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STROMATOLITES AND INDIAN BIOSTRATIGRAPHY : A REVIEW

S. KUMAR

DEPARTMENT OF GEOLOGY, LUCKNOW UNIVERSITY, LUCKNOW-226007.

ABSTRACT

The occurrences of stromatolites from both Peninsular and Extrapeninsular India are reviewed in the light of their biostratigraphic usefulness. It is concluded that there is enough scope to test the utility of stromatolites in correlation as these are abundantly recorded in the Precambrian sequences of the different sedimentary basins. However, presently not much can be said about these stromatolites as most of them are inadequately described. This creates problem in comparison. It is suggested that first the stromatolites should be described following a standard technique and evolution in the morphology of stromatolites be established in each sedimentary basin. Only after this, attempts can be made to use the stromatolites in intrabasinal and interbasinal correlation.

INTRODUCTION

In the absence of well defined and undisputed megafossils, the stromatolites, though defined as organo-sedimentary structures, have been used by geologists for correlation of pre-Phanerozoic successions in the different parts of the world. It has been said that certain groups of columnar stromatolites show definite time controlled morphological changes when traced from older to younger horizons (Cloud and Semikhatov, 1969 ; Raaben, 1969). Originally this concept was developed by the Russian workers and subsequently applied in the different parts of the world (Keller et al., 1960 ; Krylov, 1963, 1967 ; Cloud and Semikhatov, 1969 ; Valdiya, 1969a ; Kumar, 1976, a, b, 1978 ; Raha, 1978). It is surprising that a concept of time controlled evolutionary changes in the stromatolite morphology, so widely and confidently utilised for intracontinental and even intercontinental correlation, is still very vaguely understood and is definitely not well defined.

The discovery of Recent analogues of stromatolites by Black (1933) from the Andros Island, Bahamas, added a significant factor in the study of stromatolites, particularly on their utility in the biostratigraphic correlation and reconstruction of the environment of deposition. The Recent stromatolites were subsequently discovered from many other areas of carbonate sedimentation like the Florida Bay, Persian Gulf, Shark Bay, Great Salt Lake, Baja California etc. Even *Conophyton*, a form considered to be characteristic of the pre-Phanerozoic, was recorded from the hot springs of the Yellowstone National Park, U.S.A. (Walter et al., 1972, 1976). Fresh water stromatolites have also been recorded (Monty, 1972). The study of Recent stromatolites has definitely given a better understanding and a clearer insight in the stromatolite morphogenesis. It has now been conclusively proved that the stromatolite morphology is influenced both by the environment of deposition and the assemblage of stromatolite building micro-organisms. However, the same assemblage of micro-organisms can give rise to varied morphologies under the influence of varied physical parameters (Logan et al., 1964 ; Monty, 1972).

As the data from the study of both Recent and ancient stromatolites accumulated it became apparent that there are two significant disparities between the observed facts about Recent and Precambrian stromatolites. The first is that the pre-Phanerozoic stromatolites are more abundant and complex than the Recent stromatolites (Monty, 1972), and the second is that the pre-Phanerozoic stromatolites show time controlled evolutionary trends in the form morphology while the study of Recent stromatolite shows quite convincingly that the stromatolite morphology is influenced by the physical factors. Latter finding attacks the very basis for correlation of the Precambrian sequences based solely on the stromatolite morphology, and consequently much skeptecism is now being expressed on such correlations. Preiss (1977) has noted that the stromatolites of the different continents do not precisely match on the form level (i.e., on the species level) and suggested much caution in attempting such correlation. Besides, the Riphean stromatolites have also been discovered in the pre-Riphean sequences (Hofmann, 1978).

As mentioned earlier the pre-Phanerozoic stromatolites are more abundant and complex in form morphology than the Recent stromatolites and naturally this requires an explanation. It has been contended that during pre-Phanerozoic time in the absence of advanced life the micro-organisms dominated by the blue green algae colonized all the available habitat unhindered and unchallanged. Since the beginning of life approximately 3.5 billion years till the beginning of the Cambrian this situation continued unabatedly for more than 3 billion years. This situation changed only in the Cambrian when more advanced life dominated the scene and the micro-organisms particularly those which were stroma-

tolite builders had to compete with other organisms for both space and nutrients. Since the beginning of Cambrian due to competitive weakness, the blue green algae, which is the most dominant community of the stromatolite building micro-organisms, must have been driven to settle in habitates where their competitors were not able to servive (see Monty, 1972).

The blue green algae show absolute conservatism (Schopf, 1977) but it is quite logical to infer that during the span of about 3 billion years since the beginning of life, i.e., from 3.5 billion years to the base of the Cambrian, most of the important evolutionary changes must have taken place as much advanced life is seen during the Cambrian. This advanced life could not have been possible had the evolutionary trends not taken place in the microbiota. Based on this logic, recently, biostratigraphic usefulness of the Precambrian microbiota has also been attempted (Schopf, 1977). If these evolutionary changes have actually taken place in the microbiota i.e., in the stromatolite builders through geological time particularly during the Precambrian, this change is expected to manifest itself in at least some of the observable features of the stromatolite morphology (Preiss, 1977). This aspect has not yet been conclusively proved.

Thus, the knowledge about stromatolites is still incomplete and inadequate particularly concerning the time controlled evolutionary changes in the stromatolite vis-a-vis its usefulness in biostratigraphy. In the present paper an attempt has been made to review all the known occurrences of stromatolites in India in the light of their usefulness in biostratigraphic correlation.

STROMATOLITES IN INDIA

Perhaps the pseudo-organic structure, described by Oldham (1883) from the Deoban Limestone of Lesser Himalaya, Chakrata area, is the first record of stromatolitic structure from India. Auden (1933) recorded weathered spheroidal surfaces with concentric rings from the Fawn Limestone (Lower Vindhyan), Son Valley area, U. P. and compared them with *Cryptozoon*. The concentric rings in question have now been identified as transverse section of *Conophyton garganicus* (Kumar, 1976a). Thus, the credit of recording the first definite stromatolitic structure from the Indian subcontinent must be given to Dr. J. B. Auden. Later on Srinivasa Rao (1943, 1944, structures from the Cuddapah Limestone and compared 1949) recorded algal them with *Cryptozoon proliferum*. Mathur et al. (1958) used the word stromatolite for the first time and recorded the occurrence of *Collenia* from the Fawn Limestone of Mirzapur district, U. P.

Prof. R. C. Misra along with his students initiated the systematic work on Indian stromatolites in the Department of Geology, Lucknow University in the early sixties. Since the publication of his first paper jointly with Valdiya in 1961 a large number of workers have recorded and described the occurrences of stromatolites from the different stratigraphic horizons of Indian subcontinent. Unfortunately, none have used a standard technique in describing the stromatolite morphology. More often the approach in describing the morphology is rather casual with the result that most of the forms are inadequately documented. Majority of the workers have not given the three dimensional reconstruction of stromatolite colonies, and the thin section sudy of the microlamination is often not attempted. The photographs and sketches are generally of poor quality and the forms are not well compared with other well established forms. Till now the most quoted paper on Indian stromatolite is by Valdiya (1969a) but even this paper lacks the morphological details which are essential for the correct identification of different stromatolite forms. Furthermore, various systems followed by different workers for naming the stromatolites have also created problems in comparison and identification. Most of the workers used binomial nomenclature for naming the columnar stromatolites while others used classification based on geometrical shape. Even those who followed binomial nomenclature either used group name *Collenia* for all the columnar stromatolites (Misra and Valdiya, 1961, Valdiya, 1969, etc.) or used various group names as suggested by Raaben (1969) and Cloud and Semikhatov (1969) (Kumar, 1976a, Banerjee 1971, Raha 1978 etc.).

