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CORRELATION AND PALAEOBIOLOGY OF VINDHYAN AND LESSER HIMALAYAN STRATIGRAPHIC SUCCESSIONS

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ABSTRACT

The North-western Lesser Himalaya is characterised by two major sedimentary belts. The older sequence is Early Proterozoic to Neoproterozoic in age and major facies of this belt are (I) Volcano siliciclastic (Rampur-Manikaran-Chamoli-Berinag) (II) Clastic-argillaceous (Sundernagar-Hurla-Rautgara-Rudraprayag-Bhawali Qartzite and volcanics) (III) Microbial-stromatolitic carbonate phosphorite (Shali-Larji-Deoban-Lameri-Pipalkoti-Gangolihat-Dharchula) and (IV) Argillo-calcareous (Mandhali-Sor-Thalkedar) units with stromatolites. The younger sedimentary sequence is known as Blaini-Krol-Tal belt in the outer Lesser Himalaya. It is characterised by Terminal Proterozoic stromatolites, algae, Ediacaran fossil, vendotaenids and Lower Cambrian shelly, trace and body fossils. The correlation of the inner sedimentary basins with that of the Vindhyan Basin is discussed on the basis of recent discovery of sponge spicules, microbiota, microstromatolites and stromatolite assemblages from the Deoban-Gangolihat belt.

Key words: Vindhyan, Lesser Himalaya, Correlations, Neoproterozoic, Stromatolite, Palaeobiology.

INTRODUCTION

The sedimentation of the Rampur Qartzite-Volcanic sequence of the Lesser Himalaya (fig. 1) initiated with an earliest Proterozoic rifting event followed by a shelf cycle of tidal flat sedimentation during Palaeoproterozoic (Tewari, 1998b). Subsequent rifting events during Mesoproterozoic (1600-1000 Ma) and Neoproterozoic (700-650 Ma) developed Proto Tethys Ocean (PTO). The younger carbonate sedimentary succession of the Krol belt is Terminal Proterozoic to Early Cambrian in age (fig.2 a,b) and stretches over a distance of 350 km showing major facies variations at Solan, Nigalidhar, Korgai, Mussoorie, Garhwal and Nainital synclines (Kumar, Raina, Bhatt, and Jangpangi, 1983; Singh and Rai, 1983; Mathur and Shankar, 1989; Tewari 1993, 1998b). The Tal Formation (Quartzite) marks the end of sedimentation and regression of the sea from the Lesser Himalaya and its stratigraphic position over the Krol Formation is restricted to only the central part (Nigalidhar-Korgai-Mussoorie and Garhwal synclines). Valdiya (1989) suggests extension of the Tal Formation into Nainital but no definite Lower Cambrian trace or body fossils have been reported so far. After the Early Vendian rifting the Neoproterozoic glacial beds (Cryogenian/Varanger) -Blaini diamictites interbedded with quartzite and shales capped by pink microbial dolomite-were deposited. The Krol carbonates represent passive continental marginal facies variations as shaly limestone and calcareous shale facies with sheet metaphytes (multicellular algae) and purple green shales with lenticular bands of limestone and gypsum. Brecciated cherty, oolitic dolomite facies characterised by various types of oolites, bird's eyes structure, microbial laminated stromatolitic build-ups and oncolites indicate that the depositional environment was tidal flat (high energy peritidal). The relationship between stratigraphic sequence, depositional environment, palaeobiology and palaeoclimate is shown in figure 3.

The Ediacaran metazoan facies of the Krol is finely laminated siltstone with wave ripples and shale. The shaly limestone facies of the Krol grades into the chert-phosphorite facies of the Lower-Tal characterised by black chert, shale and phosphorite associated with pyrite, oncolites and stromatolites (fig.3). The Precambrian/Cambrian boundary transitional facies shows upwelling and stratification of sea as revealed by carbon isotope excursions of Krol-Tal basins(fig.4). The other Lower Cambrian facies of the Tal Formation includes bioturbated purple grey siltstonė (trace fossil) facies and channel sandstone, orthoquartzite facies of fluviodeltaic and marine shelf facies at the top of the sequence. The Krol-Tal basin was possibly obliterated during Lower

