Journal of The Palaeontological Society of India
Golden Jubilee Volume, 50(2), December 2005: 153-167

ISSN 0522-9630

CONIFORM STROMATOLITES AND THE VINDHYAN SUPERGROUP, CENTRAL INDIA: IMPLICATION FOR BASINAL CORRELATION AND AGE

Y. MISRA and **S. KUMAR***

DEPARTMENT OF GEOLOGY, UNIVERSITY OF LUCKNOW, LUCKNOW, U.P.

ABSTRACT

Five coniform stromatolites are described from the Semri Group. Two are from the Kajrahat Limestone viz., *Calypso* sp. and *Thyssagetes* sp., and three are from the Fawn Limestone viz., *Ephyaltes myriocranus*, *Siren* sp. and *Cyathotes phorbadicia*. The Upper Vindhyans are completely devoid of coniform stromatolites though other columnar forms are abundant. The coniform stromatolite assemblage supports an age assignment of 1800 to 1600 Ma for the Semri Group and confirms the utility of stromatolites in both intrabasinal and interbasinal correlations.

Key words: Stromatolite, Vindhyan Supergroup, Central India, Proterozoic, correlation

INTRODUCTION

Varied morphologies of the Precambrian stromatolites have been abundantly recorded from the different parts of the world. For successions which acquire enormous thickness measurable in kilometers, the presence of stromatolites played an effective role in suggesting correlation and also in assigning ages in absence of much needed radiometric dates and body fossils with restricted time range. In India, the Vindhyan Basin occupies the largest area among the Proterozoic basins and is known for abundant records of stromatolites which have been used for suggesting correlation as well as in assigning ages. The basic data on the Vindhyan stromatolites were generated between early sixties and early eighties. There are a number of reviews available for the Indian stromatolites (Kumar, 1980, 1984; Valdiya, 1969, 1989; Raha and Shastry, 1982; Venkatachala *et al.*, 1996; Raaben *et al.*, 2001) but the remark of Kumar (1980) made more than two decades back about the identification of stromatolites still holds good in which he has discussed the difficulty in using the stromatolite assemblages in correlation because of the poor description of stromatolites as no proper methodology had been followed by most of the workers. Poor quality photographs has also compounded the problem. With this limitation, the identification of stromatolite forms or even groups could not be confirmed with any degree of confidence. Thus, the corre-

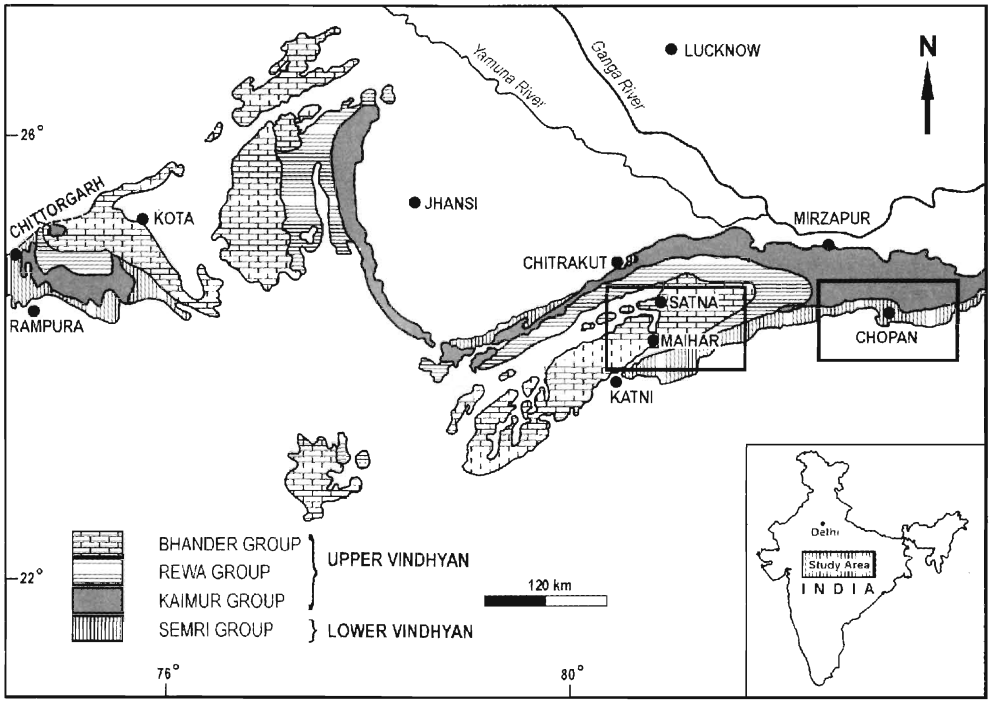


Fig. 1. Geological map of the Vindhyan Basin (after Krishnan and Swaminath, 1959). Coniform stromatolite samples were collected from the Maihar and Chopan areas shown as framed windows.

*E-mail: surendra100@hotmail.com

lation based on stromatolite assemblages was looked upon with doubt and suspicion. In recent years, new radiometric data on the Vindhyan rocks have pushed the beginning of the Vindhyan sedimentation by at least 400 million years from ca. 1400 Ma to ca. 1800 Ma. In light of the new radiometric dates, re-evaluation of the importance of stromatolites in correlation is now urgently needed. In the present paper an attempt has been made to describe the coniform stromatolites and to assess their utility in correlation and in suggesting ages.

Coniform Stromatolites : The coniform stromatolites can be defined as stromatolites which show conical laminae instead of convex laminae as seen in common columnar stromatolites. The term 'Conophyton' is normally used for forms that have conical laminae, are unlinked, have a circular plan outline and a distinctive axial zone (Grey, 1989). Grey (1989) has identified three different conical stromatolites as simple conical, linked conical and branching conical. However, there are many morphologies which have typical conical laminae but could not be grouped effectively in the simple classification as proposed by Grey (1989). Vlasov (1977) has proposed a very comprehensive classification of coniform stromatolites. He included all such forms with varied morphologies which show conical internal laminae or conical outer morphologies and described 8 morphogroups and 10 morphoforms. This classification is simple and forms can be identified with ease even in the field. In the present work the classification as proposed by Vlasov (1977) for the coniform stromatolites has been followed.

GEOLOGICAL SETTING

The Vindhyan Supergroup representing an intracratonic basin, occupies large area in central India stretching from Bihar to Rajasthan (fig.1). It attains a huge thickness of more than 4000 m. The dominant lithology is represented by sandstone, shale, porcellanites, conglomerates, limestones and dolomites. The Vindhyan rocks are unmetamorphosed with no sign of deep burial. In general, the rocks are undeformed showing very low dips but in the western part of the Vindhyan Basin some deformation is seen. The Vindhyan Supergroup has been subdivided into four groups; in stratigraphic order these are the Semri Group, the Kaimur Group, the Rewa Group and the Bhander Group. The Semri Group is referred to as the Lower Vindhyan and the remaining three groups are included in the Upper Vindhyan. Each group has been further subdivided into formations and members. The carbonate horizons are developed in both the lower as well as in the upper Vindhyans and many of them show excellent development of stromatolites.

Table 1: Lithostratigraphic subdivision of the Vindhyan Supergroup (Modified after Auden, 1933; Krishnan, 1968).