Thus, with incomplete data on stromatolite form morphology and use of different systems for naming the stromatolites, it is almost impossible to compare the stromatolite forms described from India with the stroma tolites of the other parts of the world. This prevents ameaningful discussion on biostratigraphic usefulness of Indian stromatolite because the group and form identification of stromatolites is somewhat vague. This proved to be the most important inherent difficulty in dealing with the Indian stromatolites in general and stromatolite biostratigraphy in particular. It is not possible to review the identification of each stromatolite form described from India in this paper as most of the forms need redescription and revision by using a standard technique. Thus, all the identifications of stromatolites have been accepted on their face value.

Nevertheless, in the present paper, an attempt has been made to review the Indian occurrences of stromatolites in the hope that it will help in formulating a more comprehensive project on stromatolites with special reference to their utility in biostratigraphic correlation.

Following the physiographic subdivision of India the stromatolite occurrences in India can be divided in two : (i) Stromatolites of the peninsular India lying in the south of the Indo-Gangetic Alluvium and (ii) Stromatolites of the extrapeninsular India lying in the north

of the Indo-Gangetic Alluvium. The Peninsular India constitutes a shield area, while Extrapeninsular India is a part of the Himalaya.

PENINSULAR REGION

IRON ORE FORMATION

The Iron Ore Formation, occupying vast area in Bihar, M. P. and Orissa, constitutes the most important horizon of the iron ore deposits in India. It is the younger formation of the Iron Ore Group and is represented by phyllites, tuffs, conglomerates, banded hematite quartzites and mafic igneous rocks. It has been considered as early Proterozoic in age on the basis of its similarity with Banded Hematite Quartzites of the other parts of the world.

Two occurrences of the stromatolites have been recorded from the Iron Ore Formation. From the Iron Ore Formation of Bonai area, Orissa, Awasthi (1978) recorded two types of silicified stromatolitic structures and oncolites. These are LLH type and SS type of Logen et al. (1964). The height of the forms is of the order of only few cms. However, in this area these stromatolites have been recorded from the noncalcareous rocks. Silicified stromatolites have also been recorded from the rocks of the Koira Group (Iron Ore Series) of Bihar—Orissa by Murty and Grant (1978). They have mentioned the occurrences of four types of stromatolites. These are the domal, laminar, oncolitic and clavate.

BIJAWAR GROUP

Represented by a varied lithology, the Bijawar Group overlies the rocks of definite Archean age and underlies the Vindhyan rocks (Lower to Upper Riphean). The rocks of the Bijawar Group outcrop quite extensively in M. P. and U. P. The rocks are highly deformed and show effects of low to moderate grade of metamorphisms.

The age of Bijawar Group is a matter of controversy. It has been assigned varying ages from Archean to early Proterozoic. However, on the basis of the presence of banded hematite quartzites, it has been taken as early Proterozoic.

Khan and Das (1968) have recorded structures resembling stromatolitic structures from the cherty quartzites of the lower Bijawar sequence of Chattarpur district, M.P. Krishna Murti (1972) has recorded simple and compound stromatolites and oncolites from Joga area, Hoshangabad, M. P. From the same area Balasundaram and Mahadevan (1972) have described *Collenia undosa*, *Collenia columnaris*, *Collenia symmetrica*, cf. *Collenia buriatica*, *Conophyton cylindricus* and *Conophyton jogensis*. Lakshman et al. (1977) have also recorded the occurrence of *Collenia frequence*, *Collenia columnaris* and oncolites from M. P.

CUDDAPAH SUPERGROUP, DELHI SUPERGROUP AND KALADGI GROUP

Representing deposits of different sedimentary basins, the rocks of the Cuddapah Supergroup, Delhi Supergroup and Kaladgi Group have been considered homotaxial on the basis of lithological similarity and geological setting. All are deposited over the eroded surface of the Archean rocks with a well marked Eparchean unconformity. Thus, these can be considered as pre-Riphean to Lower Riphean in age between ca 1800—1400 m.y.

CUDDAPAH SUPERGROUP

The Cuddapah Supergroup is best developed in Andhra Pradesh having a crescent shaped outline of the sedimentation basin. It covers an area of about 42,000 sq. km. with thickness varying bewteen 3000 m to 4000 m. Rb/Sr dating of lava samples from the lowest group of the Cuddapah Supergroup shows that the age of the base of the Supergroup may be as great as 1700 m.y. (Crawford and Compston, 1973). The lithostratigrpahic subdivision of the Cuddapah Supergroup is given in Table 1.

Table 1. Lithostratigraphic classification of the Cuddapah Supergroup (After King, 1872)

Group	Lithological units
Kistna Group	Srisalam Quartzite
(600 m.)	Kolamnala Shales
	Irlakonda Quartzites
..... Unconformity	
Nallamalai Group	Cumbum Shale
(1000 m)	Bairenkonda Quartzite
..... Unconformity	
Cheyair Group	Tadpatri Shales
(3,300 m)	Pulivendla Quartzites
..... Unconformity	
Papaghni Group	Vempalle Shales and Limestones
(1,400 m)	Gulcheru Quartzites
..... Eparchean Unconformity	
Archean	Gneisses and schists

Srinivas Rao (1943, 1944, 1949) was the first to record algal structures from the Cuddapah Supergroup. He mentioned the close resemblance of algal structures with *Cryptozoon proliferum*. Vaidyanathan (1961) described the stromatolitic structures from the Vampalle and Tadpatri formations. He referred these structures as *Collenia*. Prasad and Verma (1967) have recorded the occurrence of *Collenia rajarkarii* from the white dolomitic and cherty beds forming the upper part of the Vampalle Formation from Singala area. From the Cumbum Formation, a comparatively younger horizon than the Vampalle Formation, Rao and Gururaja (1978) have described *Conophyton cylindricus*.

KALADGI GROUP

Occupying an area of about 75,000 sq. km. in Karnatak State, the rocks of the Kaladgi Group attain a thickness of ca 4,000 m. It has been subdivided into Lower Kaladgis and Upper Kaladgis in which the former consists of alternating sequence of limestone and shales and the latter is made up of quartzites with local conglomerates, breccia, shales, limestones and ironstone bands.

The stromatolitic beds are seen in the upper most division of both the lower and upper formations.

Govinda Rajulu and Gowda (1966, 1968) have recorded the following forms from Lokapur area, Bijapur district: *Collenia* sp., *Collenia symmetrica, Collenia albertensis, Collenia columnaris, Collenia spissa, Collenia undosa, Collenia septentrionalis, Collenia frequence, Collenia compacta, Hydrophycus nimanis, Cryptozoon* sp. *Cryptozoon proliferum, Conophyton cylindricus* and oncolites.

Viswanathiah and Gowda (1970) have recorded *Collenia compacta, Collenia columnaris, Cryptozoon* and *Cryptozoon proliferum* from the upper most division of the Lower Kaladgis, near Alagundi, Bijapur district.

DELHI SUPERGROUP

The rocks of the Delhi Supergroup outcrop around Delhi and Rajasthan. They overlie the Archean rocks, the Aravallis, Gwaliors and Raialos. The Delhi Supergroup is overlain by the Lower Vindhyan rocks. The rocks are highly disturbed and show effects of metamorphism. The stratigraphic succession is given in Table 2. The sedimentation of the Delhi Supergroup started at least 1900 m.y. back (Crawford, 1970).

