Palaeobiology of Vindhyan

P. K. Maithy

Maithy PK 1992. Palaeobiology of Vindhyan. *Palaeobotanist* **40** : 52 72.

Biological remains and their activities, preserved in the form of ichnofossils and organosedimentary structures in the Vindhyan sediments are critically reviewed. The diversification of metaphytes and metazoans and their significance in biostratigraphy have also been discussed.

Key-words—Palaeobiology, Stromatolites, Metaphytes, Metazoans, Precambrian, Vindhyan, India.

P. K. Maithy, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

सारांश

विन्ध्य का पुराजैविक अध्ययन

प्रभात कुमार माइती

विन्ध्य अवसादों में इक्नोजीवाश्मों एवं कार्बनिक-अवसादी संरचनाओं के रूप में परिरक्षित जैविक अवशेषों तथा उनकी गतिविधियों की विवेचना की गई है। मेटाफ़ाइटीयों एवं मेटाजीवीयों में विभिन्नता तथा जैवस्तरविन्यास मे इनकी उपयोगिता की भी समीक्षा की गई है।

THE Vindhyan Supergroup of central India exhibits well developed stratified formations of sandstones, shales and limestones covering a thickness over ca. 4,200 meter of Middle to Late Proterozoic age (1,400-570 Ma). The Vindhyan Basin has an exposed area of 1,04,000 square kilometers from Sasaram and Rohtas in western Bihar to Chittorgarh on the Aravallis, with the exception of a central track in Bundelkhand, where a large area of Vindhyan rocks is covered by the Deccan trap and Gangetic alluvium. The maximum breadth of the outcrop is seen between Agra and Neemuch.

The Vindhyan Supergroup is composed of two distinct facies of deposits: a marine, calcareous and argillaceous, characteristically developed in the lower part and the other almost exclusively arenaceous of fluviatile or estuarine deposits forming the upper part. The shale, limestone and sandstone strata show very little structural displacement or disturbance of their primeval characters. They have preserved almost their original horizontality of deposition over wide areas. The shales have not developed cleavages nor have the limestones undergone any degree of crystallisation.

The Vindhyan sandstones throughout their thickness provide evidence of shallow water deposition in their often occurring ripple-marked and sun-cracked surfaces and their conspicuous current bedding or diagonal lamination characters which point shallow agitated water of the coast near the mouth of rivers and the constantly changing velocity and direction of its currents.

The Vindhyan geological succession, is as under

GROUP	FORMATION
	Dholpur Shale
	Balwan Limestone
	Maihar Sandstone
	Sirbu Shale
Bhander	Lower Bhander Sandstone
	Nagod Limestone
	Ganurgarh Shale
	Upper Rewa Sandstone
	Jhiri Shale
Rewa	Lower Rewa Sandstone
	Panna Shale
	Mangesar Sandstone

Four Decades of Indian Palaeobotany
Editors . B. S Venkatachala & H. P. Singh
Publisher : Birbal Sahni Institute of Palaeobotany, Lucknow

Kaimur	Bijaigarh Shale
	Gurma Sandstone
	Rohtas Limestone
	Basuhari Sandstone
	Bargawan Limestone
Semri	Kheinjua Shale
	Chopan Porcellanite
	Kajrahat Limestone
	Arangi Shale
	Patherwa Sandstone & Conglomerates

RADIOMETRIC DATES

On the basis of Potassium-Argon dates Vinograd *et al.* (1964) estimated the age of glauconitic sandstone as 1,110 ± 60 Ma. According to them, the age of the Lower Vindhyan (Semri) Group is between 1,100 to 1,400 Ma. Accordingly the Kaimur sequence has been estimated to range from 910 to 940 Ma by these authors. Rubidium-Strontium dates of the Vindhyan rocks by Crawford and Compston (1970) have revealed that the age of this unit extends over a very long period ranging from atleast 1,200 or possibly 1,400 Ma to perhaps 550 Ma or even later. According to these authors the base of Upper Vindhyans is about 1,150 Ma or more. Pichamuthu (1971) has indicated that the base of the Vindhyan is probably 1,400 Ma and the Upper Kaimur about 910 Ma. No dates are available for fixing the upper age limit of the Vindhyans. Recently dating of Vindhyan has been done by the fission-tracks on the surface of an authigenic mineral glauconite (Srivastava *et al.*, 1983). Systematic dating work has been carried out in the eastern part (Srivastava, 1985, 1987; Srivastava *et al.*, 1985, 1988), western part (Srivastava & Rajagopalan, 1986a, 1987, 1990) and central part (Srivastava, 1987; Srivastava & Rajagopalan, 1985, 1986b, 1989a, b) of the Vindhyan Basin. This study has indicated that the glauconitic sandstone bed in Chopan area is of 1,155 Ma age and belongs to Kheinjua Formation of the Lower Vindhyan. The Vindhyan deposits in Chitrakut area represent a condensed sequence with age ranging from 1,030 to 1,380 Ma and the pellet limestone forms the marker bed for this area indicating the age of 1,100-1,200 Ma. Glauconitic sandstone bed around Rawatbhata area, Rajasthan belonging to Upper Rewa Sandstone Formation is 740 Ma and that of Karauli area of Lower Bhander Sandstone Formation is 650 Ma.

BIOLOGICAL LIFE AND ITS ACTIVITIES

During the last four decades biological life and its relics of activities have been reported from the Vindhyan sequence from time to time. Most of these records are being reported only in the last two decades.

The evidences of the biological life are preserved as detailed below:

Structural biological remains

(i) Macrofossils

(ii) Organic-walled microfossils

Activities of biological life

(i) Ichnofossils

(ii) Organosedimentary structures, viz., stromatolites

Structural Biological Remains

The reported Vindhyan fossils mostly leaves an interpretation hurdle regarding their biologic origin. Living systems are identified by showing their capabilities for reproduction, mutation and reproduction of the mutation. These properties are not readily identifiable in most primitive fossils. Therefore, the under mentioned criteria are used jointly whenever possible for establishing biologic origin of the remains.

1. Evidences for the performance of vital functions: (a) fossilisation while performing a vital activity; for example, cell division. (b) morphologic or material evidence attributable to a biologic function.
2. Cellular differentiation combined with morphologic consistency
3. Similarities to living or known extinct forms
4. Morphological diversity in an assemblage
5. Chemical evidences.

These criteria are best applicable to higher biologic taxa, however, this facility is greatly reduced when dealing with the ancient biological remains of Vindhyan time. Not only the fossils are less abundant and little known, but they are also morphologically more primitive. We still have no unequivocal way of knowing whether the large impressions of discs or the micro-sized spheroids seen in a thin section or maceration represent the remains of reproducing mutating entities or are physiochemical structures. Therefore, the confirmation for the biologic origin is when we can observe a variety of associated, morphologically distinct remains resembling the modern. As such observations have not been possible in most of the Vindhyan remains, therefore, many of them still remain to be probably biogenic.

MACROBIOTA

Macrofossil records are tabulated below:

Year	Author	Macrofossils	Horizon & Locality
1950	Misra & Bhatnagar	Carbonaceous discs	Rohtas Limestone, Banjari
1954	Sahni & Shrivastava	*Krishnania*	Suket Shale, Ramapura
1966	Prakash	?Brachiopod	Kajrahat Limestone, Chopan
1977	Tandon & Kumar	*Katnia* & *Vindhyania*	Rohtas Limestone, Katni
1982	Sisodiya	? Jelly fish	Rohtas Limestone, Mandsor.
1982	Mathur	*Chuaria circularis* *Tawuia suketensis* *Vindhyania jonesi*	Suket Shale, Ramapura
1984	Maithy	Jelly fish	Suket Shale, Ramapura
1984a	Maithy & Shukla	*Chuaria minima*	Suket Shale, Ramapura
1984b	Maithy & Shukla	*Ramapuraea*	Suket Shale, Ramapura
1986	Maithy *et al.*	*Sekwia* & Trace fossil,	Rohtas Limestone, Rohtas
1986	Maithy & Babu	*Misraea*	Chopan Porcellanite, Chopan
1988	Maithy & Babu	*Tawuia*, *Chuaria* cf. *Sekwia* *Longfengsahnia*	Rohtas Limestone, Chopan
1989	Maithy	Middle Proterozoic & Ediacaran biota	Rohtas & Dholpura Shale

Pre-vendian Forms

Misraea Maithy & Babu 1986

Spongy body fossil, keel form, outline triangular to subtriangular, surface convexly raised with inner hollow dipression, body margin curved inwardly forming a rim, rim area smooth or with transverse thickenings.

Remarks—The affinities of this body fossil is debatable and with the present state of knowledge, it is extremely difficult to assign them to any known group of Metazoan. In their overall organisation it is speculated that they may be the portions of bivalved forms. If this is true, then these forms are the oldest Metazoan.

Misraea vindhyanensis Maithy & Babu 1986

Occurrence—Chopan Porcellanite, Chopan, Mirzapur District (Maithy *et al.*, 1986, p. 225, pl. 1, figs 1-6).

Misraea psilata Maithy & Babu 1986

Occurrence—Rohtas Limestone, east of Markundi (Maithy *et al.*, p. 225, pl. 1, fig. 7).

Chuaria Walcott 1899

Platyspermic carbonaceous discs, commonly solitary, rarely in pairs, circular or oval in outline, measuring 2-4 mm, surface smooth or with marginal thickenings; occasionally in some specimens a small central area is marked indicating possible opening. Isolated specimens show exine with fine puncta referable to *Orygmatosphaeridium* Timofeev.

Remarks—Though, these circular disc-like forms are known from the Proterozoic succession nearly a century ago, but their biological nature is still enigmatic. Recently Maithy and Shukla (1984) considered them to be the cyst structures belonging to algae. Contrary to this Sun (1986) expressed the view that they may be discs enclosing Cyanophyceae algae.

Chuaria minima Maithy & Shukla 1984

Synonymy

For list of synonymy, see Maithy and Shukla, 1984, pp. 146-147.

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1984); Rohtas Formation, Son Valley (Maithy & Babu, 1988, p. 586, pl. 1, figs 1-2).

Shoubsienia Xing 1979

Oval to dumbbell-shaped carbonaceous macrobiota, measuring 3-5 mm long and 2-3 mm broad, one end broader than the other, margin entire, surface smooth.

Remarks—*Shoubsienia* Xing (in Du Rulin, 1982) represents oval planktonic forms allied to *Chuaria*.

Shoubsienia shoubsiensis Xing 1979

Synonymy

1984 *Chuaria minima* emend. Maithy & Shukla, partim p. 148, pl. 1, fig. 5.

Occurrence—Suket Shale, Ramapura, Madhya Pradesh; Rohtas Limestone, Murlipahar, Rohtas District.

Ramapuraea Maithy & Shukla 1984 emend.

Synonymy

1989 *Cyclomedusa* sp., Sprigg *in* Shukla, Venkatachala & Sharma, p. 1012, figs 3-4.

Emended diagnosis—Circular carbonised impressions with a distinct central circular area with numerous small compactly packed globular structures; outer area with several closely spaced fine dichotomising radial thickenings.

Ramapuraea vindhyanensis Maithy & Shukla, 1984

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1984, p. 213, pl. 1, figs 1-3).

Remarks—*Ramapuraea* is found associated with *Chuaria* Walcott. It differs from *Chuaria* in possessing distinct central area, which is compactly packed with several small globular structures (Pl. 1, fig. 2). Presence of number of globular structures raises doubt about its jelly fish affinity. In all probability, it compares with the members of the family Chlorococaceae, viz., *Chlorococum*,

Neochloris, Pulchrasphaera and *Neospongiococcum*. Shukla *et al.* (1989, p. 102, figs 3-4) suggested its comparison with *Cyclomedusa* Sprigg. *Ramapuraea* in its size is much smaller than *Cyclomedusa*. Moreover the concentric circular thickenings around central zone characteristic for *Cyclomedusa* are absent.

