Biodiversity in Indian Proterozoic basins

Mukund Sharma

Birbal Sahni Institute of Palaeobotany, Lucknow-226 007

Sharma, M. 2004. Biodiversity in Indian Proterozoic basins. *Geophytology* **33**(1&2) : 87-98.

A comprehensive précis based on published fossil records from Indian Proterozoic basins is presented with a comparative status of the global record. Review of various fossils found in Proterozoic sediments suggest the biodivesity in planktic and benthic realms but show ecological conservatism as nearly all the forms are found in marine depositional environment indicating a possible preservation bias. Proterozoic biodiversity is restricted in sense that diversified animal life arose only in Terminal Proterozoic and record of fungal elements is inconclusive. Since no terrestrial forms (land forms) are recorded in the sediments, it is presumed that they did not evolve in Proterozoic.

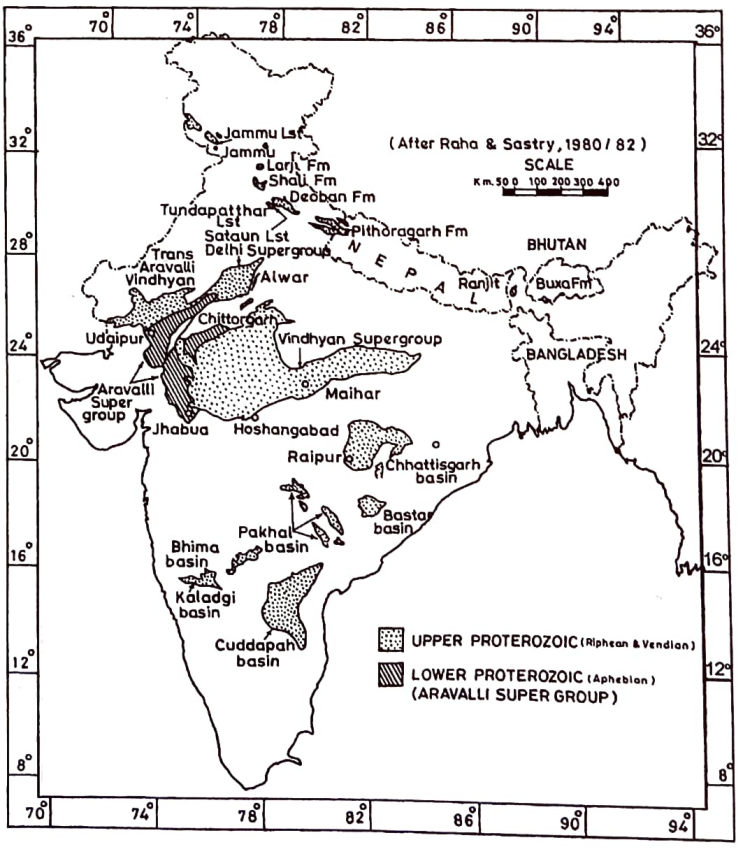
Key-words- Biodiversity, Proterozoic, Stromatolites, Microfossils, Metaphytes, Metazoa.

INTRODUCTION

DURING Proterozoic Eon the larger extent of the continental crust of India was formed. In the early part of the Palaeoproterozoic, the Indian shield constituted of Archaean granite-greenstone terrain and deeply buried crust of the granulite terrain got welded to form a stable crust of continental dimensions which was later exposed to sub aerial erosion and sedimentation for nearly 1000 million years (Radhakrishna 1987). On this crust were deposited the platformal sediments. These platformal sediments constituting the Proterozoic basins are spread over different regions of India. Most of them are confined to peninsular region such as the Bijawar/Aravalli/Delhi, the Cuddapah, the Kaladgi, the Vindhyan, the Chhattisgarh, the Indravati, the Pakhal, the Penganga and the Bhima. In the extra peninsular region, in lesser Himalaya there are well known Krol Belt (constituted of Nainital, Garhwal, Mussoorrie, Korgai, Nigalidhar, Kamlidhar, Pachmunda and Krol synclines), the Deoban Limestone Belt, the Jammu Limestone Belt and the Menga Limestone in Eastern Himalaya (Map). Besides, some of the Proterozoic basins are exposed in Higher Himalaya (Kashmir basin) and the Tethys Himalaya (Spiti-Zanskar and Kumaun basins). These rest transgressively over the early Neoproterozoic Simla Group or over the Salkhaln Group with granites dating 745±50 Ma or their equivalent (Kumar *et al.* 1997).

BIODIVERSITY IN PROTEROZOIC BASINS

The diversity in Proterozoic basins is recorded in terms of stromatolites, cyanobacterial remains, carbonaceous macrofossils, acritarchs, metazoan remains and trace fossils.



Map- Proterozoic basins of India.

<E-Mail: mukundsharma@Hotmail.com>

PENINSULAR INDIAN BASIN

Bijawar, Aravalli, Delhi Group/Supergroup

The Bijawar Group of rocks is exposed in the Chhattarpur, Hoshangabad, Jabalpur and Narsinghpur districts of Madhya Pradesh. Stromatolites have been reported in these areas by Khan and Das (1968), Murti (1972a, b) Balasundram and Mahadevan (1972), Lakshmanan *et al.* (1977) and Gupta *et al.* (1988). In the Aravalli Supergroup, Muktinath (1967) and Raja Rao *et al.*(1968) recorded the columnar stromatolites. Later, Verma and Burman (1980) reported *Collenia columnaris,* enrichment of phosphorite in stromatolite, and cryptalgal phsophorite, from the Udaipur region. Subsequent studies (Muktinath & Sant 1967; Banerjee 1971, Banerjee *et al.* 1980, Chauhan 1979, 1989) visualized the role of algae (cyanobcteria) in deposition of the phosphorite of the Bijawars. Mandal *et al.* (1983) reported microbiota from Kushalagarh Formation, Delhi Supergroup. Das Gupta and Prasad, (1995) recorded evidence of bioturbation in the Delhi Supergroup exposed in Haryana. Besides these indirect evidence of cyanobacterial remains and bioturbation, Kalia *et al.* (1992) reported some large sized metazoan fossils from the Alwar quartzite.

Cuddapah

The crescent shaped Palaeo to Mesoproterozoic basin exposed in Andhra Pradesh is well known for its palaeobiologicl remains.

Cyanobacterial remains

Schopf and Prasad (1977) reported a number of cyanobacterial sheaths and filamentous forms from the Vempalle Formation of the Papaghani Group. Gururaja *et al.* (1979) reported an assemblage of microbiota consisting of filamentous, coccoid and asteroid forms resembling *Eostrion* in stromatolitic black chert in the chert dolomite sequence of the Cumbum Formation. Mandal *et al.* (1983) recorded varied forms of catagrpahs and taxnomically dealt them.

Stromatolites

Gururaja and Chandra (1987) reproted various Riphean columnar stromatolite groups, namely, *Colonella, Columnacollenia, Cryptozoon, Conophyton, Jacutophyton, Omachtenia, Kussiella, Jurussani, Anabaria, Gymnosolen* and *Inzeria.* Sharma and Shukla (1998b) described small digitate ministromatolites from the Vempalle Formation. Sharma and Shukla (2003) have used stromatolite asemblage in establishing biostratigraphy of the Cuddapah Supergroup.

Acritarchs

Varied types of acritarch genera reported from the Cuddapah Supergroup are *Granomarginata prima, Protoleiosphaeridium* sp., *Lophosphaeridium kurnoolei* (Mandal *et al.* 1983).