From the Kushalgarh Limestone formation which is represented by an alternating sequence of limestone, dolomite, cherty and silicified quartzites associated with cupriferous and manganiferous horizons, Verma and Barman (1978) have recorded the occurrence of *Collenia baicalica, Collenia columnaris* and *Jacutophyton*. The stromatolites are generally confined to the dolomites and silicified quartzites. The same assemblage has also been recorded by Negi and Ravindra (1978).

ARAVALLI GROUP

The rocks of the Aravalli Group constitute the Aravalli Range in Rajasthan and M. P. The Aravalli Group overlies the Banded Gneiss Complex (Archean) and is unconformably overlain by the rocks of Delhi Supergroup.

The stratigraphic position of the Aravalli Group has been a matter of much debate. These have been correlated with Dharawars (Archean). According to Crawford (1969) the base of Aravallis cannot be older than 2500—2590 m.y. The Aravallis were intruded by granites with a minimum age of 1900 m.y. Dates on the basal Aravalli conglomerate component (Crawford, 1970) have given the maximum age of 1970 m.y. However, on the basis of the stromatolites which are profusely developed along with the phosphorite, Banerjee (1971) has suggested Middle to Upper Riphean age to the Aravalli Group. Thus, the stromatolites give an anamolous age to the Aravalli Group.

The lithostratigraphic succession of the Aravalli Group is given in Table 3.

Banerjee (1971b) has described five stromatolite forms from the middle part of the Matoon Formation from Udaipur district. These are *Collenia columnaris, Collenia kussiensis, Collenia symmetrica, Baicalia prima* and *Minjaria calceolata*. These stromatolites are associated with phosphorite (Banerjee, 1971a).

Banerjee and Basu (1978) have reported phosphatic stromatolites from the Aravalli rocks of Jhabua area, M. P. They have identified *Conophyton, Colonella, Masloviella columnaris, Baicalia prima, Collenia kussiensis, ?Archeozoon acandise, ?Kussiella, Conophyton* and oncolites. Deb et al. (1978) have recorded stromatolite form resembling *Gruneria biwabikia* from the Aravalli rocks of Rajpura-Dariba area, Rajasthan. These stromatolites are seen in association with pyritic lead-zinc ores.

Table 2. Lithostratigraphic classification of the Delhi Supergroup

Delhi Supergroup	Ajabgarh Group	Hornstone Breccia
	Alwar Group	Kushalgarh Limestone Formation
		..... Unconformity .....
	Raialo Group	

Table 3. Stratigraphic succession at Udaipur (after Banerjee, 1971)

Udaipur Formation	Lithic quartzite, flaggy quartzite, and current bedded orthoquartzite. Sandy phyllite, greywacke, and "wild flysch". Sandy phyllite, calcareous phyllite, biotite schist, and carbon phyllite. Orthoquartzite, brecciated calcareous quartzite, marble, and carbon phyllite. Impure marble, dolomitic limestone with rolled and rewashed fragmental phosphorite with biohermal phosphorite.
Matoon Formation	Sandy phyllite and schist. Orthoquartzite, brecciated quartzite, dolomite, marble, rolled fragmental phosphorite, and biohermal phosphorite. Impure marble, carbon phyllite with small specks of garnet and manganiferous dolomite intruded by post-Aravalli (?) aplite granite.
Dabri Formation	Buff to reddish-brown orthoquartzite with intercalated phyllite and chlorite schist. Metaconglomerate and petromictic arkose. Meta-arkose. Meta-conglomerate and felspathic qurtzite.
.....Local shears.....Faults.....	
Banded Gneissic Complex—Gneisses, granites, mica schists, marble, dolomite and quartzite.	

Recently Burman et al. (1978) have attempted biostratigraphic zonation of the Aravalli Group of Udaipur area, Rajasthan on the basis of the presence of stromatolites. These zones are as follows:

The *Collenia columnaris* Assemblage Zone is the lower most zone characterised by the presence of *Collenia columnaris*, *Collenia multiflabella*, *Cryptozoon proliferum* and *Jurasania*. The stromatolite colonies are biohermal and phosphatic.

The *Collenia baicalica* Assemblage Zone follows the *Collenia columnaris* Zone. It is characterised by *Collenia baicalica*, *Baicalia prima*, *Collenia kussiensis*, *Collenia symmetrica* and *Minjaria calceolata*. The stromatolites are biohermal in nature and are highly phosphatic.

The Oncolite Assemblage Zone is the top most zone and is characterised by the presence of oncolites which are highly phosphatic.

According to Burman et al. (1978) these three zones are well recognisable in the different sections and can be used for the search of new phosphatic horizon within the basin.

VINDHYAN SUPERGROUP

The Vindhyan Supergroup shows a very wide geographical distribution from Bihar to Rajasthan. Covering an area of about 104,000 sq. km. in Central India, it attains a thickness of several thousand metres. The entire thickness of the Vindhyan Supergroup represents a very shallow water deposit (Auden, 1933 ; Singh, 1973, 1976). The rocks are more or less undeformed and unmetamorphosed and represent one of the best preserved sedimentary sequences. Some microfossils and a few megafossils have been described from these rocks but the dispute about their organic or inorganic nature is still alive (See Misra, 1969). On the basis of the general absence of megafossils and profuse development of stromatolites the Vindhyan rocks have been assigned Lower to Upper Riphean age. This is in agreement with the age given for the Vindhyan rocks based on K/Ar dating. Table 4 gives the estimated ages for certain Vindhyan subdivisions.

The Vindhyan Supergroup has been subdivided into two lithostratigraphic groups ; the lower is the Semri Group and upper is the Upper Vindhyan Group. A generalised stratigraphic succession of the Vindhyan rocks is given in Table 5.

There are four carbonate horizons in the Semri Group of Son Valley area and all of them show development of stromatolites.

In the Basal Conglomerate member of the Basal Formation there is a thin limestone horizon from which *Kussiella kussiensis* has been reported (Kumar, 1976a). In this horizon the development of stromatolite is quite poor. The stromatolites show isolated colonies and their size is quite small.

In the upper part of the younger member of the Basal Formation, the Kajrahat Limestone, shows development of columnar stromatolites (Mohan, 1968). These are seen near its contact with the Porcellenite Formation. The following forms have been recorded *Kussiella dalaensis*, *Kussiella kussiensis*, *Conophyton vindhyaensis*, *Collenia symmetrica* and *Colonella kajrahatensis* (Kumar, 1976 a, b).

The Fawn Limestone of the Kheinjua Formation is quite thin horizon in comparison to both the Kajrahat Limestone and Rohtas Limestone (formation). It is only about 30 m. thick and yet the stromatolites are quite profusely developed. Kumar (1976 a, b) has recorded *Conophyton garganicus*, *Collenia columnaris* and

Table 4. Radiometric Ages for some Vindhyan Subdivisions (After Vinogradov & Tugarinov; see Misra, 1969)

Upper Kaimur	Mean age	910±30 million years
Lower Kaimur	,, ,,	940±30 million years
Kheinjua Glauconitic sandstones	,, ,,	1110±60 million years.

Table 5. Lithostratigraphic subdivision of the Vindhyan Supergroup (Modified after Auden, 1933)

VINDHYAN SUPERGROUP	UPPER VINDHYAN GROUP	Bhander Formation	Upper Bhander Sandstone Sirbu Shales Lower Bhander Sandstones Bhander Limestone Gunargarh Shale
		Rewa Formation	Upper Rewa Sandstone Jhiri Shales Lower Rewa Sandstone Panna Shales
		Kaimur Formation	Dhandhraul Quartzite Scarp Sandstone Bijaigarh Shales Upper Quartzite Susanai Breccea Silicified Shales Lower Quartzite
		Unconformity	
	SEMRI GROUP	Rohtas Formation	Limestone and Shales
		Kheinjua Formation	Glauconitic Sandstone Fawn Limestone Olive Shales
		Porcellenite Formation	Porcellenites
		Basal Formation	Kajrahat Limestone Basal Conglomerate
		Unconformity	
		Bijawar Group	Schists and phyllites.