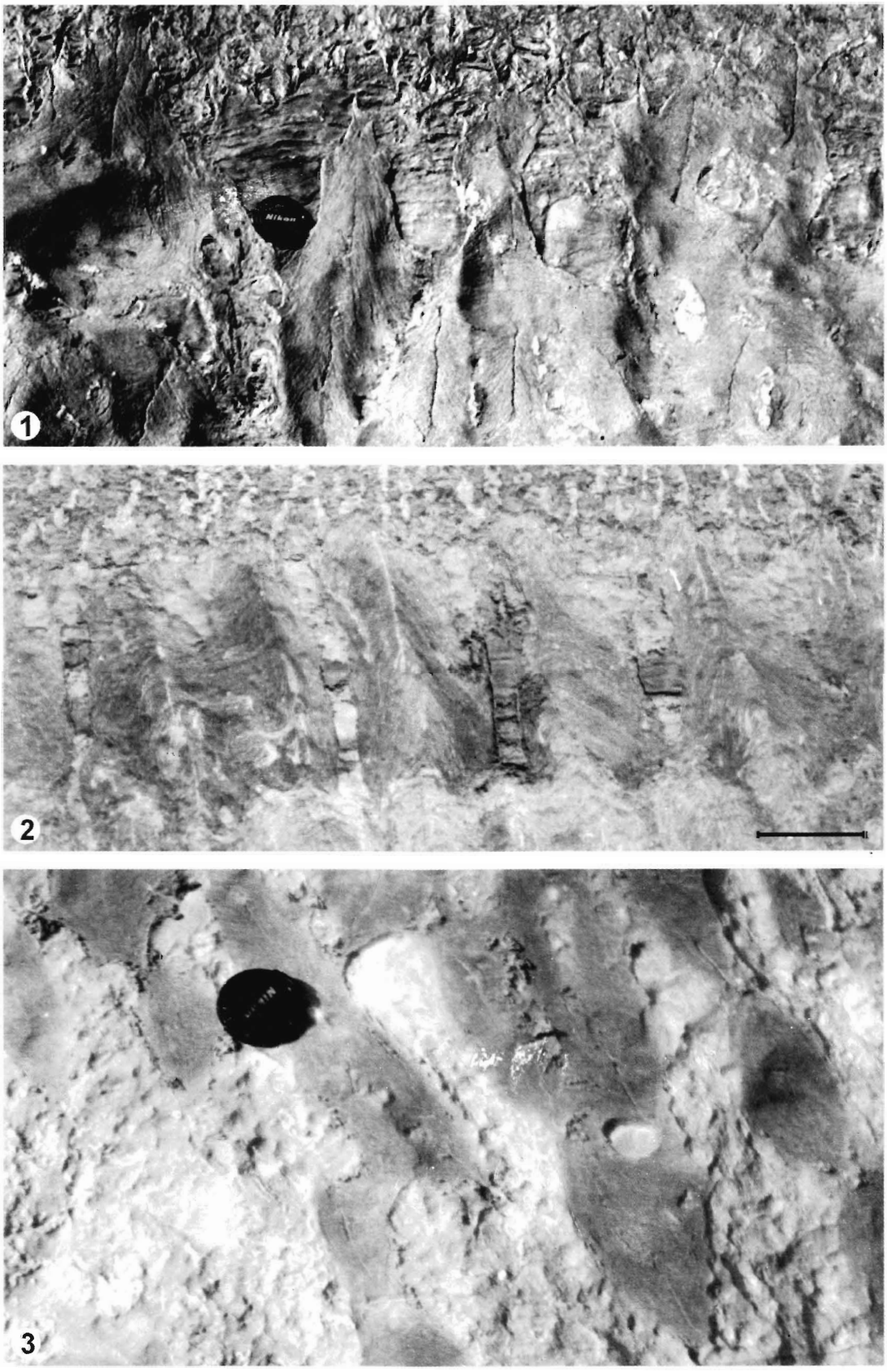
	Group	Formation	Member
Upper Vindhyan	Bhander Group	Maihar Sandstone	
		Sirbu Shale	
		Bhander Limestone	
		Ganurgarh Shale	
	Rewa Group	Upper Rewa Sandstone	
		Jhiri Shale	
		Lower Rewa Sandstone	
		Panna Shale	
	Kaimur Group	Dhandhraul Quartzite	
		Scarp Sandstone	
		Bijaigarh Shales	
		Upper Quartzite	
		Susanai Breccia	
		Silicified Shales	
		Lower Quartzite	
		Unconformity	
Lower Vindhyan	Semri Group	Rohtas Formation	Limestone and Shale
		Kheinjua Formation	Glauconitic Sandstone
			Fawn Limestone
			Olive Shale
		Porcellanite Formation	Porcellanites
		Basal Formation	Kajrahat Limestone
			Basal Conglomerate
		Unconformity	
	Bijawar Group	Schists and phyllites	

The Vindhyan succession shows well marked facies variation and the lithological succession seen as in the eastern part of the Vindhyan Basin does not match with the succession developed in the western part (Kumar and Gupta, 2002; Kumar *et al.*, 2005). The thickness also varies considerably. In addition, there is no continuity of outcrops, and the formations developed in the eastern part can not be traced in the western parts. The eastern part of the Vindhyan Basin can be referred to as the Son Valley section and the western part as the Chambal Valley section. The stratigraphic

EXPLANATION OF PLATE I

1. Longitudinal section of ***Thyssagetes*** sp., Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).
2. Longitudinal section of ***Thyssagetes*** sp., Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).
3. Transverse section of ***Thyssagetes*** sp., Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).

Plate I



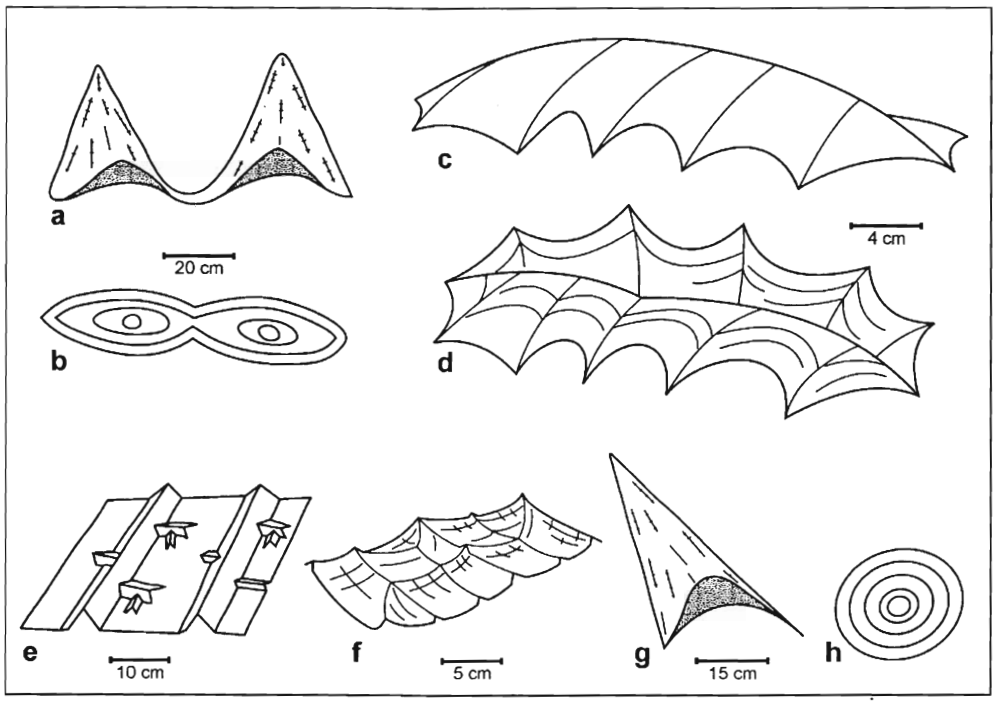


Fig. 2 Reconstruction of coniform stromatolites
a. Reconstruction of *Thyssagetes* sp., **b**. Transverse section of *Thyssagetes* sp., **c**. Reconstruction of *Calypso* sp., **d**. Transverse section of *Calypso* sp., **e**. Reconstruction of *Siren* sp., **f**. Reconstruction of *Cyathotes phorbadicia*, **g**. Reconstruction of *Ephyaltes myriocranus*, **h**. Transverse section of *Ephyaltes myriocranus*.

seccessions of both the sections are given in Tables 1 and 2.

