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Ediacaran multicellular biota from Krol Group, Lesser Himalaya and its stratigraphic significance-a review

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ABSTRACT

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Ediacaran multicellular biota, *viz.* medusoids - *Kimberella* cf. *quadrata, Beltanella* cf. *gilesi, Cyclomedusa davidi*, *Conomedusites lobatus*, *Tirasiana* sp., *Medusinites asteroides*, *Sekwia* cf. *excentrica*, *Irridinitus* sp. and *Beltanelliformis* cf. brunsae; frondoids - *Charniodiscus* cf. *arboreus, Pteridinium* cf. *simplex* and *Zolotytsia biserialis*; annelid - *Dickinsonia* sp.; ichnofossils - *Bilinichnus* sp. and metaphytic algae- cf. *Proterotaenia montana*, has been recorded from the Kauriyala Formation (Upper Krol) of the Krol Group, Lesser Himalaya India. The underlying Jarashi Formation (Middle Krol) has yielded frondoid forms - *Pteridinium carolinaense* and *Charniodiscus* cf. *arboreus* and trace fossil - *Harlaniella* sp. whereas the Mahi Formation (Lower Krol) has yielded medusoid - *Nimbia* cf. *occlusa*. This biota is generally cosmopolitan in nature except *Dickinsonia* which is restricted to Protogondwana. The Ediacaran biota is preserved at the interface of arenite / siltstone and shale which show ripple marks, rhythmic and lenticular bedding at places suggestive of tidal flat environment.

The present biota is comparable with Ediacaran multicellular biota of Ediacaran (Terminal Neoproterozoic) Period known from Australia, Canada and Russia. The fossiliferous horizons are characterised by δC^{13} values that vary from +1‰ to +6‰ PDB. Similar isotopic signatures have also been described from other Ediacaran fossil bearing horizons from northwestern Canada, Namibia, Australia, China and north Siberia.

Key-words—Ediacaran multicellular biota, Krol Group, Medusoids, Frondoids, Lesser Himalaya.

निम्न हिमालय, क्रोल समूह से प्राप्त ईडीयाकारन बहुकोशिक जीवजात तथा इसकी स्तरिक सार्थकता-एक समीक्षा

वी.के. माथुर

सारांश

निम्न हिमालय भारत के, क्रोल समूह के कौरियाला शैलसमूह से ईडीयाकारन बहुकोशिक जीवजात अर्थात मेडुसाभ-*किंबरेल्ला* तुलनात्मक *क्वॉड्रेटा, बेल्टानेल्ला* तुलनात्मक, *जिलेसी, सायक्लोमेडुसा डैविडि, कॉनोमेडुसाइट्स लोबेटस, टिरासियाना* प्रजाति, *मेडुसॉइनॉयट्सि एस्टेरॉइड्स, सेकविआ* तुलनात्मक *एक्सेंट्रिका, इर्रिडिनाइटस* जात, तथा *बेल्टनेलीफॉर्मिस* तुलनात्मक *ब्रुन्से, फ्रॉडॉइड्स-चार्निओडिस्कस* तुलनात्मक *एर्बोरेअस, टेरिडीनियम* तुलनात्मक, *सिम्पलेक्स* और *ज़ोलोटिटसिआ बाइसेरीऐलिस,* ऐनेलिड-*डिकिनसोनिआ* प्रजाति; पदचिह्न जीवाश्मों-*बिलिनिकनस* प्रजाति और मेटाफायटिक शैवाल-तुलनात्मक *प्रोटेरोटैनिआ मोन्टेना* अभिलिखित की गई है। अधःस्थ जरशी शैलसमूह (मध्य क्रोल) से फ्रॉडॉइड रूप-*टेरिडीनियम कैरोलिनैन्से* और *चारनिओडिस्कस* तुलनात्मक *आरबोरियस* तथा अनुरेख जीवाश्म-*हार्लेनीएल्ला* प्रजाति प्राप्त हुई है जब कि माही शैलसमूह (निम्न क्रोल) से मेडसॉइडस-*निम्बिआ* तुलनात्मक *ऑकलुसा* प्राप्त हुई है। यह जीवजात प्रकृति में *डिकिनसोनिआ* के अलावा सामान्यतः विश्वजनीन है जो कि प्रोटोगोंडवाना तक सीमित है। ईडीयाकरन जीवजात रेणुकाश्म/पांशु प्रस्तर एवं शेल के अंतरापृष्ठ पर परिरक्षित पाई गई है जो कि ज्वारीय सपाट पर्यावरण की सुझावित जगहों पर ऊर्तिका चिह्न, तालीय एवं मसूराकार संस्तरीकरण दर्शाती है।