Amjobrea gen. nov.

Diagnosis—Carbonised impression, outline circular with a large structureless inner body, covering half to three fourth of the overall body dimension; concentric and radial thickenings absent.

Genotype—Amjobrea rohtaseae sp. nov.

Comparison—Amjobrea gen. nov. is found associated with *Chuaria* and is characterised by its large size and with large inner body. *Ramapuraea* Maithy & Shukla 1984 differs from *Amjobrea* in being smaller and in having fine branched radial thickenings. *Sekwia* Hofmann 1981 distinguishes itself in the presence of raised inner body with globular structures. Moreover *Sekwia* is known from the Vendian strata.

Amjobrea rohtasae sp. nov.

Synonymy

1950 Carbonaceous disc-like bodies, Misra & Bhatnagar, p. 88, fig. 1.
1984 *Chuaria minima* emend. Maithy & Shukla, partim, Pl. 1, fig. 2.
1986 *Sekwia excentrica* Hofmann *in* Maithy, Narain & Sarkar, p. 1029, fig. 1.
1988 *Sekwia excentrica* Hofmann *in* Maithy & Babu, p. 586, pl. 1, figs 7-8; pl. 2, fig. 1.

Diagnosis—Carbonaceous impressions, circular to sub-circular measuring 10-40 mm; central area circular, covering nearly one half to three fourth area of the body. Surface thickenings absent. Marginal thickenings often preserved.

Holotype—Specimen no. BSIP 36862.

Locality—Murlipahar, Rohtas District, Rohtas Formation (Semri Group); Vindhyan, ± 1,000 Ma.

Occurrence—Rohtas Formation, Murlipahar, (Maithy *et al.*, 1986); and Chopan (Maithy & Babu, 1988).

Remarks—Misra and Bhatnagar (1950) reported black (carbonaceous) disc-like bodies, measuring 26 mm with a prominent border from the carbonaceous limestone beds of Rohtas Formation exposed in Banjari Quarry, Rohtas District. They considered them to be the plant remains. Maithy *et al.* (1986) reported large discs with inner body from the Rohtas Formation of Amjohre and referred them to *Sekwia* Hofmann. Subsequently, Maithy and Babu (1988) also reported similar forms the Rohtas Formation of Chopan under *Sekwia*. As pointed above that these Rohtas forms do not fit in the generic circumscription of *Sekwia* due to flat inner body, therefore, the previously described forms from the middle Proterozoic of Vindhyan are now transferred here to a new genus *Amjobrea*.

Tawuia Hofmann 1979 (in Hofmann & Aitken, 1979)

Carbonaceous impressions and compression, sausage-shaped, both ends rounded, surface smooth.

Remarks—Maithy and Babu (1988) recorded *Tawuia* and *Chuaria* together on the same rock specimen supporting their planktonic nature.

Tawuia dalaensis Hofmann 1979

Synonymy

1954 'Filament-like structure' Sahni & Shrivastava, p. 40, fig. 2.
1975 'Filament-like structure' Sahni, p. 293, fig. 2.
1984 Megascopic algal remains, Maithy, p. 5, fig. 5.
1984 *Chuaria minima* emend. Maithy & Shukla, Partim, p. 148, pl. 1, fig. 5.

Occurrence—Suket Shale, Ramapura (Maithy & Shukla, 1984, p. 213, pl. 1, fig. 4); Rohtas Limestone, Chopan (Maithy & Babu, 1988, p. 585, pl. 1, figs 1, 2).

Katnia Tandon & Kumar 1977 emend.

Emended diagnosis—Carbonaceous impressions of sausage-shape forms with distinct transverse partitions, ends rounded or pointed.

Holotype—Katnia singhii Tandon & Kumar 1977.

Remarks—Tandon and Kumar (1977) considered *Katnia* to be an annelid remain due to the presence of transverse partitions. However, this Middle Proterozoic macrobiota does not exhibit any other character by which it can be considered that they are like annelids. However, Glaessner (1987) expressed the views that *Katnia* may be large oscillatorean Cyanobacteria. Maithy (1990) opined that *Katnia* may be episodic remains of plankton blooms of mass encystment structures, i.e., algal in nature. This opinion now seems to be more justifiable as the specimens show close morphological similarity with *Tawuia* Hofmann except for the presence of transverse thickenings.

Katnia singhi Tandon & Kumar 1977

Occurrence—Rohtas Limestone, Semri Group, Tikaria about 2 km SW of Katni.

Katnia attenuata sp. nov.

Synonymy

1988 Ichnogenus : Type 'A' Maithy & Babu, p. 588, pl. II, figs 6 & 7.

Diagnosis—Elongated structure with both the ends attenuated, measuring 20-50 mm in length and 15-30 mm wide, transverse thickenings at an interval of 2-4 mm, each partitioned area may have a faint circular dipression.

Holotype—Specimen no. BSIP 36113.

Locality—Railway cutting near Saikhan Hill, Ghurma Shale, Kaimur Group.

Comparison—*Katnia singhii* Tandon & Kumar 1977 from Rohtas Limestone, Semri Group differs from *Katnia attenuata* in having blunt ends.

Grypania Walter, Oehler & Oehler 1976

Carbonised impression of linear unbranched filament, evenly curved, ends broken, surface smooth to finely granulate, no transverse septa perceptible.

Grypania spiralis Walter, Oehler & Oehler 1976

Synonymy :

1919 Spiral impression, Beer, p. 120, fig. 30.

1983 *Spiroichnus beeri* Mathur, p. 112, figs 1, 2.

Occurrence—Rohtas Formation; Murlipahar and Amjohre, Rohtas District.

Daltaenia Hofmann 1985

Slender, broadly curvilinear, untwisted ribbon-like structures of uniform submilimetric to milimetric width and centimetric length, apparent infrequent lateral branching.

Daltaenia mackenziensis Hofmann 1985

Synonymy :

1989 Megascopic sheet algae cf. *Vendotaenia* Gnilovaskaya *in* Shukla, Venkatachala & Sharma, p. 1012, figs 5-6.

1990 *Tyrastaenia* sp. Shukla & Sharma, pl. 3, fig. 1.

Occurrence—Suket Shale, Ramapura, Madhya Pradesh.

Remarks—The carbonaceous film claimed to be cf. *Vendotaenia* described by Shukla *et al.* (1989) do not conform to the diagnosis of *Vendotaenia* as the authors failed to isolate cellular material. Subsequently, Shukla and Sharma (1990) have transferred this specimen to *Tyrasotaenia* sp. The original specimens of *Tyrasotaenia* are unbranched. The figured specimen by Shukla and Sharma (1990) shows distinct branching, therefore, it compares with *Daltaenia* Hofmann and is synonymous.

Krishnania Sahni & Shrivastava 1954 emend. Maithy 1991

Carbonaceous biota comprising a foliate part and a parstem appearing stalk-like. Foliate part oval to circular in shape, surface smooth to structured.

Krishnania acuminata Sahni & Shrivastava 1954 emend. Maithy 1991

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Sahni & Shrivastava, 1954, p. 40, figs 2, 3); Rohtas, Katni (Tandon & Kumar, 1977, p. 127, fig. 2b, c); Rohtas, Murlipahar, Rohtas District (Maithy, 1991, figs 1-4).

→

PLATE 1

1. *Shouhsienia shouhsiensis* Xing, Specimen no. BSIP 36538; Amjohre, Bihar; Rohtas Formation, Semri Group.
2. *Ramapuraea vindhyanensis* Maithy & Shukla, Specimen no. BSIP 27341; Ramapura, Madhya Pradesh; Suket Shale Formation, Semri Group. × 10.
3. *Amjohrea rohtaseae* gen. et sp. nov., Specimen no. BSIP 36862; Murlipahar, Bihar; Rohtas Formation, Semri Group.
4. *Katnia attenuata* sp. nov., Specimen no. BSIP 36113; in railway cuttings 2 km WNW of Agori Khas railway station; Ghurma Shale Formation, Kaimur Group × Nat. size.
5. *Krishnania acuminata* emend. Maithy, Specimen no. BSIP 35968; Murlipahar, Bihar; Rohtas Formation, Semri Group.
6. *Cyclomedusa davidi* Sprigg, Specimen no. BSIP 36388; Bhavpura, Rajasthan; Dholpura Shale Formation, Bhander Group. × 1.
7. *Medusinites asteroides* Glaessner & Wade, Specimen no. BSIP 36392; Bhavpura, Rajasthan; Dholpura Shale Formation, Bhander Group. × 1.
8. *Nuia tandoni* (Maithy & Gupta) n. comb., Slide no. BSIP 5950; Mhow, Madhya Pradesh; Hinaoti Limestone, Semri Group. × 50.
9. *Biocatenoides sphaerula* Schopf, Slide no. BSIP 6590; West of Baisa, Madhya Pradesh; Nagod Limestone, Bhander Group. × 1000.
10. *Gloeocapsomorpha karauliensis*, Maithy & Mandal, Slide no. BSIP 5993; Near wall of Ranipura, South-east of Karauli; Semaria Shale, Bhander Group. × 1000.
11. *Aphanocapsaopsis sitholeyii* Maithy & Shukla, Slide no. BSIP 6587; Jurmani, Madhya Pradesh; Baghwar Shale, Semri Group. × 500.
12. *Vindhyacapsiopsis bhanderensis* Maithy & Mandal, Slide no. BSIP 6254; North of Karauli; Upper Bhander Sandstone, Bhander Group. × 500.
13. *Vetronostocale amoenum* Schopf & Blacic, Slide no. BSIP 9784-J27; Badanpur Limestone Quarry; Rohtas Limestone, Semri Group. × 1000.
14. *Bavlinella faveolata* Shepeleva; Slide no. BSIP 9791 052/2; Lilji nala, Madhya Pradesh; Nagod Limestone, Bhander Group. × 1000.
15. *Protosphaeridium volkovae* Maithy & Shukla; Slide no. BSIP 9783-W42; Sharda Devi Hill, Madhya Pradesh; Sirbu Shale, Bhander Group. × 1000.
16. *Lophosphaeridium jainii* Salujha *et al.*; Slide no. BSIP 9766-I 29; Sharda Devi Hill, Madhya Pradesh; Sirbu Shale, Bhander Group. × 1000.