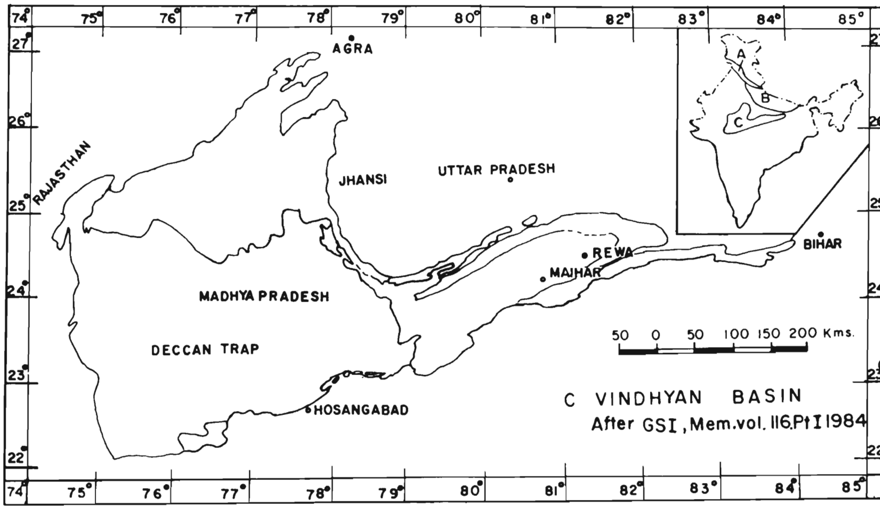

Fig 1. Map showing locations of the Lesser Himalaya (A), Indogangetic Plain (B) and the Vindhyan Basin (C) (after/n GSI Mem. **116**(1), 1984).

Cambrian due to Pan African epeirogenic movements around 550 Ma. (Singh, 1976; Tewari 1998b). The Lesser Himalayan sediments are covered by three main Phanerozoic marine transgressions of (1) Permian (II) Late Cretaceous and (III) Late Palaeocene to Eocene age in different areas of the Lesser Himalaya from Jammu in NW to Arunachal Pradesh in NE (Singh,1976; Tewari, 1998b). Tewari (1998 a, b; 2001) has attempted a correlation between the Proterozoic and Cambrian sedimentary rocks of NW and NE Himalaya with Peninsular sequence of Rajasthan (Trans Aravalli Vindhyans; Table 1). The Buxa-Miri Group of rocks in Bhutan and Arunachal Pradesh may be equivalents of the Krol-Tal sediments based on identical sedimentary facies, recent discovery of microstromatolites and microbiota from the Menga Limestone (Tewari, 2001). Therefore, these are the potential areas for search of Ediacaran biota, stromatolites and trace fossils (Tewari, 2001).

It is quite interesting that identical assemblages of Meso-Neoproterozoic stromatolites and microbiota have been recorded from the Shali-Deoban-Gangolihat carbonate belt of the Lesser Himalaya and the Semri Group of the Vindhyan Supergroup (fig. 3,5; Table 2 and 3). Vendotaenides and Ediacaran biota have been recorded from the Krol Formation of the Lesser Himalaya of India and the Sinian, Doushantuo and Dengying formations of China (Tewari, 1999) after the Neoporterozoic glaciation. A sequence of diamictites and stromatolitic carbonates similar to Blaini-Krol sequence has been reported from the west Kameng district of Arunachal Pradesh (Tewari, 2001). It may be speculated that during Neoproterozoic-Cambrian times the northern margin of the Indian Gondwana land must have included parts of Tibet and China forming a megacrustal block. It is supported by the close facies relationships and identical biotic and isotopic events from the Sino-Indian region. The present-day microcontinents of the Asian region may be the product of collision of Indian Gondwana land and Eurasia (Tewari, 2001, *in press*).

AGE AND PALAEOBIOLOGY

The Vindhyan Basin is traditionally accepted as Meso-Neoproterozoic in age. So far there is no definite record of Terminal Proterozoic fossils like Ediacaran biota from Vindhyans and complete absence of any body fossils like trilobites and trace fossil such as *Treptichnus.* The records of Middle Proterozoic (Mesoproterozoic/Riphean) micro- and megafossils such as cyanobacterial fossils, acritarchs, *Chuaria*, *Grypania,* etc. (McMenamin, Kumar, and Awaramik, 1983; Maithy and Shukla, 1984; Kumar and Srivastava, 1992; 1995; Venkatachala, Yadav and Shukla, 1990; Rai, Shukla and Gautam, 1997) from the Vindhyans are undisputable and indicate a diversified biota at 1200-1000 m.y. More recently,

Table 1: Correlation of Lesser Himalaya and the Peninsular Shield (Western Rajasthan and Trans Aravalli Vindhyans or Marwar Supergroup).