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वर्तमान जीवजात आस्ट्रेलिया, कनाडा और रुस से ज्ञात ईडीयाकारन बहुकोशिक जीवजात से तुलनीय है। जीवाश्ममय संस्तर का δC^{13} मान से विशेष लाक्षणिक है जो $+1^0/_{00}$ से $+6^0/_{00}$ पी डी बी तक परिवर्तित होती है। इसी तरह के समस्थानिक चिह्नक उत्तरपश्चिमी कनाडा, नामीबिया, आस्ट्रेलिया, चीन और उत्तरी साइबेरिया से भी अन्य ईडीयाकारन जीवाश्ममय संस्तर वर्णित की गई हैं।

संकेत-शब्द—ईडीयाकारन बहुकोशिक जीवजात, क्रोल समूह, मेडुसॉयड, फ्राँडाइड्स, निम्न हिमालय।

INTRODUCTION

THE Ediacaran multicellular biota includes soft-bodied metazoans mainly represented by primitive coelenterates, few arthropods, echinoderms, problematic taxa and trace fossils generally in the form of simple horizontal to subhorizontal burrows. The appearance of Ediacaran biota is believed to make transition in the evolution between the microbial communities that characterise the Precambrian and the shelly biota of Cambrian and younger Phanerozoic systems (Sepkoski, 1981). Before the appearance of Ediacaran biota, benthic communities were dominated by prokaryotic microorganisms alongwith some sheet like and ribbon like algae during Mesoproterozoic to mid Neoproterozoic period (Knoll, 1992). The oldest known megascopic Ediacaran type remains occur in the Twitya Formation of northwestern Canada immediately below tillites. These tillites have been correlated with Varanger / Marinoan / Nantau / Blaini glacial deposits (Hofmann *et al*., 1990; Kumar *et al*., 2000; Jiang *et al*., 2003). Ediacaran biota diversified rapidly after the end of the Neoproterozoic glaciation and is now known from all the continents except Antarctica. The known stratigraphic range of Ediacaran biota is 600-545 Ma, but diverse and complex fossils are known from the final 20 Ma of Neoproterozoic (Grotzinger *et al*., 1995). The abrupt disappearance of Ediacaran biota may be attributed to competition and predation of early skeletal animals (McMenamin, 1986) and global geochemical changes (Bartley *et al*., 1998). However, a few "Ediacaran survivors" have been reported from the Cambrian but most of the archetypical forms disappeared abruptly near Cambrian "explosion" (Grotzinger *op. cit*.). Large sized acanthomorphs (acritarchs) have been recorded from the Infra Krol Formation,

Group	Formation	Kamlidhar Syncline	Nigalidhar Syncline	Mussoorie Syncline	Garhwal Syncline	Nainital Syncline
KROL	KAURIYALA		**Medusoids** *Beltanelliformis* cf. *brunsae*, *Conomedusites lobatus*, *Tirasiana* sp. **Annelid** *Dickinsonia* sp.	**Medusoids** *Beltanelliformis* cf. *brunsae* **Frondoid** *Zolotytsia biserialis* **Metaphytic algae** cf. *Proterotaenia montana*	**Medusoids** *Beltanelliformis* cf. *brunsae*, *Cyclomedusa davidi*, *Conomedusites lobatus*, *Tirasiana* sp., *Beltanella* cf. *gilesi* **Frondoid** *Charniodiscus* sp. **Ichnofossils** *Bilinichnus* sp.	**Medusoids** *Beltanelliformis* cf. *brunsae*, *Tirasiana* sp., *Beltanella* cf. *gilesi*, *Medusinites* cf. *asteroides*, *Kimberella* cf. *quadrata*, *Sekwia* cf. *excentrica*, *Irridinitus* sp. **Frondoids** *Charniodiscus* sp., *Charniodiscus* cf. *arboreus*, *Pteridinium* cf. *simplex*
	JARASHI				**Frondoid** *Pteridinium* cf. *carolinaense*, *Charniodiscus* cf. *arboreus*	**Ichnofossil** *Harlaniella* sp.
	MAHI	**Medusoid** *Nimbia* cf. *occlusa*				

Fig. 1—List of Ediacaran biota from the Krol Group, Lesser Himalaya.

Baliana Group and Mahi Formation, Krol Group (Tewari & Knoll, 1994; Mathur & Srivastava, 2005). These are known only from the strata ranging in age from just below or coveal with Varanger tillites to diversified Ediacaran biota (Tewari & Knoll. *op. cit.* and Jiang *et al.*, 2003).