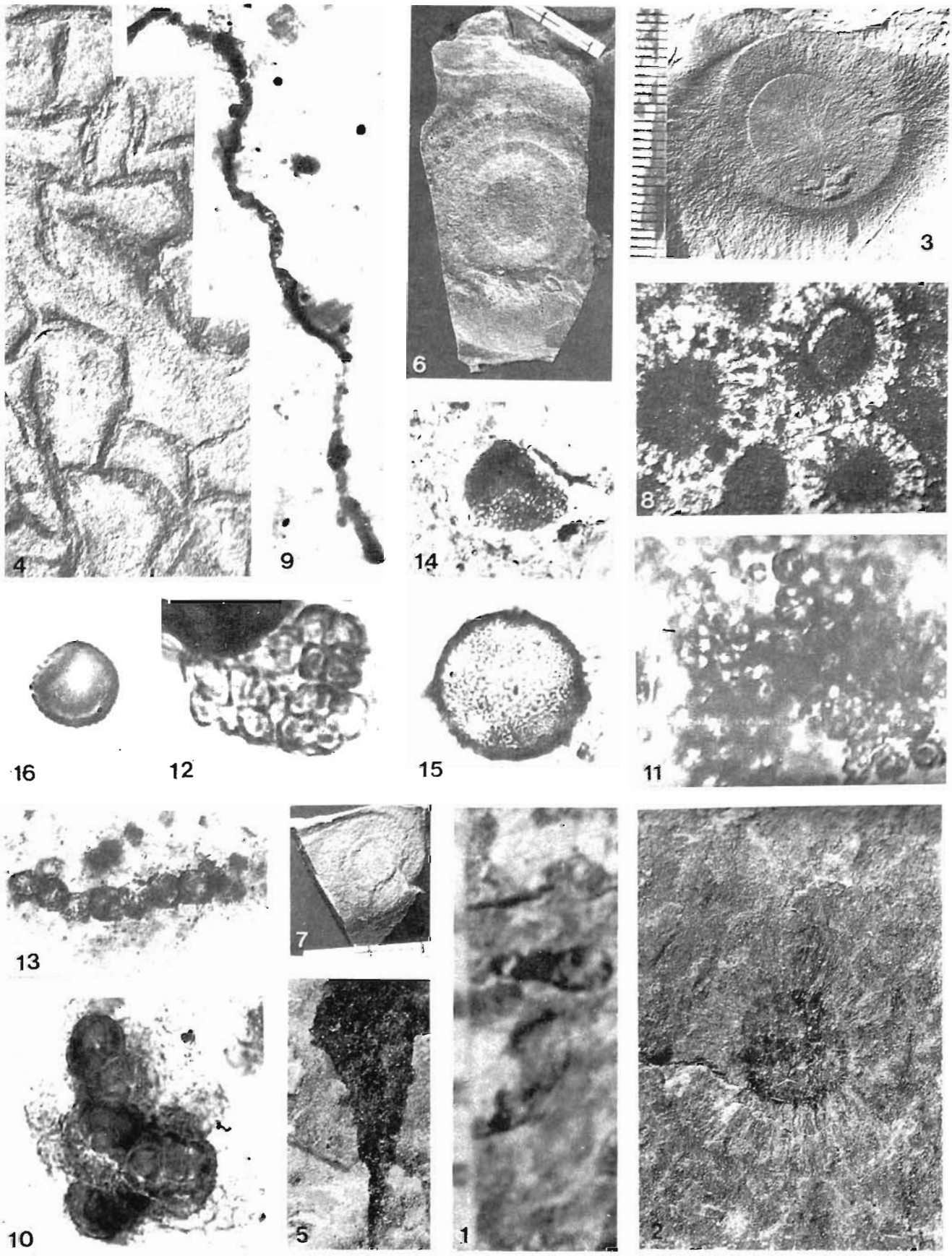

PLATE 1

Krishnania multistriata Maithy 1991

Occurrence—Rohtas, Baulia, Rohtas District (Maithy, 1991, figs 6-9).

Vendian Forms

Cyclomedusa Sprigg 1947

Outline subcircular, surface of disc with several to many concentric grooves separating slightly elevated area (rugae); their arrangement indicates an original conical shape at the center or in some species on most of the body. Many specimens show fine straight radial grooves.

Cyclomedusa davidi Sprigg 1947

Occurrence—Dholpura Shale, Bhavapura, Rajasthan (Maithy, 1989; Maithy *et al.*, 1992, figs 1-4).

Medusinites Glaessner & Wade 1966

Small, subcircular, discoidal bodies with central discs separated by deep circular groove from large outer ring with radius greater than central disc, there is a narrow marginal flange.

Medusinites asteroides (Sprigg) emend. Glaessner & Wade 1966

Occurrence—Dholpura Shale, Bhavapura, Rajasthan (Maithy, 1989; Maithy *et al.*, 1991, figs 3-5).

Dickinsonia Sprigg 1947

Broad, flat with numerous short segments, anterior body, segments fused pre-orally along median line, segmental furrows depressed dorsally and ventrally.

cf. *Dickinsonia*

Occurrence—Dholpura Shale, Bhavapura, Rajasthan (Maithy 1989).

?Calcareous Algae

Nuia Maslov 1954

Remarks—According to Maslov (1954) *in* Johnson, 1966, p. 73) the thalli of *Nuia* develop calcareous cylinders with a distinct central duct. Numerous very fine calcareous plates or needles radiate in all directions from the central duct, giving a radial structure to the cylinders in cross section. The thalli may be straight or sinuous.

The systematic position of the genus is quite uncertain; superficially it looks like a small primitive dasyclad alga. However, the supposed primary branches consist of flattened blade-like plates of calcite instead of rounded needle-like or thread-like elements. Preservation is not characteristic of Dasycladaceae. Based on this character, Johnson (1966) suggested its structural closeness to *Microcodium* Glük, possibly a blue green algae.

Maithy and Gupta (1981) reported Archaeocyatha, *Ajacicyathus tandoni* from the Hinaoti Limestone Formation, Semri Group and *Tubocyathus vindhyanensis* from the Nagod Limestone Formation, Bhander Group. Zhuraleva (1986) has doubted their identification. The so-called reported forms of Archaeocyatha show similarity with *Nuia* Maslov, therefore, they have been transfered to this genus.

Nuia tandoni (Maithy & Gupta) n. comb.

Synonymy :

1981 *Ajacicyathus tandoni* Maithy & Gupta, p. 78, pl. 1, figs 1-3; text-fig. 1.

Emended diagnosis—Thalli develop as a very small calcareous cylinder (measuring up to 300 μm) with a distinct central duct. Numerous very fine calcareous plates or needles radiate in all directions from the central duct giving a radial structure to the cylinders in cross section. Thalli may be straight or sinuous.

Occurrence—1.4 km N, 46° W of Mhow (82° 38′ 00″ : 38° 23′ 80″); Hinaoti Limestone, Semri Group.

Nuia vindhyanensis (Maithy & Gupta) n. comb.

Synonymy :

1981 *Tubocyathus vindhyanensis* Maithy & Gupta, p. 79, pl. 1, figs 4-7; text-fig. 2.

Emended diagnosis—Thallus develops as a small calcareous cylinder (measuring up to 225 μm) with a distinct central duct. Numerous anastomosing very fine, calcareous plates or needles radiate in all directions from central duct giving a radial structure to cylinder in cross section. The thalli may be straight or sinuous.

Occurrence—1.1 km S, 55°E of Kulwarn (83°00′00″ : 38°08′00″); Nagod Limestone, Semri Group.

ORGANIC-WALLED MICROFOSSILS

Acid maceration and thin section have allowed the identification of organic-walled microfossils belonging to Sphaeromorphs (Acritarch), filamentous taxa (Nematomorphs), spherical cells arranged in colonies (Synaptomorphs) and vase-shaped microfossils. Their previous records from Vindhyans are summarised below:

Year	Author	Locality	Group
1953	Sitholey *et al.*	Ramapura	Semri
1968	Maithy	Ramapura	Semri
1971	Salujha, Rehman & Arora	Sidhi	Semri & Kaimur

1971	Salujha, Rehman & Rawat	Kota-Karauli	Rewa & Bhander
1972	Shrivastava	Ramapura	Semri
1974	Sarkar	Maihar	Bhander
1977	Maithy & Shukla	Ramapura	Semri
1978	Kumar	Chopan	Semri
1983	Maithy & Gupta	Chandrehi	Semri, Rewa & Bhander
1983	Maithy & Mandal	Karauli-Sapotra	Semri & Bhander
1983	McMenamin, Kumar & Awramik	Chopan	Semri
1983a	Nautiyal	Chopan	Semri
1983b	Nautiyal	Chopan	Semri
1984	Nautiyal	Sangrampur	Tirohan
1988	Maithy & Babu	Chopan	Semri & Kaimur
1989	Maithy & Meena	Satna, Maihar	Bhander

Biocatenoides Schopf 1968

Uniseriate, unbranched chains of rod-shaped coccoid cells, less than 1 μm, broad chains up to 200 μm long or more, straight or recurved.

Biocatenoides sphaerula Schopf 1968

Synonymy :

1989 *Gunflintia minuta* Barghoorn 1965 *in* Maithy & Meena, p. 181, pl. 1, figs 5-7, 10-19.

Occurrence—Nagod Limestone, Chandrehi, Madhya Pradesh (Maithy & Gupta, 1983, p. 158, pl. 1, fig. 1); Nagod Limestone, Satna, Madhya Pradesh (Maithy & Meena, 1989, p. 181, pl. 1, figs 5-7, 10-19).

Remarks—The specimens described by Maithy and Meena (1989) under *Gunflintia minuta* do not conform to the generic circumscription of *Gunflintia*. Rather it conforms to that of *Biocatenoides*.

Huronispora

Solitary cells, spherical, exine smooth to microreticulate, enveloping sheath absent.

Remarks—Sarkar (1974, figs 5B-E) recorded *Huronispora* sp. from the Bhander Limestone. The presence of biota in calcitic facies is questionable. Further, from the photographs it is possible to ascertain that the recorded biota are mineral crystals belonging to apatite. This can be best seen in fig. 5D, which she has claimed to be spheroids with double wall.

Huronispora microreticulata Barghoorn 1965

Synonymy

1982 *Kheinjuasphaera vulgaris* McMenamin, Kumar & Awramik, pp. 267-269, fig. 13C-E.

1982 *Melasmatosphaera media* Hofmann, 1986 in McMenamin, Kumar & Awramik, p. 261, fig. 10I.

Occurrence—Kanwari Shale and Chorhat Sandstone formations, Chandrehi, Madhya Pradesh (Maithy & Gupta, 1983, p. 159, pl. 1, figs 2, 3); Fawn Limestone, Kheinjua Formation, Salkhan, Mirzapur District (McMenamin *et al.*, 1983).

Remarks—McMenamin *et al.* (1983) instituted a new genus *Kheinjuasphaera* characterised by solitary cells-like unit without an enveloping sheath. This form in its organisation cannot be differentiated from *Huronispora microreticulata* Barghoorn 1965 (in Barghoorn & Tyler, 1965) except for the fact that in some cases the size of the cells are larger. The use of size criteria to institute a new genus is not justified. These authors have also mentioned that the smaller cells of *Kheinjuasphaera* cannot be differentiated from *Huronispora reticulata*. It is proposed to consider both the forms alike and synonymous.

The solitary specimen of *Melasmatopsbaera magna* Hofmann described by McMenamin *et al.* (1985) in the Fawn Limestone is also like *Huronispora microreticulata*. Therefore, the same is also placed here under the synonymy list.

Huronispora psilata Barghoorn 1965

Occurrence—Kanwari Shale, Koldha, Ramapura Shale, Hinoti Limestone and Kokah Shale formations, Chandrehi, Madhya Pradesh (Maithy & Gupta, 1983, p. 159, pl. 1, fig. 4).

Eosynechococcus Hofmann 1976

Loosely associated group of cells, rod-shaped to ellipsoidal, occasionally slightly curved, cells lack individual sheath.

Eosynechococcus isolatus McMenamin, Kumar & Awramik 1983

Occurrence—Fawn Limestone, Salkhan, Mirzapur District (McMenamin *et al.*, 1983, p. 258, fig. 5E-G).

Sphaerophycus Schopf 1968

Cells solitary or in pairs, less frequently arranged in loosely associated groups, cells encompassed by sheath.

Sphaerophycus medium Horodyski & Donaldson, 1980

Occurrence—Panna Shale, Rewa Group, South of Sapotra (Maithy & Mandal, 1983, p. 131, pl. 2, figs 13-15).

Sphaerophycus parvum Schopf 1968

Occurrence—Baghwar Shale (Semri Group) and Nagod Limestone (Bhander Group), Chandrehi, Madhya Pradesh (Maithy & Gupta, 1983, p. 159, pl. 1, figs 5, 6); Nagod Limestone and Sirbu Shale, Satna, Maihar (Maithy & Meena, 1989, p. 181, pl. 1, fig. 30).

Gloeodiniopsis Schopf 1968

Spheroids and ellipsoids with single, double or multiple outlines, solitary or in groups of 2, 3, 4 or

up to 8 individuals within a common envelope.

Gloeodiniopsis lamellosa (Schopf) Knoll & Golubic 1979

Occurrence—Panna Shale, Rewa Group, Bapoti Village, Rajasthan (Maithy & Mandal, 1983, p. 133, pl. 1, figs 5, 6; pl. 2, fig. 30).

