PRESENT STATUS OF STROMATOLITE BIOSTRATIGRAPHY IN INDIA

S. KUMAR

Department of Geology, Lucknow University, Lucknow-226 007

ABSTRACT

The stromatolite assemblages from both Peninsular India as well as the Himalaya are reviewed in the light of their biostratigraphic usefulness. These assemblages are divided into three groups : (i) Stromatolites of the pre-Riphean sequences, (ii) Stromatolites of the Riphean sequences and (iii) Stromatolites of the Vendian-Lower Cambrian Krol-Tal succession of Lesser Himalaya. The Krol-Tal succession was assigned ages varying from Precambrian to Cretaceous. But, recently the Vendian stromatolites and Archaeocyatha have been recorded from the Krol Formation and Protoconodonts, Cambrian stromatolite and trilobites have been discovered from the Tal Formation. Precambrian-Cambrian boundary has been suggested near the contact of the Krol and Tal Formations. Stromatolites belonging to the pre-Riphean sequences have been reported only from the Peninsular India from the Delhi Supergroup, Bijawar, Aravalli and Iron Ore Groups. Riphean stromatolites have been described in Peninsular India from the Cuddapah, Delhi, Kurnool and Vindhyan Supergroups and the Kaladgi and Raipur Groups. From the Himalaya, the Riphean forms have been described from the Jammu Formation, the Simla, Deoban, Garhwal and Buxa Groups, the Shali and Larji Formations, the Tunda Patthar Limestone and the Calc Zones of Pithoragarh and Tejam. Stromatolite morphologies support a Vendian age to the Krol Formation and early Cambrian age to the Tal Formation.

In some sedimentary sequences, like the Vindhyan Supergroup, the Jammu Limestone (Formation), the Aravalli Group and the Calc Zone of Pithoragarh, the stromatolite assemblages are non-repetitive when traced from older to younger horizons and thus support their use in interbasinal correlation. At the same time the stromatolite assemblages of the Calc Zone of Pithoragarh, the Vindhyan Supergroup, the Jammu Limestone and the Buxa Group correspond well with the Riphean stromatolites of U.S.S.R. and help in interbasinal correlation. Nevertheless, the Riphean-type stromatolites have also been reported from the pre-Riphean sequences like the Aravalli and Bijawar Groups and the Delhi Supergroup and as such these stromatolites need restudy with precise identification to clarify this point. However, in all the reported occurrences of stromatolites both in the Peninsular India as well as in Himalaya, the stromatolites always belong to Precambrian sequences except inthe Tal Formation where the upper age limit may be early Cambrian.

INTRODUCTION

Stromatolites have been reported from the rocks which are generally devoid of definite megafossils both in the Peninsular as well as Himalayan regions of India. In the absence of any other data except the lithological similarity, there has been a strong tendency to use stromatolite assemblages in biostratigraphic correlation in India as the use of these assemblages has been found to be quite successful in different parts of the world (see PREISS, 1976). On the other hand, an understanding of the morphogenesis of the Recent stromatolites has raised questions about such correlations as it has been demonstrated that the stromatolites are environmental sensitive (LOGAN, 1961; LOGAN *et al.* 1964; MONTY, 1972). Yet, many of the morphologies used in biostratigraphy have no modern analog (AWRAMIK, 1977). Stromatolites, characteristic of the Riphean, have been reported from pre-Riphean sequences (HOFMANN, 1977). In the light of the above findings the present paper reviews the occurrences of Indian stromatolites with special reference to their usefulness in biostratigraphic correlation.

Geophytology, **14**(1) : 96—110, 1984.

The study of stromatolites in India is still in a developing stage. There has been a large number of reports on stromatolites from different parts of India but in most of these reports no standard methodology has been followed in describing the stromatolite forms (KUMAR, 1980). Three-dimensional reconstructions of most of the forms are still desirable for more precise taxonomic descriptions and assignments. In spite of these handicaps in dealing with stromatolite data, it is felt that published data should be objectively evaluated to know and understand the role of stromatolites in Precambrian biostratigraphy of India.

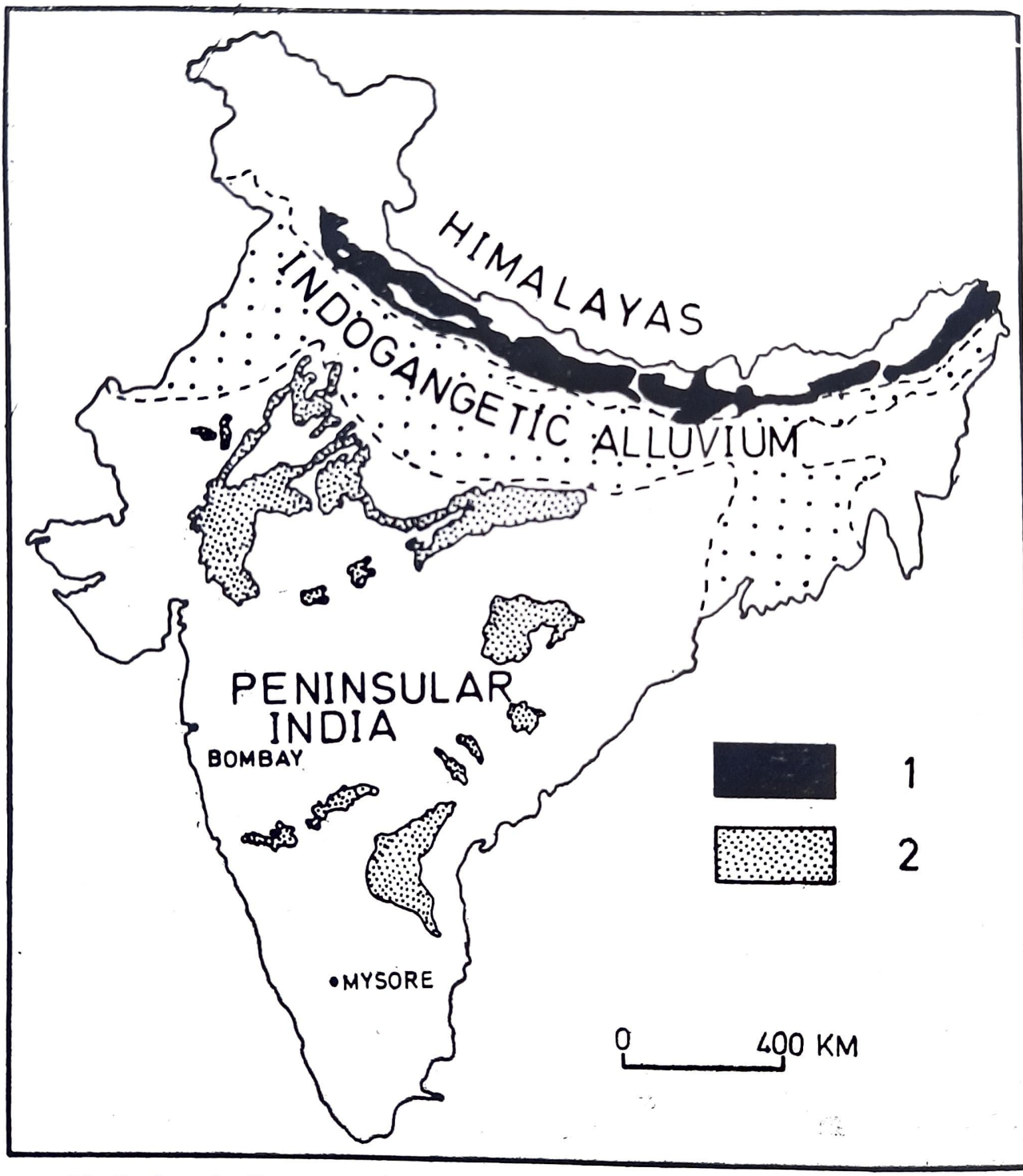


Fig. 1. Distribution of sedimentary rocks in India. 1. Precambrian sedimentary rocks in the Himalaya including the Blaini-Krol-Tal succession. 2. Precambrian sedimentary rocks in Peninsular India (Modified after Krishnan, 1960 and Gansser, 1964).

DISTRIBUTION OF STROMATOLITES

Indian stromatolite occurrences can be subdivided into two areas (Fig. 1):

I. Stromatolites of the Peninsular India
II. Stromatolites of the Himalaya

STROMATOLITES OF THE PENINSULAR INDIA

The generalised stratigraphy for the Precambrian rocks of Peninsular India is given in table 1. The stromatolite assemblages are discussed in ascending stratigraphic order.