Son Valley Section: The Semri Group shows an excellent development in the Son Valley section in the Chopan area (U.P.) which constitutes the eastern part of the Vindhyan Basin. It has been subdivided into four formations (Table 1). Stromatolites are developed in the Kajrahat Limestone, the Fawn Limestone and the Tirohan Limestone (=Rohtas Limestone). The Kaimur and the Rewa Groups are devoid of carbonate horizons and hence no stromatolites are reported from these two groups. The Bhander Group shows good development in Maihar area, (M.P.). In the Bhander Group, the stromatolites are reported from the Bhander Limestone and the Sirbu Shale (See Kumar and Gupta, 2002).

Chambal Valley Section: The stratigrphic succession developed in the Chambal Valley section in Bundi – Chittorgarh area (Rajasthan) is given in Table 2. The stromatolites have been reported from the Bhagwanpura Limestone of the Semri Group (Prasad, 1984). In this section too, no stromatolite has been recorded from the Kaimur and Rewa Groups. In the Bhander Group the stromatolites have been reported from the Sirbu Shale and the Balwan Limestone (Misra, 2004).

Age of the Vindhyan Supergroup: Not many radiometric dates are available for the Vindhyan rocks. About forty years back, a first attempt was made by the Russian workers to date the Vindhyan glauconites by the K/Ar method (Vinogradov *et al.*, 1964). The data were reinterpreted by Kreuzer *et al.* (1977) and on this basis many workers have suggested that the beginning of the Vindhyan sedimentation is at about ca. 1400 Ma. In recent years SHRIMP method of dating of zircon and Pb-Pb dating of carbonates have been used (Rasmussen *et al.*, 2002; Ray *et al.*, 2002, Sarangi *et al.*, 2004). Strontium isotope data have also been used in establishing the age (Ray *et al.*, 2003). The youngest horizon of the Semri Group has been dated as ~ 1600 Ma, and therefore the beginning of the sedimentation can be taken to be around 1800 Ma (see Kumar *et al.*, 2005). No Cambrian body fossils and /or trace fossils have so far been found. Identification of *Spriggina* by Kathal *et al.* (2000), *Ediacaria* by De (2003), and brachiopod and shelly fauna by Azmi (1998) have been rejected (see Bhargava and Srikantia, 2000; Kumar 2001; Kumar *et al.* 2005). The suggestion of Friedman and Chakraborty (1997) of a Precambrian–Cambrian boundary within the Bhander Group has also

EXPLANATION OF PLATE II

1. Longitudinal section of ***Calypso*** sp., Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).
2. Transverse section of ***Calypso*** sp., Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).
3. Transverse section of ***Calypso*** sp., Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).

Plate II

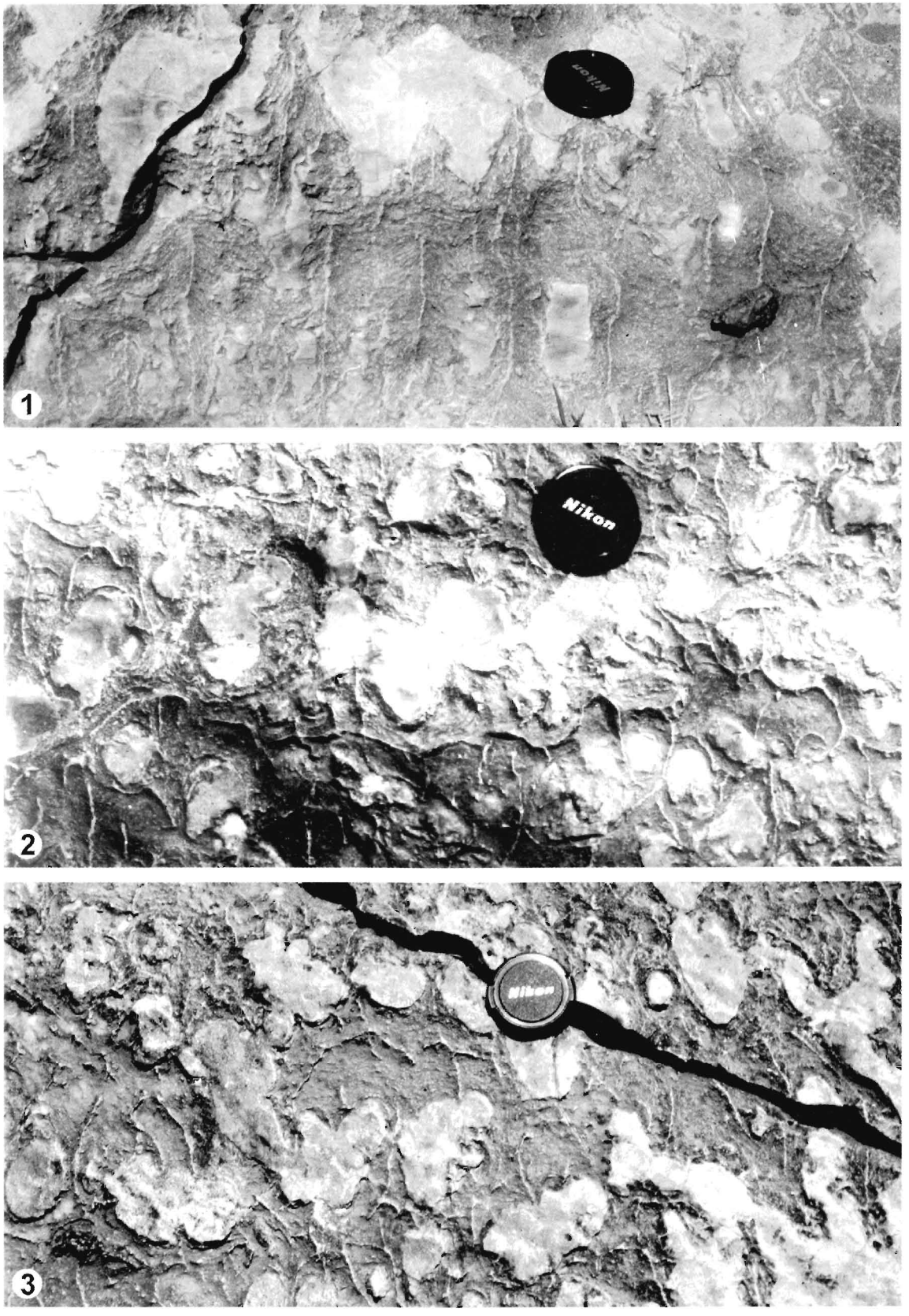


Table 2: Lithostratigraphic succession of the Vindhyan Supergroup in Kota-Chittorgarh area, Rajasthan (Modified by Kumar 2001, Prasad, 1984).