***Tetraphycus* Oehler 1977**

Cells spherical, psilate, arranged in planar tetrads, cross tetrads, diads and cluster of cells isolated or in groups surrounded by amorphous matrix.

Tetraphycus congregatus McMenamin, Kumar & Awramik 1983

Occurrence—Kheinjua Formation, Salkhan Hills, Mirzapur (McMenamin *et al.*, 1983, p. 265, fig. 13A, B).

***Myxococcoides* Schopf 1968**

Colony of compactly arranged spheroidal cells, individual cells and colony ensheathed.

Myxococcoides ramapuraensis Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 177, pl. 1, fig. 2).

Myxococcoides magnus Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 178, pl.1, fig. 3).

Myxococcoides psilata Maithy & Mandal 1983

Occurrence—Panna Shale, Bapoti, Rajasthan (Maithy *et al.*, 1983, p. 131, pl. 1, fig. 1); Rohtas Limestone, Simirawal Shale, Nagod Limestone and Sirbu Shale, Satna-Maihar (Maithy & Meena, 1989, p. 181, pl. 1, fig. 21).

***Palaeoanacystis* Schopf 1968**

Cells spheroidal, without sheath, clumped together to form a colony, colony enveloped by an organic sheath.

Palaeoanacystis suketensis Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 178, pl. 1. fig. 4).

Palaeoanacystis punctatus Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 178, pl. 1, fig. 5).

Palaeoanacystis verucosus Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 178, pl. 1, fig. 6).

Palaeoanacystis reticulatus Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 178, pl. 1, fig. 7).

***Gloeocapsomorpha* Zalessky 1916**

Spheroidal cells aggregated in a colony, daughter colonies and cells within the colony ensheathed by a non-lamellated amorphous sheath, division of cells common and occurs in two directions.

Gloeocapsomorpha karauliensis Maithy & Mandal 1982

Occurrence—Semaria Shale, Bhander; Ranipura, Rajasthan (Maithy *et al.*, 1983, p. 133, pl. 1, fig. 4).

***Glenobotrydion* Schopf 1968**

Cells with prominent circular small organic structure on inner surface of cell walls, cells loosely associated, groups of many hundred cells in pseudofilamentous organisation, enclosed in a sheath, sheath non-lamellated.

Glenobotrydion aenigmatis Schopf 1968

Synonymy :

1983 *Myxococcoides minor* Schopf 1968 *in* McMenamin, Kumar & Awramik, p. 258, fig. 5E-G.

Occurrence—Fawn Limestone, Salkhan, Mirzapur (McMenamin *et al.*, 1983, p. 260, fig. 5D-F).

Remarks—McMenamin *et al.* (1983, p. 260) have stated "Individual cells of *G. aenigmatis* and *Myxococcoides minor* are indistinguishable; we refer to cells organized into pseudofilaments as *G. aenigmatis*". The figured photograph and details of *Myxococcoides minor* by McMenamin *et al.* (1983, p. 258.) does not compare with the generic circumscription of *Myxococcoides*, i.e., cells organised in a globular colony and enclosed in a sheath. The Salkhan *Myxococcoides* described by McMenamin *et al.* (1983) is arranged in clustured groups and not in a globular colony, therefore, it is proposed here to transfer it to *Glenobotrydion*.

***Nanococcus* Oehler 1977**

Cells spheroidal to ellipsoidal, generally loosely and randomly arranged, generally colony enclosed in formless organic matrix.

Nanococcus vulgaris Oehler 1977

Occurrence—Panna shale, Rewa Group near Bapoti, Rajasthan (Maithy & Mandal, p. 131, pl. 1, fig. 2).

***Corymbococcus* Awramik & Barghoorn 1977**

Spheroidal or ellipsoidal cells aggregated in colonies, colonies enclosed in common unlamellated sheath; individual cells non-ensheathed.

Corymbococcus vindhyanensis Maithy & Mandal 1983

Occurrence—Upper Bhander Sandstone, Ranipura, Rajasthan (Maithy & Mandal, 1983, p. 131, pl. 1, fig. 3; pl. 2, fig. 12).

Corymbococcus sp. Maithy & Gupta 1983

Occurrence—Koldha, Chorhat Sandstone, Hinoti, Simrawal Shale, Chandrehi (Maithy & Gupta, 1983, p. 159, pl. 1, fig. 8).

***Saccifera* Maithy & Mandal 1983**

Solitary or in group of 2-4 cells enclosed in a broad thick fibrilar amorphous envelope.

Saccifera tirohensis Maithy & Mandal 1983

Occurrence—Tirohan Limestone, Naroli Fort, Rajasthan (Maithy *et al.*, 1983, p. 135, pl. 2, figs 16-18).

***Aphanocapsiopsis* Maithy & Shukla 1977**

Colony of loosely arranged spheroidal cells without any order.

Aphanocapsiopsis sitholeyii Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy & Shukla, 1977, p. 179, pl. 1, figs 8, 9); Bargawan Shale, Chandrehi (Maithy & Gupta, 1983, p. 159, pl. 1, fig. 7).

Aphanocapsiopsis ramapuraensis Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy & Shukla, 1977, p. 179, pl. 1, figs 10, 11).

***Eoentophysalis* Hofmann 1976**

Oval cells enclosed in a mucilage sheath.

Eoentophysalis belcherensis Hofmann 1976

Occurrence—Fawn Limestone, Salkhan (McMenamin, Kumar & Awramik, 1983, p. 282, fig. 10A-C).

Eoentophysalis magna McMenamin, Kumar & Awramik 1983

Occurrence—Kheinjua Formation, Salkhan Hills (McMenamin *et al.*, 1983, pp. 262-263, fig. 10D-E).

***Vindhyacapsiopsis* Maithy & Mandal 1983**

Cells clumped together in a rectangular colony, ensheathed within a gelatinous mass; 4-6 cells in each vertical row, arranged in opposite pairs, cells spherical, non-ensheathed.

Vindhyacapsiopsis bhanderensis Maithy & Mandal 1983

Occurrence—Upper Bhander Sandstone, Karauli, Rajasthan (Maithy *et al.*, 1986, p. 133, pl. 1, fig. 7).

***Oscillatoriopsis* Schopf 1968**

Trichome with linearly arranged tetragonal cells, broader than longer, filament ensheathed.

Oscillatoriopsis psilata Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 179, pl. 2, fig. 12).

***Neoscytonema* Maithy 1980**

Synonymy :

1977 *Palaeoscytonema* Maithy & Shukla, p. 179.

Filaments with thick sheaths, non-branched, cells broader than length, hetrocyst absent.

Neoscytonema srivastavae (Maithy & Shukla) n. comb. Maithy 1980

Occurrence—Suket Shale, Ramapura (Maithy & Shukla, 1977, p. 180, pl. 2, figs 13, 14).

***Gunflintia* Barghoorn 1965**

Trichome multicellular, uniseriate and unbranched, septa distinct, cells elongated without any sheath.

Gunflintia sp. Maithy & Mandal 1983

Occurrence—Tirohan Limestone, Karisal Bandh, Sapotra, Rajasthan (Maithy & Mandal, 1983, p. 134, pl. 1, fig. 8).

***Veteronostocale* Schopf & Blacic 1971**

Trichome multicellular, beaded in appearance, uniseriate, unbranched, septa points distinctly constricted; cells circular or ellipsoidal in shape, arranged in linear chain.

Veteronostocale amoenum Schopf & Blacic 1971

Occurrence—Rohtas Limestone, Badanpur, Madhya Pradesh (Maithy & Meena, 1989, p. 183, pl. 1, fig. 4).

***Eomycetopsis* Schopf 1968**

Tubular sheath, empty and non-septate.

Eomycetopsis psilata Maithy & Shukla, 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 180, pl. 2, fig. 15).

Eomycetopsis pflugii Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 180, pl. 2, fig. 16).

Eomycetopsis reticulata Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy *et al.*, 1977, p. 180, pl. 2, fig. 17).

Eomycetopsis ?siberensis Lo 1980

Synonymy :

1983 *Gunflintia minuta* Barghoorn 1965, *in* McMenamin, Kumar & Awramik, p. 269, fig. 10F.

Occurrence—Fawn Limestone, Kheinjua Formation, Salkhan, Mirzapur (McMenamin *et al.*, p. 265, fig. 10G-H).

Remarks—*Gunflintia minuta* Barghoorn reported by McMenamin *et al.* (1965) from the Fawn Limestone, Salkhan does not show any septation, as such it also does not compare with the generic characters of *Gunflintia*. In the absence of septa it resembles *Eomycetopsis*, therefore, it is transferred here.

Eomycetopsis sp. Maithy & Meena 1989

Occurrence—Nagod Limestone and Sirbu Shale (Maithy & Meena, 1989, p. 183, pl. 1, fig. 3).

Eomycetopsis sp. Sarkar 1974

Remarks—Sarkar (1974, fig. 5A) reported tubular filaments 6-8 μm to 23.8 μm in diameter. From photographs it can be commented that the recorded forms are abiogenic structures, probably the apatite crystals have got themselves arranged in a row.

***Animikiea* Barghoorn 1965**

Non-septate, unbranched tubes with finely arranged grana in parallel row indicating transverse septa.

Animikiea septata emend. Mandal & Maithy 1984

Occurrence—Nagod Limestone and Sirbu Shale (Maithy & Meena, 1989, Mandal *et al.*, 1984, p. 183, pl. 1, figs 8, 9).

***Taeniatum* Sin & Liu 1973**

Broad non-septate, unbranched dark tubes with irregular surface thickenings.

Taeniatum sp. Maithy & Meena 1989

Occurrence—Nagod Limestone and Sirbu Shale (Maithy & Meena, 1989, p. 182, pl. 1, figs 1, 2).

***Heliconema* Schopf 1968**

Remarks—Sarkar (1974, fig. 5G) reported *Heliconema* sp. (?) long spiral, tubular, non-septate microfossils in the styolite seams of algal limestones of the areas around Maihar and Rewa. The diameter of these structures according to Sarkar (1974) ranges from 30 to 150 μm, i.e. about 7 to 40 times larger than the recorded specimens of *Heliconema*. Therefore, the reference of these forms to *Heliconema* is questionable.

***Archaeorestis* Barghoorn 1965**

Trichome slender, non-septate, non-tubular and branched.

Archaeorestis sp. Maithy & Mandal 1983

Occurrence—Sirbu Shale, Karisal Bandh, Sapotra, Rajasthan (Maithy & Mandal, 1983, p. 134, pl. 1, fig. 11).

ACRITARCHA

Sphaeromorphida

Spherical vesicles without any operculum.

***Protosphaeridium* Timofeev**

Vesicles smooth and small in size (commonly less than 30 μm).

Protosphaeridium diatretus Salujha, Rehman & Rawat 1971a

Occurrence—Upper Rewa Quartzite Sandstone; Dalapura-Hanumanpura traverse, Rajasthan (Salujha *et al.*, 1971a, p. 73, pl. 1, figs 11-13); Semri Group, Son Valley (Salujha *et al.*, 1971b, p. 26, pl. 2, figs 8, 9); Panna Shale and Lower Bhander Sandstone, Karauli-Sapotra, Rajasthan (Maithy & Mandal, 1983, p. 136, pl. 2, fig. 23).

Protosphaeridium pristinum Salujha, Rehman & Rawat 1971b

Occurrence—Basuhari Sandstone, Son Valley, Mirzapur District (Salujha *et al.*, 1971b, p. 26, pl. 3, figs 8, 9)

Protosphaeridium densum Timofeev 1966

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy & Shukla, 1977, p. 181, pl. 2, fig. 19); Panna Shale, Jhiri Shale and Lower Bhander Sandstone, Karauli-Sapotra (Maithy & Mandal, 1983,

p. 130, pl. 2, fig. 25); Nagod Limestone & Sirbu Shale, Satna, Maihar, Madhya Pradesh (Maithy & Meena, 1989, p. 183, pl. 1, figs 31, 32).