Table 1. Generalised stratigraphic scheme for Peninsular India

Riphean	1700-700 Ma	Vindhyan Supergroup, Raipur Group Kurnool Supergroup, Kaladgi Group Cuddapah Supergroup, Aravalli Group (?)
Pre-Riphean	2000-1700 Ma	Delhi Supergroup
	2600-2000 Ma	Bijawar Group, Aravalli Group (?) Iron Ore Group
Archean	2600 Ma	Archean rocks

Iron Ore Group

The Iron Ore Group (the Iron Ore Series) is extensively developed in Orissa and Bihar and attains a thickness of thousands of meters. No definite and reliable radiometric data is available but generally it is considered as early Proterozoic in age. GRANT *et al.* (1980) have reported domal and laminated stromatolites and oncolites. AWASTHI (1980) also recorded *Collenia* but photograph looks more like an inorganic botryoidal chert as no carbonate is associated with these rocks. No age implication can be assigned to the stromatolites.

Aravalli Group

The Aravalli Group, well exposed in Rajasthan and Madhya Pradesh, is represented by various rock types of low metamorphic grade. It overlies the Banded Gneiss Complex (ca 2550 Ma) and is unconformably overlain by the Delhi Supergroup. The Aravalli has been radiometrically dated as 2500—2000 Ma (Rb-Sr dating) (see CRAWFORD, 1969, 1970 for discussion on the data).

The Aravalli Group has yielded the following stromatolites from the Udaipur and Jhabua regions of Rajasthan: *Gollenia columnaris, Collenia kussiensis, Collenia symmetrica, Conophyton, Baicalia prima, Minjaria calceolata, Archeozoon acadise* and oncolites (BANERJEE, 1971a, b; BANERJEE & BASU, 1978). DEB *et al.* (1978) have also recorded a form resembling *Gruneria biwabika*. BARMAN *et al.* (1978) recognised three biostratigraphic zones with in the Aravalli Group and content that these zones are traceable in the different areas across the region. In stratigraphic order these zones are: (i) The *Collenia columnaris* Assemblage Zone with *Collenia multiflabella, Cryptozoon proliferum* and *Jurusania,* (ii) The *Collenia baicalia* Assemblage Zone with *Baicalia prima,*

Collenia kussiensis, *Collenia symmetrica* and *Minjaria calceolata* and (iii) The Oncolite Assemblage Zone with only oncolites.

Based on the occurrence of *Minjaria calceolata* and *Baicalia prima* Banerjee (1971b) suggested a middle to late Riphean age for the Aravalli Group but the radiometric data and the stratigraphic position support a much older age. As the Aravalli underlies the Delhi Supergroup (ca 1900 Ma) it must be early Proterozoic in age. CHAUHAN (1980) has also supported pre-Riphean age.

Bijawar Group

The Bijawar Group is extensively developed in Madhya Pradesh and Uttar Pradesh. It overlies the Bundelkhand Granites (ca 2550 Ma) and uncoformably underlies the Vindhyan Supergroup. A variety of rocks are found in the Bijawar Group which show effects of low to moderate grade metamorphism. SARKAR (1972) suggested an age younger than 2500 Ma for this Group on the basis of available Sr-Rb, K-Ar and Pb isotopic data, and geotectonic considerations.

In Madhya Pradesh quite a varied stromatolite assemblage has been recorded which includes *Collenia columnaris*, *Collenia frequence*, *Collenia undosa*, *Gollenia symmetrica*, cf *Collenia buriatica*, *Conophyton cylindricus* and oncolites (BALASUNDARAM & MAHADEVAN, 1972; LAKHMANNAN *et al.*, 1977). The Bijawars are considered as pre-Riphean (SARKAR, 1972) but the stromatolite assemblage suggests Pre-Riphean to Riphean age.

Delhi Supergroup

Rocks of the Delhi Supergroup crop out around Delhi and in Rajasthan. They overlie Archean and Aravalli (early Proterozoic) rocks and are overlain by the Lower Vindhyans. The base of the Delhi Supergroup is considered to be 1900 Ma old (Rb/Sr ratio ; CRAWFORD, 1970).

VERMA AND BARMAN (1980) have reported the occurrence of *Baicalia baicalica*, *Collenia columnaris* and *Jacutophyton* from the upper part of the Delhi Supergroup. This assemblage of stromatolites suggests a middle Riphean age, but as the Delhi Supergroup is overlain by the Lower Vindhyans with a confident early to middle Riphean age, the stromatolite assemblage must be older than the early Riphean, i. e. pre-Riphean.

Cuddapah Supergroup

Rocks of the Cuddapah Supergroup are developed in Andhra Pradesh and form a crescent shaped basin. The Cuddapah Supergroup covers an area of about 42000 km^2 and attains a thickness of about 3000-4000 m. The Rb/Sr dating of the lava at the base of the Supergroup yielded 1700 Ma (CRAWFORD & COMPSTON, 1973). However, SARKAR (1972) suggested commencement of sedimentation in the Cuddapah basin at about 1500 Ma.

The Cuddapah rocks show poor development of stromatolites, From the lower part VAIDYANATHAN (1961) refers to *Collenia* structures with PRASAD AND VERMA (1967) describing *Collenia rajurkarii*. GURURAJA (in RAHA & SASTRY, 1982) has also recorded *Conophyton*, *Kussiella* and *Colonnella*. From the upper part RAO AND GURURAJA (1980) have described *Conophyton cylindricus* but their published photographs are not very clear. MEHDI *et al.* (1980) also recorded stromatolites from

the Upper Cuddapah rocks but they have not given names to individual forms. These have been described as laterally linked hemispheroids and vertically stalked hemispheroids. However, no photographs have been published by them.

Based on meagre published data it is not possible to use stromatolite with any degree of confidence for age determination of the Cuddapah Supergroup.

Kaladgi Group

The Kaladgi Group crops out in an area of ca 75000 km^2 in Karnatak State and attains a thickness of ca 4000 m. It has been correlated with the Cuddapah Supergroup and the Semri Group (the Lower Vindhyans) (SARKAR, 1972).

In all, 14 stromatolite forms have so far been described from the Kaladgi Group, including *Collenia* sp., *Collenia symmetrica, Collenia albertensis, Collenia columnari, Collenia spissa, Collenia undosa, Collenia septentrionalis, Collenia frequence, Collenia compacta, Hydrophycus mimanis, Cryptozoon proliferum, Conophyton cylindricus* and oncolites (GOVINDA RAJULU & GOWDA, 1966, 1968; VISHWANATHAN & GOWDA, 1970). RAHA AND SASTRY (1982) mention the occurrence of *Colonnella—Kussiella* assemblage in this Group.

The stromatolite assemblages of this Group are quite varied and rich and point to Riphean age.

Vindhyan Supergroup

The Vindhyan Supergroup occupies an extensive area of nearly 104,000 km^2 and shows a wide geographic distribution in Central India from Bihar to Rajasthan. It attains a maximum thickness of ca 4000 m. The Vindhyan Supergroup has been divided into two well recognised lithostratigraphic groups : the Semri Group (Lower Vindhyans) and the Upper Vindhyan Group. The upper part of the Semri Group (the Kheinjua Formation) has been radiometrically dated (K/Ar ratio) as 1100 $\pm$ 60 Ma and the lower part of the Upper Vindhyan Group (the Kaimur Formation) has been placed at 925 $\pm$ 30 Ma (VINOGRADOV & TUGARINOV, 1964). The commencement of Vindhyan sedimentation has been taken to be at ca 1400 Ma (SARKAR, 1972).

The Vindhyan rocks show best preserved stromatolites. The Semri Group (Lower Vindhyans) has yielded *Kussiella kussiensis, Kussiella dalaensis, Collenia clappii, Collenia symmetrica, Colonnella kajrahatensis, Colonnella columnaris, Conophtyton garganicus, Conophyton inclinatum, Conophyton vindhyaensis, Gollenia frequence, Cryptozoon accidentale, Collenia lodhwarensis, ?Baicalia* and oncolites (RAJA RAO & MAHAJAN, 1965; MOHAN, 1968; VALDIYA, 1969; KUMAR, 1976a, b, 1977, 1978a, b). KUMAR (1981) has recognised two stromatolite assemblages within the Semri Group; the older is the *Kussiella—Colonnella* Assemblage of early Riphean age and the younger is the *Conophyton garganicus-Colonnella* Assemblage of middle Riphean age.

In the Bhander Formation, the uppermost formation of the Upper Vindhyan Group, *Colonnella, Tungussia, Baicalia baicalica, Collenia symmetrica, Boxonia, Stratifera, Maiharia maiharensis*—and oncolites have been recorded (VALDIYA, 1969; KUMAR 1976a; RAO *et al.* 1977; PRASAD & RAMASWAMY, 1978). KUMAR (1981) has designated this assemblage as *Baicalia-Tungussia* Assemblage and has assigned it a late Riphean age. The Vindhyan stromatolites more or less conform to the stromatolite subdivision of the Riphean of USSR.

Kurnool Supergroup

The Kurnool Supergroup unconformably overlies the Cuddapah Supergroup in Andhra Pradesh attaining a thickness of about 400 m. The base of the Kurnool Supergroup is ca 1090 Ma (Rb/Sr ratio) and could be younger than 870 Ma (CRAWFORD & COMPSTON, 1973).