	Group	Formation
Upper Vindhyan	Bhander Group	Dholpura Shale
		Balwan Limestone
		Maihar Sandstone
		Sirbu Shale
		Bundi Hill Sandstone
		Samria Shale
		Lakheri Limestone
		Ganurgarh Shale
	Rewa Group	Govindgarh Sandstone
		Jhiri Shale
		Indargarh Sandstone
		Panna Shale
	Kaimur Group	Akoda Mahadev Sandstone
		Badanpur Conglomerate
		Chittorgarh Fort Sandstone
Lower Vindhyan Semri Group	Khorip Subgroup	Suket Shale (including Kota Stone)
		Nimbahera Limestone
		Bari Shale
		Jiran Sandstone
	Lasrawan Subgroup	Binota Shale
		Kalmia Sandstone
	Sand Subgroup	Palri Shale
		Sawa Sandstone
	Satola Subgroup	Bhagwanpura Limestone
		Khairdeola Sandstone
		Khairmalia Andesite
	Unconformity	
	Berach Granites/ Bhilwara Metamorphics	Granites/Metamorphic Rocks

been discarded (Kumar, 1998). Thus, on the basis of the available information, it can be suggested that the age of the Vindhyan Supergroup can be bracketed within ca. 1800 – 600 Ma. However, Kumar *et al.* (2005) have suggested that the Vindhyan sedimentation ended around ca. 700 Ma.

Stromatolites of the Vindhyan Supergroup: There are a number of reviews available for the Vindhyan stromatolites, but the basic problem with all the reviews is that they have accepted the identification of all the reported forms without any critical evaluation as most of stromatolite forms are not identified on the basis of recommended methodology. In the present work we have included coniform stromatolites which are developed only in the Semri Group and are completely absent in the Bhander Group. As mentioned earlier the classification of coniform stromatolites as suggested by Vlasov (1977) has been followed. The following five forms are described from the Semri Group of the Son Valley section:

Calypso sp. and *Thyssagetes* sp. from the Kajrahat Limestone

Ephyaltes myriocranus, *Siren* sp. and *Cyathotes phorbadicia* from the Fawn Limestone

SYSTEMATIC DESCRIPTION

Incertae Sedis

Family **Thyssagetaceae** Vlasov, 1977

Genus ***Thyssagetes***

Thyssagetes sp. Vlasov, 1977

(Pl. I, figs. 1-3, Pl. VI, fig. 3; Fig. 2a-b)

Type species: *Thyssagetes odontophyes* Vlasov from the Lower Riphean, Lower Kussa (Nizhnekusinskaya) Member, the Satka Formation, western slope of the Southern Urals, vicinity of the city of Kuss.

Material: (YMPC 22/91) Five specimens from the Kajrahat Limestone, Chhoti Mahanadi, Khutesar, M.P.

Occurrence: These stromatolites occur in the Kajrahat Limestone (Semri Group) in Chhoti Mahanadi river section near Khutesar village, M.P.

Description: They are made up of deep conical laminae which are laterally linked with distinct concavas. In transverse section the columns are oval to elliptical in shape with outer laminae encircling other columns.

Column shape and arrangement: Colonies are made up of conical laminae which are laterally linked. At the base, the columns are about 30-50 cm in height and 8-30 cm in diameter but at the top they are up to 1 m in height and up to 40 cm in diameter. The distance between the two columns is about 10-40 cm. In transverse section, the columns are oval to elliptical in shape with outer laminae encircling other columns in continuation.

Lamina shape: The laminae are conical in the vertical section showing thickening in the crestal zone. The apical angle of the cone is 40 - 90° with sufficient height, laminae move away from crestal zone. In longitudinal section, the laminae bent backwards to become concave between two columns. Laminae are mostly smooth and have in general

EXPLANATION OF PLATE III

1. ***Siren*** sp., Fawn Limestone, Muni ki Pahari, Newari, (U.P.).
2. ***Siren*** sp., Fawn Limestone, Muni ki Pahari, Newari, (U.P.).
3. ***Siren*** sp., Fawn Limestone, Muni ki Pahari, Newari, (U.P.).

Plate III

constant thickness.

Crestal zone: All the laminae are thickened in the crestal zone of the columns. In general, the crestal zone is highly recrystallized and often no structure can be seen. The crestal zone is seen in the form of wavy vertical line joining the apices of each laminae. This becomes a weak zone along which a crack develops resembling stylolite seam which is filled with secondary material. The overall shape of the crestal zone resembles Type II of Komar *et al.* (1965) as there is no markedly lateral displacement in the crest.

Microstructure: Microstructure is predominantly streaky. Laminae are distinct in hand specimen and in field but poorly differentiable under microscope due to recrystallization and secondary alteration. Only at a few places where the rock is not much altered, remnants of laminae can be seen (Plate VI, fig. 1). In dark coloured laminae the grain size is mostly constant whereas in light coloured laminae grain size increases from the border to the centre of laminae. Ferruginous material is mostly segregated in light coloured laminae.

Comparison: The form resembles *Thyssagetes* sp. Vlasov from the Satka Formation, western slope of the Southern Urals. Specimens show close resemblance with *Conophyton* due to conical laminae and characteristic axial zone as described by Maslov. However, they are not isolated columns but instead are multimember colonies of stromatolites. These stromatolites differ from *Thesaurus* in having prominent cones and from *Cyclopium* in not having large relief.

In the Chhoti Mahanadi section, the *Thyssagetes* is associated with nonconiform columnar stromatolites which grow over *Thyssagetes*. At places, the composit form compares well with *Jacutophyton*. There are repeated cycles of this combination and at least 33 such cycles have been noted. It appears that *Thyssagetes* was developed in subtidal environment of deposition and the nonconiform columnar stromatolites represent deposition in intertidal-supratidal environment. Thus, each cycle represent a transgressive-regressive event.

Genus ***Calypso***

Calypso sp. Vlasov, 1977

(Pl. II, figs. 1-3; Fig. 2c-d)

Type species: *Calypso moneres* Vlasov from the Satka Formation of the southern Urals in the vicinity of Berdyaush.

Material: (YMPC 23/91) Six specimens from the Kajrahat Limestone, Chhoti Mahanadi, Khutesar village, M.P.

Occurrence: These forms occur near Khutesar village in Chhoti Mahanadi river section, Madhya Pradesh. It is developed in a 8 m thick unit underlying the horizon showing the colonies of *Thyssagetes* sp.

Description: Monomember colonies which sometimes retain direct links among themselves by means of long bridges or non-branching daughter colonies. The shape of the colonies is made up of ridges and convexas.

Column shape and arrangements: Colonies are laterally linked with one another. The daughter colonies are mostly separated from the parent colony. Adjoining colonies are linked by means of narrow bridges. The colonies are very closely spaced mostly 2-5 cm. The colonies have the shape of cones. In cross-section there is an irregular shaped ridge and most of the colonies emerge from this ridge. At the base, the dimensions are 1.5 to 8 cm (width of the colony). Some of them grow up to 50 cm in height. The secondary relief elements, that cover the colonies are parallel to one another or diverge laterally from the centre of the colony. However, some of these colonies can be seen developing individually up to 20 cm in height. The lateral linking or bridges give the appearance of narrow ridges. The ridge constitutes the main axis along which other daughter colonies have grown parallel to each other at about a right angle to the main axis.