Carbonaceous remains

Rajurkar (1963) and Sharma and Shukla (1999) reported *Chuaria,* Tawuid, Beltanid and Moranid forms from the Owk Shale Formation and bioturbation structures in the Narji Limestone Formation of the Kurnool Group (Arya & Rao 1979).

Kaladgi

Exposed along the northern and northeastern boundaries of the Dharwar Craton, ovoid shaped basin is spread over the Maharastra and Karnataka states.

Cyanobacterial remains

Schopf and Prasad (1978) and Viswanathiah *et al.* (1980) recorded Chrooccocaceae members (*Sphaerophycus parvum*) and Oscillatoriaceae members (*Cephalopytarion delicatulum, Heliconema australiense,* and *Eomycetopsis gangathriensis*).

Stromatolites

Varied forms of stromatolites are known from the Kaladgi basin. Viswanathiah *et al.* (1964) and Viswanathiah and Gowda (1970) reported *Collenia compacta, C. columnaris, C. symmetrica* and *Cryptozoon proliferum.* Later Sharma *et al.* (1999) recognized new forms viz., *Ephyaltes edingunnensis, Eucapsiphora leakensis, Kussoidella karalundeiensis, Pilbaria deverella, Yandilla meekatharrensis* and *Yelma digitata.*

Acritarchs

Viswanathiah *et al.*(1980) reported a large

number of the acritarch forms from Kaladgi basin. These include *Protosphaeridium densum, P. acis, P. flexuosum, P. granuliferum, P. parvulum, P. punctatum, P. reticulatum, P. scabridium, Kildinella minuta, Stictosphaeridium tortulosum, Leiosphaeridia aglutinata, L. dhakshinii, Trachysphaeridium attenuatum, Trachysphaeridium* sp., *Lophosphaeridium rarum, L. conatum, Trematosphaeridium holtedahlii, Leomarginata simplex, Leomarginata* sp., *Margominuscula prima, M. prisca, M. verrucata, Gloecapsamorpha* sp., *Retispheridium dichamerum. Retisphaeridium* sp., *Micrhystridium inconspicuum, M. kaladgiensis, Veryhachium* sp., *Leiovalia oblonga, Leioligotriletum crassum.* Viswanathiah *et al.* (1976) reported acritarchs belonging to the genera *Ressochitina, Cyathochitina, Conochitina* & *Acanthichitina* from the younger Badami Group of rocks.

Vindhyan

The Vindhyan basin is considerd to be the largest Purana basin, occupying an estimated 16,000 km^2, almost half of which is concealed beneath Phanerozoic cover (Srivastava *et al.* 1982). It extends from Sasaram in the east to Chittorgarh in the west.

Cyanobacterial remains

A number of workers reported a rich assemblage of cyanobacteria from different formations of the Vindhyan Supergroup (Kumar 1978, McMenamin *et al.* 1983, Kumar & Srivastava 1995, 1997, Nautiyal 1983a, b, 1984, 1986a, b, 1988, Nautiyal & Singh, 1990, Maithy & Shukla, 1977, 1984, Maithy & Meena 1989, Maithy & Mandal 1983). The reported forms include *Animikiea septata, Aphanocapsaopsis sitholeyii, A. ramapuraensis, Biocatenoides sphaerula, Biocatenoides* sp., *Caryosphaeroides pristine, Corymbococcus vindhyanensis, Eoentophysalis belcherensis, E. cumulus, E. magna, Eomycetopsis pflugii, E. reticulata, E. septata, E. filiformis, E. siberiensis, Eosynechococcus isolatus, Gunflintia minuta, Glenobotrydion aenigmatis, G. majorinum, Globophycus rugosum, Gloeocapsamorpha karauliensis, Gunflintia grandis, G. minuta, Gloediniopsis lamellose, G. gregaria, Gloediniopsis* sp., *Heliconema* sp., *Huroniospora psilata, H. microreticulata, Myxococcoides psilata, M. inornata, M. ramapurensis, M. globosa, M. magnus, M. minor, Melasmatosphaera media, M. parva, Nanococcus vulgaris, Oscillatoriopsis psilata, O. tirohanensis, O. glauconitensis, Oscillatoriopsis* sp., *Palaeoanacystis suketensis, P. vulgaris, P. punctatus, P. verucosa, Paleopleurocapsa wopfneri, Palaeolyngbya funiculum, P. rohatsensis, Palaeonostochopsis vindhyanensis, Siphonophycus kestron, S. parvum, Sphaeriophycus medium, S. parvum, Tetraphycus major, T. conjunctum.*

Stromatolites

Varied types of organosedimentary structures formed by cyanobacteria are recorded in the Vindhyan Supergroup viz., *Collenia baicalica, C. columnaris, C. buriatica, C. symmtyrica, C. undosa, C. ramsayi, C. lodhwarensis, C. kusiensis, C. clappi, C. frequens, C. septentrionalis, Colonella kajarahatensis, Irregularia colonella, Baicalia baicalica, B. satnensis, Dalaia dalensis, Maiharia maiharensis, Conophyton cylindriocus, C. garganicus, C. vindhyanensis, Tungussia, Newlandia minuta, Indophyton, Pseuodogymnosolen nauhattensis, Stratifera irregularis,* and Cryptalgal laminites (Kumar 1980, Sharma 1996).

Acrticarchs

Diversified acritarch assemblage has been found in various formations of Vindhyan Supergroup (Maithy 1968, 1981, Maithy & Babu, 1988, Maithy & Mandal, 1983, Maithy & Gupta 1981, 1983, Nautiyal 1983a, b, 1984, 1986a,b, 1988, Nautiyal & Singh 1990), viz. *Leiosphaeridia tenella, L. pellucida, Leiosphaeridia* sp., *L. densum, L. porcellanitensis, L. microgranulosa, L. granulose, L. sarjeantii, Protoleiosphaeridium diatertus, P. densum, P. pristinum, Kildinella* sp., *K. minuta, K. rom., Lophosphaeridium jansoniusii, L. vetulum, L. granulatum, Micrhystridium sitholeyi, Baltisphaeridium scitulum, Baltisphaeridium* sp., *Pterospermopsis typicaus, Melanocyrillium hexodiadema, M. horodyskii, Melanocyrillium* sp., *M. fimbriatum Prototeroxphaeridium* sp.,

Retispheridium vindhyanensis, Retispheridium sp., *Cyclogranisporites* sp., *Leiotriletes sp., Lacunalites* sp., *Archaeofavosina venusta, A. reticulata, Trematosphaeridium inspissatum, Symplassosphaeridium bulbosum, Orygmatosphaeridium plicatum, Vavosphaeridium vindhyanensis, Vavosphaeridium* sp., *Nucellosphaeridium minimum, N. zoantum, N. minor Zonosphaeridium punctatum, Tasmanites vindhyanensis, Leiofusa actinomorpha, Granomarginata regia, Ventronostocale amoenum Melasmatosphaera media, Polyedryxium neftelenicum* (see Nautiyal 1983 a, b, Maithy & Babu 1997, Maithy *et al.* 1992).

Carbonaceous macrfossils

Beltina danai, Chuaria circularis, C. minuta, C. gigantea, C. melanocentrica, C. vindhyanensis, Chambalia minor, Tawuia dalensis, T. indica, Tasmanites, Longfenghshania stiptata, L. chopanensis, Grypania spiralis, Tilsoia khoripensis, Suketea rampurensis, Vendotaenia, Tyrasotaenia (See Beer 1919, Shukla & Sharma 1990, Kumar 1995, 2001, Rai *et al.* 1997).

