The Palaeobotanist 57(2008) : 33-52
0031-0174/2008 $2.00

The Ediacaran Period: It's lower and upper boundaries in India

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(Received 01 December, 2006; revised version accepted 27 August, 2007)

ABSTRACT

Kumar G & Maithy PK 2008. The Ediacaran Period: It's lower and upper boundaries in India. The Palaeobotanist 57(1-2) : 33-52.

The newly established Ediacaran Period (terminal Proterozoic) 'begins with termination of the last great global glaciation (Marinoan) of the Neoproterozoic Era' and ends with appearance of biologically distinct world characterised by an assemblage of diverse skeletal fossils of bilaterian animals of the Cambrian Period. Significant depletion in C-isotope values is also recorded at both the boundaries. In India, Ediacaran sequences form part of a continuous sequence that rests unconformably over the oldest platform sequences (Meso-Cryogenian) in many parts of the Lesser and Tethys/Higher Himalaya, and grade into Cambrian. Of the various sections studied, the Maldeota section of the Baliana-Krol-Tal succession, Krol Belt, Lesser Himalaya is found to be the best for the study of both the boundaries. The Lower boundary of the Period is marked at the base of red-green shale and pinkish lenticular dolomite (Member G) - the cap carbonate, forming topmost bed of the Blaini Formation, Baliana Group. There is marked change in assemblage of acritarch and cyanobacteria within upper part of the Baliana Group with appearance and extinction of Ediacaran fauna in the overlying Krol. This change is also accompanied with a significant depletion in C-isotope values in the 'cap carbonate'. The upper boundary could not be precisely demarcated in the absence of boundary diagnostic trace fossils. However, a significant depletion in C-isotope values is recorded in the upper part of the Krol Group with appearance of spiny and processed acritarch (acanthomorphs), scaphomorphs and hercomorphs, small shelly fossils, trace fossils and trilobites of Early Cambrian age in the overlying Tal Group, which is considered to mark the boundary.

A review of biota recorded from older sequences viz. Vindhyan Supergroup, Bhima, Kurnool, Chhattisgarh, and Indravati Groups, etc. of the peninsular India, suggest them to be of Mesoproterozoic-Cryogenian (pre-Sturtian glaciation) age. The paper discusses in detail both lower and upper boundaries of the Ediacaran Period and attempts at the correlation with GSSP.

Key-words—Ediacaran, Lower-Upper Boundaries, India.

ईडीयाकारन अवधि : भारत में इसकी निम्न एवं उच्च परिसीमाएं

गोपेंद्र कुमार एवं प्रभात कुमार माइती

सारांश

नवीन सिरे से स्थापित ईडीयाकारन काल (अंतिम प्रोटेरोज़ोइक) नियोप्रोटेरोज़ोइक युग के अंतिम विशाल भूमंडलीय हिमनदन (मैरीनॉअन) के समापन से शुरु होती है तथा कैंब्रियन काल के द्विपार्श्विक जंतुओं के विविध कंकाली जीवाश्मों के एक समुच्चय द्वारा विशेष रुप से वर्णित जैविक रूप से भिन्न जगत से समाप्त होती है। दोनों परिसीमाओं पर कार्बन-समस्थानिक मान में महत्वपूर्ण अवक्षय भी अभिलिखित किया गया है। भारत में, ईडीयाकारन अनुक्रम सतत् अनुक्रम का भाग गठित करता है जो निम्न एवं टेथिस/उच्च हिमालय के विभिन्न भागों में प्राचीनतम प्लेटफार्म अनुक्रमों (मीसो-क्रायोजेनियन) पर विषमविन्यासित है। अध्ययन किए गए विभिन्न खंडों से, बालिएना-क्रोल-ताल अनुक्रम के मालदेवता खंड, क्रोल पट्टी, निम्न हिमालय को दोनों परिसीमाओं के अध्ययन हेतु सर्वोत्तम पाया गया है। लाल-हरा शेल के तल पर अवधि की निम्न परिसीमा को चिह्नित किया गया है तथा गुलाबी मसूराकार डोलोमाइट (सदस्य जी)- कैप कार्बोनेट, ब्लैनी शैलसमूह,

Challenges in Indian Palaeobiology: Current Status, Recent Development and Future Directions
Editors: N.C. Mehrotra & Mukund Sharma
Publisher: Birbal Sahni Institute of Palaeobotany, Lucknow

बालिएना समूह के सर्वोच्च संस्तर को गठित कर रहा है। बाह्याकृति एवं विलोपन के साथ उपरिशायी क्रोल में ईडीयाकारन प्राणिजात के बालिएना समूह के ऊपरी भाग में एक्रिटॉर्क व सॉयनोबैक्टीरियल के समुच्चय में उल्लेखनीय परिवर्तन है। यह परिवर्तन 'कैप कार्बोनेट' में कार्बन-समस्थानिक मान में भी महत्वपूर्ण अवक्षय के साथ है। परिसीमा निदान अनुरेख जीवाश्मों की अनुपस्थिति में ऊपरी परिसीमा परिशुद्ध रूप से सीमांकित नहीं की जा सकी। फिर भी, क्रोल समूह के ऊपरी भाग में शूलीय व प्रक्रमित एक्रिटार्क (एकेन्थोमॉर्फ) की बाह्याकृति के साथ स्कैफोमॉर्फ और हर्कोमॉर्फ, लघु कवची जीवाश्म, अनुरेख जीवाश्म तथा उपरिशायी ताल समूह में प्रारंभिक कैंब्रियन काल के ट्रायलोबाइट् कार्बन-समस्थानिक मान में महत्वपूर्ण अवक्षय अभिलिखित की गई है, जिसे परिसीमा को चिह्नित करना माना गया है।

प्रायद्वीप भारत के प्राचीन अनुक्रमों अर्थात विंध्य महासमूह, भीमा, करनूल, छत्तीसगढ़, तथा इंद्रावती समूहों इत्यादि से अभिलिखित जीवजात की समीक्षा उन्हें मीसोप्रोटेरोज़ोइक-क्रायोजीनियन काल का सुझाती हैं। शोध-पत्र ईडीयाकारन अवधि की निम्न एवं उच्च दोनों परिसीमाओं का सविस्तार विवेचन करता है तथा जी एस एस पी के साथ सहसंबंध का प्रयास करता है।

संकेत-शब्द—ईडीयाकारन, निम्न-उच्च परिसीमाएं, भारत।

INTRODUCTION

THE Ediacaran Period, a new addition to geologic time scale for terminal Proterozoic, is characterised by the Ediacaran fossil assemblage that gave the period its name. In contrast to other GSSPs in Palaeozoic, which are primarily based on biostratigraphy, the demarcation of this boundary is on lithostratigraphy and chemostratigraphy. "The beginning and end of the Period are marked by remarkable negative excursions in the carbon isotope records, unusual biochemical events recognised globally in both carbonate rocks and sedimentary organic matter". The Period begins with termination of the last great global glaciation (Marinoan) of the Neoproterozoic Era, when the continental glaciers reached the sea level in tropical latitudes and ends with beginning of biologically distinct world characterised by diverse skeletal fossils of bilaterian animals (Knoll *et al.*, 2006).

The base of the period is defined by 'cap carbonate' that conformably overlies the Marinoan glacial and the initial GSSP is marked at the base of the Marinoan cap carbonate – the Nuccaleena Formation in the Enorama Creek section of the central Flinders Ranges, Adelaide Rift Complex, South Australia. No precise carbon isotopic data to constrain the age is available but recent 635 Ma U-Pb zircon age for an ash bed within glacial strata in Oman and Pb-Pb age of 599±4 Ma post-glacial phosphorites in southern China suggest an age for the GSSP younger than 635 Ma, but older than 600 Ma (Knoll *et al.*, 2006). This GSSP was selected out of three proposed candidates, the other two were: (i) Tianjiayuanzi Section, eastern Yangtze Gorges region, China (Xing *et al.* 2003) and Maldeota Section, Mussoorie Syncline, Krol Belt, Lesser Himalaya, India (Kumar *et al.*, 2000).