Microstructure: It is not very distinct due to silicification and recrystallization (Pl. VI, fig. 2). Indistinct dark and light laminae are conical in shape with slight thickening in the crestal zone. Occasionally a crack is developed vertically following the crests of laminae. Light coloured laminae consist of ferroan calcite whereas dark coloured laminae are usually made up of sparitic dolomite. Laminae forming bridges are sometimes very thick. Light coloured laminae are composed of micritic calcite. Calcite and dolomite are disseminated so profusely that micro lamination is totally obliterated.

Comparison: It compares with *Calypso* sp. described by Vlasov (1977) from the Satka Formation of the southern Urals. *Calypso* shows similarity with *Chimaera* especially in their sculpture system. The main difference between the two is in form of individuality of the monomember colonies and the lesser development of relief.

Genus ***Siren***

Siren sp. Vlasov, 1977

(Pl. III , figs. 1-3; Fig. 2e)

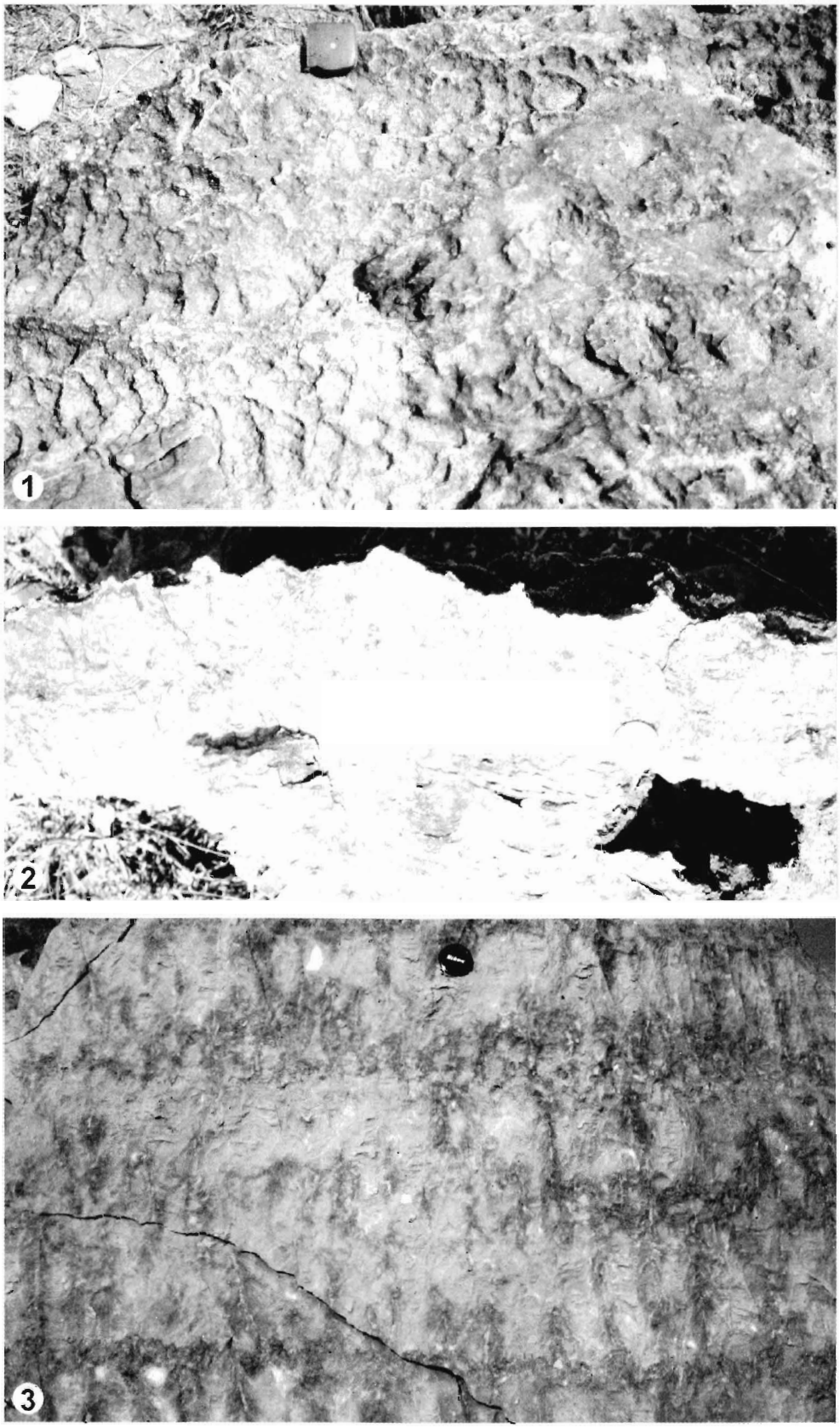
Type species: *Siren pyelodes* Vlasov, Lower Riphean, Lower Kussa Member, Satka western slope of the Southern Urals.

Material: (YMPC18/91) Seven specimens from the Newari area, U.P.

EXPLANATION OF PLATE IV

1. ***Cyathotes phorbadicia***, Fawn Limestone, Muni ki Pahari, Newari, (U.P.).
2. Transverse section ***Cyathotes phorbadicia***, Fawn Limestone, Muni ki Pahari, Newari, (U.P.).
3. Repeated cycles of ***Thyssagetes*** sp. and nonconiform stromatolites, Kajrahat Limestone, Chhoti Mahanadi section, Khutesar (M.P.).

Plate IV



Occurrence: These forms occur at Newari village in U.P. at Muni ki Pahari in the lower part of the Fawn Limestone. They are dark brownish in colour almost matching with the colour of the outcrop which is highly weathered.

Description: These stromatolites are made up of intersecting ridges with low cones at the cross points and large cocavities that are shallow. Cones and ridges of two or of several lower ranks develop very commonly. They mainly show conical laminae or ridges with an angle of 40-120° from the axis. Height reaches up to 9 cms in the main ridge with decreasing height in the intersecting ridges. The width of the main ridge is 16 cms with decreasing width in the intersecting ridges. The main ridges are parallel to each other and are between 30 to 40 cms apart. Some are curved and at times join each other. These ridges are usually parallel to each other and run up to 3 to 4 m. The smaller ridges are not always at right angles to the main ridge. Third order ridges are also developed from the secondary ridges. All the ridges show conical shape. The general orientation of the main ridges is WNW –ESE to NW – SE.

Lamina shape: Usually laminae are not clearly visible on the outcrop. Where visible, the laminae are conical, almost all the laminae are identical in a single column, except changes in slope occur at the margins. The slope of laminae on opposite sides of their crest is almost the same. Most of the laminae are nearly straight, occasionally becoming wavy at the margins. Laminae in longitudinal section sometimes show increase in thickness but for a very short distance of about 1 to 2 mm. Laminae in the axial zone become slightly thicker. Dark-coloured laminae are thin whereas light laminae are almost double the thickness of dark laminae. The crestal zone is significant due to thickening of laminae in this zone. Both the dark as well as light laminae thicken in this zone and become slightly wavy.

Microstructure: In thin sections light and dark laminae are not very clearly visible.

Comparison: This form is well comparable with *Siren* sp. described by Vlasov (1977) from the Lower Riphean of the Southern Urals. The form shows peculiar characteristics of parallel ridges and two to three distinct orders of relief with large but shallow concavas, ridges and cones.

Genus ***Cyathotes***

Cyathotes phorbadicia Vlasov, 1977

(Pl. IV; figs. 1-2; Fig. 2f)

Type species: *Cyathotes phorbadicia* Vlasov, Riphean Satka Formation; western slope of the Southern Urals, vicinity of the village of Berdyaush.