Collenia clappii. The radiometric age for the overlying Glauconitic Sandstone is 1110±60 m.y. (Vinodgradov and Tugarinov, 1964 ; see Misra, 1969).

The youngest the Semri Group, the Rohtas Formation though attains a thickness of about 500 m. but shows poor development of stromatolites. Ill developed columnar stromatolites and oncolites have been recorded from Son Valley area by Kumar (1976b, 1977b).

In the areas other than the Son Valley, the Lower Vindhyans show poor development and often it is not possible to precisely identify the different formations recognised in the Son Valley area. At places, the lower Vindhyans show condensed sequences (Singh and Kumar, 1978).

Raja Rao and Mahajan (1965) have recorded the occurrence of *Collenia frequence*, *Cryptozoon accidentale* and *Conophyton inclinatum* from the Bhagwanpura Limestone which is considered as the Basal member of the Lower Vindhyans. In M. P. coevally formed Tirohan Limestone (=Rohtas Limestone) shows development of *Colonella columnaris*, *Baicalia* and oncolites. (Kumar, 1976a ; 1977). In Chitrakut area, M. P., the stromatolites are associated with phosphorite and glauconite (Kumar, 1978).

The rocks of the Upper Vindhyan Group occupy vast geographical area stretching from U. P. to Rajasthan but the carbonate facies of the Upper Vindhyans are developed only in M. P. and Rajasthan. In the Bhander Formation of Maihar area, M. P. both domal and columnar stromatolites are well seen. In the Bhander Limestone member, *Colonella*, *Tungussia*, *Baicalia*, *Collenia symmetrica*, *Buxonia*, *Stratifera* and oncolites have been described (Kumar, 1976a, Rao et al., 1977).

Overlying the Bhander Limestone, the Sirbu Shale member also shows stromatolites in the calcareous horizon but development is very poor. Kumar (1976a) described oncolites and domal stromatolite *Maiharia*

maiharensis from Maihar area. Rao et al. (1977) have described a stratified stromatolite *Stratifera* and oncolites from Satna area, M. P.

In the Bhander Limestone of Rajasthan, Prasad and Ramaswamy (1978) have recorded *Collenia columnaris* and *Collenia baicalica.*

TRANS ARAVALLI VINDHYAN

The unfossiliferous sedimentary sequence occurring west of the Aravalli mountain chain is referred as the Trans-Aravalli Vindhyans. These cover an area of about 50,000 sq. km. in Rajasthan and have been subdivided into two :

Bilara Group
Jodhpur Group

Khilnani (1968) has mentioned the occurrence of laterally linked hemispheroids (LLH) and vertically stalked hemispheroids (SH) at the top of the Jodhpur limestone of Bilara district.

Hashmi and Ghauri (1972) have recorded two types of stromatolites which they have described as laterally linked hemispheroid (*Collenia*) and vertically stalked hemispheroid (*Cryptozoon*) from the Phalodi limestone of the Bilara Group from the western Rajasthan. These rocks have been considered as equivalent of the Upper Vindhyans. According to Barman (1978a) the stromatolites of the Bilara Group show generally stunted growth in comparison to the stromatolites of the Vindhyans of Central India. He has described the following forms from the Trans-Aravalli Vindhyans ; *Collenia frequence, Collenia pseudo-columnaris, Cryptozoon, Stratifera* and *Weedia.*

KURNOOL SUPERGROUP

The Cuddapah sediment in Andhra Pradesh is unconformably overlain by the rocks of Kurnool Supergroup. The rocks of Kurnool Supergroup are confined in two areas of the Cuddapah Basin, the western part and in the northern part. The rocks attain a thickness of about 400 m. The base of the Kurnool Supergroup is no older than 1090 m.y. and could be younger than 870 m.y. (Crawford and Compston, 1973). The lithostratigraphic subdivision of the Kurnool Supergroup is given in Table 6. Schnitzer (1971) has recorded the occurrence of stromatolites from the Narji Limestone but these have not yet been described.

RAIPUR GROUP

The rocks of the Raipur-Durg-Bilaspur area are considered as homotaxial with the Kurnool Supergroup. The stratigraphic subdivision is given in Table 7.

Banerjee and Jairaman (1978) have mentioned the occurrence of stromatolites from the Raipur area. Schnitzer (1969) has also made reference to the occurrence of stromatolites from the Raipur Formation.

EXTRAPENINSULAR REGION

In the Extrapeninsular region, i.e., in the Himalaya, the stromatolites have been recorded from widely separated regions from Jammu to Assam. All the occurrences are restricted to the sedimentary successions of the Lesser Himalaya and have been discussed here according to their geographical distribution from west to east.

Table 6. Lithostratigraphic subdivision of the Kurnool Supergroup (After King, 1872)

Group	Formation
Kundair	Nandyal Shales
	Koilkuntla Limestone
Paniam	Pinnacled Quartzites
	Plateau Quartzites
Jamalamadugu	Auk Shales
	Narji Limestone
Banganapalli	Banganapalli Sandstone

Table 7. Lithostratigraphic subdivision of the Raipur Group (Datt, 1964)

Raipur Formation (450 m)	Greenish grey and shaly limestone
Khairagarh Formation (Variable)	Current bedded subarkoses
Gunderdehi Formation (180 m)	Splintery calcareous shale, with thin sandstone layers.
Chamuria Formation (300 m)	Thin bedded limestone and shale
Chaderpur Formation (300 m)	Felspathic sandstone, conglomerate and shales.

JAMMU LIMESTONE, SIRBAN LIMESTONE AND RAISI LIMESTONE (JAMMU AND KASHMIR STATE)

In the western extremity of the Himalaya, unfossiliferous limestone and dolomite occurring in the form of chain of inliers within the Tertiary rocks of the Himalayan foot hills extending from Poonch to Raisi in Udhampur district, Jammu and Kahsmir, has variously been referred as Jammu Limestone, Sirban Limestone and Raisi Limestone. These attain a total thickness of ca 2500 m (Raha and Sastri, 1973). In spite of the unfossiliferous nature, these limestones were correlated with Infra-Trias by Medlicott (1876). Wadia (1929) doubtfully considered these limestones to be Permian or Permo-Carboniferous in age. Raha (1978) has suggested Lower to Middle Riphean age for the Jammu Limestone formation.

Gupta and Dixit (1970, 1971) were the first to record the stromatolites from these limestones. Singh and Vimal (1972) recorded the presence of *Collenia columnaris* and *Collenia purii*. Recently Raha (1978) has studied the stromatolites of the Jammu Limestone in great detail and has attempted to establish stromatolite zonation within the Jammu Limestone. Three stromatolite zones have been established. In stratigraphic order these are (i) *Kussiella* Assemblage Zone, (ii) *Colonella-Conophyton* Assemblage Zone and *Baicalia* Assemblage Zone (Table 8).

SHALI FORMATION

The rocks of the Shali Formation occupy large area in Nahan District of Himachal Pradesh. It is represented by an enormous thickness of carbonate rocks with an orthoquartzite association normally overlying the Sundarnagar Formation and the Mandi-Darla Volcanics (Srikantia and Sharma, 1976). The lithostratigraphy of the Shali area is given by West (1939). Later it was modified by Srikantia and Sharma (1969) (Table 9).