The initial GSSP for end of Ediacaran Period and beginning of Cambrian is located in the Chapel Island Formation, Fortune Head, south east Newfoundland, Canada, and the boundary placed between the trace fossil Zone-I (*Harlaniella podolika* Zone) and Zone-II (*Triptichnus (Phycodes) pedum* Zone), 2.4 m above the base of the formation (ca 545 Ma). The radiometric dates of the point are not available. However, U-Pb age from Oman coinciding with the negative carbon excursion has given an age of 542 Ma.

On the Indian Subcontinent, the Ediacaran (terminal Proterozoic) successions grading into Cambrian are exposed in north western part of the Indian Shield unconformably overlying the basement rocks of the Malani Igneous Suite of the Indian Shield, and are concealed below the Cenozoic sediments of the Indus and Gangetic plains and extend to the Himalaya where they rest unconformably over the oldest platform-deposits referred to as the Salkhala/Simla-Jaunsar/ Jutogh Groups (Supersequence III, Shanker *et al.*, 1996) (Fig. 1). These successions post-date major tectono-thermal event associated with Chengjiangian/Cadomian Orogeny in Cryogenian and possibly Sturtian glaciation, and were deposited in sea termed Palaeotethys-I (Shanker *et al.*, 2002). These were studied in detail under IGCP (Project 29 & 303) and IUGS Project on Terminal Proterozoic (Kumar, 1995; Kumar *et al.*, 1997). A review of the biota and trace fossils of other Proterozoic sequences of peninsular India such as the Vindhyan Supergroup, and its equivalents the Bhima, Kurnool, Chhattisgarh, Indravati Groups, etc. occurring in detached areas over the basement formed of the Archaean - Palaeoproterozoic terrane, suggest them to be Mesoproterozoic –Cryogenian (pre-Sturtian glaciation) (Maithy & Kumar, 2007). Hence, these are not discussed here in detail excepting comments on record of trace fossils from the Kurnool Group by Babu (2005). The record of microbiota from the Buxa or Chilleipam Formation, Arunachal Pradesh, Lesser Himalaya considered to be of Terminal Proterozoic-Cambrian age (Tiwari, 2003) is also not discussed as the succession is intruded by granite dating 1536±60 Ma (Kumar, 1997).

GEOLOGICAL SET-UP

The Protorodinia, an assembly of three Archaean-Palaeoproterozoic crustal blocks of the Indian Plate, viz. Dharwar (DB), Bundelkhand (BB), Trans-Aravalli (TAB) and each separated by a mobile belt, formed the basement for sedimentation of platform sediments commencing from Mesoproterozoic. These three blocks sutured and welded together ca 1600 Ma (Zhongyuean /Karelian Orogeny). The fourth crustal block - the South Indian-Srilankan Granuite Block (SISLGB), welded to DB around ~500 Ma (Xingkaian/Pan-

Fig. 1—Neoproterozoic-Early Cambrian sequences, Indian Subcontinent (After Maithy & Kumar, 2007).

African Orogeny) to form part of the Gondwanaland (Shanker *et al.*, 2002, 2005). During Precambrian, two platform deposits/ sequences (Supersequence III & IV, Shanker *et al.*,1989; 1996) were deposited over the basement in seas referred to as the Prototethys and Palaeotethys, each with many phases of evolution related to tectono-thermal events of global significance (Shanker *et al.*, 2002). The deposition of older sequence (Supersequence III) took place in the Prototethys commencing from Mesoproterozoic (ca 1500 Ma) and terminated with break-up of Rodinia ca 750 Ma (Chengjiangian/ Cadomian Orogeny) in Cryogenian when sea regressed followed by the Sturtian glaciation. Imprints of other tectono-thermal events, viz. the Grevillian (ca 1100 Ma) and Jinningian (ca 850 Ma) are also preserved. The Vindhyan Supergroup and its equivalents Chhattisgarh in Central India; Cuddapah-Kurnool, Pakhal/Indravati, Bhima Groups, etc. in Southern India, Bahraich-Madhubani Groups in the Indo-Gangetic Plain and are referred to as the Vaikrita/Jutogh and Jaunsar Groups in the Himalaya are relicts of this sequence on Indian shield (Shanker *et al.* 1989).

The sedimentation of the Cryogenian - Cambrian sequence (Supersequence IV) commenced with a glacio-marine succession with warming up of climate. This sea (Palaeotethys-I) remained restricted to northern part of the Protorodinia where sequences located in northwestern part of Indian Shield and in many parts of the Lesser Himalayan and Higher/Tethys zones were deposited (Fig. 1). The sedimentation terminated with Xingkaian/Pan-African Orogeny in Late Cambrian (ca 500 Ma). In Higher/Tethys Himalaya, this sequence is unconformably overlain by Ordovician – Early Carboniferous sediments while parts of the Lesser Himalaya and Peninsular Shield remained a positive area until Early Permian marine transgression. The successions located in the Krol Belt, Lesser Himalaya (Fig. 2) and northwestern part of the Indian Shield are siliciclastic in lower part and show development of thick carbonate-evaporite facies with or without phosphorite in upper part while those in the Higher/Tethys Himalaya are dominantly siliciclastic (Fig. 3) (Kumar, 1995). In the Krol Belt, the sequence has been divided into Baliana, Krol and Tal Groups. Of these, the Baliana is a glacio-marine sequence with diamictite occurring at two levels, the basal referred as the Member-A and other constituting the Member-F of the Blaini Formation. Of these, the basal one may be equivalent to the Sturtian Glacials while the top one represents the Marinoan Glacials.

In the Higher/Tethys Himalaya, the sequence in Kashmir Valley is divisible into Ramsu, Machhal, Lolab and Karihul formations in ascending order while in Spiti – Znaskar, it is represented by the Batal Formation and Debsa Khad and Parahio formations of the Kunzam La Group (Kumar *et al.*, 1997). In the northwestern part of the Indian Shield, the Marwar Supergroup may belong to this sequence.

EDIACARAN BIOTA AND ORGANO-SEDIMENTARY STRUCTURES

Cryogenian (Terminal Proterozoic)-Cambrian successions exposed in many parts of India, rich biota has only been recorded from the Krol Belt, Lesser Himalaya, and Kashmir Higher Himalaya. The sequences in the Higher/Tethys Himalaya though have yielded trace fossils of Ichno-Zone I, II and III, and Early Cambrian (Tommotian) to Middle and or early Upper Cambrian trilobites and brachiopods, the record/ yield of Terminal Proterozoic biota is poor (Maithy *et al.*, 1988; Kumar *et al.*, 1997), the diagnostic trace fossils of global Ichno-Zone I are not recorded, so far, for precise demarcation of upper boundary of the Terminal Proterozoic (Raina *et al.*, 1983). Practically, no biota has been recorded from the Marwar Supergroup of the peninsular India. The other sequences of peninsular India (Vindhyan, Bhima, Chhattisgarh, Kurnool) are not considered to belong to the Terminal Proterozoic succession (Supersequence IV) but are older as discussed by Kumar *et al.*, (1997) and Maithy and Kumar (2007).