Ediacaran biota (Fig.1) *viz.* medusoids - *Kimberella* cf. *quadrata* (Pl. 1.2), *Beltanella* cf. *gilesi* (Pl.1.3), *Cyclomedusa davidi* (Pl. 2.1), *Conomedusites lobatus* (Pl. 2.3, 4), *Tirasiana* sp., *Medusinites* cf. *asteroides* (Pl. 2.2) *Sekwia* cf. *excentrica*, *Irridinitus* sp. and *Beltanelliformis* cf. *brunsae* (Pl. 3.7); frondoids - *Charniodiscus* cf. *arboreus* (Pl. 1.1), *Charniodiscus* sp. (holdfast, Pl. 3.6) *Pteridinium* cf. *simplex* and *Zolotytsia biserialis* (Pl. 3.3); annelid - *Dickinsonia* sp. (Pl. 3.1); ichnofossil - *Bilinichnus* sp. (Pl. 3.2) and metaphytic algae- cf. *Proterotaenia montana* (Pl. 2.7) has been recorded from the Kauriyala Formation (Upper Krol) of the Krol Group, Lesser Himalaya India (Mathur, 1989; Mathur & Shanker, 1989, 1990; Shanker & Mathur, 1992; Shanker *et al.*, 1997; Mathur & Srivastava, 2004a). The underlying Jarashi Formation (Middle Krol) has yielded frondoid forms - *Pteridinium carolinaense* (Pl. 3.4) and *Charniodiscus* cf. *arboreus* (Pl. 3.5) and trace fossil - *Harlaniella* sp. whereas the Mahi Formation (Lower Krol) has yielded medusoid - *Nimbia* cf. *occlusa* (Pl. 2.5, 6) -(Mathur & Srivastava, 2002; Shanker *et al.* 2004). This biota is generally cosmopolitan in nature except *Dickinsonia* which is restricted to Protogondwana *i.e.*, Australia, Baltica (Baltic-Russian platform) and Africa (McMenamin, 1982).

GEOLOGICAL SETTING

The Ediacaran (Terminal Neoproterozoic) - Early Cambrian succession represented by the upper part of Baliana, Krol and Tal groups (Shanker *et al.*, 1989, 1993, 1996; Mathur & Srivastava, 2006) are well exposed in different synclines of the Krol Belt, Lesser Himalaya (Fig. 2). The upper part of the Baliana Group represented by the Infra Krol Formation and pink carbonate of the Blaini Formation rests unconformably over the topmost diamictite of the Blaini Formation of the Baliana Group. The lower part of the Baliana Group (Cryogenian) unconformably overlies rocks of Jaunsar / Simla Group of Early Neoproterozoic age. The above succession is unconformably overlain by the rocks of Boulder Slate Formation (Early Permian) and / or the Shell Limestone Formation (Late Cretaceous). The Baliana Group is divisible into Blaini and Infra Krol formations. The Blaini Formation represented by diamictite, conglomerate interbedded with quartz arenite, is generally capped by pink limestone. It is conformably overlain by Infra Krol Formation, which is represented by black and bleached shales intercalated with