Stromatolites are known from the Kurnool Supergroup since 1971 (SCHNITZER, 1971) but no morphological details are available.

Raipur Group

The unfossiliferous thick sedimentary sequence of the Raipur Group occupies a large area in Raipur-Durg-Bilaspur region of Madhya Pradesh. DATT (1964) correlated it with the Kurnool Supergroup. K/Ar radiometric dates of the glauconites from the base of the Group give ca 750-700 Ma and on this basis it may be correlatable to the Upper Vindhyans (KREUZER *et al.* 1977).

JAIRAMAN AND BANERJEE (1980) have reported the occurrence of *Gymnosolen* sp., *Inzeria* sp., *Baicalia* sp., *Tungussia* and *Cryptozoon occidentales* from Raipur area. However, they have not deduced any conclusion about the age or correlation. These forms represent more or less middle to late Riphean age and thus the Raipur Group can be correlated with the Vindhyan and Kurnool rocks. However, K/Ar data (750-700 Ma) gives younger age but this data is based on only two samples and thus cannot be taken as very reliable.

STROMATOLITES OF THE HIMALAYA

In the Himalaya, stromatolites occur in different tectonic zones from Jammu-Kashmir in the northwest to Assam in the northeast but are restricted only in the Lesser Himalayan Zone. RAHA AND SASTRY (1982) have attempted to correlate the different Lesser Himalayan Carbonates on the basis of stromatolite assemblages. Table 2 represents a generalised stratigraphic grouping.

Table 2. Generalised stratigraphic scheme for the Lesser Himalaya

Eocene	Subathu Formation
Cretaceous	Nilkanth Formation
Permian	Boulder Slate Sequence
Lower Cambrian	Tal Formation
Vendian	Krol Formation
Riphean	Infra Krols Blaini Formation Jammu Limestone, Shali Formation, Larji Formation, Simla Group, Deoban Group, Calc Zones of Pithoragarh and Tejam, Garhwal Group, Tunda Patthar Limestone and Buxa Group
Early Proterozoic	Crystalline Zones of Almora and Dudatoli, etc.
Archean	Central Crystallines

Except for the Blaini-Krol-Tal succession in Himachal and Kumaon Himalaya, there is a general agreement on the late Proterozoic age for all the sedimentary sequences containing stromatolites. Traditionally the Blaini-Krol-Tal succession has been assigned a Permo-Carboniferous to Cretaceous age but there are several contridictions in various age interpretations for the same stratigraphic horizons (see (BHARGAVA, 1979). Recently this age has been questioned by SINGH (1978, 1980a, b) who suggests a Precambrian age for most of the succession except for the topmost horizon of the Tal Formation which has yielded foraminifers and bryozoa of Cretaceous age. SINGH (1978) has designated this fossil-bearing horizon which has an unconformable contact with the underlying rocks, the Nilkanth Formation. The entire Blaini-Krol-Tal succession is several thousand meters thick and does not contain any shelly megafossil. A number of microfossils reported from this sequence (see BHARGAVA, 1978) are doubted by SINGH (1978, 1980, a, b). The age controvercy centres on the interpretation that the Blaini Formation is of glacial origin and is correlatable with the Permo-Carboniferous Talchir Boulder Bed of Peninsular India (PASCOE, 1959). However, the Blaini Formation is devoid of any megafossil and a number of workers have interpreted that it is of nonglacial in origin (RUPKE, 1968; VALDIYA, 1970; NIYOGI, & BHATTACHARYA, 1971, TANGRI & SINGH, 1982). Thus these two formations should not be correlated.

M. E. Raaben (in SINGH, 1983) has commented on the Krol stromatolites as belonging to uppermost Precambrian i.e., Vendian. Recent discovery of Archaeocyatha from Krol E of Mussoorie area by SINGH AND RAI (1984) undisputedly indicates the upper age limit of the Krol Formation is near the Precambrian-Cambrian boundary. AZMI *et al.* (1981) have recorded several early conodonts/protoconodonts genera of the family Circothecidae belonging to Tommotian age from the Lower Tal Formation. BHATT *et al.* (1983) have also recorded an assemblage of shelly microfossils of Tommotian age from the Tal Formation which is comparable to the trilobite lacking basal Cambrian fauna of Russia, China, Poland, Sweden, Norway and Australia. Recently RAI AND SINGH (1983), and SINGH AND RAI (1983) have discovered trilobites with primitive morphological characters and abundant trace fossils from the Tal Formation which indicate early Cambrian age to the Tal Formation. Thus, the Blaini-Krol succession appears to be Precambrian and the Precambrian-Cambrian boundary lies somewhere near the contact of the Krol and Tal Formations.

Jammu Limestone (Formation)

Extending from Poonch to Raisi in Jammu and Kashmir, the inliers of unfossiliferous limestone and dolomite within the Tertiary rocks have been referred to as the Jammu Limestone, the Sirban Limestone and the Raisi Limestone. It has been radiometrically dated (Pb isotope ratio) as 967 Ma old (RAHA *et al.*, 1978).

RAHA (1978) has recognised three stromatolite assemblage zones within the Jammu Limestone: (i) The *Colonnella -Kussiella kussiensis* Assemblage Zone with *Colonnella* cf. *laminata, Colonnella katraensis, Kussiella kussiensis, Omachenia granensis* and *Platella talwarensis,* (ii) The *Colonnella-Conophyton* Assemblage Zone with *Colonnella riasiensis* and *Conophyton cylindricus,* and (iii) The *Baicalia* Assemblage Zone with *Baicalia baicalica, Baicalia prima, Anabaria radialis* and *Muslovella columnaris.*

Other stromatolites recognised from this formation are *Nucleella irregularia* and *Collenia purrii* (SINGH & VIMAL, 1972; RAHA, 1980a). On the basis of the dis-

tinctive stromatolites the Jammu Limestone has been assigned early to middle Riphean age (RAHA, 1980a).

Shali Formation

The Shali Formation is an orthoquartzite-carbonate association attaining a thickness of several thousand meters in Nahan and Mandi districts of Himachal Pradesh. It constitutes an elongated linear belt of low grade metasediments and unconformably overlies both the Sunder Nagar Formation and the Mandi-Darla volcanics.

Two carbonate sequence in the Shali Formation contain stromatolites. From the Lower Shali Limestone (cf. WEST, 1939) *Collenia baicalica, Collenia symmetrica, Collenia columnaris, Collenia buriatica, Conophyton, Tungussia* and *Newlandia* have been reported (VALDIYA, 1967, 1969; SINHA, 1977). From the Upper Shali Limestone (cf. WEST, 1939), *Jurusania, Collenia symmetrica, Collenia columnaris* and *Conophyton* have been recorded (VALDIYA, 1969; SINHA, 1977). An early to middle Riphean age has been suggested for the Shali Formation on the basis of these assemblages of stromatolites (VALDIYA, 1969; SINHA, 1977).

Larji Formation

Occurring as north-south trending linear tectonic windows in the central part of the Himachal Pradesh, the Larji Formation is represented by about a 1200 m thick weakly metamorphosed dolomite, limestone, sandstone and shale. It has been correlated with the Shali Formation (GUPTA, 1977).

Two forms *Collenia symmetrica* and *Collenia columnaris* have been reported by THONE (see GUPTA, 1977) from this formation. No age implication can be deduced from this assemblage.

Simla Group

The Simla Group occupies a large area in Simla Hills in Himachal Pradesh and has recently been re-defined by SRIKANTIA AND SHARMA (1976) to include the Kakkarhatti Limestone and Naldera Limestone. It is represented by a varied lithology and attains a thickness of ca 4500 m.

From the calcareous horizons, SINHA (1977) has described *Jurusania* sp., *Jurusania himalayika* and *Irregularia* with an assigned middle to late Riphean age.

Tunda Patthar Limestone

Underlying the Subathu Formation of Eocene age and abutting against the Siwaliks (Upper Miocene to Pleistocene) along the Main Boundary Fault in Haryana State, a unfossiliferous carbonate sequence called the Tunda Patthar Limestone is found. It contains *Collenia baicalica* and hence has been assigned middle Riphean age (VALDIYA, 1969).

Deoban Group

In the Garhwal Himalaya, the unfossiliferous carbonate rocks overlying the Simla Slates are called the Deoban Group. The lower and upper part of this group show the development of stromatolite which have been identified as *Collenia baicalica, Jurusania, Collenia* sp. and *Jacutophyton*, and have been assigned middle Riphean age

(Valdiya, 1969; Kumar & Singh, 1979). Sinha and Raaben (1979) have recorded *Ilicta deobonica* and have suggested uppermost Precambrian or Vendian to early Cambrian age to the upper part of the Deoban Group. There is no other evidence to suggest the early Cambrian age and moreover on the basis of a new form age cannot be proposed. Recently, Raha and Sastry (1982) have recorded the occurrence of *Colonnella elongatus, C.* cf. *discreta, Kussiella kussiensis, Omachtenia, Jurusania major* and *Gymnosolen* and have suggested early to late Riphean age.