Valdiya (1962a) was the first to record stromatolites from this formation. From the Lower Shali Limestone of West (1939), Valdiya (1967, 1969) has recorded *Collenia baicalica.*, *Collenia symmetrica*, *Collenia columnaris* and *Collenia buriatica*. Sinha (1977) has described *Conophyton* from the Ropri and Khatpul members. He has also recorded *Tungussia* and *Newlandia* from Tattapani Member. All these lithostratigraphic members are part of the Lower Shali Limestone of West (1939).

The Upper Shali Limestone of West (1939) shows rather poor development of stromatolites. However, Valdiya (1967, 1969) has identified *Jurasania*, *Collenia symmetrica* and *Collenia columnaris* and Sinha (1977) has recorded *Colonella* and *Conophyton cylindricus* from this horizon.

LARJI FORMATION

The Larji Formation, exposed around Larji town, Himachal Pradesh, is made up of massive dolomites, limestones, quartzites and slates. The rocks occur as tectonic window stretching in the form of N-S trending 20 km. long linear tract. The formation covers an area of about 100 sq. km. and the total thickness attained is about 1200 m. These rocks are weakly metamorphosed and form a part of the Larji-Kulu-Rampur window. These have been correlated with the Shali Formation.

Table 8. Stromatolite zonation of the Jammu Limestone (After Raha, 1978)

Broad Div.	Thickness	Name & Assemblage Zone	Characteristic stromatolites
Dolomite & Ortho-quartzite	200—400 m	Barren of Stromatolites	No stromatalites
Biostrome III	100—200 m	*Baicalia* Assemblage Zone	*Baicablia baicalica* Kryl. *B. prima* Kryl. *Anabaria radian* Kryl., *Masloviella columnaris* Koroljuk.
Dolomites, dolorenites	300—400 m	Mostly barren with occasional domal stromatolites	*Nucleella* fm. Komar.
Biostrome II	50—100 m	*Colonella-Conophyton* Assemblage Zone	*Colonella riasiensis* f. nov. *Conophyton cylindricus* Masl
Massive dolomites & dolorenites.	200—400 m	Mostly barren zone with local development of domal & irregular stormatolites and a band of dark carbonaceous calc-argillite.	*Nucleella* fm. Komar *Irregularia* fm. Korolju
Biostrome I	100—200 m	*Colonella-Kussiella* Assemblage Zone	*Colonella* cf. *discreta* Kom. *C.* of *laminata* Kom., *C. kutraensis* f. nov., *Kussiella kussiensia* Kryl., *K.* fm. indet *Omachenia granesis* f. nov. *Platella talwarensis* f. nov.
Massive cherty dolomite.	100—200 m	Completely barren of stromatolites Base not seen	No stromatolites.

Table 9. Lithostratigraphic classification of the Shali Formation

	West (1939)	Srikantia and Sharma (1969)
MADHAN SLATES	Rusty brown sandy slates, finely joined, and micaceous.	
SHALI FORMATION	Shali Quartzite. Pure white quartzite, sometimes containing chert	8. Bandla Member-Shales, siltstone and quartzitic breccia.
	Upper Shali Limestone—Massive grey dolomitic limestone, with only occasional chert.	7. Parnali Member—Cherty dolomite, grey limestone and white quartzite.
	Shali Slates—A variety of slates and slaty limestone	6. Makrin Member—Grey, green, black and purple shales and slates with thin bedded limestone and quartzite—also sporadic cherty dolomite.
	Lower Shali Limestone—Massive, grey, dolomitic limestone, full of parallel sheets of chert.	5. Tattapani Member—Cherty dolomite, platy limestone and shale.
	Pink calcitic limestone with no chert, banded at the base	4. Sorgharwari Member, Pink and grey limestone with sporadic shale partings.
		3. Khatpul Member—Massive dolomite with a thin red shale horizon at the base.
	Khaira Quartzites—White and purple quartzites	2. Khaira Member—Purple and at places white quartzites.
		1. Ropri Member—Brick red shale and siltstone with an impersistent band of dolomitic and salt bed at places
		Mandi Volcanics—Volcanic flows and intrusive.
		Sundernagar 2. White and purple quartzite with shale.
		1. Shale, slates and phyllites with quartzite bands.

Thone (see Gupta, 1977) has recorded two forms *Collenia symmetrica* and *Collenia columnaris* from this formation.

SIMLA GROUP

The Kakkarhatti Limestone and Naldera Limestone which were previously considered as part of the Shali Formation have now been included in the Simla Group of rocks by Srikantia and Sharma (1976) which occupy vast area in the Simla hills, Himachal Pradesh. The Naldera Limestone has been included in the Basantpur Formation and Kakkarhatti Limestone in the Kunihar Formation. The Lithostratigraphic succession is given in Table 10. These occupy small outlier within the rocks of the Simla Group. These calcareous horizons attain thickness of several hundred metres. The stromatolites reported are *Jurasania himalayaica*, *Jurasania* sp. and *Irregularia* (Sinha, 1977).

TUNDA PATHAR LIMESTONE

A massive unfossiliferous limestone band underlying the Subathus (Eocene) and abutting against the Siwaliks (upper Miocene to Pleistocene) along the Main Boundary Fault, exposed in Haryana State, has been referred as Tunda Pathar Limestone. The age of the Tunda Pathar Limestone has been speculated as Palaeozoic or older by workers (Raina, 1964 ; Sahni and Kumar, 1966 ; Valdiya, 1969). Valdiya (1969) has recorded *Collenia baicalica* and Tewari and Kumar (1977) have described LLH-C and SH-V types of stromatolites of Logan et al. (1964).

These limestones may be homotaxial with the Jammu Limestone.

DEOBAN GROUP

The rocks of the Deoban Group are exposed in the Garhwal Himalaya. These unconformably overlie the rocks of the Simla Slates Rupke (1974) classified the Deoban Group in three lithostratigraphic formation (Table 11). Only lower and upper formations have shown the development of stromatolites. Valdiya (1969) has recorded *Collenia baicalica*, *? Jurasania* and *Collenia* from the upper Deobans. Recently, Kumar and Singh (1979) have also described *Jacutophyton* from the Deoban limestone of the Chakrata area and Srikantia (1978) has mentioned the occurrence of *Tungussia*.

Table 10. Lithostratigraphic classification of the Simla Group (After Srikantia and Sharma, 1976)

Formation	Members	Lithology	Thickness in metres (approximate)
Sanjauli	Upper	Conglomerate, arkosic sandstone, protoquartzite, grey and purple shale	
	Lower	Greywacke sandstone (medium to coarse grained), greywacke siltstone, shale and siltstone alternation, orthoquartzite.	1600
Chhaosa		Shale and siltstone alternation, greywacke, siltstone alternation, orthoquartzite	1300
Kunihar		Shale and siltstone alternation with limestone interbeds (earlier referred to as Kakarhatti limestone).	450
Basantpur	D	Thick bedded to platy greyish blue limestone with interbedded shale (local facies)	180
	C	Massive to bedded limestone-dolomite (local facies)	250
	B	Shale, siltstone with interbeds of lenticular limestone ; Shale is sporadically carbonaceous ; impersistent band of quartzite and dolomite	600
	A	Greyish white quartzite and conglomerate (sporadic).	19
.....		.....Unconformity.....	
Shali Formation, Mandi-Darla volcanics and Sundernagar Formation.			