Metazoan remains and trace fossils

Most of the described metazoan remains do not belong to any known group of animals. The others however, can be assigned to porifera, arthropoda and gastropoda groups viz., *Bhanrerichnus damohensis, Cyclomedusa davidii, Asteriradiatus karaluiensis, hordoichus latouchei,* Brachiopod shell, *Hyolithes rohitaswei, Sonjiwashman basuhariensis, Rampuraea vindhyanensis, Spiroichnus beerii, Allatheca, Beltanelloides, Coleolella billingsii, Rohtasia tandonii, Sekwia excentrica, Skolithos,* trace fossils, sponge spicule like forms, chitionozoa etc. (see Verma & Prasad 1980, Maithy 1990, Maithy & Babu 1986, 1988 a, b, 1989, Maithy *et al.* 1986, 1992, Sarkar *et al.* 1996, Seilacher *et al.* 1998, Azmi 1998, Kumar 1999, Kathal *et al.* 2000).

Marwar Supergroup

Mostly undeformed sedmients lying unconformably on the Malani Igneous suite in western Rajasthan are conventionally referred to as 'Trans-Aravalli Vindhyans' (Pascoe 1959, pp. 549-552). Awasthi and Prakash (1981) called them 'Marwar Supergroup'. This is one of the Proterozoic basins, which is yet to be extensively studied.

Burman (1980) recorded stromatolites from Bilara Formation that include *Collenia pseudocolumnaris, Collenia* sp., *Concollenia* sp., *Cryptozoon occidentale, Irregularia* sp., *Stratifera* sp. It was noticed that all of them show stunted growth.

Ganga Supergroup

Geological information from the Ganga Supergroup is generally credited to Oil and Natural Gas Corporation borehole data and cores being privy to the organization have resulted in restricted yet significant palaeobiological information.

Cyanobacterial remains

Sastri and Venkatachala (1968), Maithy *et al.* (1983) reported *Myxococcoides globosa, Palaeoanacystis verrucossus, Gunflintia minuta.* Sastri *et al.* (1970) reported heterocyst genus *Palaeonostoc* from the Ganga Basin.

Acritarchs

Recently, Prasad and Asher (2001) reported a large number of acritarch genera from subsurface Ganga Basin sediments. They include *Leiosphaeridia asperata, Lophosphaeridium rarum, Micrhystridium tornatum, Cristallinium cambriense, Cymatiosphaera crameri, C. ovilliness, Eupoikilofusa squama, Leiofusa, staumonense, Eliasum llaniscum, Cymatiogalea cuvillieri, C. bellicosa, Saharidia fragile, S. downiei, Annulum* (G.) *squamaceum, Veryhachium dumonti, Aliumella baltica.* (Ujhani Formation), *Navifusa granulatus, N. robustus, Leiovalia rugostriatus, Trachysphaeridium laufeldii, Germinospheaera unispinosa, Tappania tubata, Synsphaeridium sorediforme, Arctacellularia pentagonalum, Simila annulae, Pterospermella saccata.* (Avadh Formation), *Tappania plana, Navifusa majensis, Pterospermella magnus, Kildinosphaera* spp., *Pterospermopsimorpha pileioformis* (Sarda Formation).

Earlier Salujha *et al.* (1967), Sastri and Venkatachala (1968), Maithy *et al.* (1983), Saxena (1992), and Shanumukhappa *et al.* (1996) reported several acritarch genera that include *Protosphaeridium volkovae, P. densum, Granomarginata minuta, G. rotata, Orygmatosphaeridium plicatum, Vavosphaeridium vindhyanensis, Archaeofavosinia sinuta, Kildinella suketensis, Nucellosphaeridium minutum, N. zonatum, N. medianum, Zonosphaerdium punctatum, Leioligostriletum crassus.*

Chhattisgarh and Indravati

'Broken Saucer' shaped exposures covering an area of approximately 35, 000 km^2 in Chhattisgarh is the third largest Purana basin in peninsular India. Similarly uneven rhomb-shaped Indravati basin lies unconformably above the Precambrian metamorphics. It is interpreted as erosional relicts of a single Great Chhattisgarh basin (Kale & Phansalker 1991).

Cyanobacterial remains

There are only two reports of microfossils in the Chhattisgarh Supergroup (Moitra & Pal 1984 and Moitra 1999) recording *Eotetrahedron* sp., *Gunflintia grandis, Oscillatoriopsis* sp., *O. raipurensis, O.* cf. *constricta, O.* cf. *schopfii, Siphonophycus, Taeniatum* sp., *Eomycetopsis robusta, Cyanonema, Caudiculophycus.*

Stromatolites

Sen (1966), Murti (1978), Moitra (1986, 1991, 1999), Sikdar (1989) reported a diversified stromatolitic assemblsage from different formations of the Chhattisgarh viz., *Anabaria, Acaceilla* cf. *angusta, Baicalia bifurcata, B. baicalica, B. prima, B. constricta, B. capricornia, B.* cf. *burra, B. lacera, Colonella discreta, C. conica, C. elongatus, C. laminata, Conophyton, Gymnosolen rotandus, G. furcatus, Inzeria tijomusii, Jacutophyton, Tungussia inna, Kussiella kussiensis, K. irregularis, Linella* cf. *avis.*

Acritarchs

Protospheridium sp., *Trachysphaeridium* sp. (Moitra 1999).

Pranhita-Godavari basin (Pakhal) and Penganga

Pranhita-Godavari basin (also referred to as the Pakhal basin) is the only Purana basin occupying an intracratonic location in the protocontinental configuration of the Indian peninsular shield (Kale & Phansalker, 1991).

Stromatolites

Chaudhuri (1970) reported varied types of stromatolites from the lower part of Pakhal Group. Later, Reddy (1975), Sarma *et al.* (1979), Prasad *et al.* (1979) reported *Collenia symmetrica, C. columnaris, C. undosa, Cryptozoon* sp., *and Gymnosolen* sp. Subsequently Gupta *et al.* (1988) reported a variety of stromatolites from Pakhal Group viz., *Baicalia baicalica, Omachtenia, Jacutophyton, Kussiella kussiensis, Inzeria, Colonnella* sp. *Tungussia* sp., *Conophyton garganicus, Platella, Gymnosolen* sp., *Pseudokussiella.* Maithy (1980) recorded *Orygmatosphaeridium plicatum* from blackish grey limestone of Penganga Formation.

Bhima

Bhima basin exposed on the north-eastern margin of the Dharwar Craton is a sigmoidal array of en-echelon with an aggregate area of 5000 km^2 is possibly the smallest independently recognized Purana basin. It is sandwitched between the peninsular Gneissic Complex and associated granitoids in the south and Deccan Trap basalts flows in the north (Kale & Phansalker, 1991).

Cyanobacterial remains

Maithy and Babu (1996) reported colonial sphaeroidal forms comparable to *Myxococcoides* and tubular forms comparable to *Eomycetopsis* from Halkal Formation of the Bhima Group.

Carbonaceous macrofossils

Suresh and Sundara Raju (1983), Das Sarma *et al.* (1992), Sharma and Shukla (1996), and Maithy and Babu (1996) reported a large number of carbonaceous macrofossils attributed to *Sinosabellidites huainanensis, Protoarenicola baiguashaensis, Pararenicola huainanensis, Chuaria circularis* and *Tawuia dalensis.*

EXTRA PENINSULAR BASINS

Kashmir Basin

Acritarch

From the basal part of the Lolab Formation and top part of the Machal Formation Maithy *et al.* (1988) reported the cryptarchs *Protosphaeridium, Kildinella, Lophosphaeridium* and *Orygmatosphaeridium*. Tiwari (1997) reported sponge spicules from Tethyan sequence.