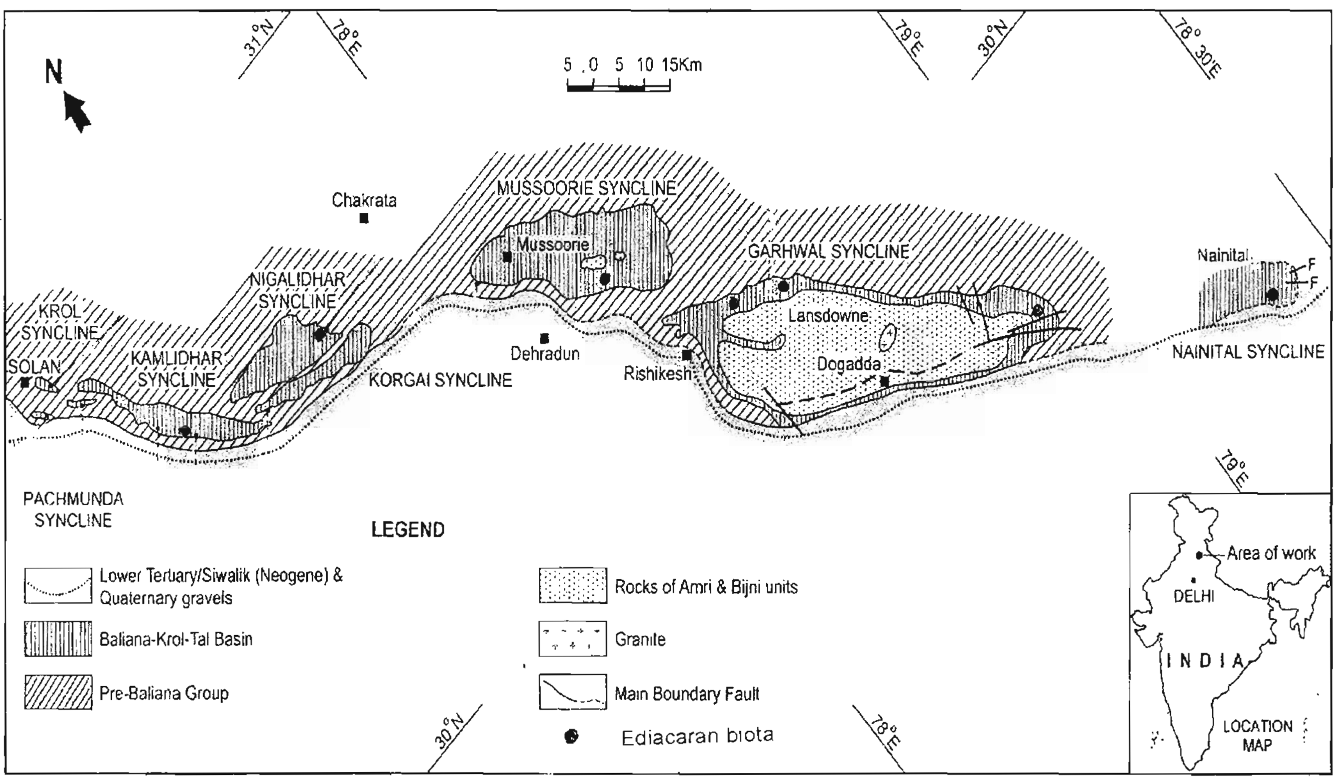

Fig. 2—Sketch geological map of the Baliana- Krol - Tal Basin, Lesser Himalaya, India modified after Auden, 1934 and Shanker *et al.*, 1993 showing locations of Ediacaran biota.