Calc Zones of Pithoragarh and Tejam

The Calc Zones of Pithoragarh and Tejam represent a thick unfossiliferous sedimentary succession lying between the Crystalline Zone of Almora and the Central Crystallines in the Kumaon Himalaya, Uttar Pradesh.

Stromatolites are developed in the lower and the upper calcareous sequences of the Calc Zone of Pithoragarh. The lower, the Thalkedar Dolomite, is characterised by *Collenia thalkedarensis, Jurusania, Collenia clappii, Colonnella columnaris, Stratifera undata, Gongylina differenticta* (Misra & Kumar, 1968, 1969; Valdiya, 1969; Kumar, 1978b; Kumar & Kumar, 1978). The Gangolihat Dolomite, the youngest horizon of the Calc Zone of Pithoragarh, shows relatively a good development of stromatolites compared to the Thalkedar Dolomite, and has yielded the following forms: *Cryptozoon, Collenia columnaris, Collenia undosa, Collenia nailensis, Collenia frequence, Collenia symmetrica, Plicatina antiqua, Collenia flagelliformis, Collenia baicalica, Collenia pseudocolumnaris, Collenia septentrionalis, Collenia mineature, Conophyton garganicus, Conophyton misrai, Stratifera, Gongylina, Gaya, Nucleela* and *Omachtenia* (Dixit, 1966; Misra & Kumar, 1969; Valdiya 1969; Banerjee, 1970; Kumar & Tewari, 1977, 1978; Kumar, 1980; Tewari, 1983a). Recently Tewari (1983b) has identified four stromatolite assemblages within the Gangolihat Dolomite.

The Calc Zone of Tejam, being the northern extension of the Calc Zone of Pithoragarh, has yielded only *Conophyton cylidricus* and oncolites (Bhattacharya, 1976).

On the basis of the stromatolite assemblages the Calc Zone of Pithoragarh has been assigned an early to late Riphean age (Valdiya, 1969; Kumar, 1978b).

Garhwal Group

In Garhwal Himalaya, the large area between the Central Crystallines and the metamorphic rocks of the Dudatoli Group is occupied by the Garhwal Group which is northwestern extension of the Calc Zone of Pithoragarh. Two forms *Collenia* sp. and *Kussiella* have been reported from these rocks (Kumar & Agarwal, 1975; Banerjee & Rawat, 1980). This group is correlatable with the Calc Zone of Pithoragarh and therefore may be assigned an early to late Riphean age.

Buxa Group

The Buxa Group constitutes a several thousand meters thick orthoquartzite-carbonate succession in the eastern Himalaya which overlies the Daling Formation. Recently Raha (1980b) has identified three distinct stromatolite assemblages from these rocks. In stratigraphic order these are (i) the *Kussiella-Colonnella* Assemblage, (ii) the *Colonnella-Conophyton* Assemblage and (iii) the *Baicalia baicalica* Assemblage with *Tungussia* and *Columnocolla*.

An early to late Riphean age has been suggested for the Buxa Group (RAHA, 1980b).

Blaini-Krol-Tal Succession

The Blaini-Krol-Tal succession occupies a linear track in the southern part of the Kumaon and Himachal Himalaya. It overlies the Simla Slates (Late Precambrian) and is overlain by the Subathu Formation (Eocene), Nilkanth Formation (Cretaceous).

The Blaini Formation is represented by boulder bed (tillites), limestone and shale. Two forms *Collenia* sp. and *Conophyton* have been recorded by SINGH AND TANGRI (1976). Traditionally the Blaini Formation is considered as Permo-Carboniferous (see BHARGAVA, 1979) but SINGH (1978) has suggested a Precambrian age. The absence of shelly megafossils, presence of stromatolites and stratigraphic position suggest a Precambrian age.

The Krol Formation is represented by dolomite, limestone, shale and marl and attains a thickness of several thousand meters. SINGH AND RAI (1977, 1978) described *Conophyton garganicus, Colonnella* and ? *Baicalia* from this formation and on this basis have suggested a middle Riphean age. A. KUMAR (1981) has also recorded the presence of stromatolites from the Krol Formation and have mentioned four different forms. However, these forms are poorly developed stromatolites and appear to be the part of the stratiform stromatolites (algal mat facies). VALDIYA (1980a) has recorded a lone brachiopod? *Linoproductus* sp. from the Upper Krol sediments of Nainital, Uttar Pradesh, but the sample in question was not collected by him and the fossilliferous horizon to which the sample is supposed to belong could not be located and traced in the field. No other shelly fossil has been recovered from this area. Recently, without giving any specific reason VALDIYA (1980b) AND A. KUMAR (1981) have questioned the identification of *Conophyton garganicus* reported by SINGH AND RAI (1977) and have insisted that the age of the Krols is Palaeozoic. However, RAABEN (1983; in SINGH, 1983) has confirmed the identification of *Conophyton* but opined that it is a new form. She has suggested that the age of the Krol stromatolites is latest Precambrian i. e., Vendian. From Mussoorie hills *Conophyton, Irregularia, Stratifera, Patonia* and *Aldania* have been recorded by SINGH AND RAI (1983).

The Tal Formation is mainly an argillo-arenaceous succession which is unconformably capped by the thick package of shelly fossiliferous Nilkanth Formation of SINGH (1978). It conformably overlies the Krol Formation. The Tal Formation has been assigned Cretaceous-Palaeocene age by various workers (see BHARGAVA, 1979) but SINGH (1978) has suggested a Precambrian age. As earlier discussed the age of the Tal Formation is early Cambrian. Concentrically laminated cones, oncolites and *Collenia* type stromatolites have been recorded from the Mussoorie area, Uttar Pradesh (RAHA, 1972; SHARMA, 1976). PATWARDHAN (1980) has also mentioned the occurrence of certain columnar and domal stromatolites but has not confidently compared them with well known forms. Recently TEWARI (1983) has identified *Gollumnaefacta vulgaris* from the Chert Member which is a characteristic form of the Lower Cambrian of Russia. SINGH AND RAI (1983) compared some forms with *Stratifera, Paniscollenia* and *Irregularia*.

Record of *Gollumnaefacta vulgaris* is an important discovery which also supports Lower Cambrian age to the Tal Formation.

DISCUSSION AND CONCLUSION

1. A large number of sedimentary sequences in both Peninsular India and the Himalayan region contain stromatolites which can be subdivided into three broad groups:
   i. Stromatolites of the pre-Riphean sequences
   ii. Stromatolites of the Riphean sequences
   iii. Stromatolites of the Vendian-Lower Cambrian succession
2. Stromatolites belonging to the pre-Riphean sequences have been found only in Peninsular India from the Delhi Supergroup and the Bijawar, Aravalli and Iron Ore Groups.
3. Stromatolites belonging to the Riphean sequences have been reported from Peninsular India in the Vindhyan, Cuddapah and Kurnool Supergroups and in the Raipur and Kaladgi Groups. In the Himalaya, the stromatolite bearing Riphean sequences are Simla, Deoban, Garhwal and Buxa Groups, the Shali and Larji Formations, the Jammu Limestone, the Calc Zones of Pithoragarh and Tejam, and the Tunda Patthar Limestone.
4. The age of the Krol Formation is Vendian which is also supported by stromatolite assemblage. Thus, the age of the Blaini Formation is late Riphean. The presence of *Conophyton* in Blaini also indicate Precambrian age.
5. The Tal Formation is early Cambrian. This age is also supported by the stromatolite form *Collumnaefacta vulgaris*.
6. The Simla-Blaini-Krol-Tal succession offers a unique opportunity for the detailed morphological study of Riphean-Vendian-Lower Cambrian stromatolites.
7. In many sedimentary sequences like the Vindhyan Supergroup, the Aravalli and Buxa Groups, the Jammu Limestone and the Calc Zone of Pithoragarh where stratigraphically nonreptetitive stromatolite assemblages have been recorded, the stromatolites are useful in the intrabasinal correlation. At the same time in the Vindhyan Supergroup, the Calc Zone of Pithoragarh, the Jammu Limestone and the Buxa Group the stromatolite assemblages more or less correspond well with the Riphean stromatolite assemblages of U. S. S. R. and thus help in interbasinal correlations. The Vendian and Lower Cambrian stromatolite forms have also been recorded whose age has been confirmed by other methods.
8. Comparison of the different stromatolite assemblages also reveals that the typical Riphean stromatolites have also been reported from certain pre-Riphean sequences of Peninsular India like the Delhi Supergroup, and the Bijawar and Aravalli Groups. This situation may be the result of casual and imprecise identification of stromatolite forms. More precise morphological identification of stromatolites is absolutely essential to clarify this point.
9. In conclusion it can be said that there are quite positive evidences for the stratigraphic testimony of stromatolites. In all the cases except in the Tal Formation the stromatolites occur only in Precambrian sequences. In the Tal Formation they represent early Cambrian age.