Material: (YMPC 20/91) Eight specimens from Newari village, U.P.

Mode of occurrence: These forms can be seen at the Muni ki Pahari near Newari village, Son Bhadra district, U.P. in the Fawn Limestone. They are developed in association with *Siren*. In outcrop they can be seen in the form of ridges forming hollow but shallow cup like structures.

Description: Multimember colonies with a relief of the concave type. No cones are present. Multigrammae and multistigmata of a higher order are typical features of this form.

Column shape and arrangements: They are arranged in the form of ridges which are 0.5 – 2 cm in height, all the ridges are joined in the form of mesh-like structure. In transverse section they are conical in shape with axial angle in the range of 60 - 120°. These ridges when joined make hollow cup-like depressions which are subrounded, ellipsoidal or ovate in plan view. Usually these ridges unite to make a polygon. The diameter of these concavas ranges from 3 cm to 6 cm and height ranges between 2-3 cm. Usually 3-4 ridges meet at one point to form a junction, this junction is raised about 0.5 cm above the main ridges. The ridges surrounding the concave have bend angle of 50° to 70°

Lamina shape: The laminae is not visible in outcrop. The rocks are highly weathered but stigmata and grammae are still visible to some extent on the ridges. These stigmata and grammae are absent in the concavas. The stigmata are very small in size ranging from 0.1 – 0.2 mm and are arranged very close to each other. Grammae can be seen linking these stigmata.

Comparison: This form can be very well compared with *Cyathotes phorbadicia* described by Vlasov (1977) from the Riphean Satka Formation; western slope of the Southern Urals, near the vicinity of the village of Berdyaush. *Cyathotes* differs with *Chimaera* which also shows concavas and ridges in having fewer stigmata and grammae. It differs from *Siren* and *Thesaurus* in the absence of prominent conical laminae, also it does not show a prominent development of axial zone which is characteristic of the other members of the Family *Thyssagetaceae*.

Genus ***Ephyaltes***

Ephyaltes myriocranus Vlasov, 1977

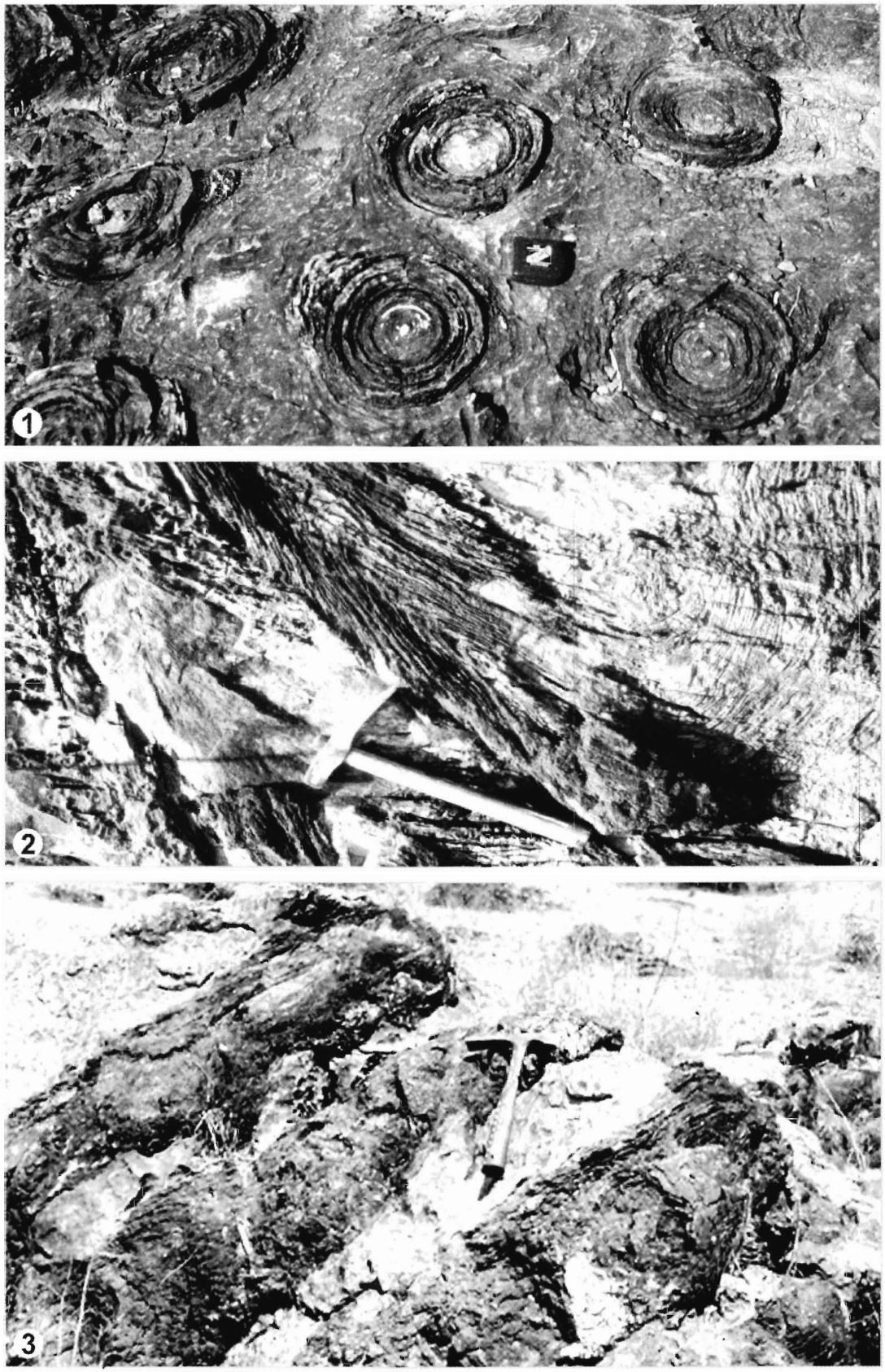
(Pl. V, figs. 1-3; Fig. 2g-h)

Type species: *Ephyaltes myriocranus* Vlasov, 1977 from the Satka Formation, western slope of Southern Urals, vicinity of Berdyaush.

EXPLANATION OF PLATE V

1. Transverse section of ***Ephyaltes myriocranus***, Fawn Limestone, Salkhan hill, Salkhan (U.P.).
2. Longitudinal section of ***Ephyaltes myriocranus***, Fawn Limestone, Salkhan hill, Salkhan (U.P.).
3. Inclined columns of ***Ephyaltes myriocranus***, Fawn Limestone, Salkhan hill, Salkhan (U.P.).

Plate V



Material: (YMPC 33/91) Two specimens from the Fawn Limestone, Salkhan, U.P.

Mode of occurrence: At Salkhan hill, *Ephyaltes myriocranus* is well preserved in the Fawn Limestone. Most of the columns show silicification.

Description: The colonies are multimember or monomember. The main relief element is the cone whose surface is marked by ridges. The relief surface is marked by poorly developed stigmata and grammae.

Column shape, size and arrangement: These forms are in the shape of cones. It is an assemblage of monomember colonies. These forms are usually very weakly linked with each other and deep concavities are not observed. The cones have a vertical or inclined orientation. The height of these columns varies from 20-100 cm, and a width of 10-30 cm at the base. Axial angle ranges from 30-40°. The height of the columns is more in the basal part as compared to the upper part where they are very scanty and not very well preserved. In transverse section they are almost rounded in shape.