	WESTERN RAJASTHAN		LESSER HIMALAYA
Recent/Holocene	Alluvium and Desert sand		Newer Alluvium(River)
Middle to Late Pleistocene			Terraces Older Alluvium
			Dun Gravels
Upper Miocene to Early Pleistocene			Siwalik Group
		Unconformity	
Late Paleocene to Eocene	Mandai/Jogira Palana Formation		MT3-Marine Transgression-3 Subathu Formation
		Unconformity	
Late Cretaceous	Deccan Trap/Basalt Abur/Fatehgarh Formation		MT2-Marine Transgression-2 Manikot Shell Limestone Formation
		Unconformity	
Jurassic	Parihar Formation Bedesar Formation Baisakhi Formaton Jaisalmer Formation Lathi Formation		Missing
		Unconformity	
Permian to Carboniferous	Badhaura Formation Bap Boulder Bed		MT1-Marine Transgression-1 Boulder Slate (Lower Bijni)
		Unconformity	
Early Cambrian	Nagaur Formation Pokharan		Tal Group Boulder Bed
	Unconformity		Locally diastem
Terminal Neoproterozoic (Vendian-Sinian) Marwar Supergroup	Bilara Formation Jodhpur Formation Sonia Formation Basal Formation		Krol Group Blaini Group
	Unconformity		
Neoproterozoic (Cryogenian)	Malani Suite of rocks		Jaunsar/Simla Group
	Unconformity		
Mesoproterozoic (Riphean)	Erinpura Granite Delhi Supergroup		Deoban Group Damta Group
	Unconformity		
Palaeoproterozoic	Granites, basics and ultrabasic Intrusives, Aravalli Supergroup		Central Crystallines Granites and Porphyries (1900+100 Ma) Rampur Volcanics(2.4 Ga)
	Unconformity		
Archaean	Granite and basic intrusives Pre-Aravalli basement (Banded Gneissic Complex, Granites and Granitic Gneisses)		(Basement not exposed)

Kumar (2001) has reported *Chuaria-Tawuia* association from 1000 Ma old Suket Shale of the Semri Group (Lower Vindhyan) from Rampura area. The occurrence of typical Riphean stromatolite taxa from the Lower and Upper Vindhyans such as *Kussiella kussiensis*, *Colonnella columnaris, Conophyton garganicum*, *C. cylindricus, Baicalia* Maslov, *B. satnaensis, Tungussia* sp. and *Gymnosolen* sp. are identical to the Southern Urals, in Russia/former USSR (Valdiya, 1969, 1989; Raha and Das 1989; Raaben and Tewari, 1987; Tewari, 1989). It is important to mention here that no Vendian or Lower Cambrian stromatolite taxa described from the Krol-Tal sequence of the Lesser Himalaya or Siberian platform is present in Vindhyans (Tewari, 1989, 1993). However, Kumar (1999) and Tewari, Pant and Tewari (2000) have discovered Neoproterozoic sponge spicules from the Upper Vindhyan Bhander Limestone and the Gangolihat Dolomite of the Kumaun Lesser Himalaya respectively.