Cyanobacteria

Maithy *et al.* (1988) recorded *Myxococcoides, Palaeoanacystis, Sphaerophycus, Gloeocapsomorpha, Gunflint, Palaeonostoc, Eomycetopsis, Animikea, Palaeopleurocapsa, Palaeoscytonema,* and *Ghosia*.

Shimla Group

Nautiyal (1982) reported a variety of acritarchs from Shimla Group viz., *Granomarginata primitiva, G. simlaensis, G. dhalii, Vavososphaeridium,* and some cyanophytes *Satpulispora silata, S. microreticulata* and *S. major.*

Krol Belt

Cyanobacterial remains

Siphonophycus robustum, Siphonophycus rugosum, Eophormidium orculiformis, Huroniospora microreticulata, Eomycetopsis, Siphonophycus, Tetraphycus hebeiensis, Obrucevella, Microcystis (Acharyya *et al.* 1989, Venkatachala *et al,* 1990, Kumar & Rai 1992, Tiwari & Azmi 1992, Maithy *et al.* 1995, Tiwari 1996, Tiwari & Knoll 1994).

Stromatolites

Poorly developed stromatolites are recorded from the Nainital syncline and *Collmnaefacta vulgaris, Stratifera undata* are reported from Mussoorie syncline (Singh & Rai 1977, Tewari 1984a, Sharma *et al.* 1994).

Acritarchs

Acritarchs such as *Trachyhystrichosphaera vidalii, Gorgonisphaeridium maximum, Siphonophycus septatum, Satka colonica, Melanocyrillium hexodiadema, Eomicrocystis malgica, Granomarginata primitiva, Leiosphaeridia crassa, Bavlinella faveolata, Micrhystridium echinatum, Micrhystridium regulare, M. eatonensis, Archaeohystrichosphaeridium cellulare, Archaeohystrichosphaeridium semireticulatum, Paracrassosphaera dedalea, Margominuscula simplex, Microconcentrica incrustata, Germinosphaera unispinosa, Baltisphaeridium perravum, Leiosphaeridia effusa* are reported from Krol belt (Venkatachala *et al.* 1990, Tiwari & Azmi 1992, Tiwari 1996).

Metazoan remains and trace fossils

Maximum numbers of metazoan fossils are reported from Krol belt. These metazoans remain belong to various groups viz.,

Ediacaran fossils-Pteridinium simplex, Charniodisucs sp., *Zolotytsia* sp., *Beltanelliformis brunsae, Tirasiana* sp., *Medusinites* sp., *Beltanella* sp., *Kimberella* sp., *Conomedusites* sp., *Cyclomedusa davidi, Cyclomedusa* sp., *Sekwia* sp., *Irridintus* sp. *Trace fossils-Gordia* sp., *Bilinichnus* sp. (Mathur & Shanker 1989, 1990, Shanker & Mathur 1992, Shanker *et al.* 1997).

Deoban Limestone Belt

Cyanobacterial remains

Archaeotrichion contortum, Biocatenoides sp., *Caryosphaeroides pristine, Circulinema jinningence, Cladophora* sp., *Clonophycus* sp., *Conjunctiophycus* sp., *Cyanonema* sp., *Cylindrospermum* sp., *Diplococcus* sp., *Eoentophysalis belcherensis, E. cumulus, E. magna, Eomicrocolieus crassus, Eomycetopsis robusta, E. filiformis, E. siberiensis, Eosynechococcus isolatus, E. medius, E. moorei, E. grandis, Glenobotrydion aenigmatis, G. majorinum, Globophycus rugosum, Gunflintia grandis, G. minuta, Gloediniopsis lamellose, G. gregaria, Huroniospora psilata, H. microreticulata, Myxococcoides grandis, M. inornata, M. minor, Melasmatosphaera media, M. parva,*

Oscillatoriopsis obtusa, O. ornata, Oscillatoriopsis sp., *Obruchevella* sp., *Palaeoscytonema* sp., *Paleopleurocapsa* sp., *Palaeolyngbya* sp., *Polytrichoides* sp., *Ramacia carpentariana, Rhicnonema* sp., *Scissilisphaera gradata, Siphonophycus kestron, S. robustum, S. inornatum, Sphaeriophycus parvum, Tolypothix* sp., *Tetraphycus major, T. conjunctum* (Kumar & Singh, 1979, Shukla *et al.* 1986, Kumar & Srivastava, 1992, Srivastava & Kumar 2003).

Stromatolites

Varied assemblages of stromatolites have been reported in Deoban Limestone belt: *Collenia-Baicalia baicalica* assemblage (Valdiya, 1969), the *Kussiella-Boxonia-Collenia columnaris-Collenia symmetrica-Stratifera* assemblage (Prashra, 1977), *Jacutophyton* (Kumar & Singh, 1979) and the *Kussiella-Conophyton-Baicalia* assemblage (Tewari, 1984b), Tiwari *et al.* (2000) recorded Neoproterozoic sponge spicules from the Gangolihat Dolomite.

Jammu Limestone Belt

Cyanobacterial remains

Maithy *et al.* (1988) and Venkatachala and Kumar (1996) recorded *Obruchevella, Myxococcoides* sp., *Nostocomorpha, Eomycetopsis, Sphaerocongregus*, *Glaeocapsomorpha* sp., *Gunflintia* sp., *Eomycetopsis* sp., *Animikea* sp., *Palaeosiphonella* sp. from Jammu Limestone.

Stromatolites

Anabaria radialis, *Baicalia prima, Colonella discreta, C. elongatus, C. katraensis, C. laminata, C. riasiensis, Conophyton cylindricus, Masloviella columnaris, Nucleella irregularia, Omachtenia granensis, Kussiella kussiensis, Platella talwarensis.* (Singh & Vimal 1972, Raha 1980, 1984).

Acritarchs

Protosphaeridium sp., *Granomarginata* sp., *Lophosphaeridium* sp., *Kildinellasphaera* sp., (Maithy *et al.* 1988). *Chuaria, Leiosphaeridia Laminariata, Ferrimonolis, Arctacellularia, Micrhystridium, Lophosphaeridium, Kildinosphaera* (Venkatachala & Kumar 1996).

Menga Limestone Formation

Stromatolites

Stratifera and *Nucliella* (Tewari 2001).

THE BIODIVERSITY TRENDS

In India, the Palaeoproterozoic basins of the Bijawar, Aravalli, Delhi, Cuddapah and Kaladgi contain stromatolites, poorly preserved microfossils and few problematic remains (Khan & Das 1968; Maithy *et al.* 1983; Banerjee 1971; Verma & Burman 1980; Schopf & Prasad 1978). Large-scale development of stromatolites and a few reports of microfossils in these basins indicate that taphonomy played a major role in preservation of these remains.

The Mesoproterozoic microfossils are best known in Indian basins from early diagenetic chert nodules occurring in peritidal carbonates (Shukla *et al.* 1986, Kumar & Srivastava 1992, Srivastava & Kumar 1995, 2003, Kumar & Rai 1992). During this period stromatolites occupied nearly entire shelf part of all the basins (Gururaja & Chandra 1987, Gowda & Govind Rajalu 1980). Varied types of benthic remains mainly constituted of cyanobacteria are found in different basins. Planktic remains are also abounding open shelf area.