Lamina shape: Laminae are conical. Almost all the laminae are identical in a single column except changes in slope which occur at margins. The slope of laminae on opposite sides of their crests is almost the same. Most of the laminae are nearly smooth, crinkling or waviness is usually not observed except in the axial zone. Laminae in transverse sections often show increase in thickness, but for a very short distance of about 1 to 2 mm. Laminae in the axial zone are thinner (0.05 mm) but away from centre they are about 1 mm to 1.5 mm thick. Alternate dark and light laminae are seen. Dark laminae are thin whereas light laminae are almost triple in thickness to dark laminae. The thicknesses of light coloured and dark laminae are not uniform throughout the sections.

Crestal zone: The crestal zone is the zone of maximum curvature and thickening of lamina. Both the dark as well as light coloured laminae are thickened in this zone. The thickening of laminae is more than 3 times that in the crestal zone.

Microstructure: In thin sections light and dark laminae are clearly visible (Pl. VI, fig. 3). The light laminae are thicker than dark laminae. They are about 0.5 mm to 1.2 mm at the margins and maximum 2.1 mm in crestal zone. The dark laminae are 0.02 to 0.75 mm in thickness and in crestal zone they show variable thickness ranging from 0.4 mm to 1.1 mm. The thickness of light laminae is more in the crestal zone as compared to dark laminae.

Comparison: This form is compared with *Ephyaltes myriocranus* described by Vlasov, 1977 from the Satka Formation, western slope of Southern Urals. The form differs from *E. gorgonotus* in the greater integrity of the multimember colony, the lesser number of ridges in the relief and the absence of concavas. Earlier, this form has been described as *Conophyton circularis* (Valdiya, 1969) and *Conophyton garganicum* (Kumar, 1976).

The black chert associated with *Ephyaltes* has yielded filamentous form (Kumar, 1978), and the black chert interbedded with overlying and underlying horizons of *Ephyaltes*-bearing zone has yielded well-preserved microbial assemblage mainly made up of both the coccoid and the filamentous forms dominantly of cyanobacterial affinity (McMenamin *et al.*, 1983; Kumar and Srivastava, 1995).

THE BHANDER GROUP

No coniform stromatolite has so far been recorded from the Bhander Group, though other columnar forms are well developed (Kumar, 1980; Prasad, 1984; Misra, 2004).

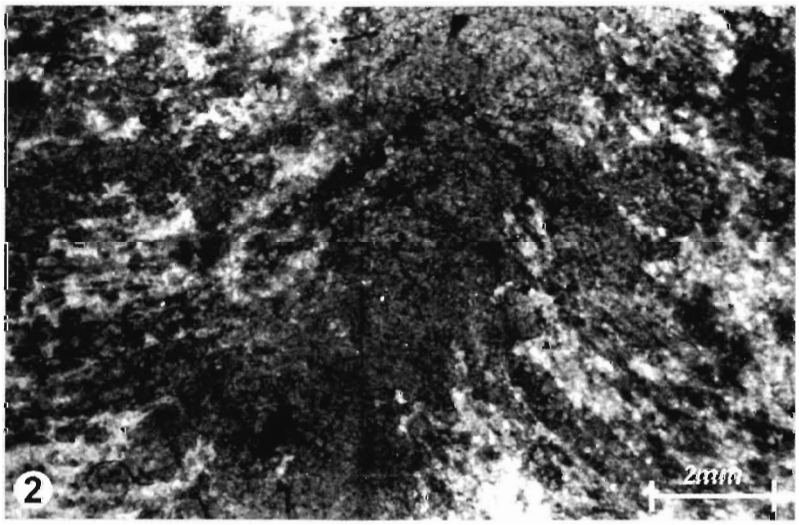
DISCUSSION

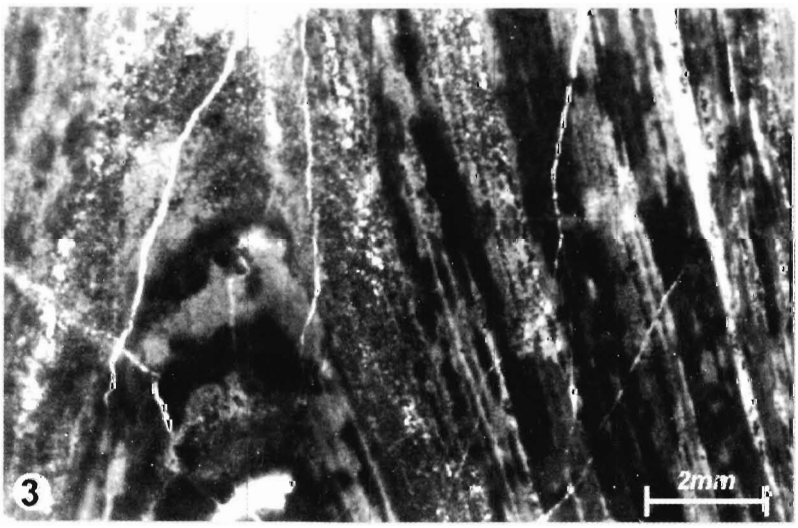
1. Five different types of coniform stromatolites are described from the Semri Group. They vary in size from a few cms to more than a meter and where ever they are present they are conspicuous by their presence. They have been reported both from the eastern as well as the western part of the Vindhyan Basin. But in the Bhander Group which is the youngest group of the Vindhyan Supergroup, not a single coniform stromatolite has so far been discovered, whereas nonconiform stromatolites are abundantly recorded. Thus, the absence of coniform stromatolites needs explanation. One possible explanation is that the coniform stromatolites flourished only between ca. 1800 Ma and ca. 1600 Ma but were absent in the Bhander Group whose age can be taken as somewhere between ca. 900 Ma and 700 Ma. The absence of coniform forms from the Bhander Group can be be linked to the evolution of microbial communities and not to the physical parameters as the environmental setting for both the Semri Group as well of the Bhander Group was comparable and stromatolites were profusely developed in both the groups. Thus, the presence of coniform stromatolites is a characteristic feature of the Semri Group while absence of these forms is a unique feature of the Bhander Group.
2. Since the Vindhyan sediments occupy a very large area of more than one hundred thousand square kilometers,

EXPLANATION OF PLATE VI

1. Photomicrograph of ***Thyssagetes*** sp. showing streaky lamination.
2. Photomicrograph of ***Calypso*** sp. showing streaky lamination and axial zone
3. Photomicrograph of ***Ephyaltes myriocranus*** showing banded structure and axial zone.

Plate VI





the presence and absence of coniform stromatolites in different groups can also be used for intrabasinal correlation.

3. The occurrences of coniform stromatolites as given by Vlasov (1977) from the Riphean Satka Formation compare well with the forms described from the Vindhyan Supergroup, indicating that these forms are typically present in the rocks of the Lower Riphean age. Thus, all the coniform stromatolites of the Semri Group suggest a Lower Riphean age. It follows from this that the Basal Formation, the Porcellanite Formation and the Kheinjua Formation can be bracketed with the Lower Riphean, and the the Rohtas Formation with the Middle Riphean. On the basis of the available radiometric dates, the age of the Semri Group can be taken as ranging from ~1800 to 1600 Ma. This age assignment is in broad agreement with the age given by the coniform stromatolites. Thus, it can be concluded that the stromatolites can be used for both intrabasinal and interbasinal correlations and age determination as well.
4. The repeated cycles of *Thyssagetes* and nonconiform columnar stromatolites represent trangressive-regressive events.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to Dr. P. Srivastava and Dr. Mukund Sharma for the help during the course of the investigation. Prof. H. J. Hofmann (McGill University, Canada) is thanked for his helpful comments on the orginal manuscript.