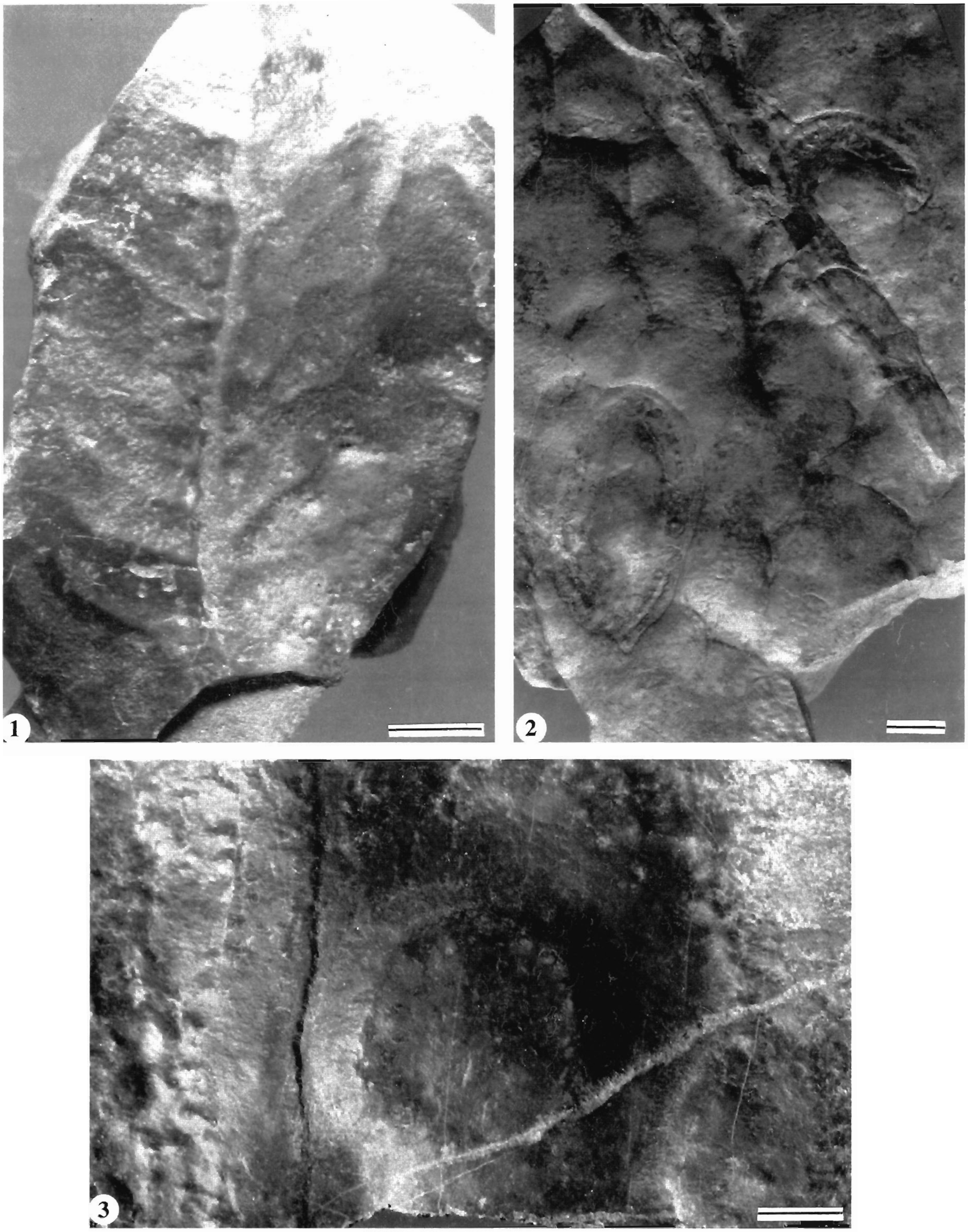

PLATE 1

Ediacaran biota (bar = 5 mm)

1 *Kimberella* cf. *quadrata*

2. *Beltanella* cf. *gilesi*

3. *Charniodiscus* cf. *arboreus*

thin silty layers. The Krol Group conformably overlies the Infra-Krol Formation. It comprises four formations namely, Chambaghat (Krol Sandstone), Mahi (Krol A), Jarashi (Krol B), Kauriyala (Krol C, D and E) in the ascending order. The Chambaghat Formation comprises quartz arenite with or without lenticles of phosphatic chert and shale. It is restricted in the northwestern part of the Krol Belt**.** The Mahi Formation is represented by argillaceous limestone interbedded with greyish shale and siltstone with or without chert nodules. The Jarashi Formation comprises of purple and green shale with thin lenticular bands of dolomite limestone and gypsum beds. In the Garhwal and Nainital synclines, the upper part of this formation shows shale/siltstone intercalations with rhythmic and lenticular bedding. The Kauriyala Formation comprises bluish grey limestone, microbial dolomite with black lenticular chert at places, calcareous shale, siltstone and quartz- arenite. The Krol C unit is represented by blue crystalline limestone, occasionally oolitic and showing vuggy and bird's eye structures while the Krol D unit is represented by microbial laminated dolomite with thin lenticular black chert interbedded with thin layers of grey and purple shale, siltstone and quartz-arenite. Both Krol C and Krol D laterally interfinger in the central part of the basin. The Krol E unit is characterised by grey limestone interbedded with calcareous shale, siltstone and argillaceous limestone. The Krol Group is overlain conformably with a local diastem by the Tal Group of Early Cambrian age, comprising thick argillo – arenaceous succession with thin beds/lenses of carbonate. In the basal part of the Tal Group occur chert and rock phosphate. Kumar (1984) and Jiang *et al*., 2003) noticed a close stratigraphic similarity of the Baliana-Krol-Tal succession with Nantuo-Tsanglangpu succession of Sinian-Early Cambrian age of China. Eight regional Stratigraphic discontinuities have been identified in the post glacial Neoproterozoic succession of the Krol Belt, Lesser Himalaya (Jiang *et al*., 2002). The Baliana Group has yielded stromatolites,Cyanophyceae algae and organic walled microfossils whereas the Krol Group has yielded stromatolites, OWM and Ediacaran multicellular biota, also known from the Late Neoproterozoic sediments elsewhere in the world. In the Tal Group, the Chert Member of the Deo Ka Tibba Formation has yielded small shelly fossils and stromatolites of Early Cambrian age (Meishucunian Zone I), small shelly fossils and trace fossil assemblage (Ichnozone III, Crimes, 1987) of Early Cambrian age (Meishucunian Zone III = Upper Tommotian Stage) were recorded from the Arenaceous Member excepting its upper part (25 cm). This upper part along with the overlying Calcareous Member has yielded redlichid trilobites, microgastropods and inarticulate brachiopods of Early Cambrian age (Qiongzhusian = Atdabanian Stage). The Dhaulagiri Formation of Tal Group has yielded stromatolites, inarticulate brachiopods and redlichid trilobites of Early Cambrian age (Tsanglangpuian = Botomian Stage**)** in Shanker *et al*., 1993; Mathur & Srivastava, 2006**.**

