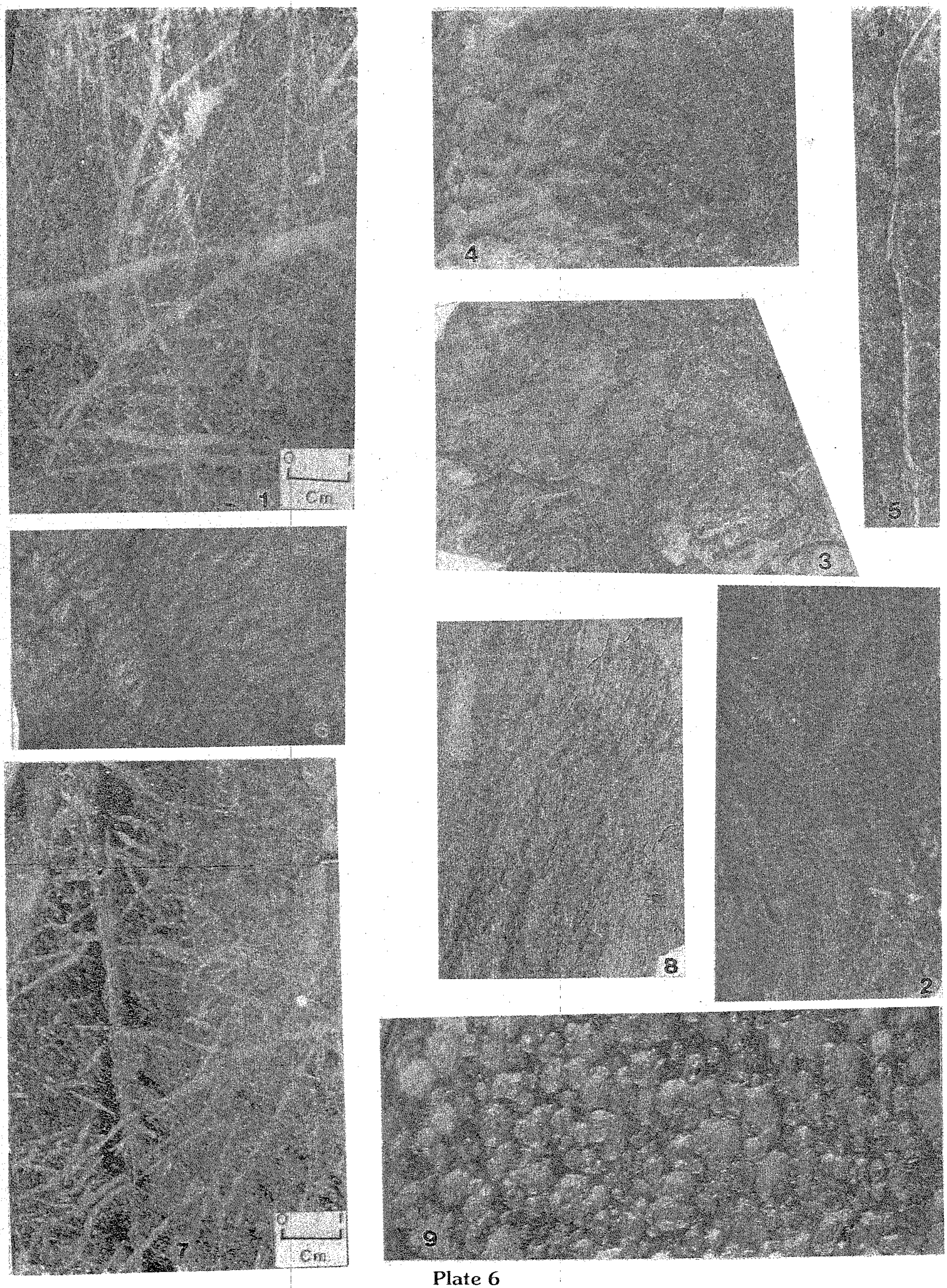

Plate 6

The Blaini Formation (Varangian) is correlated with Lower Vendian (Laplandian) and the Krol Formation (Ediacaran) is equivalent to the Upper Vendian System (Yudoma Complex) of the Siberian Platform. The Upper Krol stromatolite taxa, algae and oncolites are similar to the Kotlinian assemblage and the shelly micro fauna bearing Krol D may be correlated with the Nemakit Daldynian beds which occur below the Precambrian-Cambrian boundary beds characterised by the presence of *Anabarites trisulcatus and Purella antiqua* assemblage. The Tommotian stromatolite taxa recorded from the Chert-Phosphorite Member of the Lower Tal Formation are correlated with the Pestrotsvet Formation (Precambrian-Cambrian Boundary) in the Siberian Platform, USSR.

DECLINE OF STROMATOLITES AND EMERGENCE OF EDIACARAN BIOTA IN THE KROL-TAL SUCCESSION OF LESSER HIMALAYA

The possible link between the decrease in carbonate microbial sedimentation and decline of large subtidal conical and columnar stromatolites *Conophyton, Jacutophyton* and *Baicalia* of Deoban cycle during Late Riphean (Tewari, 1991b) and the first appearance of complex acritarchs in Blaini-Infra Krol (Tewari, 1988, 1989, 1991; Venkatachala *et al.,* 1990) and emergence of Ediacaran biota like impressions of soft bodied metazoans *(Charniodiscus/Charnia),* metaphytes *(Vendotaenia* sp., *Vendotaenia antiqua, Krolotaenia gnilovskayi* Tewari, *Tyrasotaenia),* trace fossils *(Gordia), Beltanelliformis*/spheroids (Pl. 6, figs 1 to 9) from Krol succession (Tewari, 1989, 1991 a, b, c; 1992 a, b and present record) is perhaps related with the