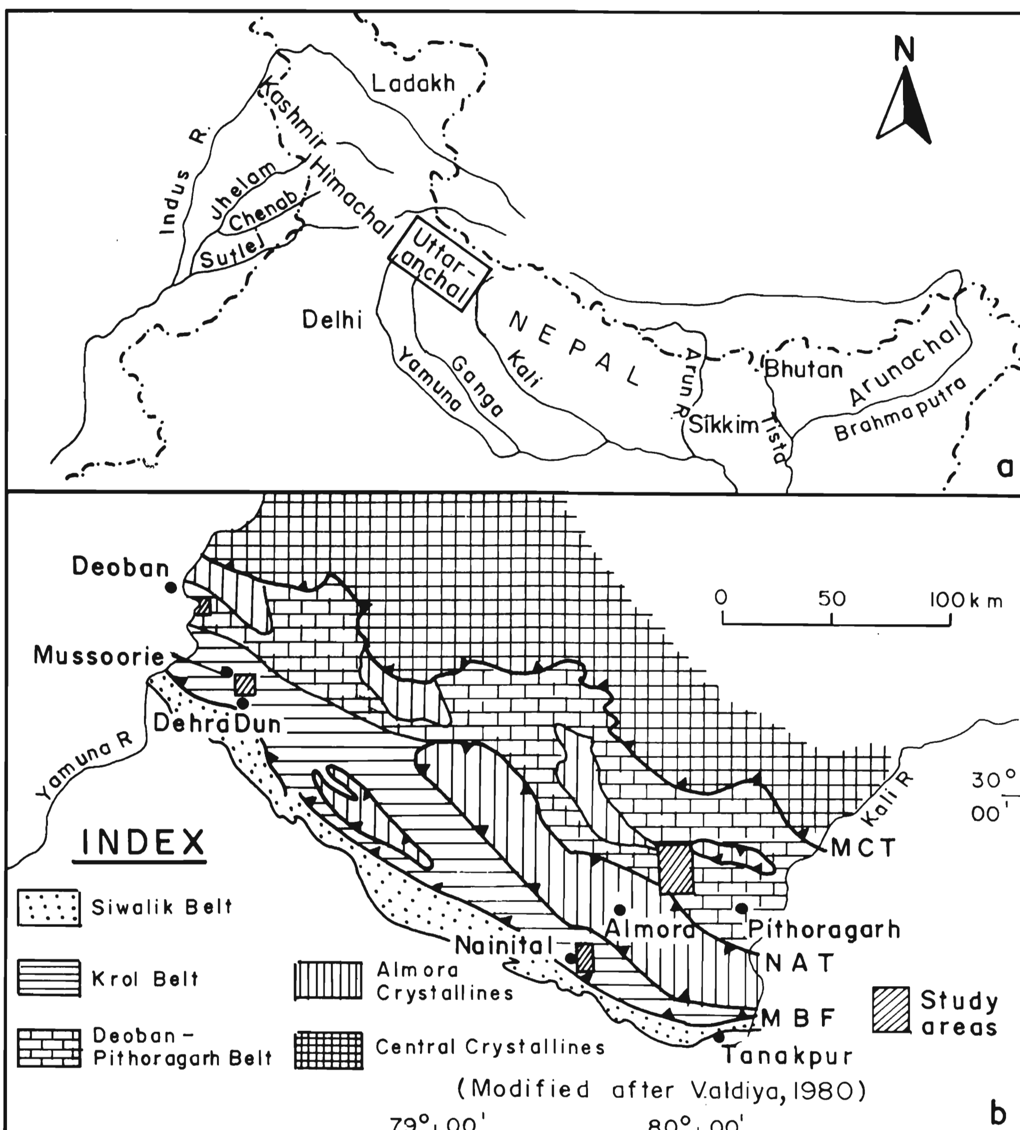

Fig. 2. Location (a) and simplified geological map of the Kumaon, Lesser Himalaya (b) (after Valdiya, 1980).

Table 2: Correlation of Vindhyan and Lesser Himalayan stratigraphic sequences (Modified after Kumar, 1999).

	VINDHYAN			LESSER HIMALAYA		
	GROUP	FORMATION	AGE	GROUP	FORMATION	AGE
UPPER VINDHYAN	Bhander Group	Maihar Sandstone Sibru Shale Bhander Limestone	Ca 600 Ma	Krol Group	? Krol Formation	Terminal Proterozoic
	Rewa Group	Rewa Sandstone Rewa Shale	Ca 650 Ma	Infra Krol Formation		
	Kaimur Group	Kaimur Sandstone	K/Ar dates1080+ 40 Ma(After Vinogradov *et al.*, 1964; Kreuzer *et al.*, 1977)	Blaini Formation		(T.P.S. Base)
			------------Unconformity	------------	------------	
		--------Unconformity--------		Jaunsar- Simla Group	Nagthat Formation Chandpur formation Mandhali formation	Newproterozoic
		Rohtas Formation Kheinjua Formation		Deoban Group	Deoban Formation	Mesoproterozoic
LOWER VINDHYAN	Semri Group					
		Porcellanite Formation Basal Formation		Damta Group	Chakrata Formation Rautgara Formation	
----------	----------	----------	----------Unconformity	----------	----------	----------
Metamorphics and Granite					Berinag Quartzite	Palaeoproterozoic

ISOTOPIC AGE OF VINDHYANS

The Lower Vindhyan (Glauconitic Sandstone) has been radiometrically dated at 1110±60 m.y. (Vinogradov *et al.*, 1964). The Fawn Limestone underlies the Glauconitic Sandstone and thus confirms the Lower Riphean age based on the stromatolites (Valdiya, 1969; Kumar, 1976). The Rohtas Formation overlying the Glauconitic Sandstone may be accepted as the Middle Riphean (1000-1100 m.y.) in age. The Glauconite-bearing Kaimur Formation (Upper Vindhyan) has given K-Ar ages of 940-910 m.y. (Vinogradov *et al.*, 1964). The above radiometric dating has been examined by Tugarino, Shannian, Karakov and Arakelynian (1965) and Vinogradov *et al.* (1966) who found them correct. Crawford and Compston (1970) based on Rb/Sr ratio in phlogopite found in Kimberlites which is intrusive in the Kaimur Group assigned 1150 m.y. age. They suggested that the Lower Vindhyans should be 1200 m.y or older. Kumar (2001) has doubted the recent $^{40}Ar/^{39}$ age of 617 ±3.5 Ma assigned to the Semri Group by Banerjee and Frank (1999). He also suggested that the age of the Suket Shale underlying the Kaimur Group should be older than 950 Ma.