ACKNOWLEDGEMENT

The author is very much indebted to Prof. S. M. Awramik for reviewing the earlier draft of the manuscript, Prof. C. L. Monty for helpful discussion and Prof. G. Muller for encouragement. He is also thankful to Dr. A. K. Jain who offered

many valuable suggestions. The earlier draft of the paper was written during the tenure of a fellowship of the Alexander von Humboldt Foundation, W. Germany.

REFERENCES

AWASTHI, R. K. (1980). Stromatolites from Iron Ore Formation of Bonai-Keonjhar district, Orissa. *Stromatolites : Characteristics and Utility, Geol. Surv. India*, Miscellaneous Publ. **44** : 54-56.

AWRAMIK, S. M. (1977). Paleobiology of Stromatolites. In *Chemical Evolution of the early Precambrian*, (Ed.) C. Ponnamperuma : 111-131.

BALASUNDARAM, M. S. & MAHADEVAN, T. M. (1972). Stromatolites from Bijawars of Joga, Hoshangabad district, M. P. *Rec. geol. Surv. India*, **99** : 127-132.

BANERJEE, D. M. (1970). A study of stromatolites from the Calc Zone of Sarju Pungar Valley areas, Kumaon Himalaya. *Jour. palaeont. Soc. India*, **14** : 66-76.

BANERJEE, D. M. (1971a). Precambrian stromatolitic phosphorite, Udaipur, Rajasthan, India. *Bull. geol. Soc. America*, **82** : 2319-2330.

BANERJEE, D. M. (1971b). Aravalli stromatolites from Udaipur, Rajasthan, *J. geol. Soc. India*, **12** : 349-355.

BANERJEE, D. M. & BASU, P. C. (1980). Stromatolites in the Jhabua phosphorite-lithostratigraphy, age and paleoenvironment. *Stromatolites : Characteristics and Utility, Geol. Surv. India*, Miscellaneous Publ. **44** : 240-254.

BANERJEE, D. M. & RAWAT, R. S. (1980). Stromatolitic structures in Lameri—A member of Garhwal Group near Rudraprayag, Garhwal Himalaya, U. P. *Stromatolities : Characteristics and Utility, Geol. Surv. India*. Miscellaneous Publ. **44** : 80-85.

BARMAN, G., VERMA K. K. & PURI, S. N. (1978). Biostratigraphic zonation of the stromatolite bearing horizons in the Aravallis of Udaipur District, Rajasthan. *J. geol. Soc. India*, **19** : 264-267.

BHARGAVA, O. N. (1979). Lithostratigraphic classification of the Blaini, Infra-Krol, Krol and Tal Formations—A review. *J. geol. Soc. India*, **20** : 7-16.

BHATT, D. K., MAMGAIN, V. D., MISRA, R. S. & SRIVASTAVA, J. P. (1933). A shelly microfossils of Tommotian age (Lower Cambrian) from the Chert-Phosphorite Member of Lower Tal Formation, Maldeota, Dehra Dun District, Uttar Pradesh. *Geophytology*, **13** : 116-123.

CHAUHAN, D. S. (1980). Aravalli Stromatolites and biostratigraphy. *Stromatolites : Characteristics and Utility. Geol. Surv. India*, Miscellaneous Publ. **44** : 128-133.

CRAWFORD, A. R. (1969). Reconnaissance Rb-Sr. dating of the Precambrian rocks of the southern Peninsular India. *J. geol. Soc. India*, **10** : 118-166.

CRAWFORD, A. R. (1970). The Precambrian geochronology of Rajasthan and Bundelkhand, northern India. *Can. J. Earth Sci.*, **7** : 91-110.

CRAWFORD, A. R. & COMPSTON, W. (1973). The age of the Cuddapah and Kurnool Systems, southern India. *J. geol. Soc. Australia*, **19** : 453-464.

DATT, N. V. B. S. (1964). Suggested succession of the Purana Formations of Chattisgarh. *Rec. geol. Surv. India*, **93** : 143-148.

DEB, M., BANERJEE, D. M. & BHATTACHARYA, A. K. (1978). Precambrian stromatolite and other structures in the Rajpura—Dariba polymetallic ore deposit, Rajasthan, India. *Min. Deposita*, **13** : 1-9.

DIXIT, P. C. (1966). A study of stromatolites from Girechhina area, District Almora, Kumaon Himalayas. *Centre Adv. Stu. Geol. Panjab University, Chandigarh*. **3** : 83-92.

GANSSER, A. (1964). *Geology of the Himalayas*. Interscience Publishers, London.

GOVINDA RAJULU, B. V. & GOWDA, M. J. C. (1965). Stromatolitic limestone from Kaladgi Formation around Lokapur, Bijawar district, Mysore State. *J. Mysore University*, **20** : 7-16.

GRANT, P. R., MURTY, V. N. & SENGUPTA, S. (1980). The first record of stromatolites from the Koira Group (Iron Ore Series), Precambrian of Bihar and Orissa, India. *Stromatolities : Characteristics and Utility, Geol. Surv. India*, Miscellaneous Publ. **44** : 49-53.

GUPTA, V. J. (1977). *Indian Precambrian Stratigraphy*. Hindustan Publishing Corporation, India.

HOFMANN, H. J. (1977). On the Aphebian stromatolites and Riphean stromatolite stratigraphy. *Precambrian Res.*, **5** : 175-205.

JAIRAMAN, R. & BANERJEE, D. M. (1980). Preliminary studies of the stromatolites from the Raipur area, Chattisgarh basin. *Stromatolites : Characteristics and Utility, Geol. Surv. India*, Miscellaneous Publ. **44** : 57-67.

KRISHNAN, M. S. (1960). *Geology of India and Burma*. Higginbothams, Madras.

KUMAR, A. (1981). Upper Krol Stromatolites from Nainital Hills, Kumaon Himalaya, India. In *Phanerozoic Stromatolites*, (Ed) C. L. Monty : 36-44.

KUMAR, G. & AGARWAL, N. C. (1975). Geology of the Srinagar—Nandpryag area (Alaknanda Valley), Chamoli, Garhwal and Tehri-Garhwal districts, Kumaon Himalaya, Uttar Pradesh. *Him. Geol.*, **5** : 29-59.

KUMAR, S. (1976a). Stromatolites from the Vindhyan rocks of the Son Valley-Maihar area, districts Mirzapur (U.P.) and Satna (M. P.). *J. palaeont. Soc. India*, **18** : 13-21.

KUMAR, S. (1976b). Significance of stromatolites in the correlation of Semri Series (Lower Vindhyan) of Son Valley and Chitrakut area, U. P. *J. palaeont. Soc. India*, **19** : 24-27.

KUMAR, S. (1977). Stromatolites and phosphorite in the Tirohan Limestone of Chitrakut area, Satna district, M. P. *Curr. Sci.*, **46** : 341-342.

KUMAR, S. (1978a). Stromatolites and environment of deposition of the Vindhyan Supergroup of Central India. *J. palaeont. Soc. India*, **21** : 22 : 33-43.

KUMAR, S. (1978b). Sedimentaries of the Zone of Badolisera and the Vindhyan Supergroup, Uttar Pradesh—A re-appraisal of correlation. *J. palaeont. Soc. India*, **21-22** : 96-101.

KUMAR, S. (1980). Stromatolites and Indian Biostratigraphy. A review. *J. palaeont. Soc. India*, **23-24** : 166-183.

KUMAR, S. (1982). Vindhyan Stromatolites and their stratigraphic testimony. In *Geology of Vindhyanchal*, (Ed.) K. S. Valdiya, S. B. Bhatia & V. K. Gaur : 102-112.

KUMAR, S. & KUMAR, R. (1973). Stratified stromatolites and environment of deposition of the Thalkedar Dolomite, Gurna area, Pithoragarh district, U. P. *Him. Geol.*, **9** : 626-632.

KUMAR, S. & SINGH, S. N. (1979). Significance of *Jacutophyton* in the Deoban Limestone, Chakrata area, Dehra Dun district, Uttar Pradesh. *Curr. Sci.*, **48** : 401.

KUMAR, S. & TEWARI, V. C. (1977). A new form *Conophyton misrai* from Gangolihat Dolomites, Kathpuria Chhina area, Almora district, U. P. *Curr. Sci.* **46** : 641-642.

KUMAR, S. & TEWARI, V. C. (1978). Occurrence of *Conophyton garganicus* from the Gangolihat Dolomite, Kathpuria Chhina area, district Almora, U. P. *J. geol. Soc. India*, **19** : 174-178.

LAKHMANAN, S., PATEL, N. P. & DAS, B. (1977). A study of stromatolites from the Bijawars of Madhya Pradesh. *J. palaeont. Soc. India*, **20** : 327-330.