evolutionary stages of the metazoa and metaphytes and the earth's early history of evolution of life. Walter and Heys (1985) have discussed this on a global scale. The positive $\delta^{13}C$ signature obtained in the Upper Deoban stromatolitic carbonates is followed by a negative $\delta^{13}C$ shift in Blaini microbial limestone and again a positive $\delta^{13}C$ shift in Upper Krol carbonates (Tewari, 1991 a) suggests that possibly there has been an extinction (decrease of biomass prior to the evolution of the Ediacaran biota (metazoan and metaphytes). The metazoans and metaphytes marks the first appearance of multicelluar soft bodied organisms and macroscopic plants on the earth. The end of Krol stromatolitic carbonate cycle, development of commercial phosphorite, stromatolites and the diversification of small shelly fauna of Tommotian/Meischucunian Zone I (Brasier & Singh, 1987; Bhatt *et al.,* 1983) age in Lower Tal Formation is a global phenomenon at Precambrian-Cambrian boundary (Tewari, 1984 a, 1992 b, 1991 b). The negative $\delta^{13}C$ values of Lower Tal carbonates indicate a negative shift in isotopic signature which is consistent with the global data available from Morocco, Siberia, Iran and China (Tewari, 1991a and the references therein).

The Ediacaran/Krolian Period (Terminal Proterozoic System) is recently recognized in the Krol Belt of the Lesser Himalaya based on the Pre-Ediacaran and Ediacaran biota (Tewari, 1991c, 1992c; Table 4). The Ediacaran System is represented by Infra Krol and Krol formations which is overlying the Blaini Formation (Varanger) and underlying the Lower Tal Formation (Tommotian).