Himalaya

Lesser Himalaya (Krol Belt)—The Cryogenian to Cambrian succession – the Baliana, Krol and Tal groups is exposed in a linear zone stretching over 350 km in outer Lesser Himalaya in many synclinal outliers such as the Pachmunda, Nigalidhar, Korgai, Mussoorie, Garhwal and Nainital Synclines. The biota is characterised by cyanobacteria and acritarchs, appearance and extinction of Ediacaran fossils, calcareous algae, Conophytonoid and Gymnosolonid stromatolites and development of evaporite and phosphate deposits. The sequence is conformably overlain by Early Cambrian succession (Tal Group) yielding trace fossils of global Ichno-Zone III, small shelly fossils and stromatolites of the Meischucunian Zone I & III (Tommotian), redlichid trilobites, microgastropods and inarticulate brachiopods of Qiongzhusian (Atdabanian) and Tsanglangpuian (Botomian) Stage (Kumar, 1984)(Fig. 4). Locally, the contact between the Krol and the Tal Group is unconformable/disconformable (Shanker, 1971; Kumar & Dhaundiyal, 1978; Jiang *et al.*, 2002).

A review of the biota (Maithy & Kumar, 2007) showed a marked change within the Baliana Group from cyanophycean algae *Blainiella* comparable to extant algal form *Hyella* (Maithy *et al.*, 1995), restricted to B-D Members of the Blaini Formation, to a rapid diversification of biota after Marinoan glaciation. Post-Marinoan Glacials Ediacaran biota is represented by microbialite *Stratifera unduata* from Member F, Blaini Formation (Sharma *et al.*, 1994), organic walled microfossils (OWM) such as acritarchs belonging to Sphaeromorphida and Sphaerohystrichomorphida Groups, vase-shaped microfossils, Cryptarch: Synaplomorphitae Subgroup and Nematomorphitae Subgroup, large acanthomorphic acritarchs (*Ericasphera, Echinosphaeridium, Asterocapsoides),* and Cyanobacterial remain *Salome* in Infra Krol of the Baliana Group (Acharyya

Group	Formation	Member	Lithology	Fossils
Tal	Dhaulagiri	E	Quartz arenite with thin shale and siltstone, pebbly and ferruginous at places, cross bedded (+1186 m).	
		D	Interbebbed sequence of algal limestone, siltstone and quartz arenite (61 m).	Trilobites & stromatolites
		C	Feldspathic arenite. Cross-bedded (375 m).	
		B	Greyish black shale interbedded with thin quartz arenite (23 m).	Redlichiid trilobites and brachiopods of Tsanglangpuian (Botomian) Stage.
		A	White and greyish white quartz arenite, cross-bedded and ripple marked, pebbly at base (70 m).	
	Deo Ka Tibba	Calcareous	Calcareous siltstone and siliceous limestone (0-35 m).	Brachiopods, microgastropods of Qiongzhusian (Atdabanian) Stage
		Arenaceous	Greyish and purplish siltstones, occasionally laminated, micaceous, at places calcareous (382 m).	Trace fossils of zone III, small shelly fauna of Meishucunian zone III (Up. Tommotian) and ill-preserved Redlichiid trilobites.
		Argillaceous	Grey to black pyritous and micaceous shale, often carbonaceous, with thin lenticular calcareous bands (254 m).	
		Chert	Black chert interbedded with black shale and rock phosphate with occasional limestone bands (0-150 m).	Small shelly fauna of Meishucunian Zone- I (Lower. Tommotian), stromatolites.
Krol	Kauriyala	Upper	Calcareous ferrugious shale interbedded with argillaceous limestone (228 m).	Arctitarch and algal filaments.
		Middle	Dolomite, thick bedded, grey with thin beds of shale-siltstone. It contains nodules and thin lenticluar beds of black chert (636 m).	Ediacaran fossils: Charniodiscus sp., Conomedusites sp., Beltanella sp., and Beltanelliformis sp. and stromatolites
		Lower	Dolomitic Limestone showing vuggy and bird's eye structure with pockets of gypsum (134 m)	
	Jarashi	Upper	Rhythmitic alternation of calcareous siltstone and shale (40 m).	Ediacaran fossils: Pterinidium sp.
		Lower	Purple siltstone, shale and green shale with lenticular dolomite (14 m). In adjoining Garhwal Syncline also contains lenticular beds of gypsum.	
	Mahi		Argillaceous limestone interbedded with greenish grey calcareous shale (254 m).	Ediacaran metazoans
Baliana	Chambaghat		Sandstone & shale with lenticular chert.	
	Infra - Krol		Black shale bleaching to ash grey.	Microfossils (OWM)
	Blaini	G	Red-green shale and pinkish lenticular dolomite (4 m).	Stromatolite
		F	Diamictite (55 m).	
		E	Dark grey shale interbedded with thin bands of quartz arenite (4:1) (249 m).	Microbiota.
		D	White quartz-wacke interbedded with shale (342 m). Conglomerate, at places with calc. matrix (56 m)	
		C	Greyish white arenite (106 m). Diamictite with calcareous bands (50 m). Greenish to purple quartz arenite, current bedded with thin shales (296 m).	Microbiota
		B	Rhythmite - greenish & grey shale interbedded with thin arenite (805 m).	Microbiota.
		A	Lenticular diamictite and or conglomerate (137 m).	
~~ Unconformity ~~~~~~~~~				
Basement rocks of the Simla/Jaunsar Group (Mesoproterozoic - Neoproterozoic pre-Sturtian glacials)				

Fig. 2—Generalised lithostratigraphy of the Baliana-Krol-Tal Groups, Krol Belt Lesser Himalaya, India.

et al., 1989; Prasad *et al.*, 1990; Venkatachala *et al.*, 1990; Tiwari & Azmi 1992; Tiwari & Knoll, 1994; Tiwari, 1996; Shukla *et al.*, 2005a, b).

Within Krol Group the biota recorded includes rich assemblage of Ediacaran fossils and acritarchs characterised by smooth and sculptured-walled forms besides stromatolites and calcareous algae. Shukla *et al*. (2005a) recorded an assemblage of microbial remains comprising cyanobacteria, multicellular tissues of algal thalli (thalophytes) belonging to Rhodophyta, acritarchs and vase-shaped microfossils from lenticles of phosphatic black chert and shale partings associated with sandstone from the Chambaghat Formation, algal filamentous forms, coccoid forms represented by acritarchs and spheroid colonies, (Kumar & Rai, 1992), empty sheaths of unbranched filaments, branching filaments resembling eukaryotic forms and a form comparable to Bangiophyceae (Gautam & Rai, 1997), Ediacaran fossils *Nimbia* sp. cf. *N. occlusa* from the Mahi Formation and *Pterinidium* sp. cf. *P. carolinaense* and *Charnodiscus* sp. cf. *C. arborens* from Jarashi Formation (Shanker *et al.*, 2004), *Cyclomedusa, Conomedusites, Charniodiscus, Dickinsonia* sp., *Kimberella* sp. cf. *K. quadrata,* and *Beltanella* sp. cf. *B. gilesi* from (Mathur & Shanker, 1989, 1990; Shanker & Mathur, 1992; Shanker *et al.*, 1997; Mathur & Srivastava, 2004) and calcareous algae *Epiphyton* and *Renalcis* along with *Oleckmia* are known from the Kauriyala Formation (Gansser, 1964; Singh & Rai, 1983). Prasad *et al.* (1990) recorded acritarchs belonging to Sphaeromorphida Group from Mussoorie. The assemblage is characterised by smooth and sculptured-walled acritarchs.

Stromatolites are reported from Kauriyala Formation (Krol D) of Nainital and Mussoorie Synclines (Fuchs & Sinha 1974; Singh & Rai, 1977; Tewari, 1984). Linked *Conophyton, Stratifera, Aldania* and *Irregularia* and branching stromatolites are important forms.