LOGAN, B. W. (1961). Cryptozoon and associated stromatolites from the Recent of Shark Bay, Western Australia. *J. Geol.*, **69** : 517-533.

LOGAN, B. W., REZAK, R. & GINSBURG, R. N. (1964). Classification and environmental significance of stromatolites *J. Geol.*, **72** : 68-83.

MISRA, R. C. & KUMAR, S. (1963). A note on the occurrence of stromatolites from the Thalkedar Limestone from Raintola, district Pithoragarh, U. P. *J. palaeont. Soc. India*, **5-9** : 31-33.

MISRA, R. C. & KUMAR, S. (1969). Stromatolites from the Zone of Badolisera, districts Pithoragarh-Almora, U. P. *J. palalont. Soc. India*, **12** : 12-20.

MOHAN, K. (1968). Stromatolite structures from the Lower Vindhyans, India with additions from South Africa, Australia and North Korea. *Neues Jahrb. Geol., Paloont.* Abh., **130** (3) : 335-353.

MONTY, C. L. (1972). Recent algal stromatolitic deposits, Andros Island, Bahamas-Preliminary Report. *Geol. Rundsch.*, **61** : 742-783.

NIYOGI, D. & BHATTACHARYA, S. C. (1971). A note on the Blaini Boulder beds of the Lower Himalaya. *Him. Geol.*, **1** : 111-122.

PASCOE, E. H. (1959). *A manual of the Geology of India and Burma*. Vol. II. Controller of Publication, Government of India. 1338p.

PATWARDHAN, A. M. (1980). Phosphate-pyrite association and the genesis of stromatolitic pelletal phosphorite. *Proc. 3rd. Ind. Geol. Cong. , Poona:* **34:** 341-365.

PRASAD, B. & RAMASWAMY, S. M. (1980). Stromatolites in Upper Vindhyan from Bundi, Kota and Swai Madhopur districts, Rajasthan. *Stromatolites : Characteristics and Utility, Geol. Surv. India.*, Miscellaneous Publ. **44** : 275-277.

PRASAD, K. N. & VERMA, K. K. (1967). Stromatolites from the Vempalle Formation of Cuddapah, Andhra Pradesh. *J. Ind. Geol. Sci. Assoc.*, **7** : 95-96.

PREISS, W. V. (1976). Intercontinental Correlations. In *Stromatolites*, (Ed.). M. R. Walter: 359-370.

RAABEN, M. E. (1969). Columnar stromatolites and the late Precambrain Stratigraphy. *Am. J. Sci.* **267** : 207-219.

RAHA, P. K. (1972). Algal stromatolites from the Krol Formation of the Mussoorie Syncline, Uttar Pradesh. *Palaeobotanist*, **21** : 227-230.

RAHA, P. K. (1980a). Stromatolite Zonation in Jammu Limestone, Udhampur district, Jammu. *Stromatolites: Characteristics and Utility, Geol. Surv. India.* Miscellaneous Publ. **44** : 134-171.

RAHA, P. K. (1980b). Stromatolite Biostratigraphy of the Buxa Dolostone, Sikkim and Bhutan Himalaya and its correlation with stromatolitic formations of western Himalaya. *XIth Himalayan Geology Seminar, Dehra Dun, India* (Abstract): 20.

RAHA, P. K. & GURURAJA, M. N. (1970). The occurrence of algal (stromatolitic) structures in phosphatic limestone of the Tal Formation of Mussoorie syncline, U. P. *Ind. Min.*, **24** : 396-399.

RAHA, P. K., CHANDI, K. C. & BALASUBRAHMANYAN, M. N. (1978). Geochronology of the Jammu Limestone, Udhampur district, Jammu and Kashmir State, India. *J. geol. Soci. India*, **19** : 221-223.

RAHA, P. K. & SASTRY, M. V. A. (1982). Stromatolites and Precambrian Stratigraphy in India. *Precambrian Res.* **18** : 293-318.

RAI, V. & SINGH, I. B. (1983). Discovery of trilobite impression in the Arenaceous Member of Tal Formation, Mussoorie area, India. *J. palaont. Sci. India*, **28** : 113-116.

RAJA RAO, C. S. & MAHAJAN, V. D. (1965). Note on stromatolites and possible correlation of Bhagwanpura Limestone, Chittorgarh district, Rajasthan. *Curr. Sci.*, **30** : 82-83.

RAO, B. B. & GURURAJA, M. N. (1980). On the occurrence of stromatolite in the Cumbum Formation (Upper Cuddapah), Zangamrajupalle, Andhra Pradesh. *Stromatolites : Characteristics and Utility. Geol. Surv. India.* Miscellaneous Publ. **44** : 38-42.

RAO, K. S., LAL, C. & GHOSH, D. B. (1977). Algal stromatolites in the Bhander Group of formations, Vindhyan Supergroup, Satna district, Madhya Pradesh. *Rec. geol. Surv. India*, **109** : 38-47.

RUPKE, J. (1968). Note on the Blaini Boulder Bed of Tehri Garhwal, Kumaon Himalayas. *J. geol. Soc. India*, **9** : 131-133.

SARKAR, S. N. (1972). Present status of Precambrian geochronology of Peninsular India. *24th Int. Geol. Cong.* Section 1 : **1** : 260-271.

SCHNITZER, W. A. (1971). Das Jungprakambrium Indiens (The Late Precambrian of India 'Purana System'. *Erlanger Geol.*, **85** : 1-44.

SHARMA, K. K. (1976). On the occurrence of stromatolitic limestones in lower Tal Formation of Pasi Tiba, Mussoorie (Uttar Pradesh) and their palaeoecological significance. *Ciayanica Geologica*, **2** : 91-99.

SINGH, I. B. (1978). Sedimentological evolution of the Krol belt sediments. *Him. Geol.*, **8** : 657-682.

SINGH, I. B. (1980a). Palaeoecology and Biostratigraphy of the Lesser Himalaya—an analysis. *XIth Himalayan Geology Seminar, Dehra Dun, India.* (Abstract) : 29.

SINGH, I. B. (1980b). Discovery of Late Palaeozoic Brachiopod in the Upper Krol of the Nainital hills, Kumaon Himalaya. *J. geol. Soc. India*, **21** : 518-520.

SINGH, I. B. (1983). A note on the nature of stromatolites of Krol sediments, Nainital, Kumaon Himalaya, with special reference to *Conophyton*. *Geophytology*, **13** : 111-115.

SINGH, I. B. & RAI, V. (1977). On the occurrence of stromatolites in the Krol Formation of Nainital area and its implications on the age of Krol Formation. *Curr. Sci.*, **46** : 736-738.

SINGH, I. B. & RAI, V. (1978). Some observations on the depositional environment of the Krol Formation in Nainital area. *Him. Geol.*, **8** : 633-656.

SINGH, I. B. & RAI V. (1983). Fauna and Biogenic structures in Krol-Tal succession, Lesser Himalaya: Their biostratigraphic and palaeonotological significance. *J. palaont. Soc. India*, **28** : 67-90.

SINGH, I. B. & RAI V. (1984). Discovery of Archaeocyatha in the upper Krol carbonates, Mussoorie hills, Uttar Pradesh, India *Curr. Sci.*, **53** : (5) 243-246.

SINGH, I. B. & TANGRI, A. K. (1976). Some observations on the sedimentolcgy of the Blaini Formation, Himachal Pradesh and U. P. Himalaya. *Proc. 125th Ann. Celebr. Geol. Surv. India., Symposium, Lucknow.* (Unedited and uncorrected preprint.)

SINGH, P. & VIMAL, K. P. (1972). Discovery of stromatolites from the Sirban Limsetone of Riasi, Jammu Province, Jammu and Kashmir State. *J. palaeont. Soc. India*, **15** : 6-9.

SINHA, A. K. & RAABEN, M. E. (1979). Lower Cambrian stromatolite from the Deoban Limestone of Lesser Himalaya. *Him. Geol.*, **9A** : 317-323.

SINHA, A. K. (1977). Riphean stromatolites from western lower Himalaya. In *Fossil Algae*, (Ed.) E. Flugel: 86-100.

SRIKANTIA, S. V. & SHARMA, R. P. (1976). Geology of the Shali belt and adjoining area. *Mem. Geo. Surv. India*, **106** : 31-166.

TEWARI, V. C. (1983a). On the occurrence of *Plicatinae atiqua* Raaben, 1980 from Kumaon Himalaya, U. P. *Geoscience Jour.*, **4** : 87-98

TEWARI, V. C. (1983b). The systematic study of Precambrian stromatolites from the Gangolihat Dolomite, Kumaon Himalaya. *Him. Geol.*, **11** : 119-146.

TEWARI, V. C. (1984) Discovery of the Lower Cambrian stromatolites from the Mussoorie Tal Phosphorite,

India. *Curr. Sci.*, **53** (6) : 319-321.