PALAEOBIOLOGY

Azmi (1998) has reported doubtful microfossils from the Lower Vindhyans and compared them with Lower Cambrian assemblage of the Chert-Phosphorite Member of the Lower Tal Formation. However, the typical Lower Cambrian taxa *Protohertzina*, *Anabarites* and *Circotheca* are not found in the Vindhyan assemblage. *Taliella* n . gen. has no biostratigraphic significance independently (Bhatia, 1999). Some of the reported microfossils by Azmi (1998; Plate 1, Figs. 2,10,11,17,18) are most probably cone in cone structures of nonbiogenic origin. Kumar (2001) has reported an assemblage of five different conophytons, namely *Thyssagates*, *Ephyaltes*, *Calypso*, *Cyathotes* and *Siren* from the Semri Group.

The small shelly fossils have not been recorded from any Riphean sequence of the world so far and according to the evolution of life on earth, S.S.Fs appeared after Ediacaran fossils in the Late Vendian-Early Cambrian. The Lower Vindhyan sedimentary facies is also not suitable for the preservation of the Ediacaran biota and phosphatic SSF's. Therefore, there is no question of delineating precise PC/C boundary in the uppermost strata of the Rohtasgarh Limestone as proposed by Azmi (1998). The PC/C boundary according to the decision of IUGS/IGCP is based on the first appearance of *Treptichnus*. Moreover, the PC/C boundary in most of the Asian sections (China, Lesser Himalaya Krol-Tal, Mongolia and Iran) is in phosphorites. (Tewari, 1984, 1993; Aharon, Schidlowski and Singh, 1987; Brasier and Singh, 1989).

Recently, Kathal, Patel and Alexander (2000) has also reported doubtful Ediacaran-like pseudofossil *Spriggina floundersi* from the Lower Vindhyans. The identification, recovery and lithology of the *Spriggina*-like fossil has been questioned by Kumar (2001). The discovery of triploblastic metazoans from the Lower Vindhyans (1.1 billion years) by Seilacher, Bose and Pfluger (1998) suggests that multicellularity must have existed during Mesoproterozoic and contradicts the Lower Cambrian age of the Lower Vindhyans. However, Rai and Gautam (1999) consider these metazonas as pseudo-trace fossils or casts of some megascopic algae and question the triploblastic nature of their purported animals. The biostratigraphic correlation between the Terminal Proterozoic-Lower Cambrian Mussoorie Group of the Lesser Himalaya (fig.3) and the Semri Group of the Lower Vindhyan (Mesoproterozoic) is also not tenable and unacceptable since the Blaini-Krol-Tal sequence is firmy established as a Terminal Proterozoic-Lower Cambrian succession (~650-550 m.y.) based on palaeontological and isotopic signatures (fig. 4) (Braiser and Singh; 1989; Bhatt, Mamgain, Misra and Srivastava, 1983; Kumar *et al.*, 1983; Tewari, 1984, 1989, Mathur and Shankar, 1989; Singh and Rai, 1983; Aharon *et al.*, 1987; Kumar and Tewari, 1995, Tewari, 1998b).

DISCUSSION AND CONCLUSIONS

Valdiya (1969), Kumar and Tewari (1978), Raha and Das (1989), Shukla, Tewari and Yadav (1986), Tewari (1989, 1993, 1996), Raaben and Tewari (1987), Kumar and Srivastava (1995) have correlated the Jammu-Shali-Deoban-Pithoragarh belt (Meso-Neoproterozoic) with the Lower Vindhyan on the basis of identical stromatolite taxa, microbiota and isotopic age. The Precambrian-Cambrian boundary carbon isotope curve (fig.4) of the Krol-Tal sequence (Aharon *et al.*, 1987;Tewari,1989; Kumar and Tewari, 1995) is also different from that of the Upper Vindhyan. However, Friedman and Chakroborty (1997) have shown the PC-C boundary in the Upper Vindhyan without any fossil evidence. Kumar (2001) doubted the variation in δ^{13} C values of Bhander Group (Friedman and Chakraborty,1997) since the difference in the values is only 2.1‰ (PDB).Tewari (1996,1997,1998a,b,1999) has further established that the Deoban belt (Meso-Neoproterozoic pre-Blaini) is entirely different from the Krol Belt (Terminal Proterozoic-Cambrain post Blaini) in biota, sedimentary facies and isotopic signatures. The Deoban belt is correlatable with the Lower Vindhyan

Table 3: Stromatolite biozonation of Lesser Himalaya, North India (Tewari, 1989).