SEDIMENTARY ENVIRONMENT AND MODE OF FOSSILISATION OF EDIACARAN MULTICELLULAR BIOTA

The Ediacaran multicellular biota is preserved at the interface of arenite/siltstone and shale which show ripple marks and rhythmic and lenticular bedding at places suggestive of tidal flat environment. The shales represent areas of temporary calm conditions between shifting current tracks where fine particles could settle until they were covered again by sand/ silt waves. The animal remains which came to rest on the muddy or silt flats and pool bottom either made impressions in the sediment or were retained there bodily until covered with sand by the next shifting currents (Glaessner & Wade, 1966). The fossils are mostly preserved as impressions/moulds/casts on the lower surface of the arenite/ siltstone. The Ediacaran biota is generally found associated with microbial mat structures. These microbial structures are inferred to have been responsible for the fossiliferous bedding plane textures which provided necessary physical and chemical ingradients for the early diagenesis of a sole surface on which Ediacaran organisms were moulded (Gehling, 1999; Mathur & Srivastava, 2004b).

BIOGENECITY OF EDIACARAN FAUNA

The biogenecity must be considered along with the primary sedimentary characteristics of the enclosing beds and superimposed post depositional deformational features. The fossils impressions were recorded from a rhythmically lenticular bedded sequences of shale-siltstone suggestive of tidal flat environment of deposition. In addition, micro and meso-scale ripple marks, wrinkle marks and load structures were also observed in the sequence over which fossil impressions were found.

Superimposed over these primary sedimentary features are remnants of Ediacaran fossil elements in the form of discoidal impression, spheroids, frond like structures and some other problematic forms which show consistent morphology and organisation, suggestive of a biological affinity (Shanker & Mathur,1992; Shanker *et al*., 1997).

The discoidal features reported as medusoids have characteristic features like disc, annulus, marginal flange, concentric and radial markings. All these features easily distinguish them from load structures. The absence of vertical tubes in their cross sections indicate that they are neither water nor gas escape structures (Shanker *et al*., 1997, Pl. 1, figs c, f, g).

The frond-like features classified here as *Pteridinium* and *Charniodiscus* greatly resemble present day pennatulid coelenterates (sea pens). Foliate structures-including the median rhachis, the stalk and attachment disc were distinguished (Glaessner, 1984). Structural deformation of