***Higher /Tethys Himalaya*—**In Kashmir, Sphaeromorphida acritarchs, tubular cyanophyte forms and globular colonies recorded from upper 480 m of the Machhal Formation to 580 m of the overlying Razdain Member of the Lolab Formation (Maithy *et al.*, 1988) and of the two trace fossil assemblages, the assemblage-I *Planolites beverleyensis – P. reticulatus* in association with *Skolithos* and *Brgaueria* from the Razdain Member, Lolab Formation, Kashmir suggest presence of Ediacaran elements in the Kashmir Valley. The overlying upper part of the Razdain Member, Lolab Formation has yielding trace-fossil Assemblage II and III of Early Cambrian age (Raina *et al.*, 1983, Kumar *et al.*, 1984). Thus, the conglomerate occurring at top of the Ramsu Formation may be equivalent to the Marinoan Glacials.

In Spiti Valley and Zanskar area, the yield of biota below the trace fossil assemblage III is very poor (Kumar *et al.*, 1984, Kumar, 1995). Therefore, it is not possible to define both the boundaries viz. Cryogenian-Ediacaran and Ediacaran-Cambrian, in terms of GSSPs. However, entire Batal Formation may be of Ediacaran age.

Indo-Gangetic Plain (Ganga Plain)

The Vindhyan sequence, unconformably overlying the Bundelkhand Gneissic Complex, continues northwards and is concealed below the Cenozoic sediments. It is divided into the Bahraich and Madhubani groups, the latter is further subdivided into the Ujhani, Tilhar and Karanpur formations in ascending order (Shukla *et al.*, 1994). Maithy and Kumar (2007) have reviewed the records of biota. According to them, the Bahraich Group is dominated by acritarchs belonging to Sphaeromorphida Group, Ujhani contains acritarchs *Granomarginata, Orygmatosphaeridium, Vavosphaeridium, Kildinella, Nucellosphaeridium* and algae *Myxococcoides, Palaeoanacystis* and *Gunflintia* (Maithy *et al*., 1983), Tilhar Formation records *Protosphaeridium* and *Vavosphaeridium* and the Karanpur contains *Leiosphaeridia, Granomarginata, Lophosphaeridium, Ellipsaletes* and *Dictyotidium* (Prasad & Asher, 2001). They, thus, disagreed with Prasad & Asher (2001) on age assignment of the Madhubani Group to range from latest Vendian to Lower Devonian, and considered the Bahraich and Ujhani to be equivalent to the Semri Group (Mesoproterozoic) while the Tilhar and Karanpur represent the Bhander Group ranging in age from Mesoproterozoic to Cryogenian (pre-Sturtian glaciation). A review of the overall OWM indicates that the assemblage is dominated by ornate acritarchs in association with simple ones and Chitinozoa with simple morphology. In Silurian and Devonian, acritarchs with complex spine (branched) and ornamentation are known along with complex Chitinozoa and trilete spores. The present analysis, however, indicates the upper age limit may extend only up to Cambrian.

Peninsular Region

A review of biota from the platform sequences, viz. Vindhyan, Chhattisgarh, Pakhhal Supergroups, Kurnool and Bhima Groups by Maithy and Kumar (2007) shows that these sequence range in age from Mesoproterozoic to Cryogenian (pre-Sturtian glacials). It is only from the Marwar Supergroup, northwestern India some elements indicative of Cryogenian-Lower Cambrian age are known.

***Marwar Supergroup*—**It unconformably overlies the Malani Igneous Suite (Malani Rhyolite 745±10 Ma; Siwana Granite 731±14 Ma) or Palaeoproterozoic metasediments. Based on subsurface data (Pareek, 1981, 1984; Das Gupta & Bulgauda, 1994; Peters *et al.*, 1995) divided the Marwar Supergroup into five groups, viz. the Jodhpur, Bilara, Hanseran Evaporite, Nagaur and Birmania (Upper Carbonate) in an ascending order. Sinha-Roy *et al.* (1998), on the other hand, divided the Marwar Supergroup into the three groups, viz. (i) the Jodhpur comprising Pokhran Boulder Bed, Sonia Sandstone and Girbhakar Sandstone, (ii) Hanseran/Bilara divisible into Dhanapa Dolomite/Birmania Formation, Gotan Limestone and Pondlo Dolomite, and (iii) Nagaur Group made up of Nagaur Sandstone and Tunklian Sandstone in an ascending order. Mazumdar and Strauss (2006), on the basis

Geologic Age	Spiti				Kashmir				Eastern Kumaun		
	Group	Formation	Member	Lithology	Group	Formation	Member	Lithology	Group	Formation	Lithology
Ordo.	Thango Formation				Margan Formation				Ralam Formation		
Mid. to early Upper Cambrian	Haimanta	Kunzam La	Parahio	Alternation of olive green shale and siltstone with brown weathered dolomite, Trilobites	Hapatnar	Karihul		Alternation of greenish grey, micaceous sandstone and shale with thin lenticular limestone/dolomite, occasionally oolitic. Trilobites	Martoli		
Lower Cambrian			Debsakhad	Grey quartzite flaggy to massive with shale partings. *Redlichia* sp.		Lolab	Yel	Dark grey laminated shale and arenite. *Paokonnia* sp.		Milam	Thin laminated greenish grey, brown, purple quartzite-slate with thin calcareous lenses in upper part and massive greenish quartzite at base (950 m). *Redlichia noetlingi* in upper part.
											Interbedded grey purple slate/phyllite and quartzite (550 m).
				Greyish green shale, slate, siltstone and flaggy quartzite			Razdain	Rhythmic alternation of thin bedded grey shale and arenite			Purple, grey, greenish grey phyllite with quartzite bands (450 m).
Ediacaran		Batal		Grey green phyllite, grey quartzite and carbonaceous phyllite. Sporadic clasts in lower part		Machhal					Thinly interbedded greenish grey phyllite and quartzite (864 m)
							D	Dark grey phyllite and siltstone.		Bilju	Silver grey phyllite with arenaceous bands (313 m). Dark grey to black carbonaceous phyllite, at places graphitic, and chloritic phyllite (450 m). Dominantly grey phyllite with bands of quartzite towards base (290 m).
Cryogenian							C	Diamictite in greenish areno-argillaceous matrix.		Rilkot	Silver grey phyllite with interbedded thin quartzite (206 m).
							B	Slate, slaty phyllite with occasional, bands of quartzite.			Garnetiferous grey phyllite and quartzite (165 m) and foliated quartzite with biotite bearing phyllite (67 m).
							A	Greenish schistose quartzite with occasional pebble to cobble sized clasts			Kyanite-, sillimanite-, saturolite-, garnet mica schist with micaceous quartzite and banded calc-silicate intruded by granite, aplite (239 m).

Fig. 3—Generalised lithostratigraphy of Cryogenian-Ediacaran-Early Cambrian successions in Spiti, Himachal Pradesh and Kashmir Valley, J & K.

BIOTA	Baliana Group								Krol Group						Tal Group								
	Blaini Formation											Kauriyala Formation			Deo Ka Tibba Fm.				Dhaulagiri Fm.				
	Member																						
	A (137 m)	B (805 m)	C (452 m)	D (398 m)	E (249 m)	F (55 m)	G (Cap Carbonate) (4 m)	Infra Krol Fm. (380 m)	Chambaghat Fm. (Local facies)	Mahi Fm. (254 m)	Jarashi Fm. (54 m)	L. Mem. (Krol C) (134 m)	Mid. Member (Krol D) (636 m)	Upper Member (Krol E) (228 m)	Chert Member (0-150 m)	Argillaceous Member (254 m)	Arenaceous Member (382 m)	Calcareous Member (0-35 m)	A- Member (70 m)	B- Member (23 m)	C- Member (375 m)	D- Member (61 m)	E- Member (1186 m)
Ediacaran:																							
Kimberella sp.										?													
Pteridium sp. cf. *P. carolinaense*										?													
Charniodiscus sp. cf. *arboreus*										?			???										
Beltanelliformis sp.													???										
Medusinites sp.													???										
Tirasiana sp.													???										
Cyclomedusa sp.													???										
Beltanella sp.													???										
Sekwia sp.													???										
Iridinitus sp.													???										
Nimbia sp. cf. *N. occlusa*										??													
cf. *Dickinsonia*													???										
Conomedusites sp.													???										
Acritarcha:																							
Sphaeromorphida:																							
Leiosphaeridia crassa								??															
L. effusa								??															
L. holtedahlii									??														
Baltisphaeridium perraum								??															
Margominuscula simplex								??	?														
Granomarginata primitiva								??															
G. prima									??														
Gorgonisphaeridium maximum								??															
Trachyhystrichosphaera vidalii								??															
Microconcentrica incrustata								??															
Trachysphaeridium attenuatim		??	??	??				??					???										
Saharidia downii														??	?								
Protosphaeridium volkovae		??	??	??																			
P. densum														??									
Vavosphaeridium sp.														??									
Favosphaeridium sp.														??									