No.	Biozone	Stromatolite Assemblage	Age
VII	*Ilicta*	*Ilicta talica collumnefacta korgaiensis, Aldania birpica*	LENIAN/TOYONIAN (Lower Cambrian)
VI	*Collumnaefacta-Boxonia*	*Collumnaefacta vulgaris, Boxonia gracilis,Aldania mussoorica,Colleniella, Acaciella, Compacto-Collenia, Conophyton durmalacus, Conophyton* msp.	TOMMOTION (Precambrian-Cambrian (PC/C) Boundary)
V	*Yugmaphyton*	*Yugmaphyton* g. nov., *Minicolumellae, Stratifera, Conophyton, Tungussia* msp.	LATE VENDIAN
IV.	*Jurusania-Parmites*	*Jurusania* msp. *Jurusania himalaiyka, Paramites, Tungussia, Poludia*	UPPER RIPHEAN TO EARLY VENDIAN
III	*Baicalia*	*Baicalia nova, Baicalia Chandakia* f. nov., *Minjaria uralica, Jacutophyton*	MIDDLE RIPHEAN
II	*Conopyton*	*Conophyton cylindericus, Conophyton garganicus, Columnellla columnaris*	LOWER RIPHEAN
I	*Rahaella-Kussiella*	*Rahaella* g. nov. *Rahaella elongata, Rahaelle katraensis, Kussiella kussiensis, Kussiella vittata*	LOWER RIPHEAN

on the basis of identical occurance of stromatolite assemblages *Kussiella kussiensis, Conophyton garganicum, Colonnella columnaris, Jacutophyton, Baicalia nova and* microbial assemblage of *Myxococcoides minor, M. grandis, Huroniospora* sp., *Glenobotrydion aenigmatis, Sphaerophycus parvam, Siphonophycus kestron, Oscillatoriopsis media, Eomycetopsis robusta, Gunflintia minuta* (McMenamin *et al.*, 1983; Shukla *et al.*, 1986; Tewari, 1989; Kumar and Srivastava, 1992, 1995). Maithy and Rupendra Babu (2000) have recently reported *Myxococcoides* and *Eomycetopsis*