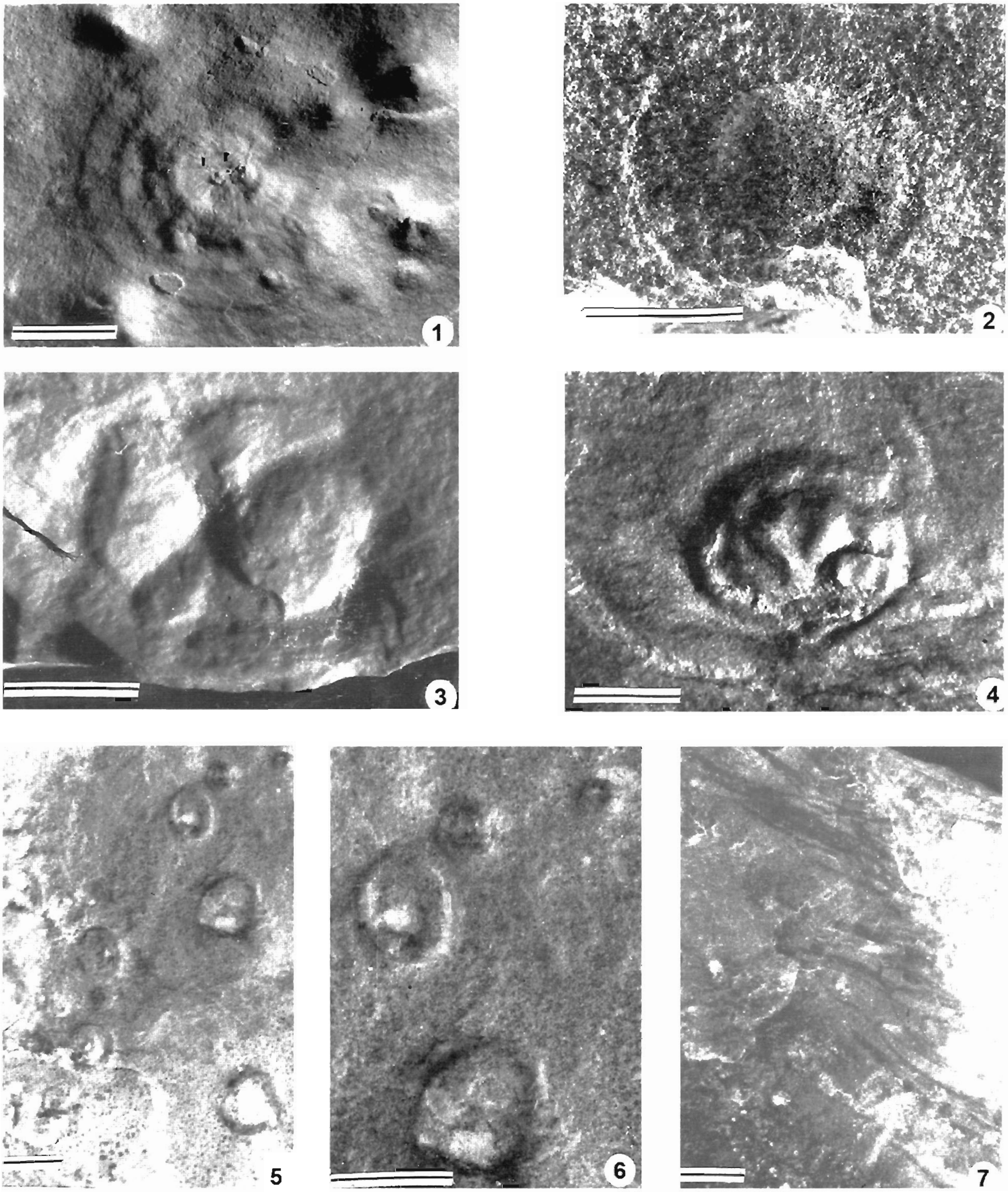

PLATE 2

Ediacaran biota (bar = 5 mm)

1 *Cyclomedusa* cf. *davidi*
2. *Medusinites* cf. *asteroides*
3. *Conomedusites* cf *lobatus* (external mould)
4 *Conomedusites* cf. *lobatus* (internal mould)
5. *Nimbia* cf. *Occlusa*
6. *Nimbia* cf. *occlusa* (enlarged view of northeastern part of Fig e)
7 metaphytic algae- cf *Proterotaenia montana*