Protosphaeridium volkovae Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy & Shukla, 1977, p. 181, pl. 2, fig. 18); Sirbu Shale, Satna-Maihar (Maithy & Meena, 1989, p. 184, pl. 1, figs 28, 29).

Remarks—*Zonosphaeridium dignatum* described by Salujha *et al.* (1971a, p. 77, Pl. 1, figs 27-30) from the Sirbu Shale, Chambal Valley is identical to *Protosphaeridium densum* Timofeev 1966, therefore, it is considered here to be the junior synonym.

Protosphaeridium cambriense Timofeev 1959

Occurrence—Panna Shale, Karauli-Sapotra (Maithy & Mandal, 1983).

Remarks—Salujha *et al.* (1971a, pl. 1, figs 17, 18, 19) reported a new species of *Cymatiosphaera, C. compta* from the Maihar Sandstone of Mandral-Karauli traverse which compare morphologically with *Protoleiosphaeridium diatretus* (Salujha *et al.*, 1971a) described from the same area. Therefore, *Cymatiosphaera compta* is referred as a junior synonym of *P. diatretus.*

Likewise, *Tasmanites* sp. described by Salujha *et al.* (1971a, pl. 1, fig. 31) is similar to *Protosphaeridium densum* Timofeev and synonymous too. The same also holds true for the specimen described by Salujha *et al.* (1971b) under *Tasmanites* sp. A (pl. 2, fig. 23) and *Tasmanites* sp. B (pl. 2, fig. 2) from Son Valley.

Leiosphaeridia Eisenack 1958

Vesicles thin-walled with smooth to shar green surface.

Leiosphaeridia vindhyana Salujha, Rehman & Rawat 1971a

Occurrence—Maihar Sandstone, Mandral-Karauli traverse (Salujha *et al.*, 1971a, p. 72, pl. 1, figs 5-7).

Leiosphaeridia pellucida Salujha, Rehman & Arora 1971b

Occurrence—Bijaigarh Shale, Son Valley (Salujha *et al.*, 1971b, p. 25, pl. 2, figs 1-3).

Kildinosphaera Vidal 1983

Remarks—The forms described now under *Kildinosphaera* were earlier described under *Kildinella* Timofeev, 1963. Vidal (in Vidal & Knoll, 1983) pointed that the later name is preoccupied, therefore, the specimens described under *Kildinella* were transferred by him to a newly proposed name *Kildinosphaera.*

Kildinosphaera suketensis Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 182, pl. 3, fig. 21).

Kildinosphaera sp.

Occurrence—Panna Shale, Karauli—Sapotra, Rajasthan (Maithy & Mandal, 1983, p. 136, pl. 2, fig. 26); Rohtas Limestone, Nagod Limestone and Sirbu Shale, Satna-Maihar (Maithy & Meena, 1989, p. 184, pl. 1, figs 23, 27).

Orygmatosphaeridium Timofeev 1959

Vesicle thin, surface closely pitted, pits small.

Orygmatosphaeridium plicatum Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 181, pl. 3, fig. 26); Koldha Shale (Semri) and Simrawal Shale (Bhander), Maithy & Gupta, 1983, p. 159, pl. 1, fig. 9); Semaria Shale (Bhander) Ranipura, Karauli (Maithy & Mandal, 1983, p. 136, pl. 2, fig. 27).

Orygmatosphaeridium vulgarum Maithy 1975

Occurrence—Nagod Limestone and Sirbu Shale (Maithy & Meena, 1989, p. 184, pl. 1, figs 24-25).

Granomarginata Naumova 1969

Vesicle with grana-like structures.

Granomarginata primitiva Salujha, Rehman & Arora 1971b

Occurrence—Basuhari Sandstone, Son Valley (Salujha *et al.*, 1971b, p. 28, pl. 3, figs 18-20).

Granomarginata rotata Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 181, pl. 3, fig. 23).

Granomarginata minuta Maithy 1975

Occurrence—Sirbu Shale, near Karisal Bandh, Sapotra, Rajasthan (Maithy & Mandal, 1983, p. 136, pl. 2, fig. 28).

Granomarginata prima Naumova 1969

Occurrence—Maihar Sandstone, north of Karauli (Maithy & Mandal, 1983, p. 136, pl. 2, fig. 29).

Remarks—*Archaeofavosinia venusta* Salujha *et al.* (1971b, p. 27, pl. 3, figs 2, 3) compares to *G. prima* due to presence of closely spaced grana and seems to be synonymous.

Granomarginata nagodensis Maithy & Gupta 1983 n. comb.

Synonymy :

1983 *Bavlinella nagodensis* Maithy & Gupta, p. 160, pl. 1, figs 10, 11.

Occurrence—Nagod Limestone Formation, west of Baisa, Madhya Pradesh.

Remarks—As per description the surface of the organic-walled microfossils has closely spaced grana, which compares with the generic circumscription of *Granomarginata*, therefore, *Bavlinella nagodensis* is transferred to *Granomarginata*.

Symplassosphaeridium Timofeev 1959

Vesicle spheroidal, body divided to several rounded areas.

Symplassosphaeridium bulbosum Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura (Maithy & Shukla, p. 181, pl. 2, fig. 20).

Symplassosphaeridium sp. A Salujha, Rehman & Rawat 1971a

Occurrence—Vindhyan, Rajasthan (Salujha *et al.*, 1971a, p. 72, pl. 1, fig. 9).

?*Symplassosphaeridium* sp. B, Salujha, Rehman & Rawat 1971a

Occurrence—Vindhyan, Rajasthan (Salujha *et al.*, 1971a, p. 73, pl. 1, fig. 10).

Remarks—The identification of *Symplassosphaeridium* sp. A Salujha *et al.*, 1971a, p. 72, pl. 1, fig. 9) and ?*Symplassosphaeridium* sp. B. Salujha *et al.*, 1971b, p. 73, pl. 1, fig. 10) seems to be doubtful as the photographs show that small globular cells are enclosed within a fine enveloping sheath. Accordingly, it shows morphological closeness to *Bavlinella* Shepleva 1962. Both the specimens also compare with recently figured specimens of *Bavlinella* by Hofmann (1984, pl. 32, figs A-G) from the latest Proterozoic of the Wernecke Mountains, Yukon.

Lophosphaeridium Timofeev 1969

Vesicle spherical, exine covered with bulbose processes.

Lophosphaeridium jainii Salujha, Rehman & Rawat 1971a

Occurrence—Kaimur Sandstone, Mandral-Karauli traverse, Rajasthan (Salujha *et al.*, 1971a, p. 74, pl. 1, figs 14-16).

Lophosphaeridium jainsoniusii Salujha, Rehman & Arora 1971a

Occurrence—Bijaigarh Shale, Son Valley, Mirzapur (Salujha *et al.*, 1971b, p. 26, pl. 2, figs 10-13).

Lophosphaeridium vetulum Salujha, Rehman & Arora 1971b

Occurrence—Rohtas Limestone, Son Valley, Sidhi District (Salujha *et al.*, 1971b, p. 27, pl. 3, figs 10, 11).

Remarks—The above named three species seem to be synonymous owing to their morphological similarity. They also overlap in the size range. As such *Lophosphaeridium jainii* has priority over the later two described species *L. jainsonusii* and *L. vetulum*.

Microhystridium sitholeyi Salujha *et al.* (1971b, p. 30, pl. 2, figs 15-17) has exine and broad processes with rounded tips. This character conforms to the generic identity of *Lophosphaeridium*. Further, the figured specimens also compare with the figured specimens of *L. jainii* Salujha *et al.* (1971a, pl. 1, figs 14-16).

Lophosphaeridium echinatum Salujha *et al.*, 1971 comb. nov.

Synonymy :

1971 *Priscogalea echinata* Salujha, Rehman & Rawat, p. 76, pl. 1, figs 23, 24.

Remarks—The species is transferred to *Lophosphaeridium* due to the presence of closely set spines, ± 2 μm long. The species differs from *L. jainii* Salujha *et al.* 1971 in being larger in size and pointed structures.

Vavosophaeridium Timofeev 1956

Vesicle spherical, exine covered with muri forming reticulations.

Vavososphaeridium bharadwajii Salujha, Rehman & Rawat 1971a

Synonymy :

1971a *Dictyotidium aerolatus* Salujha, Rehman & Rawat, p. 75, pl. 1, figs 21, 22.

Occurrence—Maihar Sandstone, Mandral-Karauli traverse, Rajasthan (Salujha *et al.*, 1971a, p. 75, pl. 1, figs 21, 22); Vindhyan, Son Valley (Salujha, Rehman & Arora, 1971b, p. 29, pl. 3, figs 24, 25); Nagod Limestone and Sirbu Shale; Satna-Maihar (Maithy & Meena, 1989, p. 484, pl. 1, fig. 26).

Remarks—Salujha *et al.* (1971a, p. 75, pl. 1, figs 21, 22) reported *Dictyotidium aerolatus*, a new species from the Maihar Sandstone, Mandral-Karauli

traverse. These specimens in their gross morphology are like *Vavososphaeridium bharadwajii.*

Vavososphaeridium vindhyanensis
Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, pl. 4, fig. 27).

***Archaeofavosina* Naumova 1960**

Vesicle with broad reticulum, reticulum free area pitted.

Archaeofavosina reticulata Maithy & Shukla 1977

Occurrence—Suket Shale Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, pl. 3, fig. 24).

***Bavlinella* Shepleva 1962**

Spheroidal aggregates of dark brown organic material tightly packed isodiametric globular to subpolyhedral globular cell-like units, 0.3-1.0 μm in diameter.

Bavlinella faveolata (Shepleva, 1962) emend. Vidal 1976

***Nucellosphaeridium* Timofeev 1969**

Vesicle sphaeroidal with inner body.

Nucellosphaeridium minimum Maithy & Shukla 1977

Synonymy :

1971b *Pterospermopsis typicanus* Salujha, Rehman & Arora, p. 30, pl. 2, figs 18, 19.

1971b *Baltisphaeridium scitulum* Salujha, Rehman & Arora, p. 30, pl. 2, fig. 26.

Occurrence—Suket Shale; Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 182, pl. 4, figs 30, 31).

Remarks—*Pterospermopsis typicanus* Salujha, Rehman and Arora (1971b, pl. 2, figs 18, 19) compares closely to *N. minimum* Maithy & Shukla (1977, pl. 4, figs 30, 31). It does not compare with the morphological features of *Pterospermopsis.* Therefore, it is a synonym of *N. minimum.* The specimen described and figured by Salujha *et al.* (1971b, p. 30, pl. 2, fig. 26) shows a distinct circular body, therefore its assignment to *Baltisphaeridium scitulum* is not correct. In gross morphology it resembles *Nucellosphaeridium minimum* Maithy *et al.*, 1977 and is synonymous.

Nucellosphaeridium maithyi (Maithy & Shukla) emend. Fensome *et al.* 1990

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy & Shukla, 1977, p. 182, pl. 4, figs 30, 31).

Remarks—Fensome *et al.* (1990) pointed out that *N. zonatum* Maithy & Shukla 1977 is junior homonym of *N. zonatum* Maithy 1975, therefore, proposed *N. maithyi* for it.

Tasmanites (Newt.) Eisenack 1958

Large size vesicle, surface with numerous puncta or pores.

Tasmanites vindhyanensis Maithy & Shukla 1977

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1977, p. 182, pl. 4, figs 32, 33).

Tasmanites punctatum (Maithy & Shukla) emend. Fensome *et al.* 1990

Synonymy :

1977 *Zonosphaeridium punctatum* Maithy & Shukla, p. 182, pl. 4, fig. 28.

Occurrence—Suket Shale, Ramapura, Madhya Pradesh (Maithy *et al.*, 1971, p. 182, pl. 4, fig. 28).