VAIDYANATHAN, R. (1961). Stromatolites in the Lower Cuddapah Limestones (Precambrain) in the Cuddapah Basin. *Curr. Sci.*, **33** : 221.

VALDIYA, K. S. (1967). Occurrence of magnesite deposit and time controlled variation of stromatolites in the Shali Series, district Mahasu, Himachal Pradesh. *Bull. geol. Sci. India*, **4** : 125-128.

VALDIYA, K. S. (1969). Stromatolites of the Lesser Himalayan Carbonate formations and the Vindhyans. *J. geol. Soc. India*, **10** : 1-125.

VALDIYA, K. S. (1970). Simla Slates: The Precambrian flysch of the Lesser Himalaya, its turbidites, sedimentary structures and palaeocurrents. *Bull. geol. Soc. America*, **81** : 451-468.

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

VALDIYA, K. S. (1980b). Discovery of Late Palaeozoic brachiopod in the Upper Krol of the Nainital hills, Kumaon Himalaya. A reply. *J. geol. Soc. India*, **21** : 520.

VERMA, K. K. & BARMAN, G. (1980). On the discovery of algal stromatolites from Delhi Supergroup, Rajasthan, India. *Stromatolites: Characteristics and Utility, Geol. Surv. India*, Miscellaneous Publ. **44** : 86-89.

VINOGRADOV, A. & TUGARINOV, A. (1964). Geochronology of Indian Precambrian. *22nd. Int. Geol. Congress* (Late Abstract).

VISWANTHIAH, M. N. & GOWDA, M. J. C. (1970). Algal stromatolites from the Kaladgi (Precambrian) formations, near Alagundi, Bijapur district, Mysore State. *J. geol. Soc. India*, **11** : 378-385.

WEST, W. D. (1939). Structure of the Shali Window near Simla. *Rec. geol. Surv. India*, **74** : 133-163.

ARASPORITES GEN. NOV.—A NEW ACAVATE TRILETE SPORE FROM LOWER GONDWANA OF INDIA

SURESH C. SRIVASTAVA AND RAKESH SAXENA

Birbal Sahni Institute of Palaeobotany, Lucknow-226 007

ABSTRACT

A new miospore genus *Arasporites* gen. nov. has been described from the Barakar Formation (Lower Permian) of the Lower Gondwana Sequence of West Bokaro Coalfield, Bihar, India. It is a thick, circular trilete with spines present on both the surfaces of the miospore. Its occurrence is restricted to the seam XI of Ara Block, West Bokaro Coalfield.

INTRODUCTION

A number of trilete miospores have been described from the Lower Gondwana Sequence of India. BHARADWAJ (1962) described some trilete genera from the Raniganj Formation of Raniganj Coalfield. BHARADWAJ AND SALUJHA (1964) further added a triangular trilete genus as *Horriditriletes* from the same area. TIWARI (1964) described some zonate and cingulate triletes from Korba Coalfield. Subsequently, VENKATACHALA AND KAR (1965) also described two triletes, *Didecitriletes* and *Lacinitriletes*, from North Karanpura Coalfield which have restricted distal ornamentation. BHARADWAJ AND SRIVASTAVA (1969) described three trilete miospores viz., *Callumispora*, *Brevitriletes* and *Pseudoreticulatispora* occurring in Chirimiri, Sohagpur, Bisrampur and Talchir Coalfields. TIWARI AND MOIZ, (1971) described *Godavarisporites* and *Lobatisporites* from Godavari Valley coalfields. BHARADWAJ AND DWIVEDI (1977) described a cavate trilete, *Insignisporites*, from the Barakar Formation of South Karanpura Coalfield. TIWARI AND SINGH (1981) have instituted another, varitrilete genus, *Imparitriletes*, from Korba Coalfield. However, the study of the sporae dispersae of the Lower Gondwana sediments in West Bokaro Coalfield, Bihar, India has revealed a new association of morphographic characters which has been described in the present paper under the genus *Arasporites* gen. nov. Morphographic characters have been studied in detail under transmitted light, differential interference contrast (DIC) and also scanning electron microscopy (SEM).

Genus **Arasporites** gen. nov.

Type Species—*Arasporites crassus* sp. nov.

Generic Diagnosis—Miospores circular to subcircular. acavate; triletes distinct, raised. Exine thick, ornamented with spines on both the surfaces.

Generic Description—Miospores circular in shape, but may assume subcircular shape due to folding or flattening. Trilete mark distinct, rays straight, tapering, equal to each other and placed at equal angles (Pl. 1, Fig. 2), labra thin and vertex slightly raised. Exine fairly thick as is usually distinct along the equatorial margin in normally flattened specimens (Pl. 1, Fig. 1). Exine ornamented with long spines, protruding out of the equatorial margin (Pl. 1, Figs. 1, 3). Spines present on both

the surfaces of the miospore. Ornamentation considerably reduced on proximal surface (Pl. 1, Fig. 2).

Comparison—The genus *Arasporites* gen. nov. compares with the radial, baculate genus *Cyclobaculisporites* Bhardwaj (1955) in over all shape but differs in having spines as its ornamentation. *Verrucosisporites* Ibr. emend. Smith & Butterworth (1967) has a circular shape but bears verrucae on the exine. Similarly *Cyclogranisporites* Pot. & Kr. (1954) is ornamented with grana and thus differs from the new taxon proposed here. *Raistrickia* (Schopf, Wilson & Bentall) Pot. & Kr. (1954) is a roundly triangular trilete and bears stout baculae over the exine. *Phidiaesporites* Foster (1979) is a circular, trilete miospore having differentially thickened exine set with apiculate elements and thus has a superficial resemblance. In *Bipartitisporites* Segroves (1970) the exine is thick, intrapunctate and is irregularly intragranulose and intrabaculate. *Osmundacidites* Couper (1953) compares in its radial symmetry but differs in being scluptured by coni, baculae and irregular grana. Among other trilete miospores, *Acanthotriletes* (Naum.) Pot. & Kr. (1954) resembles in having spinose ornamentation but differs in being triangular in shape. Thus, the genus *Arasporites* gen. nov. is distinctly different from the known taxa of the Lower Gondwana and is represented by a significant population in the sporae dispersae of West Bokaro Coalfield. A number of specimens have been studied with respect to their overall size, exine thickness and the nature of ornamentation.

Arasporites crassus sp. nov.

Pl. 1, Figs 1-8

Holotype– Pl. 1, Fig. 2; Size 86 μm; Slide No. S 87/R; BSIP Museum Reg. No. 8505.

Locus typicus—XIth Seam, Ara Block, West Bokaro Coalfield, Bihar, India.

Stratum typicum—Barakar Formation, Permian, Lower Gondwana, India.

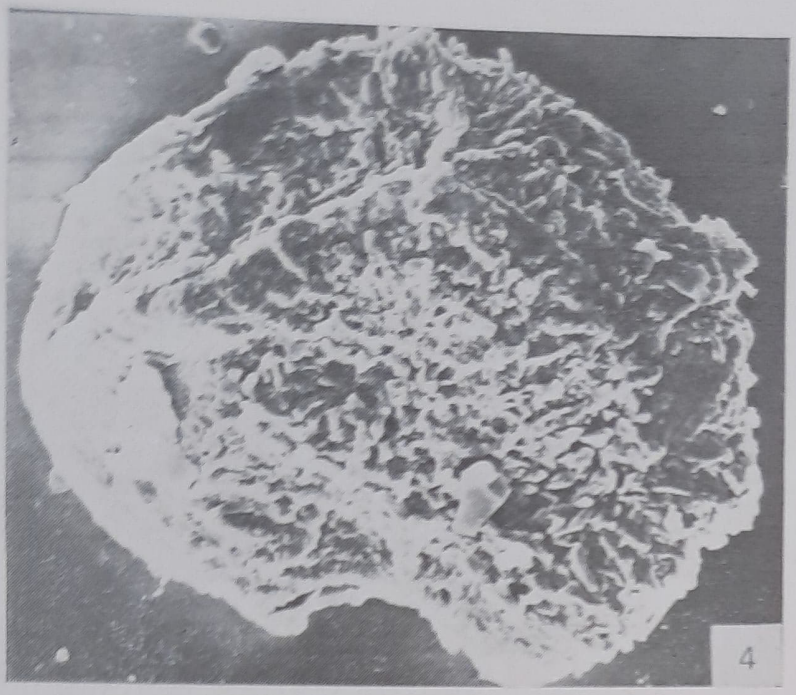
Specific Diagnosis—Miospores circular to subcircular, size 86 μm. Trilete mark present, rays tapering, reaching upto 2/3 area of the spore. Exine 2-6 μm thick. Spines 1-5 μm long and 1-2 μm wide at base.