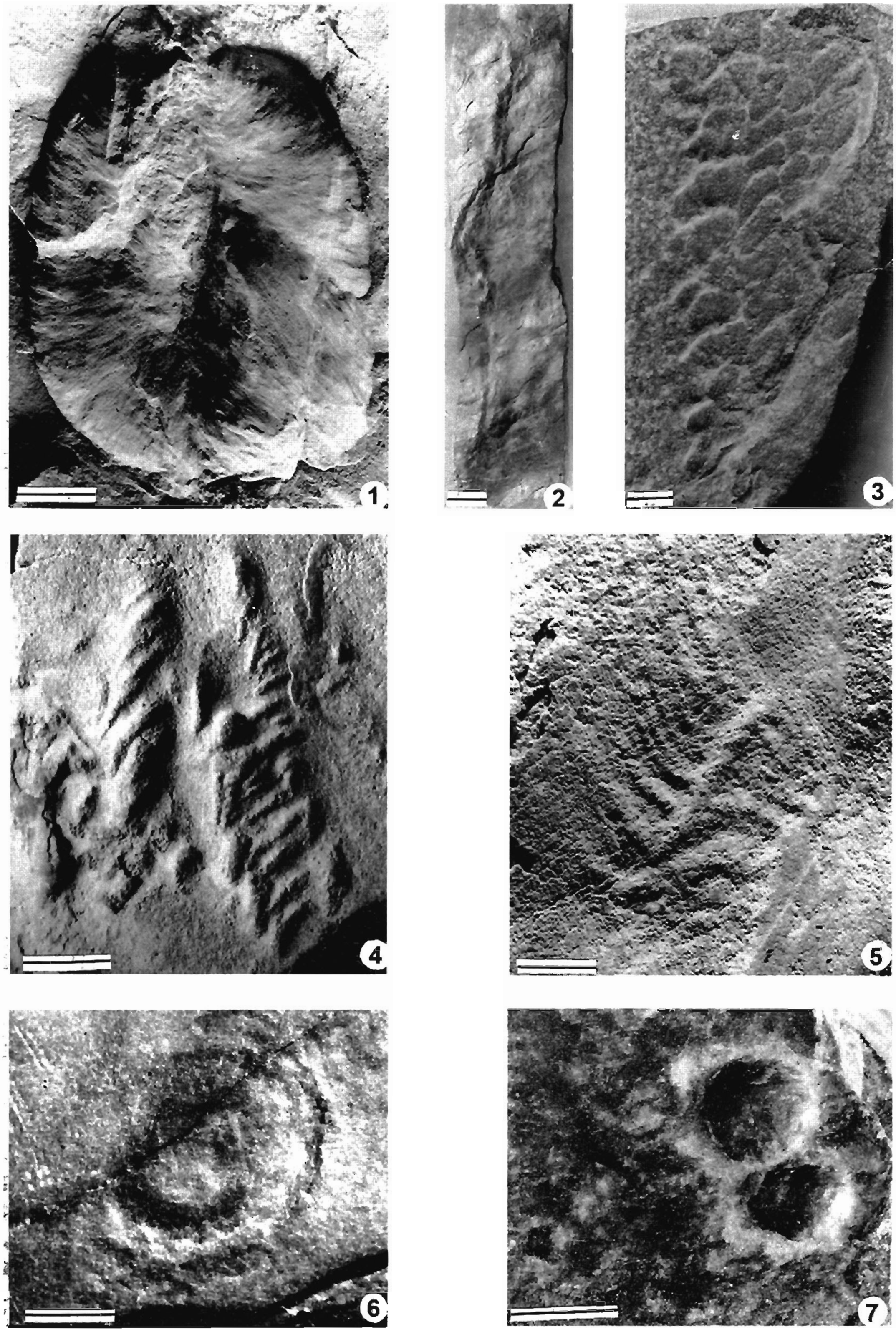

PLATE 3

Ediacaran biota (bar = 5 mm)

1 *Dickinsonia* sp.
2. *Bilinichnus* sp.
3 *Zolotytsia biserialis*
4. *Pteridinium carolinaense*
5. *Charniodiscus* cf. *arboreus*
6. *Charniodiscus* sp. (holdfast)
7. *Beltanelliformis* cf. *brunsae*

the area might have led to the deformation and destruction of specimens. Consistent morphology and bilateral symmetry are observed in the frond like impressions. All these features are not at all typical of wrinkle marks/dendritic structures as contended by Bhatt and Mathur (1990). The non penetrative nature of these forms rules out the possibility that these features are tectonic/deformational structures as contended by Misra (1990).

CARBON ISOTOPIC SIGNATURES OF EDIACARAN FOSSILIFEROUS HORIZON

The present Ediacaran fossil bearing horizon is characterised by δC^{13} values that vary from +1‰ to +6‰ PDB (Aharon *et al*.,1987; Kumar & Tewari,1995; Bhattacharya *et al*., 1996; Kaufman *et al.*, 2006). Similar isotopic signatures have also been described from the Blue Flower Formation, northwestern Canada Schwarzrand Subgroup of Namibia, Rodda Group strata equivalent to Ediacara Member in Australia, Dengying Formation in China and Khatyspyt Formation in Siberia (Narbonne *et al.,* 1994). Substantial depletion in δC^{13} values has been recorded in carbonates overlying the Ediacaran biota bearing horizon and continues in the overlying Tal Group yielding small shelly fossils of Meishucunian Zone I gains significance in identifying an event which led to diversification and evolution of life.

CONCLUSIONS

The present biota is comparable with Ediacaran multicellular biota of Ediacaran (Terminal Neoproterozoic) Period known from Australia, Canada and Russia.

The Ediacaran biota occurs in Krol Group, Krol belt, Lesser Himalaya in the intercalations of shale and siltstone deposited in a tidal flat environment. It is generally found associated with microbial mat structure which is inferred to be responsible for the preservation of the Ediacaran biota.

This biota is generally cosmopolitan in nature except *Dickinsonia* which is restricted to Protogondwana, i.e. Australia, Baltica (Baltic-Russian Platform) and Africa.

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The present fossiliferous horizon is characterised by δC^{13} values that vary from +1‰ to + 6‰ PDB. Similar isotopic signatures have also been described from other Ediacaran fossil bearing horizons from northwestern Canada, Namibia, Australia, China and north Siberia.

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