The tentative position of Precambrian-Cambrian boundary in the Upper Krol-Lower Tal succession of the Mussoorie Syncline has already been established by various workers in recent years (Tandon *et al.,* 1988; Brasier & Singh, 1987; Bhatt *et. al.,* 1983; Tewari, 1984a, b, 1987, 1989, 1991, 1992 b). However, the precise demarcation of the Precambrian-Cambrian boundary is still a matter of dispute and the criteria and selection of strato type section both are subjected to change as per recommendations of the IGCP/IUGS working group and subcommissions on Precambrian-Cambrian boundary, Terminal Proterozoic system and Cambrian stratigraphy, It has been ratified in the 29th I.G.C. held in Kyoto, Japan (1992) that the strato type for the PC-C boundary at southeastern Newfoundland in Canada should be considered the global strato type based on the trace fossil assemblage *Phycodes pedum.*

However, stromatolites have also been found very useful in delineation of Precambrian-Cambrian (Vendian-Tommotian) boundary in Siberian platform, USSR (Korolyuk, 1966; Krylov, 1967; Krylov *et al.,* 1981). Walter (1972) and Schmidt (1983) have also attempted such studies in Australia and Africa respectively on the basis of stromatolites.

Recently, Tewari (1984 a, b, 1988, 1989, 1991 a, b, c, 1992 a, b) used the stromatolites for demarcation of Precambrian-Cambrian boundary in the Krol-Tal succession of the Lesser Himalaya in Mussoorie Syncline. The change in stromatolite microstructures can also be used to some extent (Joshi, 1992; Tewari & Joshi, 1993).

The currently internationally focussed Asian Precambrian-Cambrian boundary sections of China, Iran and Pakistan and the most highly potential and best developed south Asian (Krol-Tal) sequence of the Indian subcontinent needs further international attention as G.S.S.P. for Neoproterozoic stratigraphy and seems to be of vital significance for intercontinental correlation and building the regional Asian palaeobiogeography during Late Precambrian and Early Cambrian times.

The earlier proposed Precambrian-Cambrian boundary strato type in the Meishucunian Stage (between zone I and Zone II) of China is very significant for Sino-Indian correlation. The Lower (Zone I) of Meishucunian Stage is recognized by ACP shelly fauna zone (*Anabarites-Circotheca-Protohertzina)* and these elements are commonly found in Siberian, Russian and Mongolian sections and correlated with *Aldanocyathus sunnaginicus* Zone of Tommotian Stage (Rozanov, 1984). The Chert Phosphorite Member of Lower Tal Formation from Maldeota area also contains same ACP shelly fauna assemblage (Brasier & Singh, 1987; Bhatt *et al.*, 1983) and may be correlated with Zone I Meisuchucunian Stage of China and Tommotian Stage of USSR. M.D. Brasier (personal discussion) also supports the correlation of Lower Tal shelly fauna with Lower Tommotian and Zone I of Meishucunian Stage and agree with the author's idea that Chert-Phosphorite Member is of Tommotian/Meischucunian Zone I age (Tewari, 1984b, 1989, 1991a, b, c, 1992 a, b,). If this correlation is valid and accepted then the Tommotian shelly fauna recorded from the Krol D Member of Mussoorie Syncline may be included in the Late Vendian. In Siberian platform also the shelly fauna *Anabarites trisulcatus Zone* and *Purella antiqua* Zone which is found in Nemakit Daldyn (Yudomian) beds below the *Aldanocyathus sunnaginicus* Zone (base of the Pestrosvet Formation, Tommotian) is included in the uppermost stage of Vendian (Khomentovskii *et al.*, 1986). This also supports the author's view on the basis of the occurrence of stromatolites and isotopic studies that the Krol D Member is of Late Vendian (Ediacaran/Yudomian) age and Chert Phosphorite Member is of Tommotian age. This is further supported by the recent records of Ediacaran biota from the Upper Krol Formation (Tewari, 1989, 1991a, b, c, 1992a, b; Shankar & Mathur, 1991).

However, keeping in view the recent decision of the working group on the PC-C boundary, the precise delineation of Precambrian-Cambrian boundary in Krol-Tal succession further needs to be studied in detail in the light of Ediacaran biota, shelly fauna, microbial reefs, carbon isotopic variations and trace fossils.

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