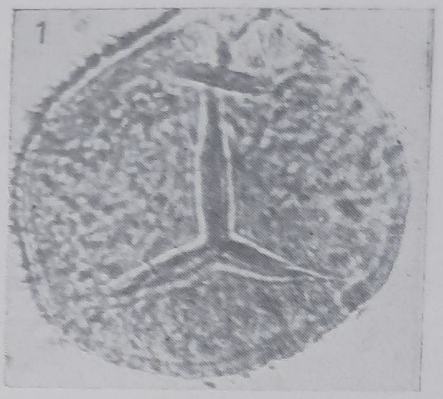
Specific Description—Miospores circular to subcircular in shape, golden dark brown in colour, size range 60-86 μm. Trilete mark distinct, rays broad at apex and taper to a pointed end reaching upto 2/3 area of the miospore radius, ray length 41.05 μm. Exine 2-6 μm thick as distinct along the equatorial margin. Spines 1-5 μm long and 1-2 μm wide at base, sharply pointed to round tipped (Pl. 1, Figs. 2, 6-8). Spines thin, delicate and semitransparent. Distally spines close, 1-3 μm, bases separated from the adjacent ones. Spines considerably reduced in contact area on the proximal surface.

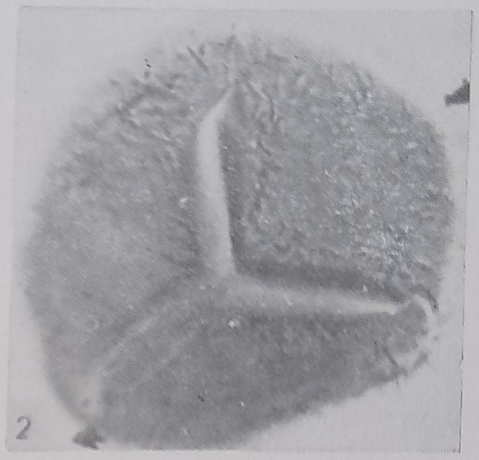
This species occurs (upto 2%) in XI seam of Ara Block, West Bokaro Coalfield while it is absent in the overlying and underlying coal seams. This taxon may be utilised as marker of similar horizons lying at the same time level in adjacent areas of the coalfield.

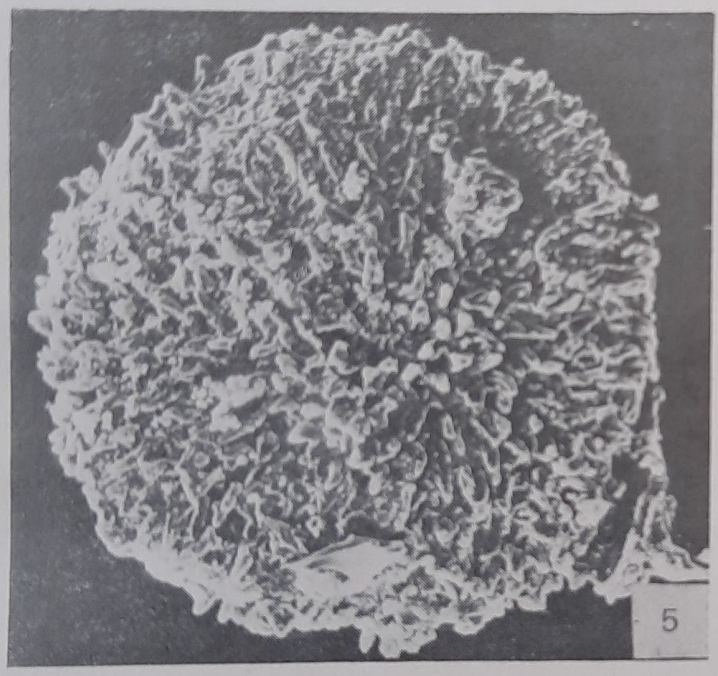
ACKNOWLEDGEMENT

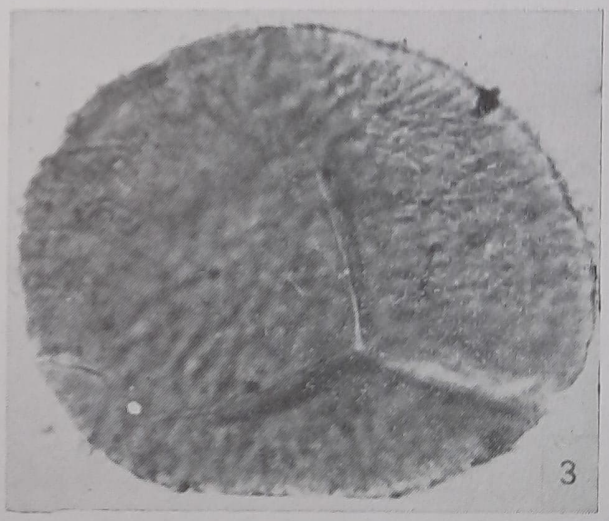
The authors are thankful to Dr. C. D. Bharadwaj for his valuable suggestion during the present work. They are also thankful to the authorities of National Botanical Research Institute, Lucknow for providing facilities over the Scanning Electron Microscope.

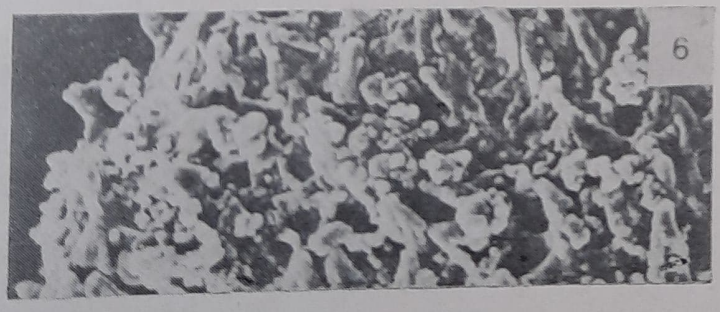


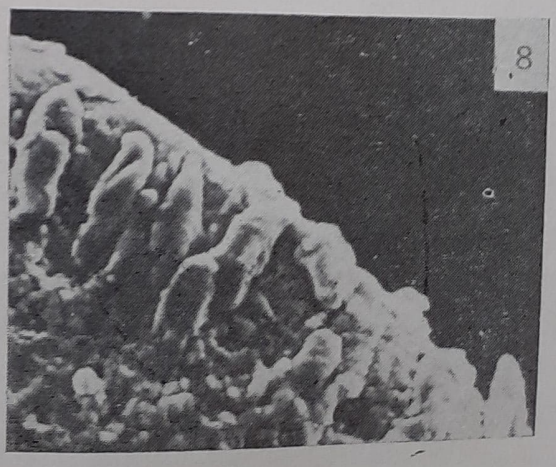












REFERENCES

BHARADWAJ, D. C. (1962). The miospore genera in the coals of Raniganj Stage (Upper Permian), India. *Palaeobotanist*, **9** (1, 2): 68-106.

BHARADWAJ, D. C. & SALUJHA, S. K. (1964). Soprological study of seam VIII in Raniganj Coalfield, Bihar (India). Part I-Descripitions of sporae dispersae. *Palaeobotanist*, **12** (2) : 181-215.

BHARADWAJ, D. C. & SRIVASTAVA, S. C. (1969). Some new mispore genera from Barakar Stage, Lower Gondwana, India. *Palaeobotanist*, **17** (20) : 220-229.

BHARADWAJ, D. C. & DWIVEDI, A. (1977). *Insignisporites* gen. nov., a new cavate mispore genus from Barakar Stage (Lower Gondwana) of India. *Geophytology*, **7** (1) : 113-120.

TIWARI, R. S. (1964). New miospore genera in the coals of Barakar Stage (Lower Gondwana) of India. *Palaeobotanist*, **12** (3) : 250-259.

TIWARI, R. S. & MOIZ, A. A. (1971). Palynological study of Lower Gondwana (Permian) coals from Godavari Basin, India-1. On some new miospore genera. *Palaeobotanist*, **19** (1) : 95-104.

TIWARI, R. S. & SINGH, V. (1981). Morphographic study of some dispersed trilete miospores (Infraturma Varitrileti) from Lower Gondwana of India. *Palaeobotanist*, **27** (3) : 252-296.

VENKATACHALA, B. S. & KAR, R. K. (1965). Two new trilete spore genera from the Permian of India. *Palaeobotanist*, **13** (3) : 337-340.

EXPLANATION OF PLATE 1

Figs 1 to 8-*Arasporites crassus* gen. *et* sp. nov.

1. Proximal view showing trilete and exine thickness, ×500 (Transmitted light).
2. Proximal view showing reduced ornamentation in the contact area, ×750(DIC).
3. Proximal view (Holotype), ×750 (DIC).
4. Slightly lateral view, ×1200 (SEM).
5. Distal view, ×1000 (SEM).
6. Exine ornamentation, ×2000 (SEM).
7. Exine ornamentation, ×3000 (SEM).
8. Exine ornamentation, ×3600 (SEM)