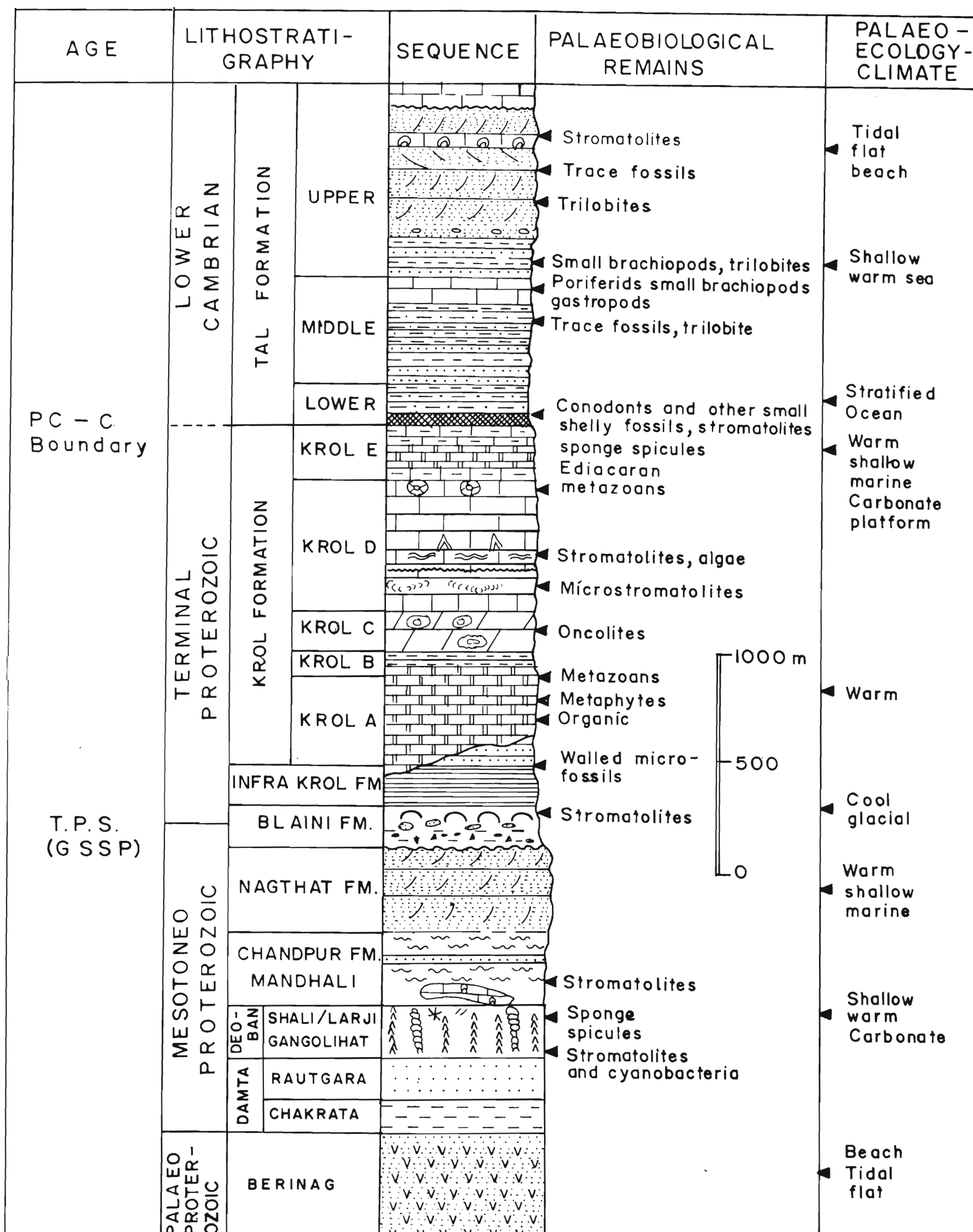

Fig 3. Lithocolumn showing revised stratigraphic sequence, palaeobiology and palaeoclimate of the Lesser Himalaya.

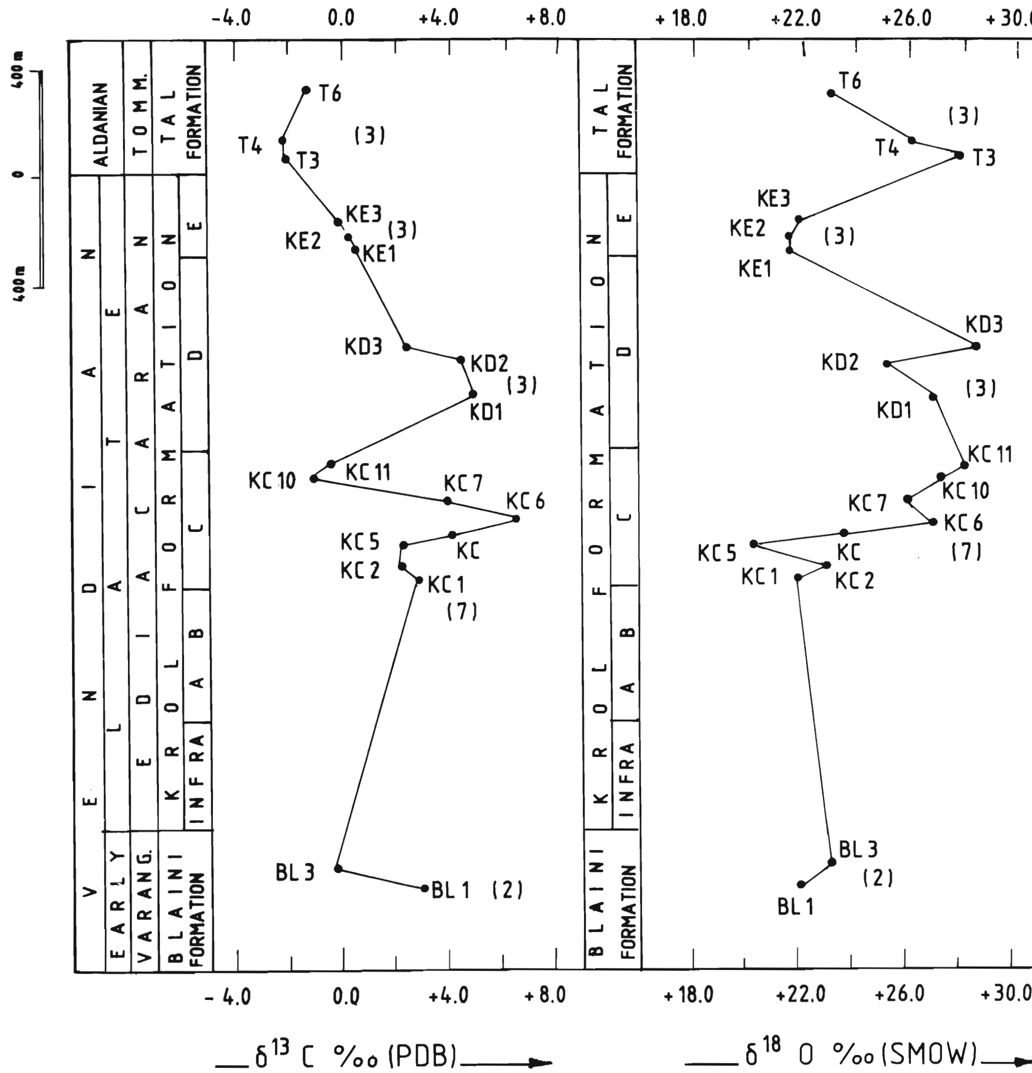

Fig 4. Carbon and Oxygen isotope excursions of the Terminal Proterozoic-Lower Cambrian sequence (Blaini-Krol-Tal) of the Lesser Himalaya.

from Bhagwar Shale, Rohtasgarh and suggest 1000 Ma age for Lower Vindhyan. This contradicts the Lower Cambrian age proposed by Azmi (1998). This assemblage is globally distributed in the rocks dated around 1200-1000 m.y. in age except few long ranging forms (Shukla *et al.,* 1986).