REFERENCES

Auden, J.B. 1933. Vindhyan sedimentation in Son Valley, Mirzapur district. *Mem. Geol. Surv. India*, **62**: 141-250.

Azmi, R.J. 1998. Discovery of lower Cambrian small shelly fossils and brachiopods from the Lower Vindhyan of Son Valley, Central India. *Jour. Geol. Soc. India*, **52**: 381–389.

Bhargava, O.N. and Srikantia, S. V. 2000. Vindhyan Fossil Controversy. *Jour. Geol. Soc. India*, **55**: 675–680.

Bhattacharyya, A. 1996. Foreword. Recent Advances in Vindhyan Geology (Ed. A. Bhattacharyya). *Geol. Soc. India, Bangalore*: i - viii.

Grey, K. 1989. Handbook for the study of stromatolites and associated structures. *Stromatolite News Letter*, **14**: 82–140.

De, C. 2003. Possible organisms similar to Ediacaran forms from the Bhander Group, Vindhyan Supergroup, Late Neoproterozoic of India. *Jour. Asian Earth Sci.* **21**: 387–395.

Friedman, G.M. and Chakraborty, C. 1997. Stable isotopes in marine carbonates: their implications for the palaeoenvironment with special reference to the Proterozoic Vindhyan carbonates (Central India). *Jour. Geol. Soc. India*, **50**: 131–159.

Kathal, P.K., Patel, D.R. and Alexander, P.O. 2000. An Ediacaran fossil *Spriggina* (?) from the Semri Group and its implication on the age of the Proterozoic Vindhyan Basin, Central India. *N.Jb. Geol. Palaönt. Mh.* **2000**(6): 321–332.

Komar, V.A., Raaben, M.E. and Semikhatov, M.A. 1965. Conophytons in Riphean of the USSR and their stratigraphic significance. *Tr. Geol. Inst. Akad. Nauk SSSR*, **131**: 72p. (in Russian).

Kreuzer, H., Harre, W., Kursten,M., Schnitzer, W.A., Murti, K.S. and Srivastava, N.K., 1977. K/Ar dates of two glauconites from Chanderpur Seris (Chhattisgarh/India). *Geol. Jahrb.* B**28**: 23-26.

Krishnan, M.S. 1968. *Geology of India and Burma*. Higginbothems (P) Ltd. Madras.

Krishnan, M. S. and Swaminath, J. 1959. The great Vindhyan Basin of northern India. *Jour. Geol. Soc. India*, **1**: 10–30.

Kumar, S. 1976. Stromatolites from the Vindhyan rocks of Son Valley-Maihar area, districts Mirzapur (U.P.) and Satna (M.P.) *Jour. Pal. Soc. India*, **18**: 13–21.

Kumar, S. 1978. Discovery of micro-organisms from the black cherts of the Fawn Limestone (Late Precambrian) Semri Group, Son Valley, Mirzapur district, U.P. *Curr. Sci.* **47**(13): 461.

Kumar, S. 1980. Stromatolites and Indian Biostatigraphy: A review. *Jour. Pal. Soc. India*, **23-24**: 166–183.

Kumar, S. 1984. Present status of stromatolite biostratigraphy in India. *Geophytol.* **14**(1): 96–110.

Kumar, S. 1998. Stable isotope in marine carbonates: their implications for the palaeoenvironment with special reference to the Proterozoic Vindhyan carbonates, central India. Discussion. *Jour. Geol. Soc. India*, **51**: 415–416.

Kumar, S. 2001. Mesoproterozoic megafossil *Chuaria – Tawuia* association may represent parts of a multicellular plant, Vindhyan Supergroup, central India. *Precamb. Res.* **106**: 187–211.

Kumar, S. and Gupta, S. 2002. International Field Workshop on the Vindhyan Basin, Central India. Field Guide Book. *Pal. Soc. India*, Luckow: 72p.

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

Kumar, S., Schidlowski, M. and Joachimski, M. M. 2005. Carbon isotope stratigraphy of the Palaeo-Newoproterozoic Vindhyan Supergroup, central India: implications for Basin evolution and intrabasinal correlation. *Jour. Pal. Soc. India*, **50**(1):65–81.

McMenamin, D.S., Kumar, S. and Awramik, S.M. 1983. Microbial fossils from the Kheinjua Formation of Middle Proterozoic Semri Group (Vindhyan) Son Valley Area, Central India. *Precamb. Res.* **21**: 247-271.

Misra, Y. 2004. Stromatolite Biostratigraphy of Vindhyan Basin. *Ph. D. Thesis, Lucknow University, Lucknow.*

Prasad, V. 1984. Geology, sedimentation and palaeogeography of the Vindhyan Supergroup, Southeastern Rajasthan. *Mem. Geol. Surv. India*, **116**(I): 1–107.

Raaben, M.E., Sinha, A.K. and Sharma. M. 2001. Precambrian stromatolites of India and Russia. Birbal Sahni Institute of

Palaeobotany, Lucknow: 1-125.

Raha, P.K. and Shastry, M.V.A. 1982. Stromatolites and Precambrian stratigraphy in India. *Precamb. Res.* **18**: 293–318.

Rasmussen, B., Bose, P.K., Sarkar, S., Banerjee, S., Fietcher, I.R. and McNaughron, N.J. 2002. 1.6 Ga U-Pb zircon age for the Chorbat Sandstone, Lower Vindhyan, India: Possible implications for early evolution of animal. *Geol.* **30**: 103-106.

Ray, J.S., Marin, M.W., Veizer, J. and Bowning, S.A. 2002. U-Pb. zircon dating and Sr isotope systematics of the Vindhyan Supergroup, India. *Geol.* **30**: 131-134.

Ray, J.S., Veizer, J. and Davis, W.J. 2003. C, O, Sr and Pb isotope systematics of carbonate sequence of the Vindhyan Supergroup, India : age, diagenesis, correlations and implications for global events. *Precamb. Res.* **121**: 103-140.

Sarangi, S., Gopalan, K. and Kumar, S. 2004. Pb-Pb age of earliest megascopic , eukaryotic alga bearing Rohtas Formation, Vindhyan Supergroup, India: implications for Precambrian atmospheric oxygen evolution. *Precamb. Res.* **132**: 107–121.

Valdiya, K.S. 1969. Stromatolites of the Himalayan carbonate formations and the Vindhyans. *Jour. Geol. Soc. India*, **10**: 1–25.

Valdiya, K.S. 1989. Precambrian stromatolite biostratigraphy of India - A review. *Him. Geol.* **13**: 181–214.

Venkatachala, B.S., Sharma, M. and Shukla, M. 1996. Age and Life of the Vindhyans – Facts and Conjectures. *Mem. Geol. Soc. India*, **36**: 137–165.

Vinogradov, A.P., Tugarinov, A.I., Zhirkov, C.I., Stupnikova, N.I., Bibikov, E.V. and Khorre, K. 1964. Geochronology of Indian Precambrian. *Report 22nd Int. Geol. Cong. New Delhi*, **10**: 553-567.

Vlasov, F. Yu., 1977. Precambrian stromatolites from the Satka Formation in southern Urals. *Akademiya Nauk SSSR. Trudy Instituta geologii I geokhimii.* **126**: 1–52.

Manuscript Accepted September 2005