Table 11. Lithostratigraphic subdivision of the Deoban Group (After Rupke, 1974)

(*c*) Upper Deoban Formation	Thin bedded limestones, shales and minor siltstones/quartzites.
(*b*) Middle Deoban Formation	Slates, ophiolites, quartzites, minor limestones and intra-formational conglomerates.
(*a*) Lower Deoban Formation	Coarse non-bedded limestones, shaly black limestones and brown blackish shales.

LAMERI FORMATION (GARHWAL GROUP)

The Lameri Formation is a part of the Garhwal Group of rocks exposed in the Garhwal region of the Kumaon Himalaya between Central Crystallines and the metamorphic rocks of the Dudatoli Group. The Lameri Formation has been correlated by Mehdi et al., (1972) with the rocks of the Calc Zone of Pithoragarh.

Kumar and Agarwal (1975) have mentioned the occurrence of *Collenia* from the dolomites of the Lameri Formation. Recently Banerjee and Rawat (1978) have described poorly developed form of *Kussiella* from the Lameri Formation of Rudraprayag area.

BLAINI FORMATION

The Blaini Formation is perhaps the most important lithostratigraphic horizon of the sedimenatries of the Kumaon and Himachal Himalaya. It overlies the Simla Slates (Precambrian) and is overlain by the Infra Krol—Krol succession. It is represented mainly by two facies, the boulder bed or tillite and limestones. The Blaini Formation has been correlated with the Talchir Boulder Bed of the Peninsular India which is definitely of Permocarboniferous age. On this basis the age of the Blaini Formation is also taken as Permocarboniferous. However, Singh and Tangri (1976) have recorded well developed columnar stromatolites *Collenia* and *?Conophyton* from the Baliyana River valley section, Himachal Pradesh. They have suggested Precambrian age to the Blaini Formation.

KROL FORMATION

The Krol Formation is an important lithostratigraphic horizon of the Lesser Himalaya. It is represented by dolomites, limestones, shales and marls and attains a thickness of several thousand metres. The rocks of Krol Formation are well exposed in both Inner and Outer Krol belts of Bhargava (1972).

The Krols have been assigned age varying from Precambrian to Jurassic. No mega fossil has yet been recorded from these rocks. Microfossils recorded are mostly acritarchs and pollen and spores whose stratigraphic value is of doubtful nature (Singh and Rai, 1977).

Singh and Rai (1977, 1978) have discovered well preserved stromatolites from the Krols of the Nainital area. They have recorded *Conophyton garganicus*, *Baicalia baicalica*, *Colonella*, algal mats and algal balls and on this basis have suggested Middle Riphean age to the Krol Formation in contrast to much younger age (upper Palaeozoic to Jurassic) suggested by many (see Bhargava, 1979). Recently Kumar (1979) has described six stormatolite forms *Plumia*, *Crossia*, *Nainitalia*, *Krolia*, domal stromatolites and cryptalgalaminites from the same area. He has

assigned Permo-Carboniferous age to this assemblage.

TAL FORMATION

The Tal Formation is the youngest lithologic horizon of the Krol belt of the Lesser Kumaon and Himachal Himalaya. It overlies the Krol Formation and underlies the Subathu Formation (Eocene). It has been assigned varying ages from Permian to Cretaceous (see Bhargava, 1979). Recently Singh (1979) has suggested age varying between Precambrian to Cretaceous. Sharma (1976) has recorded stromatolitic limestone from the lower Tal Formation. He has described stacked cones (most probably *Conophyton*) concentrically stacked spheroides (SS-C) (Oncolites) and close linked hemispheroides (LLH-C) (*Collenia*) from Mussoorie area, Uttar Pradesh.

CALC ZONE OF PITHORAGARH

The unfossiliferous sequence lying between the Crystalline Zone of Almora in the south and the Central Crystallines in the north has been designated as the Zone of Badolisera by Heim and Gansser (1939). Valdiya (1962) has subdivided the rocks of the Zone of Badolisera into two lithostratigraphic groups : the Calc Zone of Pithoragarh and the Berinag Quartzites. Misra and Valdiya (1961), Valdiya (1962, 1964, 1969) and other workers considered the sedimentary Zone of Badolisera as inverted but Heim and Gansser (1939), Gansser (1964), Kumar and Tewari (1978) and a number of other workers considered the sedimentary Zone as normal. Presently the consensus of opinion is in favour of accepting the normal stratigraphic position for the rocks of this zone.

Valdiya (1962b, 1968) subdivided the Calc Zone of Pithoragarh into four lithostratigraphic formations (Table 12). Valdiya (1969) has suggested Middle to Upper Riphean age for the Calc Zone while Kumar (1978) has assigned Lower to Middle Riphean age.

In the Calc Zone of Pithoragarh there are two thick carbonate sequences and both show excellent preservation of stromatolites.

The older carbonate horizon i.e., the Thalkedar Dolomite exposed in the southern part of the Pithoragarh district attains a thickness of about 300 m. It is basically an argillo-calcareous sequence. Misra and Kumar (1968) were the first to discover stromatolite from this formation. *Collenia thalkedarensis*, *Collenia symmetrica* and *Jurasania* have been recorded from the Thalkedar Dolomite (Valdiya, 1969, Misra and Kumar, 1969). Recently Kumar (1978) has doubted the identification of *Collenia symmetrica* and *Jurasania* and suggested that the *Collenia symmetrica* is nothing but the transverse section of *Collenia thalkedarensis* and *?Jurasania* is perhaps a new form which needs redescription. He has suggested Lower Riphean age to the Thalkedar Dolomite.

Kumar and Kumar (1978) have described two stratified stromatolites *Stratifera undata* and *Gongylina differentiata* from Gurna area, Pithoragarh district. The other forms present are *Colonella columnaris* and *Collenia clappii*.

The Gangolihat Dolomite formation, the younger carbonate horizon of the Calc Zone, occupies large area in Pithoragarh and Almora districts. It attains a thickness of more than 600 m. and is well known for its deposits of magnesite and talc. Occurrences of phosphorite has also been recorded from this horizon (Valdiya, 1969b). All these three minerals are found to be associated with stromatolites. Whether, this association is fortuitous or has some genetic relationship, is still to be conclusively proved.

The Gangolihat Dolomite shows good development

Table 12. Lithostratigraphic succession of the Calc Zone of Pithoragarh
(After Valdiya 1968, Modified by Kumar and Kumar 1978)

ZONE OF BADOLISERA	Berinag Quartzites		Orthoquartzites and amphibolites.
	Calc Zone of Pithoragarh	Gangolihat Dolomite	Lower member comprises massive dolomites and dolomitic limestones development of both Columnar and stratified Stromatolites (*Conophyton garaganicus—Baicalia-Colonella* assemblage). It includes the lentiform deposits of magnesite. The upper member consists of tuffaceous purple phyllites and light coloured dolomites.
		Sor Slate	Olive green, brown, grey and black slates with orthoquartzites and subordinate argillaceous dolomitic limestone.
		Thalkedar Dolomite.	Siliceous dolomite, dolomitic limestones and slates, with well developed stratified stromatolites. *Stratifera* and *Gongylina*.
		Rautgara Quartzite.	Brown and greyish pink protoquartzite and purple green and brown slates.
		North Almora Thrust	
	Crystalline Zone of Almora.		Porphyries, schists quartzites and gneisses.

of stromatolites. Misra and Valdiya (1961) were the first to report the stromatolites from this horizon.