Remarks—Fensome *et al.* (1990) pointed out that the genus *Zonosphaeridium* Timofeev is not validly published, therefore, they transferred the forms placed under *Zonosphaeridium* to *Tasmanites*, which is a senior synonym.

***Leiovalia* Eisenack 1965**

Oval organic-walled microfossils, exine smooth.

Leiovalia sp. Salujha, Rehman & Rawat 1971a

Occurrence—Vindhyan, Karauli-Kotah (Salujha *et al.*, 1971a, p. 76, pl. 1, fig. 25).

Remarks—Most probably the reported specimen by Salujha *et al.* (1971a, p. 76, pl. 1, fig. 25) is a modern fungal spore. Similar fungal spores have also been reported in association of organic-walled microfossils from the Vindhyans of Son Valley by Salujha, Rehman and Arora (1971b, pl. 3, figs 21-23).

Vase-shaped microfossils

Melanocyrillium Bloesser 1985

Remarks—Vase-or flask-shaped microfossils are well known from the Precambrian rocks (Knoll, 1982). Bloesser (1985) put all of them under a new genus *Melanocyrillium* as encystment structures belonging to unidentified alga. *Melanocyrillium* was reported by Salujha *et al.* (1971a, p. 32, pl. 3, fig. 31) from the Vindhyan rocks of Son Valley and from the Upper Vindhyan rocks of Rajasthan by Salujha *et al.* (1971b, p. 70, pl. 1, fig. 35). Maithy and Babu (1989) recorded *Melanocyrillium fimbriatum* sp. in the Arangi Formation, Semri Group and Markundi Quartzite Formation, Kaimur Group exposed around Chopan, Mirzapur District, Uttar Pradesh.

ACTIVITIES OF BIOLOGICAL LIFE

Ichnofossils

Several markings were noted by early workers in the Vindhyan rocks, but were dismissed as of inorganic origin. Verma and Prasad (1968) reported the occurrence of three types of trace fossils in the Bhander Limestone in Bankuiyan area, Rewa District. *Bostricophyton bankuianensis* are large spiral thread-like markings, slightly broader in the middle, tapering ends with transverse ridges, thick, prominent, slightly arched and closely spaced. Marking appears to represent crawling tracks of a worm or an arthropod. *Rouaulita rewaensis* is a smooth bilobate crawling trail with two very distinct lateral furrows and one median furrow, body almost flat. *Tasmanadia dassi* has double rows of very sharp transverse foot-like imprints, longer axis of the imprint is slightly diagonal to the direction of movement; foot-like imprints, single, thick and varying in size. Sarkar (1974, p. 150) reported in brown and grey limestone outcrop sections of Lakheri Limestone the presence of slightly raised ridges mostly sheet-like, straight to sinuous or irregular, spindle-shaped, most of which wedge out peripherally. The length and breadth of the structures vary from 0.5 to 5 cm and 0.5 to 4 mm, respectively. Generally both the ends of these structures are tapering. Some forms are not tapering but simply rod-shaped. Some burrows show flat crescent U-shaped body with two arms-like projections. Kumar (1978c) described a horizontal trail *Muniaichnites* from glauconitic sandstone.

Mathur (1982, fig. 2A) reported *Asteriradtus karaulensis* in Karauli Quartzite of Panna. However, no details have been provided and as such it is *nomen nudum*. *Sonjiwashman basuharensis* claimed to be a trace fossil by Mathur (1982, fig. 2B) from the Basuhari Sandstone is actually a drag mark. Mathur and Verma (1983, fig. 1) reported *Bhanderichnus damohensis* in the Maihar Quartzite Formation, Sagoni, Madhya Pradesh. The specimen is a trail with lobe-like structure, placed symmetrically on either side of the main trail. Four pairs of such lobes are seen.

Trails with paired circular marks with a inter-spacing gap of 1-4 mm from one another are arranged in a linear fashion up to 8-10 cm; circular markings nearly less than 1 mm in dimension. Linear distance between two pairs less than 2 mm was reported by Maithy *et al.* (1986, fig. 2) in the Murli Sandstone Formation (Kaimur) of Murlipahar, Bihar and Maithy and Babu (1988, pl. 2, fig. 7) in the Ghurma Shale (Kaimur) of Chopan.

Chakrabarti (1990) recorded traces and dubiotraces from the Lower Bhander Sandstone exposed around Maihar, Madhya Pradesh. Burrows have been detected on exposures as small sand lump exposures in rippled or plane bedding surface. Two groups of burrows were found (a) large diameter burrows with diameters varying between 0.5 and 4.5 cm, and (b) micro-burrows with diameter 1.5 mm. Burrow discloses two different patterns in the nature of burrow fill (i) staggered concave upward internal laminae showing 'V'- in 'V' or broad-based 'U'- in 'U' structures resembling *Monocraterion*, and (ii) an ill-defined arrangement of the upward laminae of the burrow fill, the stubby thumb-like burrow being bordered by clay lining on the burrow wall. Dissection of the 'bean-shaped' forms reveal that these represent the lower part of *Diplocraterion* burrows.

ORGANOSEDIMENTARY STRUCTURES

The principal organosedimentary structures of Vindhyan are stromatolites These records of stromatolites have been summarised by Kumar (1984). Incidentally, in most of earlier works the identification of stromatolites is based on field data and three dimensional reconstructions for the taxonomic identification were not prepared. Further, in many cases the descriptions are also incomplete. Kumar (1984) identified three distinct stratigraphical assemblage zones. Of these, two assemblages are recognised within the Semri Group, the older is *Kussiella-Colonella* Assemblage of the Early Riphean age and the younger is *Conophyton garganicus-Colonella* Assemblage of Middle Riphean age. The Bhander Group assemblage is dominated by *Baicalia-Tungussia* Assemblage of Late Riphean age. The stromatolite records are tabulated below.

CONCLUDING REMARKS

The paper indicates that very little evidences of the Vindhyan life were available before 1970. All the earlier reports are poorly documented. Since 1970, proper attention was given to record various biological remains from the Precambrian rocks.

Macrofossils—Presence of *Chopania* in the rock as old as ± 1,300 Ma suggests that the lineage separation between Metaphyte and Metazoan began sometimes during the early part of Middle Proterozoic. The younger bed of Semri and the older beds of Kaimur preserve characteristic macrofossil assemblages dominated by the planktonic forms—*Chuaria* alongwith *Tawuia* and the benthic form *Krishnania*. This association also includes elongated

Semri Group

HORIZON	LOCALITY	AUTHOR	FORMA
Rohtas	Mirzapur	Kumar, 1976b	*Collenia clappii* Poorly developed stromatolite
Bargawan	Mirzapur	Valdia, 1969	*Colonella columnaris* *Conophyton garganicus* *Colenia clapii*
		Kumar, 1982	*Conophyton garganicus* *C. garganicus, Colonella columnaris*
	Dabua	Maithy, 1990	*Newlandia minuta*
Bhagwanpura Limestone	Hatipura Rajasthan	Raja Rao & Mahajan 1965	*Collenia frequence, Conophyton indinatum, Cryptozoan accidentale* and *Weedia.*
		Prasad, 1975	*Collenia columiaria* *C. kussiensis, Conophyton cylindrica, Cryptozoan accidentale, Weedia*
	Chainpur Rajasthan	Prasad, 1975	*Collenia columnaris* *C. frequence* *C. baicalica, C. spissa* *C. kussiensis, C. oompaeta* *Cryptozoan accidentale,* *Conophyton cylindricus* *C. inelinatum, Weedia*
	Bhojenda Rajasthan	Barman & Verma 1975	*Conophyton cylindricus,* *Collenia* sp., *Collenia baicalica, C. frequence, Weedia*
		Prasad, 1976, 1978	*Collenia columnaris, C. baicalica* *C. kussiensis, Gymnosolen* *Cryptozoan accidentale,* *Conophyton cylindricus,* *Weedia* sp.
Kajrahat Limestone	Mirzapur	Kumar, 1976a, b, c, 1982	*Kussiella kussiensis, Kussiella kussiensis, K. dalaensis,* *Conophyton vindhyaensis,* *Colonella symmetrica,* *C. kajrahatensis*
Tirohan Limestone	Chitrakoot	Valdia, 1969 Kumar, 1976b 1977b, 1982	*Colonella lodwarensis,* *C. columnaris, Collenia symmetrica, Kussiella kussiensis*
Tirohan Limestone	Sapotra-Karauli	Maharajasingh & Banerji, 1980	*Conophyton cylindricus,* *Collenia kussiensis,* *C. baicalica*

Rewa Group

HORIZON	LOCALITY	AUTHOR	FORMA
Jhiri Shale	Barwas, Akher	Prasad, 1984	*Baicalia baicalica,* *Gymnosolen ramasayi*

Bhander Group

HORIZON	LOCALITY	AUTHOR	FORMA
Balwan Limestone	Balwan	Prasad, 1984	*Baicalia baicalica, Linella*
Upper Bhander Limestone	Sawai-Madhopur	Prasad & Ramaswamy, 1980	*Collenia baicalica*
	Lakheri	Prasad, 1984	*Collenia (Baicalia) baicalica* & *Linella*
Sirbu-Shale (Megardha Member)	Satna	Rao, Lal & Ghosh, 1977	*Stratifera*
Nagod-Limestone	Maihar	Kumar, 1978	*Maiharia maiharensis*
	Sawai-Madhopur	Prasad & Ramaswamy, 1980	*Collenia baicalica* & *C. collumnaris*
	Bundi	Prasad, 1984	*Collenia baicalica, C. buricata* & *Oncolites*
	Maihar	Valdiya, 1969	*Collenia baicalica*
	Maihar	Misra & Awasthi 1962	*Collenia*
	Maihar, Satna Nagod & Rewa	Sarkar, 1974	*Baicalia baicalica, Colonella, Cryptozoan, Collenia undosa, Stratifera* & *Weedia*
	Maihar	Kumar, 1978	*Baicalia baicalica* & *Colonella columnaris*
	Satna	Kumar, 1978	*Baicalia satanensis* (? *Tungussia*)
	Satna	Rao, Lal & Ghosh, 1977	*Collenia* = *(Colonella) Baicalia, Boxonia* identical to *Baicalia) Tungussia, Stratifera* & Oncolite
	Rewa	Rao, Rao & Ghosh, 1977	*Colonella, Collenia, Symmetrica, Baicalia, Kussiella* & *Anaberia*
Samaria Limestone	Sawai-Madhopur	Prasad & Ramaswamy, 1980	*Collenia (Baicalia) baicalica*
	Satur, Lonaba Naygoan Singlore	Prasad, 1984	*Weedia, Stratifera, Collenia (Baicalica)*

tubular types—*Grypania* and *Daltaenia*, planktonic sphaeroid with inner body, viz., *Amjohrea, Ramapuraea* and elongated-oval forms *Katnia* and *Shoubsienia*. *Krishnania* is the oldest benthic form. The assemblage suggests extensive shallow seas on a peneplained landscape for the Vindhyans. Most of the Middle Proterozoic forms seem to be Eucaryotic due to their large size, though affinities of many of them are still uncertain. This assemblage is known world wide from the equivalent strata, i.e., 800-1,000 Ma of China (du Rulin, 1982; Duan, 1982) and north-west Canada (Hofmann, 1985). Considering this, Maithy and Babu (1988) indicated that this is a time marker assemblage and therefore denoted this time period as "Chuarian Period".

The youngest bed of the Vindhyan-Dholpura Shale preserves Ediacaran biota, comprising mainly of Vendian Radialia medusoids dominated by oligocytic forms of 'Cyclomedusa complex'. This type of biotic composition is now known from Australia, China, Europe and Canada. The presence of Ediacaran biota in the youngest beds of the

Vindhyan indicates the uppermost limit of Vindhyan is restricted to Vendian.