The stromatolite biozones of the Lesser Himalaya (Zone, I, II, III, Table 3) found in the Deoban and equivalent carbonates are also recorded from the Lower Vindhyan Semri Group (Tewari, 1989, 1993). The zone IV is common in the Upper Vindhyan and Mandhali-Thalkedar carbonates. The Krol-Tal stromatolite assemblage (Zone V,VI and VII) are unique to the Lesser Himalaya and not reported from the Vindhyans. This clearly shows that Terminal Proterozoic-Lower Cambrian sedimentation of the Lesser Himalaya is not identical to that of the Vindhyan Basin. A tentative correlation of the Vindhyan Supergroup with Lesser Himalayan sediments is given in table 2. Thus, in conclusion, the Terminal Proterozoic-Lower Cambrian events e.g. glaciation and phosphogenesis are lacking in the Vindhyan Basin. The complete absence of Ediacaran metazoans, *treptichnus* and small shelly fossils do not support Precambrian/ Cambrian boundary or Terminal Proterozoic age for sequences in the Vindhyan Basin.

ARAVALLI	DELHI	VINDHYAN Lower	VINDHYAN Upper			MARWAR Supergroup			STROMATOLITE TAXA	AGE
	Ajabgarh	Semri	Kaimur	Rewa	Bhander	Jodhpur	Bilara	Nagaur		
+									*Baicalia prima*	PALAEO TO MESOPROTEROZOIC
+					+				*Collenia baicalica (Baicalia) Maslov*	
+		+		+	+				*Collenia buriatica (Eucopsiphora) Maslov*	
+	+	+			+				*Collenia columnaris Fenton and Fenton*	
+		+			+				*Collenia kussiensis (Kussiella kussiensis)*	
+					+				*Linella (?)*	
+									*Minjaria calceolata*	
+									*Acaciella sp.*	
+									*Kussiella sp. Krylov*	
	+	+			+				*Baicalia baicalica (Maslov) Krylov*	
	+								*Collenia sp. Walcott*	
	+								*Jacutophyton Shapovalova*	
		+							*Kussiella kussiensis*	
		+			+		+		*Conophyton cylindricus Maslov*	
		+							*Cryptozoon occidentale (Kussiella) Dawson*	
		+					+		*Stratifera Korolyuk*	
		+							*Tungussia Semikhatov*	
		+			+				*Weedia Walcott*	
				+					*Collenia ramsayi*	
				+	+		+		*Oncolites Pia*	VENDIAN Lr. CAMBRIAN
							+		*Collenia pseudocolumnaris Maslov*	
							+		*Colleniella Korolyuk*	
							+		*Conocollenia Maslov*	
							+		*Irregularia Korolyuk*	

Fig 5. Distribution of stromatolite taxa in the Aravalli, Vindhyan and Marwar supergroups of the Peninsular India.

Stromatolites, microstromatolites and their microstructures are still successfully being used the world over for biostratigraphic correlations of Proterozoic rocks in Siberian platform, Canada, South Africa, Australia, China, India and elsewhere (Schenfil, 1989; Krylov, 1975; Grey,1982; Hofmann and David, 1998: Tewari and Joshi, 1993; Tewari, 2001; Zhu, S.X., 1982). Stromatolites (microbialites) are the most convincing evidence of microbial activity in Precambrian sequences (Schopf, 1993); however, occasionally the biogenicity of some stratified structures is questioned from mathematical modelling (Grotzinger and Rothman, 1996) but in nature the influence of biologic activity, presence of microorganisms and biomolecules in the Proterozoic stromatolites is generally accepted by majority of workers. Walter (1996) points out that there are good reasons for thinking that most stromatolites are biogenic mainly: there are numerous modern analogues, e.g. Shark Bay in Australia, where biological influences in their morphogenesis can be directly observed (Bauld, Amelio and Farmer, 1992) (ii) some stromatolites contain microfossils arranged in patterns indicating that they are responsible for the construction of the laminae and (iii) in the modern world it is difficult to find any stromatolite-like object that is demonstrably abiotic. Furthermore, Jones, Renaut and Resin (1997) document that microbes have controlled development of stromatolitic fabric in geyserites, hot springs vents, New Zealand. All these above-mentioned examples clearly indicate that stromatolites are not abiogenic. More rently, Laval *et al.* (2000) have reported modern fresh water microbialite analogues for ancient dendritic reef structures from Pavillion lake, Canada. The cone shaped structures are comparable with the Lower Vindhyan conical microbialites.

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