They have described three forms of *Collenia* which have been designated as species A, B and C from the Pithoragarh area. Dixit (1966) has reported the occurcnce of stromatolitic forms which have been compared with *Cryptozoon, Collenia columnaris, Collenia undosa* and *Collenia flagelliformis* from the Girichhina area, Kumaon Himalaya. Misra and Kumar (1969) have recorded two forms *Collenia columnaris* and *Collenia nailensis* from the Ganai area where the later is profusely developed. Valdiya (1969) has reported *Collenia baicalica, Collenia columnaris, Collenia kussiensis, Minjaria uralica* and *Collena symmetrica* from the Pithoragarh area. In the Gangolihat Dolomites of the Sarju-Pungar Valley area, Almora District, Banerjee (1970) has described the occurrence of *Collenia columnaris, Collenia baicalica, Collenia frequence, Collenia frequence* var. *dafautensis, Collenia frequence* var. *dwarfous, Collenia frequence* var. *kandaensis, Collenia pseudocolumnaris, Collenia septentrionalis* and *Collenia miniature*. Kumar and Tewari (1977, 1978) have recorded *Conophyton garganicus* and *Conophyton misrai* from the Kathpuria Chhina area. Tewari (1979) has also recorded stratified stromatolites *Stratifera* and *Gongylina* from Kathpuria Chhina area (V. C. Tewari personal communication).

CALC ZONE OF TEJAM

In the northern part of Pithoragarh district, south of the Central Crystallines, the calcareous succession of the Zone of Badolisera has been termed as the Calc Zone of Tejam by Heim and Gansser (1939). The Calc Zone of Tejam has been designated as Kapkot Formation by Bhattacharya (1979). It attains a thickness of several thousand metres.

Bhattacharya (1976) has recorded the occurrence of *Conophyton cylindricus* and oncolites from this horizon.

BUXA GROUP

In the eastern Himalaya from Eastern Nepal to Arunachal Pradesh there is a discontinuous stretch of unfossiliferous orthoquartzite carbonate sequence overlying the Daling Formation which has been designated as Buxa Formation. It attains a huge thickness and is divisible into two formations ; the lower is the Sinchu La Formation and upper is the Jainti Formation (Acharya, 1974). The Sinchu La Formation is made up of quartzite, phyllite and slates, and the Jaintia Formation consists of dolomites, quartzites and slates. The dolomites show profuse development of stromatolites. These stromatolites have not been studied in detail but they appear to belong to *Colonella* and *Baicalia* types (Srikantia, 1978). Acharya (1974) has also recorded the presence of stratiform, nodular and columnar types from Buxa dolomites.

The Buxa Group has been correlated with Deoban-Shali, etc. by Valdiya (1969).

MATUKA FORMATION

From the Matuka Formation of southern Tuensang district, Nagaland, which has been assigned Eocene age, Adiga and Singh (1978) have recorded LLH type stromatolitic structure.

DISCUSSION AND CONCLUSION

1. The study of stromatolites in India is still in the developing stage. Though the first reference of stromatolitic structure was made as early as 1933 by Auden, only 4 papers in the form of short notes were published till 1960. Between 1960 till to date i.e., in about 19 years more than 130 papers were published and most of the significant discoveries were made only in the last 10 years.

2. The stromatolites have not yet been recorded from the Archean rocks of India but it does not prove their absence. Presently the oldest record of stromatolites from India is from the Iron Ore Formation of Singhbhum area which has been assigned about 2400—2200 m.y. i.e., Early Proterozic. From this formation one report is of LLH and SS types of siliceous stromatolites from Bonai area, Orissa. The size of these stromatolites is quite small, only of the order of a few cms in height. A significant point associated with these stromatolites is the total absence of calcareous nature of the associated rocks. This absence of calcareous rocks thus casts some doubts on the organic nature of the structures. The other record is from the Koira Group, Bihar-Orissa, from which four types of stromatolites have been recorded. Two of these stromatolites are also associated with dolomites. No age implication has been attached to them.

3. The stromatolites have been reported from the Bijawar Group, Cuddapah Supergroup, Delhi Group and Kaladgi Group of Peninsular India. All these lithostratigraphic units are considered as Middle to Late Proterozoic in age. Only 4 and 3 morphological forms have been reported from the Cuddapah Group and Delhi Group respectively, 9 forms from the Bijawar Group and 14 forms from the Kaladgi Group (Table 13). Even though the number of stromatolite forms present in any stratigraphic horizon should not be taken as any indication of the state of evolution in the stromatolite morphology, neverthless it is quite logical to expect more varied forms in the younger horizons of the Precambrian sequences. With this logic the number of forms present may also give an idea of the state of evolution in the stromatolite morphology. Since the Kaladgi Group shows the maximum number of forms in comparison to Delhi Group, Cuddapah Supergroup and Bijawar Group it can be taken to be the youngest amongst them.

4. The stratigraphic position of Aravalli Group is debatable. Generally the Aravallis are considered as Pre-Vindhyan in age i.e., older than 1400 m.y., as these overlie the Banded Gneiss Complex of Archean age and underlie the rocks of the Delhi Group. This has been confirmed by the radiometric age data also. However, on the basis of the presence of *Baicalia* and *Minjaria calceolata* Banerjee (1971) has suggested Middle to Upper Riphean age to the Matoon Formation. The forms which have been recorded so far from the Aravalli rocks indicate a much varied assemblage of stromatolites. This points to a relatively younger age. Thus, for the Aravallis the stromatolites give a rather anomalous results. A more detailed study is needed to clarify this point.

5. The Vindhyan rocks (including the Trans Aravalli Vindhyan) show best preserved stromatolites. These are abundantly recorded in both space and time. At least 20 different forms have been recognised. This is the maximum number of stromatolite forms which have recorded from any group so far. It appears that Lower to Upper Riphean age given to the Vindhyan rocks on the basis of the study of columnar stromatolites by Valdiya (1969) and Kumar (1976a, 1978) is quite justified as it is also supported by the radiometric age data given by Vinogradov and Tugarinov (see Misra, 1969). They have given mean ages for the Kheinjua Formation and the Kaimur Formation as 1110 ± 60 and 925 ± 30 m.y. respectively.

6. Nothing can be said about the stromatolites of the Kurnool and Raipur groups as no details are available about their stromatolite assemblages. However, it appears that the study of these stromatolites will be quite interesting and rewarding.

7. In the Extra-peninsular region, the Lesser Himalayan unfossiliferous sequences are tectonically deformed due to which it is often difficult to establish the lithostratigraphy and structure of the region. Misra and Valdiya (1961) for the first time attempted to use convexity of stromatolite laminae to establish the lithostratigraphy in the Lesser Himalayan region. These unfossiliferous sequences in the Lesser Himalaya occupy more than a thousand kilometre stretch from Jammu to Arunachal Pradesh and attain thickness of several thousand metres. However, the stromatolites are less commonly reported from these rocks either due to their poor development in the rocks or they have not yet been searched and recorded as in the Himalaya the exposures are less easily accessible.

In general all the carbonate sequences of the Lesser Himalaya which have yielded stromatolites are considered as late Precambrian. These are the Calc Zones of Pithoragarh and Tejam, Deoban Limestone, Shali Formation, Kakkarhatti and Naldera limestones (Simla Group), Tunda Pathar Limestone, Jammu Limestone, Lameri Formation (Garhwal Group) and Buxa Group (Table 14). In this regards, the position of the Blaini, Krol, and Tal Formations is, however, somewhat debatable. The Krol Formation has been assigned age either Precambrian, upper Palaeozoic or Mesozoic. The Mesozoic age is mainly given because of the fact that it overlies the Blaini Formation. And the Blaini Formation has been correlated with the Talchir Boulder Bed of the Peninsular India which is definitely of Permo-Carboniferous age. However, the Blaini sediments have failed to yield definite Permo-Carboniferous fossil assemblage. On the other hand Singh and Tangri (1976) have argued in favour of the Precambrian age to the Blaini Formation on the basis of the presence of stromatolites. Recently Singh (1979) has also suggested Precambrian age to the Blaini —Infrakrol, Krol—Tal succession.