Organic-walled microfossils—In the past, doubts have been raised concerning synsedimentary deposition of the organic-walled microfossils in the rocks. Workers have also questioned the authenticity of the macerated organic residues. Many of them tried to call them organic contaminants of modern vegetation. In recent years this point is over-ruled by the methodology of study suggested by Pflug and Maithy (1977). According to them synsedimentary deposition of biota can be well proved by studying them first in thin sections and later by maceration.

Identification of organic-walled microfossils too, is problematic due to ill preservation. The Precambrian organic-walled microfossils are black to dark-brown in colour and the original wall structure also gets altered due to diagenetic changes in the course of fossilisation. Therefore, probability remains that the identified forms under different species and generic names may be the preservation variants. In view of the same, due caution is now needed while instituting new forms.

The study indicates that relationship exists between the biota and preserved rock. The stromatolite bearing rocks preserve distinct biotic composition in comparison to non-stromatolitic ones. The stromatolitic beds preserve Synaptomorphs (colonial forms) and the Nematomorphs (tubular forms) indicate lagoonal deposit while non-stromatolitic beds preserve Cryptarchs (including Acritarcha) indicating open shelf deposit.

Organic-walled microfossils particularly Cryptarch-Sphaeromorphs play significant role in biostratigraphy. The available data indicates that Semri Group Cryptarch shows dominance of *Protosphaeridium, Orygmatosphaeridium* and *Leiosphaeridia* and the Bhander Group is characterised by the presence of large-sized sphaeromorphs—*Nucellosphaeridium, Vavosphaeridium, Micryhystridium, Cymatopshaeroides* associated with *Bavlinella*.

Trace fossils—Ichnofossil evidences from the Vindhyan are scanty in comparison to the Late Precambrian records. However, the ichnofossil records indicate the existence of metazoan in the early part of Upper Proterozoic. The preserved traces indicate the presence of vagile benthos. In sedimentary strata, these organisms moved owing to persistaltic changes in the shape of entire body (in the same way living nemertines, annelids, etc.) passing through their digestive canal, a residue rich in organic matter. Proterozoic Metazoa moved by persistaltic waves, passing through the ventral parts of body, like living planarians, chitons, etc. The ichnofossil records indicate that metazoan life possibly developed sometimes in the early part of Middle Proterozoic.

Organosedimentary structures—The Vindhyan stromatolites indicate that non-branched and domal forms (*Conophyton*) dominate the Semri Group and the branched stromatolites are characteristic of the Bhander Group. The branched forms indicate Upper Riphean to Vendian age for the Bhander Sequence.

REFERENCES

Awramik SM & Barghoorn ES 1977. The Gunflint microbiota. *Precambrian Res.* **5** (2) : 121-142.

Barghoorn ES & Tyler SA 1965. Microorganism from the Gunflint Chert. *Science* **148** : 27-35.

Barman G & Verma KK 1975. Biostratigraphic zonations of stromatolite bearing Lower Vindhyan rocks of Chittorgarh District, Rajasthan. *Sem. on Recent Advance in Precambrian Geol. Min. Resources with special reference to Rajasthan,* : 37.

Beer EJ 1919. Note on spiral-impression on Lower Vindhyan limestone. *Rec. geol. surv. India* **50** : 109.

Bloesser B 1985. *Melanocyrillium*, a new genus of structurally complex Late Proterozoic microfossils from the Kwagunt Formation (Chuar Group), Grand Canyan, Arizona. *J. Palaeontol.* **59** (3) : 741-785.

Chakrabarti A 1990. Trace and dubiotraces : example from the so-called Late Proterozoic siliciclastic rocks of the Vindhyan Supergroup around Maihar, India. *Precambrian Res.* **47** (1-2) : 141-153.

Crawford AR & Compston W 1970. The age of Vindhyan System of peninsular India. *Q. J. geol. Soc. Lond.* **125** (3) : 351-371.

Du Rulin 1982. The discovery of the fossil such as *Chuaria* in the Qinpaikoa System in northwestern Hebi and their significance. *Geol. Mag.* **28** : 1-7.

Duan C 1982. Late Precambrian algal megafossils *Chuaria* and *Tawuia* in some areas of eastern China. *Alcheringa* **6** : 52-68.

Eisenack A 1958. *Tasmanites* Newton 1875 and *Leiosphaeridia* n.g. als gattugen der Hystrichosphaeridia. *Palaeontographica* **110** : 1-19.

Eisenack A 1965. Microfauna der Ostseekalke (1) Chitinozoan Hystrichosphäeren. *N. Jb. geol. palaeontol. Abh.* **123** : 115-148.

Fensome RA, Williams GL, Barss MS, Freeman, JM & Hill JM 1990. Acritarchs and fossil Parasinophytes : an index to genera, species and infraspecific taxa. *AASP Contrib.* Ser. Nr. **25** : 1-771.

Glaessner MF 1987. Discussion about some worm like fossils. *Precambrian Res.* **36** (3, 4) : 353-356.

Glaessner MF & Wade M 1966. The Late Precambrian fossil from Edicaran, South Australia. *Palaeontology* **9** (4) : 599-628.

Hofmann HJ 1976. Precambrian microflora from Belcher Island, Canada. *J. Palaeont.* **50** : 1040-1073.

Hofmann HJ 1981. First record of a Late Proterozoic faunal assemblages in North American Cordillera. *Lethaia* **14** : 303-314.

Hofmann HJ 1984. Organic-walled microfossils from the latest and earliest Cambrian of Wernecke mountains, Yukon. *Rec. geol. Surv. Canada* **84** (B) : 285-297.

Hofmann HJ 1985. The Mid-Proterozoic Little Dal macrobiota

from Mackenzie mountain, north western Canada. *Paleontology* **28** (2) : 331-338.

Hofmann HJ 1985. Precambrian carbonaceous megafossils. *In* Toomey DF & Witecki MH (editors)—*Palaeoalgology : contemporary research and applications* : 20-30. Springer-Verlag, Berlin.

Hofmann HJ & Aitken JD 1979. Precambrian biota from the Little Dal Group, Mackenzie Mountain, northwestern Canada. *Canadian J. Earth Sci.* **16** : 150-166.

Horodyski RJ & Donaldson JA 1980. Microfossils from the Middle Proterozoic Dismal Lakes Group, Arctic Canada. *Precambrian Res.* **11** : 125-159.

Johnson JH 1966. A review of the Cambrian algae. *Coloradosschool Mines Quart.* **61** : 1-162.

Knoll AH 1982. Microfossils from the Late Precambrian Draken Conglomerate, NY, Friesland, Svalbard. *J. Palaeontol.* **56** (3) : 775-790.

Knoll AH & Gloubic S 1979. Anatomy and taphonomy of Precambrian algal stromatolites. *Precambrian Res.* **10** : 115-151.

Kumar S 1976a. Stromatolites from the Vindhyan rocks of the Son Valley-Maihar area, district Mirzapur (U.P.) and Satna (M.P.). *J. Palaeontol. 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. Palaeontol. Soc. India* **19** : 24-27.

Kumar S 1977. Stromatolites and phosphorites in the Tirohan Limestone of Chitrakut area, Satna Distict, M.P. *Curr. Sci.* **46** : 341-342.

Kumar S 1978a. Discovery of micro-organisms from the black cherts of the Fawan Limestone (Late Precambrian), Semri Group, Son Valley, Mirzapur District, Uttar Pradesh. *Curr. Sci.* **47** : 461.

Kumar S 1978b. Stromatolites and environment of deposition of Vindhyan Supergroup of central India. *J. palaeontol Soc. India* **21-22** : 33-43.

Kumar S 1978c. On the Kheinjua Formation of the Semri Group (Lower Vindhyan) Newari area, Mirzapur District, U.P. *Proc. Indian natn. Sci. Acad.* **44** (A) : 144-154.

Kumar S 1982. Vindhyan stromatolites and their stratigraphic testimony. *In* Valdia KS, Bhatia SB & Gaur VK (editors)—*Geology of Vindhyanchal* : 102-112.

Kumar S 1984. Present status of stromatolites biostratigraphy in India. *Geophytology* **14** (1) : 96-110.

Lo SC 1980. Microbial fossils from the Lower Yudoma Suite, earliest Phanerozoic, eastern Siberia. *Precambrian Res.* **13** : 109-196.

Maharaja Singh HJ & Banerjee AK 1980. Stromatolites in the Vindhyan Group of northeastern Rajasthan. *Misc. Publ. 44 geol. Surv. India* : 278-283.

Maithy PK 1968. The occurrence of micro-remains from the Vindhyan Formation of India. *Palaeobotanist* **17** : 48-51.

Maithy PK 1975. Microorganisms from the Bushimay System (Late Precambrian) of Kanshi, Zaire. *Palaeobotanist* **22** 133-149.

Maithy PK 1980. *Neoscytonema* : a new name for *Palaeoscytonema*. *Geophytology* **10** : 261.

Maithy PK 1984. Problems and prospects of Precambrian palaeobiology in India. *In* Sharma AK (Editor)—*Symp. Evolutionary Botany and biostratigraphy (A. K. Ghosh Commemoration Vol).* : 1-8. Today & Tomorrow Print. & Publ., New Delhi.

Maithy PK 1989. Evidence of Proterozoic metaphytes and metazoan from India (Abstract). *Origins of Life* **19** (3-5) : 452-453.

Maithy PK 1990. Metaphyte and metazoan remains from the Indian Proterozoic successions. *In* Jain KP & Tiwari RS (editors)—*Proc. Symp. Vistas in Indian Palaeobotany, Palaeobotanist,* **38** : 20-28.

Maithy PK 1991. On *Krishnania* Sahni & Shrivastava: a mid-Proterozoic macrofossil. *J. Palaeont. Soc. India* **36** : 000-000.

Maithy PK & Babu R 1986. *Misraea*, a new body fossil from the Lower Vindhyan Supergroup (Late Precambrian) around Chopan, Mirzapur District, U.P. *Geophytology* **16** : 223-226.

Maithy PK & Babu R 1988. The mid-Proterozoic Vindhyan macrobiota from Chopan, south-east Uttar Pradesh. *J. geol. Soc. India* **31** : 584-590.

Maithy PK & Babu R 1989. Chitinozoa-like remains from the Vindhyan exposed around Chopan, Mirzapur District, Uttar Pradesh. *Palaeobotanist* **37** : 77-80.

Maithy PK & Gupta S 1981. *Archaeocyatha* from the Vindhyan Supergroup of India. *Indian J. Earth Sci.* **8** (1) : 86-91.

Maithy PK & Gupta S 1983. Biota and organosedimentary structures from the Vindhyan Supergroup around Chandrehi, Madhya Pradesh. *Palaeobotanist* **31** : 154-164.

Maithy PK & Mandal J 1982. Significance of algal remains from the Bhander of Vindhyan Supergroup, Rajasthan. *In* Sharma AK *et al.* (editors)—*Symp. Evolutionary Bot. & Biostratigraphy, Calcutta (1979).* 245-250. Today & Tomorrow Print. & Publ., New Delhi.

Maithy PK & Mandal J 1983. Microbiota from Vindhyan Supergroup of Karauli-Sapotra region of northeast Rajasthan, India. *Palaeobotanist* **31** : 129-142.

Maithy PK & Meena KL 1989. Organic-walled microfossils from the Proterozoic succession of Vindhyan Supergroup exposed around Satna, Madhya Pradesh, India. *Indian J. Earth Sci.* **16** (3-4) : 178-188.

Maithy, PK, Meena KL & Babu R 1992. First report of Ediacaran biota from the Upper Bhander of Vindhyan Supergroup, northeast Rajasthan, India. *Indian J. Earth. Sci.*

Maithy PK, Narain K & Sarkar A 1986. Body and trace fossils from the Rohtas Formation (Vindhyan Supergroup) exposed around Akbarpur, Rohtas District. *Curr. Sci.* **55** (20) : 1029-1030.