Orygmatosphaeridium plicatum		??	??	??																			
Symplassoapheridium sp.		??	??	??																			
Satka colonialica								??	??														
Paracrassophaera dedalea									??														
Lophospaheridium sp.									??														
Micrhystridium lanceolantum									??														
Vandalosphaeridium reticulatum									??														
Gorgonisphaeridium pindyium									??														
Sphaerohystrichomorphida:																							
Ericiasphaera spjeldnaesii								??															
Echinosphaeridium maximum								??															
Asterocapsoides sp.								??															
Micrhystridium echinuatum								??															
M. tornatum								??								?							
Microconcentrica incrustata								??															
Germinosphaera unispinosa								??															
Paracrassosphaera dedalea								??															
Micrhstridium echinuatum								??															
M. regulare								??															
M. eatonensis								??															
Archaeohystrichosphaeridium celluare								??															
A. semireticulatum								??															
Cyanobacteria																							
Blainiella polymorpha		??????	??	??				??	??														
B. faveolata									??														
Miyxococcoides minor									??														
Eoentophysalis gilensis									??														
Syphonophycus kestron																							
S, typicum																							
S. septatum								??															
Globophycus rugosum								??	??														
Tetraphycus hebeinsis								??															
Eomicrocystis malgica								??															
Palaeoanacystis vulgaris								??															
Eosphaera sp.									??														
Veteronostocale moniliforme									??														
Eomicrocoleus crassa																							
Gunflintia sp. cf. *G. minuta*								??															
Eomycetopsis robusta								??		??													
Salome hubeiensis								??															
Siphonophycus sepatum										??													
S. robustum								??		??													
S. rugosum										??													
S. inornatum								??															

Eomorphidium orculiformis								??																	
Satka colonialica																									
Obruchevella parva									??																
Obruchevella sp.								??		??						?									
Vase-shaped Microfossil:																									
Melanocyrillium hexadiadema								??																	
Rhodophyta																									
Wengania globosa									??																
W. minuta									??																
Thallophyca ramosa									??																
Calcareous Algae:																									
Renalcis sp.												?			??										
Epiphyton sp.										??					??										
Algal oolites												?													
Stromatolites:																									
Stratifera undata							?																		
Stratifera irregularis													???												
Conophyton garganicus													???												
Baicalia baicalia													???												
Colonella sp.													???												
Paniscollenia sp.													???												
Patomia sp.													???												
Gordia sp													???												
Collumnaefacta vulgaris															?										
Collumnaefacta korgaensis																								?	
Aldania birpa																								?	
Illicta talica																								?	
Small Shelly Fossils (SSF)																									
Hyolitha																									
Circotheca longiconia																?									
C. obesa																?									
C. sp.																?									
Turcutheca sp. *aff. T. annae*																?									
Turcutheca sp.																?									
T. lubrica																?									
T. maldeolensis																?									
Anabaritidae																									
Allatheca concinna																?									
Anabarites trisulcatus																?									
Tiksitheca korobovi																?									
T. sp. *aff. T. korobovi*																?									
Hyolithelminthes																									
Hyolithellus tenuis																?	??????	?							
Chancelloriida																									
Dimidia simplexa																?	???	??	?						
Dimidia sp.																?									
Allonia erromenosa																?									

Globomorphs																								
Olivooides alveus														?										
Paraconodonta (?)																								
Protohertzina anabarica														?										
P. sp. *aff. P. robusta*														?										
P. siciformis														?										
Gastropoda																								
Auriculatispira aduca														?										
A. madianensis														?										
Pelagiella lorenzi														?										
Miscellaneous																								
Spirellus columnorus														?										
Maikhanella sp.														?										
Fomitchella sp. aff. *Infundibuliforma*														?										
Brachiopoda																								
Diadongia cf. pista																	?							
(?) Kutorgina sp.																?								
Obella crassa																			?					
Walcottina sp.																			?					
Magnicanalis sp.																			?					
Obolus kashmiricus																			?					
Lingulella sp.																			?					
Trace Fossils:																								
Astropolithon																?								
Diplichnites																?								
Dimorphichnus																?								
Monomorphichnus lineatus																?								
Rusophycus																?								
Aulichnites																?								
Taphrhelminthopsis circularis																?								
Skolithos																?								
Gordia sp.												???												
Bilinichnus biserialis												? ? ?												
Ichnogenus A												???												
Cruziana sp.																						?		
Arthropda (Trilobite)																								
Redlichia noetlingi																			?					
Redlichia sp.																			?					
Xela mathurjoshi																			?					
? *Pagetid*																					?			
Sponge (?) spicules																								
Hexactinellid spicules														?										
Demospongia (?)														?										
Geological Age	**Cryogenian**						**Ediacaran**								**Tommotian**			**Botomian**						
	Neoproterozoic														**Lower Cambrian**									

Fig. 4—Distribution of biota and organo-sedimentary structure in Baliana- Krol- Tal Groups, Krol Belt, Lesser Himalaya, India.

Vindhyan Supergroup (Bhattacharyya,1996)			Chhattisgarh Supergroup (After Murti, 1987)		Pakhal Supergroup/ Indravati Group (After Rao, 1987; Ramakrishnan, 1987)		Cuddapah Supergroup & Kurnool Group (After Ramam & Murty, 1997)		Bhima Group (After Misra *et al.* 1987)	Characteristic biota
Upper Vindhyan	Bhander Group	Bhavpura					Kurnool Group	Nandyal Sh.	Harwal	**Carbonaceous**: *Chuaria - Tawuia;* **Sponge:** *Palaeophragmodictaya*
		Balwan Limestone						Koikuntla Limestone	Katamdevarhalli Limestone	**Algae**: *Vindhyacapsiopsis, Palaeoglauocystis;* **Acritarcha**:*Granomarginata*
		Maihar/ Shikaoda Sst						Paniam Quartzite		
		Sirbu Shale						Owk Shale	Halkal Shale	**Acritarch**: *Leiosphaeridia, Granomarginata, Baltisphaeridium. Favaosphaeridium;* **Cryptarch**:*Eomycetopsis, Sphaerocongregus, Obruchevella, Gloeocapsomorpha,* , **Carbonaceous** *Chuaria circularis - Tawuia dalensis, Sinosabellidites huainanensis, Beltina danai, Protoarenicola baiguashansis.*
		Bundi Hill Sst.	Raipur Group	Tarenga Formation						
		Lakheri Limestone		Chandi Formation	Penganga Gp.	Putnur Limestone		Narji Limestone	Shahabad Limestone	**Stromatolite**: *Baicalia,Tungussia* and *Gymnosolen;* Siliceous sponge spicules; *Sekwia excentrica* , ? Trace-fossils
		Ganurgarh Shale		Gunderdehi Formation		Takalapalli Arcose		Baganapalli Quartzite	Rabanapalli Conglomerate	**Acritarch**: *Leiosphaeridia, Orygmatosphaeridium, Granomarginata, Vavosphaeridium. Nucellosphaeridium, Cymatisophaerides, Polytrichoides*
	Rewa Group	Govindgarh Sandstone		Charmuria Formation						
		Jhiri Shale								**Carbonaceous**: *Chuaria circularis, Tawuia dalensis*
		Asan Sst.								
		Panna Shale								
	Kaimur Group	Dhaundraul Quartzite								
		Mangesar Formation								
		Bijaigarh Shale								**Acritarch**:*Leiosphaeridia, Archaehystrichosphaeridium, Lophosphaeridium*,
		Ghaghar Sandstone								
		Susnai Breccia								
		Sasaram Fm.								