The Krol Formation has not yielded any undisputable megafossil assemblage. The microfossils and pollen and spores which have been recovered from the rocks of the Krol Formation have not given any conclusive age.

The discovery of *Baicalia-Conophyton* assemblage from the Krol Formation by Singh and Rai (1978) from the Nainital area is quite significant. On this basis they have suggested Precambrian age and have correlated it with the Gangolihat Dolomite formation. Kumar (1979) has erected four new form genera of essentially ill developed algal mats and not of the typical columnar stromatolites from the Krol Limestone of the Nainital area, U. P. He considers them to be typical of the Late Palaeozoic age. However, as they are new forms and there is not enough definite palaeontological evidence for the Late Palaeozoic age for the sediments, the age implication attached by Kumar (1979) to these forms is unwarranted. Only the availability of radiometric data will solve this controversy.

The discovery of stromatolites (*Conophyton* and *Collenia*) from the Tal Formation is also quite significant. It is likely that some part of the Tal Formation may be Precambrian in age.

Nothing can be said about the stromatolites of the Matuka Formation.

8. It is concluded that there is enough scope in India to test the utility of stromatolites in correlation as these organosedimentary structures are abundantly recorded from the different litho-stratigraphic formations in both the Peninsular and Extra-peninsular regions. Most of the workers who have recorded stromatolites have used different techniques and styles for describing the stromatolite morphology which creates problems in comparison of forms. Due to this reason the correlation on the basis of these poorly described stromatolite forms becomes vague and unreliable, though it does show some promise in many cases. Unless all the forms are

Table 13. Distri

IRON ORE FORMATION	BIJAWAR GROUP	CUDDAPAH SUPERGROUP	KALADGI GROUP	DELHI SUPERGROUP
LLH and SS type silicified stromatolites. Laminar, domal clavate and oncolitic stromatolites	*Collenia undosa* *Collenia columnaris* *Collenia symmetrica* cf *Collenia buriatica* *Conophyton cyclindricus* *Conophyton jogensis* *Collenia columnaris* *Collenia frequence* and oncolites.	*Cryptozoon proliferum* *Collenia* *Collenia rajarkarii* *Conophyton cylindricus*	*Collenia* sp. *Collenia symmetrica* *Collenia albertensis* *Collenia columnaris* *Collenia spissa* *Collenia undosa* *Collenia septentrionalis* *Collenia frequence* *Collenia compacta* *Hydrophycus mimanis* *Cryptozoon* sp. *Cryptozoon proliferum* *Conophyton cylindricus* and oncolites.	*Collenia baicalica* *Collenia* *Jacutophytone*

Table 14. Distributi

JAMMU LIMESTONE (SIRBAN LIMESTONE, RAISI LIMESTONE)	SHALI FORMATION	LARJI FORMATION	SIMLA GROUP (KAKKARHATTI LIMESTONE, NALDERA LIMESTONE)	TUNDA PATHAR LIMESTONE	DEOB GRO
Baicalia baicalica *Baicalia prima* *Anabaria radian* *Masloviella columnaris* *Nucleella* *Colonella riasiensis* *Conophyton cylindricus* *Nucleella riasiensis* *Irregularia* *Colonella discreta* *Colonella laminata* *Colonella kutraensis* *Kussiella kussiensis* *Omachenia granensis* *Platella talwarensis* *Collenia purii.*	*Collenia baicalica* *Collenia symmetrica* *Conophyton cylindricus* *Tungussia* *Colonella* *Jurasania* *Collenia buriatica* *Newlandia.* *Collenia columnaris*	*Collenia symmetrica* *Collenia columnaris*	*Jurasania himalayaica* *Jurasania* sp. *Irregularia*	*Collenia baicalica* LLH-C and SH-V type stromatolites.	*Collenia ba* *Jurasania* *Collenia* *Jacutophyt* *Tungussia.*

bution of stromatolites in the Peninsular India

	ARAVALLI GROUP	VINDHYAN SUPERGROUP	TRANS ARAVALLI VINDHYAN	
	Collenia multiflabella	*Accidentaleol*	*Collenia*	(
	Collenia columnaris	*Cryptozoon*	*Collenia frequence*	
	Collenia kussiensis	*Stratifera*	*Collenia pseudocolumnaris*	]
	Collenia symmetrica	*Collenia columnaris*	*Cryptozoon*	
	Baicalia prima	*Collenia frequence*	*Stratifera*	
	Minjaria calceolata	*Maiharia maiharensis*	*Weedia*	
	Colonella	*Conophyton inclinatam*		
	Conophyton	*Buxonia*		
	Masloivella columnaris	*Baicalia baicalica*		
	Baicalia prima	*Tungussia*		
	Kussienlla kussiensis	*Collenia clappii*		
	Archeozoon acandise	*Collenia symmetrica*		
	Cryptozoon proliferum	*Conophyton garganicus*		
	Jurasania.	*Colonella kajrahatensis*		
	Gruneria biwakikia	*Conophyton vindhyaensis*		
		Kussiella dalaensis		
		Kussiella kussiensis		
		Colonella lodhwarensis and oncolites.		

on of stromatolites in the Extrapeninsular India

AN UP	GARHWAL GROUP (LAMERI FORMATION)	BLAINI FORMATION	KROL FORMATION	TAL FORMATION
icalica	*Kussiella*	*Collenia*	*Colenella*	Concentrically
		?Conophyton	*Baicalia baicalica*	stacked spheroides
			Conophyton garganicus	(SS-C) (oncolites)
n			*Nainitalia*	Close linked hemi-
			Plumia	spheroids
			Crossia ..	(LLH-C) (*Collenia*)
			Krolia ..	Stacked cones
			Domal stromatolites	(*?Conophyton*).
			Cryptalgalaminites	
			Algal balls	

KURNOOL SUPERGROUP	RAIPUR GROUP
Occurrence of stromatolites recorded. Forms not mentioned.	Occurrence of stromatolites recorded. Forms not mentioned.

CALC ZONE OF PITHORAGARH	CALC ZONE OF TEJAM	BUXA GROUP	MATUKA FORMATION
Collenia nailensis *Collenia baicalica* *Collenia columnaris* *Collenia kussiensis* *Minjaria uralica* *Collenia symmetrica* *Conophyton garganicus* *Conophyton misrai* *Collenia clappii* *Collenia thalkedarensis* *Collenia frequenee* *Collenia frequence* var. *kandaensis* *Collenia frequence* var. *defautensis* *Collenia frequence* var. *clwarfous* *Collenia pseudo-columnaris* *Collenia s ptentronalis* *Collenia miniature* *?Jurasania* *Stratifera undata* *Gongylina differentiata.*	*Conophyton cylindricus* and oncolites.	*Colonella* and *Baicalia* type stromatolites.	LLH type stromatolite structure

adequately described by using a standard technique it is useless to attempt intraregional and interregional correlation on the basis of stromatolites. Thus, presently not much can be said about the Indian stromatolites as the data is still insufficient for objective evaluation and meaningful discussion.

9. It is suggested that first the evolution in the morphology of stromatolites be established in each sedimentary basin and only then their utility in intrabasinal correlation should be, attempted. In case it works out, as it appears to be attempt can be made to use it for interbasinal and inter continental correlation.

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