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

Maithy PK & Shukla M 1984a. Reappraisal of *Fermoria* and allied remains from Suket Shale Formation. *Palaeobotanist* **32** : 146-152.

Maithy PK & Shukla M 1984b. Biological remains from Suket Shale Formation. *Geophytology* **14** : 212-215.

Mandal J, Maithy PK, Barman GI & Verma KK 1984. Microbiota from the Kushalgarh Formation, Delhi Supergroup, India. *Palaeobotanist* **32** : 1-19.

Mathur SM 1982. Organic materials in Precambrian Vindhyan Supergroup. *In* Valdiya KS *et al* (editors)—*Geology of Vindhyachal* : 125-131.

Mathur SM 1983. A reappraisal of trace fossils described by Vredenburg (1908) and Deer (1919) in rocks of Vindhyan Supergroup. *Rec. geol. Surv. India* **113** : 111-113.

Mathur SM & Verma NK 1983. A new ichnofossil from the Bhander Group, Vindhyan Supergroup. *Curr. Sci.* **52** (9) : 426-428.

McMenamin DS, Kumar S & Awramik SM 1983. Microbial fossils from the Kheinjua Formation, Middle Proterozoic, Semri Group (Lower Vindhyan), Son Valley area, central India. *Precambrian Res.* **2-1** (3-4) : 247-272.

Misra RC & Awasthi N 1962. Sedimentary markings and other structures in the rocks of Vindhyan Formation of the Son Valley and Maihar-Rewa area, India. *J. Sediment. Petrol.* **19** : 88-89.

Misra RC & Bhatnagar AA 1950. On carbonaceous discs and algal dust from the Vindhyan Precambrian. *Curr. Sci.* **19** : 88-89.

Numova SN 1969. Spore complexes of the Riphean and Cambrian in U.S.S.R. *Int. geol. Congr.* **1** : 21.

Nautiyal AC 1983a. Discovery of Late Algonkian microplankton from the porcellanite stage and its environment of deposition at Son Valley (Mirzapur District). *Geoscience* **4** (1) : 75-86.

Nautiyal AC 1983b. Algonkian (Upper to Middle) micro-organisms from the Semri Group of Son Valley (Mirzapur District), India. *Geoscience* **4** (2) : 169-198.

Nautiyal AC 1984. Discovery of Algonkian (Upper to Middle) microorganisms from the Semri Group at Sangrampur Hills, Banda District, India. *Geoscience* **5** (1) : 81-86.

Oehler DZ 1978. Microflora of the Middle Proterozoic Balbirini Dolomite (Mc-Arthur Group) of Australia. *Alcheringa* **2** : 269-309.

Oehler JH 1977. Microflora of the HYC Pyritic Shale Member of Burney Creek Formation (Mc-Arthur Group), Middle Proterozoic of Northern Australia. *Alcheringa* **1** : 315-349.

Pichmuthu CS 1971. Precambrian geochronology of peninsular India. *J. geol. Soc. India* **12** (3) : 262-273.

Pflug, HD & Maithy, PK 1977. Nachweisverfahren für organische mikrofossilien in Präkambrischen Tonschiefern. *Oberheiss Natur. Ziet.* **43** : 15-23.

Prakash R 1966. Shell-like forms in Basal Stage, Vindhyan System. *Curr. Sci.* **35** : 466-467.

Prasad B 1975. Lower Vindhyan formations of Rajasthan. *Rec. geol. Surv. India* **106** (2) : 33-53.

Prasad B 1978. Vindhyan stromatolite biostratigraphy in south eastern Rajasthan. *Workshop on stromatolites characteristics and utility. Geol. Surv. India Udaipur* : 16-17.

Prasad B 1984. Geology, sedimentation and palaeogeography of Vindhyan Supergroup, southeastern Rajasthan. *Mem. geol. Surv. India* **116** (1) : 1-107.

Prasad B & Ramaswamy SM 1980. Stromatolites in Upper Vindhyan from Bundi, Kota and Sawai Madhopur District, Rajasthan. *Stromatolites characteristic and utility. geol. Surv. India. Misc. Publ.* **44** : 275-277.

Raja Rao CS & Mahajan VD 1965. Note on stromatolites and possible correlation of Bhagwanpura Limestone, Chittorgarh District, Rajasthan. *Curr. Sci.* **30** : 82-83.

Rao KS, Lal C & Ghosh DB 1977. Algal stromatolites in the Bhander Group formations, Vindhyan Supergroup, Satna District, Madhya Pradesh. *Rec. geol. Surv. India* **109** : 38-47.

Sahni MR 1975. Vindhyan palaeobiology, stratigraphy and depositional environments : critical review. *J. Palaeontol. Soc. India* **20** : 289-304.

Sahni MR & Shrivastava RN 1954. New organic remains from the Vindhyan System and probable systematics of *Fermoria* Chapman. *Curr. Sci.* **23** : 34-41.

Salujha SK, Rehman K & Arora CM 1971a. Plant microfossils from the Vindhyans of Son Valley, India. *J. geol. Soc. India* **12** (1) : 24-33.

Salujha SK, Rehman K & Rawat MS 1971b. Fossil palynomorphs from the Vindhyan of Rajasthan (India). *Rev. Palaeobot. Palynol.* **1** : 65-83.

Sarkar B 1974. Biogenic sedimentary structures and microfossils of the Bhander Limestone (Proterozoic) in India. *Q. J. geol. Min. metall. Soc. India* **46** : 143-156.

Schopf JW 1968. Microflora of the Bitter Spring Formation, Late Precambrian, central Australia. *J. Palaeontol.* **42** : 651-688.

Schopf JW & Blacic JM 1971. New microorganisms from the Bitter Spring Formation (Late Precambrian) of north central Amadeus Basin, Australia. *J. Palaeontol.* **45** : 925-950.

Shepleva ED 1962. Plant fossils of unknown taxonomic position from the deposits of the Bablinskya Series in the Volga-Urals Oil Province. *Dok. Akad. Nauk. Earth Sci. Trans.* **142** : 170-171.

Shrivastava RN 1972. Microorganic remains from the Vindhyan Formation of India. *Proc. Sem. Palaeopalynol. Indian Stratigr., Calcutta (1971)* : 1-14.

Shukla M & Sharma M 1990. Palaeobiology of Suket-Shale, Vindhyan Supergroup—age implications. *Workshop on Precambrian of central India, G.S.I. Spl. Publ.* no. **28** : 411-434.

Shukla M, Venkatachala BS & Sharma M 1989. Interaction of lithosphere and biosphere : some evidence from early metazoan and metaphytes from India. *Lunar and Planet. Conf., Houston, U.S.A.* : 1012-1013.

Sin Y & Liu K 1973. On Sinian microflora in Yenliao region of China and its geological significance. *Acta geol. sin.* **1** : 1-64.

Sisodiya DS. 1982. Fossil impression of jelly fish in the Nimbahera Limestone, Semri Group in Vindhyan Supergroup rocks. *Curr. Sci.* **55** : 1070-1071.

Sitholey RV, Srivastava PN & Verma CP 1953. Microfossils from the Upper Vindhyans with a discussion of the age of the Vindhyan in the light of the plant fossils discoveries. *Proc. natn. Inst. Sci. India* **19** : 195-202.

Sprigg RC 1947. Early Cambrian (?) Jelly fishes from the Flinders Range, South Australia. *Trans. R. Soc. South Australia* **71** : 212-224.

Srivastava AP 1985. Fission-track studies of authigenic sedimentary mineral glauconite and its application to date Lower Vindhyan deposits. *Ph.D. Thesis*, Kurukshetra University.

Srivastava AP 1987. F.T-dating of stratigraphy using authigenic mineral gluaconite. *In* Baliga BB, *Proc. natn. SSNTDS, Calcutta* : 229-251.

Srivastava AP & Rajagopalan G 1985. Fission-track dating technique applied to glauconite *Bull. Lias Inf. IGCP Project-196* **5** : 42-47.

Srivastava AP & Rajagopalan G 1986. Fission-track chronometers for dating sedimentary deposits. *Proc. IV natn. Sem./Workshop on SSNTDS (Debradun)* : 31-40.

Srivastava AP & Rajagopalan G 1986. FT dating of Precambrian deposits of Vindhyan Group at Chitrakut, Banda District (U.P.-M.P.) *In* Sharma KK (Editor)—*Nuclear Tracks application to Earth Sci., Space Physics and Nuclear Physics, Debradun* : 41-52.

Srivastava AP & Rajagopalan G 1988. F-T ages of Vindhyan glauconite sandstone beds exposed around Rawatbhata area, S.W. Rajasthan. *J. geol. Soc. India* **32** : 527-529.

Srivastava AP & Rajagopalan G 1989. Glaucony age of Vindhyan sediments in Rajasthan. *Indian J. Phys.* **64A** : 358-364.

Srivastava AP, Rajagopalan G & Nagpaul KK 1985. Fission-track ages of Lower Vindhyan glauconitic beds at Mirzapur, U.P. *Indian J. Earth Sci.* **12** (2) : 89-92.

Srivastava AP, Saini HS & Rajagopalan G 1983. Dating of glauconite from three sedimentary formations of peninsular India. *In* Virk HS (Editor)—*Proc. of the 3rd National SSNTDS Conference* : 15-19.

Sun WG 1986. Precambrian medusoid. The *Cyclomedusa plexus* and *Cyclomedusa*-like pseudofossils. *Precambrian Res.* **32** : 567-574.

Tandon KK & Kumar S 1977. Discovery of annelid and a arthropod remains from Lower Vindhyan rocks of central India. *Geophytology* **7** : 126-129.

Timofeev BV 1956. Hystrichosphaeridae from the Cambrian *Dokl. Akad. Nauk. SSSR* **106** : 130-132 (in Russian).

Timofeev BV 1959. The ancient flora of the Prebaltic and its stratigraphic significance. *Mem. V.N.I.G.R.I.* **129** : 1-350.

Timofeev BV 1963. On organic remains in the Eocambrian of Norway. *Norsk. Geol. tidrkr.* **43** (4) : 1-14.

Timofeev BV 1966. Micropalaeophytological study of ancient sedi-

ments. *Akad. Nauk. SSSR, Leningrad* : 1-147.

Timofeev BV 1969. Proterozoic sphaeromorphs. *Akad. Nauk. SSSR, Institute, Precambrian Geol. Geochronol. Leningrad* : 146 (Russian).

Valdia KS 1969. Stromatolites of the lesser Himalayan Carbonate formations and the Vindhyan. *J. geol. soc. India* **10** : 1-125.

Verma KK & Prasad KN 1968. On the occurrence of some trace fossils in Bhander Limestone (Upper Vindhyan) of Rewa District, M.P. *Curr. Sci.* **37** : 557-558.

Vidal G 1976. Late Precambrian microfossils from the Visingso beds in southern Sweden. *Fossil and Strata* **9** : 1-57.

Vidal G & Knoll AH 1983. Proterozoic plankton in Proterozoic geology. *Geol. Am. Mem.* **161** : 265-277.

Vinogradov A, Tugarinov A, Zhykova C, Stapnikova N & Bivikova E 1964. Geochronology of Indian Precambrian. *22nd Int. Geol. Congr., New Delhi Rep.* **10** : 553-567.

Walcott CD 1899. Precambrian fossiliferous formations. *Geol. Soc. Am. Bull.* **10** : 199-244.

Walter MR, Oehler JH & Oehler DZ 1976. Megascopic algae 1300 million years old from the Belt Supergroup Montana- a reinterpretation of Walcott's *Helmunithoidichnites*. *J. Palaeontology* **50** : 872-881.

Zalessky MD 1916. In Eisenack, A. 1960. *Senckenb. Leth.* **41** (1/5) : 13-16.

Zhuraleva A Yu 1986. Evolution of *Archaeocyatha* and palaeobiography of Early Cambrian. *Geol. Mag.* **123** (4) : 377-385.