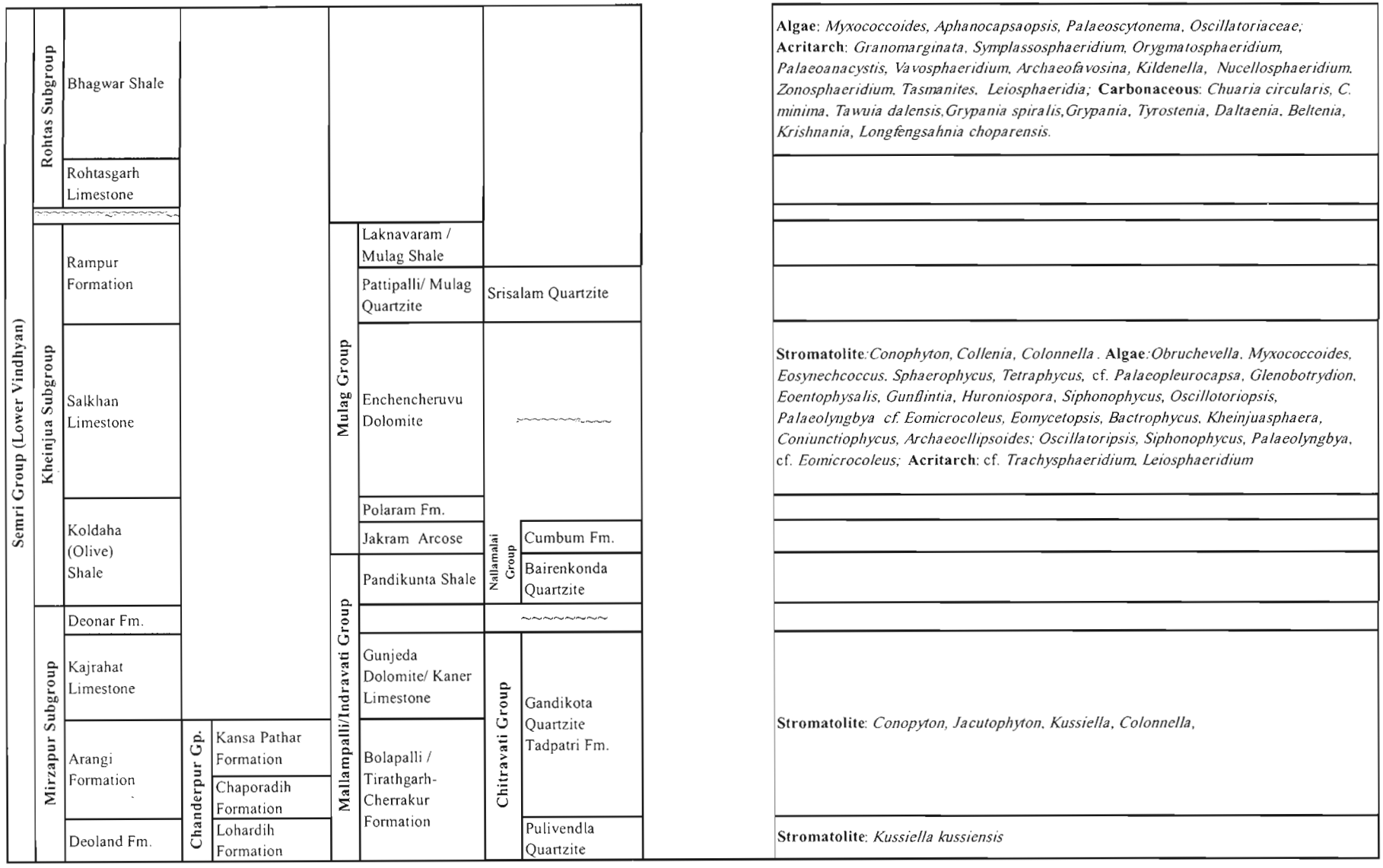

Fig. 5—Biota and correlation of Mesoproterozoic - Neoproterozoic II sequences in Peninsular India (After Maithy & Kumar , 2007).

SYSTEM/ PERIOD	AUSTRALIA	ASIA					EUROPE		NORTH AMERICA		AFRICA
	Flinders Ranges, Australia	Yangtze Platform, China	Lesser Himalaya, India			Olenek Uplift,	Vendian, Russian Platform	Finnmark, North Norway	Avalon Penninsula, Canada	Mackenzie Mts. NW Canada	North & south Nimibia
Cambrian	Uratanna	Shuunto	Tal Group	Deo Ka Tibba Fm.	Chert Mem	Kessyusa	Rovno	Breivik	Brigus	Ingta	Nomtsas
		Denying	Krol Group	Kauriyala Fm.	Krol E (Up. part)						
Ediacaran	Pound				Krol E (Lr. Part)	Turkut	Kotlin	Stappogede	Singnal Hill	Risky	Urusis
	----------				----------	Khatyspyt	Redkino		St John's	Blue Flower	Nudaua
	Wonoka				Krol D	Mastakh				Gametrail	Kubris
						~~	Volhyn		Conception	Sheephed (Cap carb. at base)	?
					Krol C						?
	Bunyeroo	Doushantuo		Jarashi Fm. (Krol B)			Glusica	Morttensnes	Gaskers		?
	ABC Range Qzte.			Mahi Fm. (Krol A)					~~~~~~~~		
				Chambaghat Fm.(local)							
	Brachnia		Baliana Group	Blaini Fm.	Infra Krol		Blon	Nyborg (Carb. = cap carb. at base.)			Tsumeb (Carb. = cap carb. at base)
	Nuccaleena (cap carb.)				Blaini G (cap carb.)						
Cryogenian	Elatina	Nantuo			Blaini F			Bamalford		Icebrook	Ghalub
	Tapley-Sunderland-Etina-Enorama Sh. - Trezona-Yaltiena	?			Blaini D & E						
	Pualco-Holowwilena-Wilyerpa	Chenjiang (Lientuo)			Blaini B & C						
					Blaini A						

Glacial diamictite Diamictite = Marinoan glacials Diamictite = Sturtian glacials

Fig. 6—Correlation of Ediacaran System (modified after Knoll *et al.*, 2005)

of sulfur and strontium isotopic composition of carbonate and evaporite rocks, have considered coeval nature of the Bilara Formation and Hanseran Evaporite. According to them the strontium isotopic composition "are comparable to the contemporaneous global seawater $^{87}Sr/^{86}Sr$ ratios, recording an increase during post-Varangerian time". No diamictite horizons are known. The Jodhpur Group may represent the Cryogenian Period as stromatolites *Collenia pseudocolumanaris, Collenia* sp., *Concollenia, Cryptozoan accidentalis, Irregularia* sp. and *Stratifera,* recorded from overlying Bilara (Burman, 1980), are known from Ediacaran Period. Moreover, a significant depletion in $\delta^{13}C$ values in the upper part of the Bilara Formation and short lived positive excursion in $\delta^{13}C$ values in Birmania Formation at the level of phosphorite (Kumar *et al.*, 1997) may be correlative to similar excursions noticed elsewhere at the Precambrian-Cambrian boundary (Kumar *et al.,* 1997).