In Indian Neoproterozoic basins, the diversity in stromatolites, cyanobacteria, acritarchs, metazoan and trace fossil remains are well documented and show that it is parallel to those documented for Neoproterozoic biodiversity in global records. The morphological diversity in Neoproterozoic is supported by the biomarker molecules (Summons & Walter, 1990). Besides, there is distinct evidence for diverse prokaryotes and eukaryotes, including the red algae, green algae and heterotrophic protists (Summons *et al.* 1988). The Neoproterozoic fossil assemblage is a testimony of diversity of biosphere and seems to be modern complement of prokayotes and protists including some seaweeds. Some indirect evidence of life on land has been reported from Torridonian rocks of north-west Canada (Parve 2002).

CONCLUSION

1. An assessment of the recorded microfossils and macrofossils indicates that Proterozoic biosphere was diversified in terms of morphological and physiological entities.
2. A comparison of the cyanobacterial remains shows that their forms and functions are mirror image of the present counterparts and inhabit almost similar niches. Distribution pattern follows the bathymetric gradient occupied by cyanobacteria in the present day sea.
3. Stromatolites—organo-sedimentary structures—are indirect evidence of biotic activity in the Proterozoic. Like the varied orders and genera of cyanobacteria they too proliferated and occupied various niches of the Proterozoic basins. Their diversity is also indicator of varied depositional environment and organisms in the formation of organo-sedimentary structures.
4. Carbonaceous megaremains of the Proterozoic Eon especially during the Neoproterozoic time period are unique in the sense that similar entities are neither found in younger sediments nor in the present day biosphere. Their taxonomic assignments to any of the plant or animal groups are still far from conclusive and many parallel/divergent views have been proposed for their origin and assignment.
5. True animal remains are comparatively meagre and confined to the Terminal Proterozoic sequences restricted in the extra peninsular regions of India. Plausible remains in older strata are inconclusive and occur mainly in the Kurnool and Vindhyan basins.
6. Trace fossil records from the Vindhyan, Chhattisgarh, Cuddapah Supergroups, Kurnool and Bhima Groups are not equivocal and need further corroborative data to support the existence of metazoan life in these sediments.
7. Since most of the recorded forms have been recovered from the rock sequences deposited in the marine realm they represent one side story of biodiversity. Therefore an overall assessment of Proterozoic record presents incomplete picture of the biodiversity in Proterozoic.
8. Fresh water deposits are yet to be investigated for biotic remains to give the complete understanding of biodiversity.

REFERENCES

Acharyya, SK, Raha, PK, Das, DP, Moitra, AK, Shukla, M & Bansal, R 1989 Late Proterozoic microbiotic from the Infra Krol rocks from Nainital Synform, U .P . Himalaya, India. *Indian Jour. Geol.* **61**(3): 137-147.

Arya, BC & Rao, CN 1979. Bioturbation structures from the Middle Proterozoic Narji Formation, Kurnool Group, Andhra Pradesh, India. *Sedimentary Geology* **22**: 127- 134.

Awasthi, AK & Prakash, B 1981. Depositional environments of unfosiliferous sediments from the Jodhpur Group, Western India. *Sedimentary Geology* **30**: 15-42.

Azmi, RJ 1998. Discovery of lower Cambrian Small Shelly Fossils and brachipods from Lower Vindhyan of Son Valley, Central India. *Jour. Geol. Soc. India* **52**: 381-389.

Balasundram, MS & Mahadevan, TM 1972. Stromatolites from the Bijawars of Joga, Hoshangabad district, M.P., India. *Rec. Geol. Surv. India* **99**: 127-132.

Banerjee, DM 1971. Precambrian stromatolitic phosphates of Udaipur, Rajasthan, India. *Geol. Soc. Am. Bull.* **82**: 2319-2330.

Banerjee, DM, Basu, PC & Srivastava, N 1980. Petrology, mineralogy, geochemistry and origin of the Precambrian Aravallian phosphorites of Udaipur and Jhabua, India. *Econ. Geol.* **75**: 1181-1199.

Beer, EJ 1919. Note on spiral impression on Lower Vindhyan Limestone. *Rec. Geol. Surv. India* **50**: 109.

Burman, G 1980. An analysis of the Marwar Basin, Western Rajasthan, in the light of stromatolite study. *Geol. Surv. India Misc. Publ.* **44**: 292-297.

Chaudhuri, A 1970. Precambrian stromatolites in Pranhita-Godavari Valley (South India). *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **7**: 309-340.

Chauhan, DC 1979. Phosphorite-bearing stromatolites of the Precambrian Aravalli phosphorite deposites of Udaipur region, their environmental significance and genesis of phosphorite. *Precambrian Res.* **8**: 95-126.

Chauhan, DC 1989. Microbial activities and genesis of Aravalli phosphorite, Udaipur, Rajasthan. *Him. Geol.* **13**: 39-51.

Das Gupta, G & Prasad, S 1995. Evidence of bioturbations in the Delhi Supergroup of Harayana. *Jour. Geol. Soc. India* **45**: 595-598.

Das Sarma, DC, Raha, PK, Moitra, AK, Ashok Kumar, P, Anantharaman, S, Rama Rao, U & Sundram, V 1992. Discovery of Precambrian-Cambrian transitional fossils sabellitids from India. *Curr. Sci.* **63**: 140-142.

Gowda MJC & Govinda Rajulu, BV 1980. Stromatolites of the Kaladgi Basin and their significance in palaeo environmental studies. *Geol. Surv. India Misc. Publ.* **44**: 220-239.

Gupta, S. Udhoji, SG & Verma, KK 1988. Algal stromatolites in Pakhal Group in parts of Gadchiroli district, Maharastra. *Rec. Geol. Surv. India* **117**: 148-161.

Gururaja, MN & Chandra, A 1987. Stromatolites from Vempalle and Tadpatri formations of Cuddapah Supergroup (Proterozoic) Andhra Pradesh and their significance. In Purana basins of Peninsular India. *Mem. Geol. Soc. India* **6**: 399-427.

Gururaja, MN, Jagannatha Rao, BR & Bhaskara Rao, B 1979. Stromatolitic microbiota from black chert of Cumbum Formation, Upper Cuddapah, Andhra Pradesh. *Jour. Geol. Soc. India* **20**: 138-140.

Kale, VS & Phansalker, VG 1991. Purana basins of peninsular India: a review. *Basin Research* **3**: 1-36.

Kalia, P, Bhagwat, RJ, Banerjee, A, Pande, PK & Trivedi, V 1992. Probable fossils from Alwar Quartzite, Aravalli range, North India. *Curr. Sci.* **62**: 427-430.

Kathal, PK, Patel, DR & Alexander, PO 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. Palaont. Mh.* **2000**(6): 321-332.

Khan, SU & Das, B 1968. Stromatolitic structures from the type area of Bijawars, rocks, Chhattarpur district, M.P., *India. Curr. Sci.* **37**: 171-172.

Knoll AH 1996. Archean and Proterozoic Paleontology. *In: Palynology:principals and applications*, Jansonius, J. & Mc Gregor DC (Ed.): 51-80.

Knoll AH & Sergeev, VN 1995. Taphonomic and evolutionary changes across the Mesoproterozoic-Neoproterozoic transition. *N. Jb. Geol. Palaeont. Abh.* **195**(1-3): 289-302.