Vindhyan, Chhattisgarh, Pakhhal Supergroups, Kurnool and Bhima Groups

Maithy and Kumar (2007) have already reviewed the biota from the Vindhyan, Chhattisgarh, Pakhhal Supergroups, Kurnool and Bhima groups of Peninsular India. The biota recorded from these successions is summarised (Fig. 5).

Stromatolites—Two distinct types of stromatolite assemblages are known. The lower assemblage is characterised by *Kussiella, Conophyton cylindricus, Jacutophyton, Anabaria* and *Colonnella* suggesting Early to Middle Riphean age for Semri Group and its equivalents. The upper zone preserves *Tungussia, Baicalia* and *Gymnosolen*. The assemblage suggesting an Upper Riphean age is known from Raipur (Chhattisgarh Supergroup) and Bhander groups (Upper Vindhyan) (Moitra, 2003). No stromatolite has been recorded from the Kaimur and Rewa groups due to absence of carbonate horizon.

Carbonaceous macrofossils—The carbonaceous macrofossils *Chuaria* and *Tawuia* are recorded from the Vindhyan Supergroup at different horizons, viz. the Baghwar (Suket) Shale (Semri Group), Jhiri Shale (Rewa Group) to the Sirbu Shale and Bhavpura (Dholpura) Shale of Bhander Group (Maithy, 2003), Kurnool Group (Owk Shale by Sharma & Shukla, 1999) and Bhima Group (Halkal Shale) (Maithy & Babu, 1996). The record of *Chuaria-Tawuia* association in the youngest formation of the Vindhyan indicates that the entire Vindhyan succession and its equivalents are older than Sturtian glaciation. Up till now this assemblage is known below Sturtian glaciation (Cryogenian).

Hofmann (1992) has speculated that *Chuaria* and *Tawuia* may represent an alternation of generations of eukaryotic organism. Maithy (2003) presumed that *Chuaria* and other discoid forms are representing the gametophytic generation and *Tawuia* and other elongated forms are representing sporophytic generation of an extinct member of an alga. Das Sarma *et al.* (1992) claimed presence of macrofossil *Sabellidites* from the Halkal Formation, Bhima Group. The specimen was examined and fresh collections were made from the same bed during a field trip during 1993 under the aegis of IGCP Project 303 – Precambrian – Cambrian Event Stratigraphy. In the collection there were *Chuaria circularis* and *Tawuia* with circular structures at the terminal end and *Beltina* (Maithy & Babu, 1996). Similar forms are now well known from Meso-Neoproterozoic sequence of India and all of these forms are now considered representing different stages of life cycle of *Chuaria-Tawuia* (Maithy, 2003) and Maithy and Babu (1996) compared *Sabellidites* with *Tawuia dalaensis.*

Acritarchs—These are well known from sediments ranging from youngest bed of Semri Group – Bhagwar Shale, Kaimur Group, Rewa Group and Bhander Group (Maithy, 2003). The available data indicates that the Semri, Kaimur and Rewa groups are characterised by dominant presence of *Leiosphaeridia* sensu Jankauskas. In younger Bhander Group, the Sphaeromorphida acritarchs are more complex in organisation. They may have inner body – *Nucellophaeridium,* walls with broad reticulam – *Favosphaeridium* and with encircling narrow wing-like structure – *Cymatosphaera*. Additionally, few Acanthomorphida acritarch vesicles are recorded with simple short processes, viz. *Baltisphaeridium* and *Michrystridium*. The presence of vase-shaped microfossil *Melanocyrillium* Bloesser, a Neoproterozoic form is important (Maithy & Babu, 1997). Until now typical Cambrian Acritarcha groups Ellipsomorphida, Ooidomorphida and Versimorphida are not known, thus indicating absence of Terminal Proterozoic elements in the Vindhyan sequence.

Trace-fossils and reports of other fossils—Presence of ichno-fossils in form of surface trails and tubes reported from the Vindhyan Supergroup (Semri and Bhander groups) by many workers, and Kurnool Group (Owk Shale, Paniam Quartzite, Kolikuntala Limestone and Nandyal Shale as listed by Babu, 2005). The reports from Vindhyan were dismissed as most of them have been are of inorganic in origin (Maithy, 2003; Sharma, 2003). Most of recent reports of trace fossils attributed to triploblastic animals from Chorhat Sandstone belonging to Kheinjua Formation (Semri Group) (Seilacher *et al.*, 1998) have been debated (Hofmann, 2005). Knoll and Carroll (1999), and Kumar (1999) have doubted the interpretation. Surface trails in single and paired rows from the Nagod (Lakheri) Limestone from Bainkurian, Rewa District and large diameter burrows from Bundi Hill Sandstone, Bhander Group from Maihar (Maithy, 2003), however, need careful analysis for their biogenic or abiogenic origin.

Some of these 'trace fossils' from the Kurnool Group, available in the Palaeontology Laboratory, Geological Survey of India, Hyderabad, were also examined during 1993. In our opinion, most of these reports are either inorganic structures or synaeresis mud cracks, hence not of any stratigraphic use and are dismissed. Moreover, the Owk Shale contains definite

<table>
<tr><th>Geological Age</th><th colspan="2">Siberian</th><th colspan="2">China</th><th>Avalon</th><th>Laurentian</th><th>Baltic</th><th>Himalaya</th></tr>
<tr><td rowspan="11">Lower Cambrian</td><td>Series</td><td>Stages</td><td colspan="2">Stages</td><td>Zones</td><td>Zones</td><td>Zones</td><td>Zones (Lesser & Higher Himalaya)</td></tr>
<tr><td rowspan="2">Linean</td><td rowspan="2">Toyonian</td><td colspan="2">Maozhuangian</td><td rowspan="2">Protolenus</td><td rowspan="3">Bonnia-Olenellus</td><td rowspan="3">Proampyx linnarssoni</td><td></td></tr>
<tr><td colspan="2">Longwangmiaon</td><td>Redlichia - Paokannia</td></tr>
<tr><td rowspan="2">Botomian</td><td colspan="2">Canglangpuian</td><td rowspan="2">Strenuella</td></tr>
<tr><td rowspan="3">Aldanian</td><td rowspan="2">Atdabanian</td><td rowspan="2">Qiongzhusian</td><td>V</td><td rowspan="2">Callavia</td><td rowspan="2">Nevadella</td><td>Holmia kjerulfi</td><td>?</td></tr>
<tr><td>IV</td><td>Holmia inusitata</td><td>Pelagiella -Auriculatespira</td></tr>
<tr><td rowspan="2">Tommotian</td><td rowspan="6">Meishucunian</td><td rowspan="3">III</td><td>Camenella</td><td>Fallotapsis</td><td rowspan="2">Schmidtiellus</td><td rowspan="2">SSF II - Allonia - Dimidia & TF III-Monomorphicnus-Diplichnites-Aatropolithon)</td></tr>
<tr><td rowspan="3">Nemakit-Daldynian</td><td rowspan="2">Sunnaginia imbricata</td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>II</td><td>Watsonella crosbyi</td><td>?</td></tr>
<tr><td rowspan="2">I</td><td>III- Rusophycus avalonensis</td><td rowspan="2">SSF I -Anabarites - Protohertzina - Circotheca</td></tr>
<tr><td>II- Phycodes pedum</td><td>TF II - Arenicolites-Gordia-Phycodes</td></tr>
<tr><td>Neoproterozoic (Ediacaran)</td><td></td><td></td><td colspan="2">Sinian</td><td>I- Harlaniella podolika</td><td></td><td></td><td>TF I - Planolites beverleyensis - P. reticulatus</td></tr>
</table>

SSF - Small shelly fossils; TF - Trace Fossils

Fig. 7—Correlation of Neoproterozoic Ediacaran - Lower Cambrian bio-zones of Himalaya with other global sections (enlarged after Kumar *et al.*, 1997)

early Neoproterozoic *Chuaria-Tawuia* (Sharma & Shukla, 1999). Therefore, the records of Cambrian trace fossils are doubtful and so are other associated fossils from conformably overlying Paniam Quartzite to Nandyal Shale. Babu (2005) has listed but not illustrated and described the reports.