Kumar, G, Shanker, R, Maithy, PK, Mathur, VK, Bhattacharya, SK & Jani, RA 1997. Terminal Proterozoic-Cambrian sequence in India: a review with special reference to Precambrian-Cambrian Boundary. *Palaeobotanist* **46**(1&2): 19-31.

Kumar, S 1978. Discovery of microorganisms from the black cherts of the Fawn Limestone, Late Precambrian, Semri Group, Son valley, Mirzapur distt. U .P . *Curr. Sci.* **47**(13): 461.

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

Kumar, S 1995. Megafossils from the Mesoproterozoic Rohtas Formation (the Vindhyan Supergroup), Katni area, Central India. *Precambrian Res.* **72**: 171-184.

Kumar, S 1999. Siliceous sponge spicules-like forms from the Neoproterozoic Bhander Limestone, Maihar area, Madhya Pradesh. *Jour. Palaeontol. Soc. India* **44**: 141-148.

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

Kumar, S & Rai, V 1992. Organic-walled microfossils from the bedded chert of Krol Formation (Vendian) Solan, Himachal Pradesh, India. *Jour. Geol. Soc. India* **39**: 229-234.

Kumar, S & Singh, SN 1979. Significance of *Jacutophyton* in the Deoban Limestone, Chakrata area, Dehradun district, Uttar Pradesh. *Curr. Sci.* **48**(9): 401.

Kumar, S & Srivastava, P 1992. Middle to Late Proterozoic microbiota from the Deoban Limestone, Garhwal Himalaya, India. *Precambrian Res.* **56**: 291-318.

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

Kumar, S & Srivastava, P 1997. A note on the carbonaceous megafossils from the Neoproterozoic Bhander Group, Maihar Area, Madhya Pradesh. *Jour. Palaeontol. Soc. India* **42**: 141-146.

Lakshmanan, S, Patel, NP & Das, B 1977. A study of stromatolites from the Bijawars of Madhya Pradesh, India. *Jour. Palaeontol. Soc. India* **20**: 327-330.

Maithy, PK 1968. The occurrence of microremains from the Vindhyan formation of India. *Palaeobotanist* **17**(1): 48-51.

Maithy, PK 1980. Record of Microbiota from the Penganga Formation (Precambrian), Wardha Valley. *Geophytology* **10**(2): 267.

Maithy, PK 1981. Vindhyan microbiota from Suket Shales, Ramapura, M.P. *Misc. Publ. Geol. Surv. India* **50**: 183-188.

Maithy, PK 1990. Metaphyte and metazoan remains from the Indian Proterozoic successions. *Palaeobotanist* **38**: 20-28.

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**(2): 223-226.

Maithy, PK & Babu, R 1988a. Chitinozoa-like remains from Vindhyan Supergroup of Son valley. *Palaeobotanist* **37**: 77-80.

Maithy, PK & Babu, R 1988b. The Mid-Proterozoic Vindhyan Macrobiota from Chopan, south east Uttar Pradesh. *J. Geol. Soc. India* **31**(6): 584-590.

Maithy, PK & Babu, R 1996. Carbonaceous macrofossils and organic-walled microfossils from the Halkal formation, Bhima Group, Karnataka with reference on age. *Palaeobotanist* **45**: 1-6.

Maithy, PK & Babu, R 1997. Upper Vindhyan biota and Precambrian/Cambrian Boundary. *Palaeobotanist* **46**(1&2): 1-6.

Maithy, PK, Babu, R, Kumar, G & Mathur, VK 1995. New cyanophycean remains from the Blaini Formation (Terminal Neoproterozoic Sequence) of Mussoorie Syncline, Lesser Himalaya, India. *Palaeobotanist* **43**(1): 39-44.

Maithy, PK, Babu, R, Raina, BK & Kumar, G 1988. Proterozoic microfosils from the Machhal and Lolab formations of the Kashmir Himalaya, India. *N. Jb. Geol. Palaeont. Mh.* **10**: 639-644.

Maithy, PK and Gupta, S 1981. Archaeocytha from the Vindhyan Supergroup, India. *Indian Jour. Earth Sci.* **8**(1): 76-81.

Maithy, PK and Gupta, S 1983. Microbiotic and organsedimentary structures from the Vindhyan Supergroup exposed around Chandrehi, Madhya Pradesh. *Palaeobotanist* **42**(2): 101-107.

Maithy, PK & Mandal J 1983. Microbiota from Vindhyan Supergroup of the Karauli-Sapotra region of North-East Rajasthan, India. *Palaeobotanist* **31**(2): 129-142.

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

Maithy, PK, Meena, KL & Babu R 1992. Ediacaran (?) Biota from the Dholpura shale, Upper Part of Vindhyan Supergroup, Near Lakheri, Rajasthan, India. *Indian Jour. Geology* **64**(4): 359-364.

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

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

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

Maithy, PK, Venkatachala, BS & Lele, KM 1983. Microbiota from subsurfaces of Ganga basin. *Geophytology* **13**(2): 190-194.

Mandal J, Maithy PK & Mehdi SH 1983 Microbiota and catagraphs from the Varikunta area of Cuddapah Supergroup. *Palaeobotanist* **31**(2): 191-199.

Mandal, J, Maithy, PK, Verma, KK & Barman, G 1983. Microbiota from the Kushalgarh Formation, Delhi Supergroup, India. *Palaeobotanist* **32**(1): 1-19.

Mathur, VK & Shanker, R 1989. First record of Ediacaran fossils from the Krol Formation, Nainital Syncline. *Jour. Geol. Soc. India* **34**: 245-254.

Mathur, VK & Shanker, R 1990. Ediacaran medusoids from the Krol Formation, Nainital syncline. *Jour. Geol. Soc. India* **36**: 74-78.

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.* **21**: 247-272.

Moitra, AK 1986. A preliminary study of the stromatolites of the Raipur Formation, Madhya Pradesh. *Proc. XI Colloquium on micropalaeontology and stratigraphy*: 124-130.

Moitra AK 1991. Four new forms of stromatolites from Chhattisgarh Basin, India. *Indian Minerals* **45**: 79-90.

Moitra AK 1999. Biostratigraphic study of stromatolites and microbiota of the Chhattisgarh Basin, M.P. India. *Palaeontologia Indica* **51**: 95.

Moitra AK & Pal, AK 1984. Microbiota from Raipur Formation Chhattisgarh Group, M.P. *Rec. Geol. Surv. India* **116**: 163-171.

Muktinath 1967. Phosphate deposits in Rajasthan. *Indian Minerals* **21**(2): 83-101.

Muktinath & Sant, VN 1967. Occurrence of algal phosphorites in the Precambrian rocks of Rajasthan. *Curr. Sci.* **36**(23): 638.

Murti, KS 1972a. Stromatolites from the Bijawars of the Joga area, Hoshangabad district, M.P.*Jour. Geol. Soc. India.* **13**(2): 181-182.

Murti, KS 1972b. Stromatolites from the Bijawars of the Joga area, Hoshangabad district, M.P. *Jour. Indian Acad. Geol. Sci.* **15**: 83-89.

Murti, KS 1978. A study of stromatolites of Chhattisgarh Basin. *Proc. Symp. on Purana Formations of Peninsular India.* Uni. Saugar: 268-275.

Nautiyal, AC 1982. Microplanktons from the Late Precambrian Shimla Group, Himachal Pradesh. *Curr. Sci.* **51**(6): 273-276.

Nautiyal, AC 1983a. Discovery of Late Algonkian microplanktons from PorcellaniteStage and its environment of Deposition at Son Valley (Mirzapur District), India. *Geosci. Jour.* **4**(1): 75-86.

Nautiyal, AC 1983b. Algonkian (Upper Middle) microorganisms from the Semri Group of Son Valley (Mirzapur district), *India. Geosci. Jour.* **4**(2): 169-198.

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

Nautiyal, AC 1986a. Lower Vindhyan (Algonkian) microflora, (Microfauna) and biostratigraphy of Sangrampur Hill, Banda District, Northern India. *Geosci. Jour.* **7**(1): 1-22.

Nautiyal, AC 1986 b. Late Algonkian microflora (Microfauna, Zone IV) of Rohtas Formation (Semri Group) in Son Valley (Mirzapur District), Northern India. *Geosci. Jour.* **7**(2): 103-124.

Nautiyal, AC 1988. Biostratigraphic significance of late Algonkian microorganisms (Zone IV) in Upper Tezam and Semri groups of lesser Himalaya, Subsurface Ganga Valley and Plains region, northern India. *Geosci. Jour.* **9**(1): 89-102.

Nautiyal, AC & Singh, S. 1990. First record of Upper Proterozoic microbiota zone IV in Tirohan Limestone and upper green sandstone (Semri roup) of Lachman Pahari (SW of Chitrakut, Banda District), Uttar Pradesh. *Geosci. Jour.* **11**(1): 123-138.

Parve, AR. 2002. Life on land in the Proterozoic evidence from the Torridonian rocks of northwest Scotland. *Geology* **30**: 811-814.

Pascoe, EH 1959. A manual of the Geology of India and Burma. *Geological Survey of India* 1 (3rd edition): 1-485.

Prasad, B & Asher, R 2001. Acritarch Biostratigraphy and lithostratigraphic Classification of Proterozoic and Lower Paleozoic Sediments (Pre- unconformity Sequence) of Ganga Basin, India. *Paleontographica Indica* **5**: 1-151.

Prasad, KN, Rao, HRJ & Gururaja, MN 1979. Observations on stromatolites from the Precambrian formations of South India. Proc. Collo. Palaeontolo. Studies in Southern Region. *Geol. Surv. India Misc. Publ.* **45**(1): 23-29.

Prashra, KC 1977. Algal stromatolites of the deoban, Atal Quartzite and Mandhali Formation in the Tona Valley, H.P. *Rec. Geo. Surv. India* **109**: 112-132.

Radhakrishna, HP 1987. Introduction. In: Purana basins of Peninsular India. *Mem. Geol. Soc. India* **6**: i-xv.

Raha, PK 1980. Stromatolite zonation in Jammu Limestone, Udhampur District, Jammu. *Geol. Surv. India Misc. Publ.* **44**: 134-171.

Raha, PK 1984. Stratigraphy of the Jammu Limestone (Great Limestone) Udhampur District, Jammu and Kashmir, with special reference to stromatolites. *Palaeontologia Indica* (New Series) **47**: 1-103.

Raha, PK, & Sastry MVA 1980. Stromatolites of Precambrian stratigraphy in India. *Proc. 26th International Geol. Wngr*

Paris **7**: 611 (Abstr.)

Raha, PK & Sastry MVA 1982. Stromatolites and Precambrian stratigraphy in India. *Precambrian Res.* **18**: 293-318.

Rai, V, Shukla, M & Gautam, R 1997. Discovery of carbonaceous megafossils (Chuaria-Tawuia assemblage) from the Neoproterozoic Vindhyan succession (Rewa group), Allahabad-Rewa area, North India. *Curr. Sci.* **73**(9): 783-788.

Raja Rao, CS, Iqbaluddin & Mathur, RK 1968. Algal structures from Aravalli beds near Dakan Kotra, Udaipur district, Rajasthan. *Curr. Sci.* **37**(19): 560-561.

Rajurkar, ST 1963. Discoidal impressions akin to Fermoria from Owk Shales of Kurnool district, Andhra Pradesh. *Indian Minerals* **17**(3): 306-307.

Reddy PH 1975. Note on the stromatolites in the Pakhal Series. *Curr. Sci.* **34**(3): 82-83.

Salujha, SK, Rawat, MS & Rehman, K 1967. Palynological study of Pre- Tertiary (Ujhani) Sediments in Uttar Pradesh, India. *ONGC Bull.* **4**(1): 56-61.

Sarkar, S, Banerjee, S & Bose PK 1996. Trace fossils in the Mesoproterozoic Koldaha Shale, Central India and their implications. *N. Jb. Geol. Palaeont. Mh* **7**: 425-438.

Sarma, TS, Gururaja, MN & Rao, BRJ 1979. Algal stromatolites from Pakhal near Kottapalle, Adilabad district, Andhra Pradesh. Proc. Coll. Palaeont. Studies in Southern Region. *Geol. Surv. India Misc. Publ.* **45**(1): 31-33.

Sastri VV & Venkatachala, BS 1968. Organic remains, age and environments of Pre Siwalik sediments encountered in some deep wells drilled in Southern part of GangaValley. *ONGC Bull.* **5**(1): 75-82.

Sastri VV, Venkatachala, HS & Desikachary, TVD 1970. A fossil Nostocacea from India. *Proc. Sym.Taxon. Biol. Blue-Green algae* 159-160. Madras Uni. Publi.

Saxena, RK 1992. Palynology of Pre-unconformity sequence of subsurface sediments of Ganga and Punjab basins of India. *Geosci. Jour.* **13**(1): 1- 7.

Schopf, JW & Prasad KN 1978 Microfossils in *Collenia* like stromatolites from the Proterozoic the Vempalle Formation of Cuddapah Basin, India. *Precambrian Res.* **6**:347-366.

Schopf, JW & Walter, MR 1983. Archaean microfossils and "microfossils-like" objects- a critical appraisal. In: *Extended Abstracts, Second International Archaean Symposium* (*Geological Society of Australia and International Geological Correlation Project: Perth, Australia*) Glover JE and Groves, DI (ed.): 23-34.

Seilacher, A, Bose, PK & Pfluger, F 1998. Triploblastic animals more than 1 Billion years ago: Trace fossil evidence from India. *Science* **282**: 80-83.

Sen, S. 1966. Stromatolites in Raipur Limestone, M.P. *Indian Minerals* **20**(1): 57-58.

Shanker, R & Mathur, VK 1992. The Precambrian-Cambrian sequence in Krol belt and additional Ediacaran fossils. *Geophytology* **22**: 27-39.

Shanker, R, Mathur, VK, Kumar, G & Srivastava, MC 1997 Additional Ediacaran biota from the Krol Group, Lesser Himalaya, India and their significance. *Geosci. Jour.* **18**(1): 79-94.

Shanmukhappa, M, Singh RN & Poovedan A 1996. Precambrian (Proterozoic) acritarchs from Subsurface Vindhyan sequence Jabera well-A, Madhya Pradesh. *Proc. XV Indian Colloq. Micropalaeontol. Strat.* Dehradun 554-549.

Sharma, M 1996. Microbiolites (stromatolites) from the Mesoproterozoic Salkhan Limestone, Semri Group, Rohatas, Bihar: Their systematics and siginificance. *Mem. Geol. Soc. India* **36**: 167-196.

Sharma, M, Mathur, VK, Srivastava, MC & Shukla, M 1994. Systematics and significance of microbialite (stromatolite) Stratifera undata from Mussoorie syncline, Lesser Himalaya. *Jour. Geol. Soc. India* **43**: 705-712.