Presence of *Sekwia*, a Neoproterozoic form, reported from Lakheri Limestone, Bhander Group, has been considered to be cocoons of Annelida (Maithy & Babu, 1997) and Neoproterozoic sponge genus *Palaeophragmodictya* was reported from the youngest beds of Vindhyan, Bhavpura Shale, Lakheri, Rajasthan (Shanker *et al.*, 2000). This possibly suggest their evolution may have started much earlier in the history of earth in light of molecular clock estimates suggesting that the divergence of protostome and deuterostome animals took place as early as 1,000-1,300 Ma (Sharma, 2003).

Babu (2005) has listed a number of trace-fossils from conformably overlying Paniam Quartzite without any illustrations and description. Report of variety of small Shelly Fossils from the topmost part of the Rohtasgarh Limestone and Shale, Semri Group (Lower Vindhyan) from two areas namely Maihar and Rohtas in the Son Valley assigning basal Meischucunian/Tommotian (Early Cambrian) age Azmi (1998) has been debated and examined by several workers (Bhatt *et al.*, 1999; Bhatt, 2003; Sharma, 2003). They considered the reported specimens to be inorganic material some were diagenitically produced sedimentary structure 'cone-in cone' which has a pointed apex that flares outwards with undulatory surface or principally mineral growth or made up of fibrous calcite/secondary calcite vein.

C, O, Sr and Pb isotopic studies—Recent C, O, Sr and Pb isotope systematics of carbonates sequence of the Vindhyan Supergroup do not support Ediacaran (Vendian) – Cambrian age for the Bhander Group. According to Ray *et al.* (2003), the Pb-Pb isochron age (ca. 650 Ma) for the Bhander Limestone is not reliable due to small spread in $^{206}Pb/^{204}Pb$. The $^{87}Sr/^{86}Sr$ ratios, on the other hand, suggest a Mid-Neoproterozoic (~750 Ma) age for the Bhander Limestone and an early Late-Neoproterozoic age (~650 Ma) for the Lakheri Limestone which according to them may be more altered.

In the Bhima Group, the results of $\delta^{13}C$ and $\delta^{18}O$ values range between +0.89 to 3.59‰ PDB (majority custering around 2‰ PDB) and -5.37 to -9.18‰ PDB, respectively. Kumar *et al.* (1999) and Das Sharma and Kumar (1999), on the other hand, also record carbon isoptope values varying from 0 ‰ to 4‰ PDB along with $^{87}Sr/^{86}Sr$ ratios on a few samples ranging between 0.7075 and 0.7083. They are of the opinion that these point to post-Varanger depositional age (Termial Proterozoic) for the Bhima carbonates. There are minor deflections within positive carbon isotopic values but no negative deflection comparable either to Cryogenian-Ediacaran boundary or to Precambrian-Cambrian transition has been recorded. The oxygen isotope values are 9.18‰ PDB in basal part of the Sahabad Formation which gradually decrease to -6‰ PDB as one moves upwards to middle part (Bhattacharya *et al.*, 1996). Since only a few representative samples of carbonates were analysed by them for $^{87}Sr/^{86}Sr$ ratios it is difficult to arrive some definite conclusions for inter/intrabasinal correlation and age. Kumar and Maithy (1999) have already argued against such a correlation. In addition, absence of well established record of global events such as Cryogenian (Vendian) glaciations (Sturtian and Marinoan), and development of phosphorite at Precambrian-Cambrian boundary from the Vindhyan Supergroup, also do not support latest Cryogenian - Ediacaran (late Vendian) age (ca 650-544 Ma) as suggested by the authors. These global events are well known from other parts on Indian subcontinent and are globally correlatable (Knoll *et al.*, 2006). It is on the basis of overall biota, the Bhima Group is considered older than the Sturtian glaciation.

CROGENIAN–EDIACARAN BOUNDARY

On the Indian platform, as per GSSP, the lower boundary of the Ediacaran Period is defined lithostratigraphically at the base of the Pink Limestone (Member G) in the Baliana Group in the Lesser Himalaya. Significant depletion in $\delta^{13}C$ values is also recorded in pink carbonate (Kumar *et al.*, 2000). This bed overlies the top bed of diamictite (Member F) of the Blaini Formation which is considered equivalent to the Marinoan Glacials. Global correlation is given (Fig. 6).

In absence of 'cap carbonate' from Higher/Tethys Himalayan successions of Kashmir Valley, Spiti Valley and Zanskar area, and in northwestern peninsular India, Rajasthan, the boundary could not be defined precisely.

EDIACARAN–TOMMOATIAN BOUNDARY

The Upper boundary with the Cambrian cannot be ascertained in terms of GSSP (Landing, 1994) due to absence of Cambrian trace fossil of global Ichno-Zone – II (Kumar, 1995; Kumar *et al.*, 1997) (Fig. 7). However, a significant depletion in $\delta^{13}C$ values has also been recorded in the upper part of carbonate facies of the Krol Group between the horizons yielding Ediacaran fossils and Early Cambrian phosphorite bed containing small shelly fossils of the Meischucunian Zone – I in the overlying Tal Group (Bhattacharya *et al.*, 1996; Jiang *et al.*, 2002). This depletion has also been recorded in the Marwar Supergroup below the phosphorite bed, and can be correlated with that recorded from Precambrian-Cambrian transition sequences (Kumar *et al.*, 1997).

CONCLUSIONS

An analysis of the biological remains and organo-sedimentary structures from the Neoproterozoic of the Indian Subcontinent suggest that:

1. Biological remains and ichno-fossils from the Lesser Himalaya – Krol Belt, Higher/Tethys Himalaya, Kashmir, possibly Karanpur Formation of the Madhubani Group, Ganga Plain and Marwar Supergroup, northwestern part of Indian Shield suggest presence of Ediacaran successions. Of these, the Baliana-Krol-Tal succession of the Krol Belt, exposed in the Maldeota Section, Mussoorie Syncline, is the best where the Lower and Upper Boundaries of the Ediacaran Period are identifiable on the basis of lithology and or depletion in $\delta^{13}C$ values.
2. The Lower boundary of the Ediacaran Period is defined lithostratigraphically at the base of the Pink Limestone (Member G, Blaini Formation) in the Baliana Group in the Lesser Himalaya. Significant depletion in $\delta^{13}C$ values is also recorded in pink carbonate.
3. Of the two levels of the diamictite of the Blaini Formation, the top one (Member F) is equivalent to Marinoan Glacials while the Lower (Member A) may be correlative to the Sturtian Glacials.
4. The upper boundary of the period could not be precisely defined due to absence of age-diagnostic trace fossil assemblage. However, the significant depletion in $\delta^{13}C$ values recorded in the upper part of the Kauriyala Formation (Krol E) may be considered to mark the boundary as the excursion is correlatable globally.
5. In the northwestern peninsular India (Rajasthan), Higher/ Tethys Himalaya (Kashmir Valley, Spiti Valley and Zanskar area), though the data suggest presence of Ediacaran Period deposits, it is not possible to define both the boundaries, viz. Cryogenian-Ediacaran and Ediacaran-Cambrian, in terms of GSSPs due to absence of diagnostic biota/horizon.
6. Biotic evidences from the Vindhyan Supergroup, Chhattisgarh Supergroup, Bhima and Kurnool groups do not suggest their age ranging from Ediacaran (terminal Proterozoic) – Cambrian. Presence of macroscopic fossil *Chuaria – Tawuia* and dominant acritarchs belonging to Sphaeromorphida suggest the date earlier than pre-Sturtian glaciation.

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