Sharma, M & Shukla, M 1996. Diversity and gigantism of Carbonaceous macrofossils in Terminal Proterozoic Bhima basin of India. 30th IGC Abstract volume **2**: 52.

Sharma, M & Shukla, M 1998. Microstructure and Microfabric studies of Palaeoproterozoic small digitate stromatolites (ministromatolites) from the Vempalle formation, Cuddapah Supergroup, India. *Jour. Palaeontol. Soc. India.* **43**: 89-100.

Sharma, M & Shukla, M 1999. Carbonaceous megaremains from the Neoproterozoic Owk Shales Formation of the Kurnool Group, Andhra Pradesh, India. *Curr. Sci.* **76**: 1247-1251.

Sharma, M & Shukla, M 2003. Palaeo-Mesoproterozoic stromatolites from the Vempalle and Tadpatri Formation Cuddapah Supergroup, India: Microstructure, microfabric and morphogenesis. (DD Pant Memorial Volume, In Press).

Sharma, M, Shukla, M & Kale, VS 1999. Stromatolites of the Kaladgi Basin: Their systematics, age implications and biostratigraphy. In: *Field workshop on integrated evaluation of the Kaladgi and Bhima Basins*, 36-37 Abst. Vol Organised by Geol. Soc. India. October 1999.

Shukla, M, & Sharma, M 1990. Palaeobiology of Suket Shale, Vindhyan Supergroup-age implications. *Spec. Publ. Geol. Surv. India* **28**: 411-434.

Shukla, M, Tewari, VC and Yadav, VK 1986. Late Precambrian microfossils from the Deoban Limestone Formation, Lesser Himalaya, India. *Palaeobotanist* **35**(3): 347-356.

Sikdar, PK 1989. Stromatolites and depositional environment of Raipur ormation, Chhattishgarh Groupo, Nandini-Jamul area, Durg district, M.P. *Him. Geol.* **13**: 87-92.

Singh, IB & Rai, Vikram 1977. On the occurrence of stromatolites in the Krol Formation ofNainital area and implications on the age of Krol Formations. *Curr. Sci.* **46**: 736-739.

Singh, P & Vimal, KP 1972. Discovery of stromatolites from the Sirban Limestone of Riasi Jammu Province, Jammu and Kashmir state. *Jour. Palaeontol. Soc. India* **15**: 6-9.

Srivastava, BN & Kumar, S 2003. New microfossils from the Meso-Neoproterozoic Deoban Limestone, Garhwal Lesser Himalaya, India. *Palaeobotanist* **52**: 13-47.

Srivastava, BN, Rana, MS & Verma, NK 1982. Geology and hydrocarbons prospects of the Vindhyan basin. In: *Petroliferous Basins of India* (Ed. Bhandari A. *et al.*) ONGC, Dehradun: 179-189.

Summons, DY & Walter MR 1990. Molecular fossils and

microfossils of prokaryotes and protists from Proterozoic sediments. *Am. Jour. Sci.* **290-A**: 212-240.

Summons RE, Brassell, SC, Eglinton, G, Evans, EJ, Horodyski, RJ, Robinson, N & Ward, DM 1988. Distictive Hydrocarbon biomarkers from fossiliferous sediments of the late Proterozoic Walcott Member, Chuar Group, Grand Canyon, USA. *Geochemica et Cosmochemica Acta* **52**: 2625-2673.

Suresh, R & Sundara-Raju, TP 1983. Problematic Chuaria from the Bhima Basin, South India. *Precambrian Res.* **23**(3): 79-85.

Tewari, VC 1984 a. Discovery of lower Cambrian stromatolite from Mussorie Tal Phosphorite, India. *Curr. Sci.* **53**(6): 319-321.

Tewari, VC 1984b. Stromatolites and Precambrian-Lower Cambrian Biostratigraphy of the Lesser Himalaya, India. *Proc. V Indian Geophytol. Con. Lucknow, Spl. Publ.* 71-97.

Tewari, VC 2001. Discovery and sedimentology of microstromatolites from Menga Limestone (Neoproterozoic Vendian), Upper Subansiri district, Arunachal Pradesh, NE Himalaya, India. *Curr. Sci.* **80**(11): 1440-1444.

Tiwari, M 1996. Paleobiology of Late Proterozoic (Vendian) microbiota: evidences from the Infrakrol Formation of Lesser Himalaya. In: *Contributions to XV Indian Colloquim on Micropaleontology and Stratigraphy*. Pandey J, Azmi, RJ, Bhandari, A & Dave, A (Editors). pp. 559-566.

Tiwari, M 1997. *Nabaviella acanthomorpha* n. sp. A sponge spicule from the Precambrian- Cambrian Boundary Interval in the Tethys Sequence of north-western Kashmir. *Jour. Geol. Soc. India* **50**: 655-658.

Tiwari, M & Azmi, RJ 1992. Late Proterozoic Organic-walled microfossils from the Infra Krol of Solan, Himachal Lesser Himalaya: An additional age constraint in the Krol Belt Succession. *Palaeobotanist* **39**: 387-394.

Tiwari, M & Knoll, AH 1994 Large acanthomorphic acritarchs from the Infra Krol Formation of the Lesser Himalaya and their significance. *Him. Geol.* **5**(2): 193-201.

Tiwari, M, Pant, C & Tewari, VC 2000. Neoproterozoic sponge spicules and organic-walled microfossils from the Gangolihat Dolomite, Lesser Himalaya, India. *Curr. Sci.***79**: 651-654.

Valdiya, KS 1969. Stromatolites of the Lesser Himalayan carbonate formations and the Vindhyans. *Jour. Geol. Soc. India* **10**: 1-25.

Venkatachala, BS & Kumar, A 1996. Significant microbiota from the great Limestone of Jammu, Lesser Himalaya. In: *Contributions to XV Indian Colloquim on Micropaleontology and Stratigraphy*. Pandey J., Azmi, R.J., Bhandari, A. and Dave, A. (Editors): 551-557.

Venkatchala, BS, Shukla, M, Bansal, R & Acharyya, SK 1990 Upper Proterozoic microfossils from the Infra-Krol rocks from Nainital Synform, U.P. Himalaya, India. In Jain K.P. & Tiwari, R. S. (eds.) Proc. Symp. *"Vistas in Indian Palaeobotany", Palaeobotanist* **38**: 29-38.

Verma, KK & Burman, G 1980. Relationship between algal stromatolites and Phosphate Localisation within the Carbonate Sequence of the Aravalli Supergroup in Udaipur and Banswara Districts, Rajasthan. *Geol. Surv. India Misc. Publ.* **44**: 355-363.

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

Viswanathiah, MN, Govindarajulu, BV & Sathyanarayan, S 1964. Stromatolitic limestone in the Lower Kaldagis (precambrian) Mysore State. *Geol. Soc. Ind. Bull.* **1**(1): 25-27.

Viswanathiah MN & Gowda, MJC 1970. Algal stromatolites from the Kaladgi (Precambrian) formations near Alagudi Bijapur district, Mysore state. *Jour. Geol. Soc. India* **11**(4): 378-385.

Viswanathiah, MN, Venkatachalapathy, V & Khadeer, A 1976. Some acritarchs from the Badami group, Karnataka State. *Sem. Geol. Kaladgi, Badami, Bhima and Cuddapah Sediments*. Mysore, p. 31 (Abst.).

Viswanathiah, MN, Venkatachalapathy, V & Mahalakshmamma, AP 1980. Microfossils of the stromatolites of Lokapur region, Karanataka. *Misc. Publ. Geol. Surv. India* **44**: 16-32.