Journal of Nepal Geological Society, 1998, Vol. 18, pp. 37-57

Regional correlation of the Lesser Himalayan and Tethyan basin sediments of Kali valley, Indo-Nepal area

V.C. Tewari

Wadia Intitute of Himalayan Geology

33 General Mahadev Singh Road, Dehra Dun 248001, India

ABSTRACT

The Uttarakhand Lesser Himalaya of India (Kumaon-Garhwal basins) is the most important central sector of the Himalayan arc between Kali River, Nepal in the east and Tons River, Himachal in the west. The Lesser Himalayan sedimentary belts are bound by the Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) in the north in Indo-Nepal border across the Kali River. The revised biostratigraphy, carbon isotope and event stratigraphy has established a Mesoproterozoic age for the Deoban belt and Lower Cambrian age for the Krol-Tal belt in the Indian part. Identical sedimentary facies and stromatolites are found in western Nepal across the Kali River (Kali-Gandaki Group) and is in fact the extension of the Indian Lesser Himalaya (Deoban-Tejam belt) into western Nepal.

The Tethyan sedimentary zone is separated from the Central Crystallines in the north of the Lesser Himalaya of Indo-Nepal region by Tethyan Thrust/Malari Thrust/Trans-Himadri Thrust. Recent fossil finds, sedimentological and carbon isotopic signatures from Ralam, Garbyang, Shiala and Yong formations indicate continuous sedimentation from Terminal Proterozoic to Silurian period. The Precambrian/Cambrian boundary is tentatively placed within the Garbyang Formation. A detailed correlation of the Lesser and Tethyan Himalayan sedimentary belts of the Indo-Nepal border region across the Kali River is attempted and discussed in this paper.

INTRODUCTION

The Kumaon-Garhwal Himalaya (Uttarakhand) falls in the central sector of the Himalayan Chain (Fig. 1a, b) between Nepal and Himachal Himalaya. In the Kumaon-Garhwal and bordering Nepal region across Kali River, the thick succession of Palaeoproterozoic to Phanerozoic sedimentary rocks represents the passive continental margin of the Indian plate in the north (Fig. 1b and 2). Recent fossil finds of stromatolites Ediacaran fossils, microbiota, ichnofossils, vendotaenids, organic walled microfossils, small shelly fossils, Redlichiid trilobites, etc. from the Lesser Himalaya of Uttarakhand region firmly established a Palaeoproterozoic to Terminal Proterozoic/ Cambrian age for the Beringag-Tejam (Deoban)-Jaunsar (Simla)-Blaini-Krol-Tal succession (Tripathi et al, 1984; Kumar et al, 1987; Tewari, 1984 a, b, 1993a, b, 1994a, 1998; Tewari and Joshi, 1993; Singh and Rai, 1983; Shankar et al, 1997; Mathur and Shankar, 1989; Bhatt et al., 1983; Tiwari and Knoll, 1994). The stable carbon and oxygen isotope chemostratigraphy of the Deoban Group (Mesoproterozoic) of the type area Chakrata near Dehra Dun (Fig. 3, Tewari, 1991, 1997a) and Blaini-Krol-Tal sequence (Neoproterozoic to Lower Cambrian from Mussoorie, Garhwal and Korgai synclines (Aharon et al., 1987; Tewari, 1991; Kumar and Tewari, 1995) suggest that the isotopic events recorded from the Lesser Himalaya are of global significance and these isotopic curves can be correlated with identical curves from Mesoproterozoic to Cambrian successions of the world. The end of sedimentation in Lesser Himalayan basins after Lower Cambrian and the implication of the Pan-African orogeny is discussed by Valdiya (1995) and Tewari (1984b, 1994a) in detail.

The Tethyan basin sediments of Uttarakhand ranging in age from Mesoproterozoic to Cretaceous

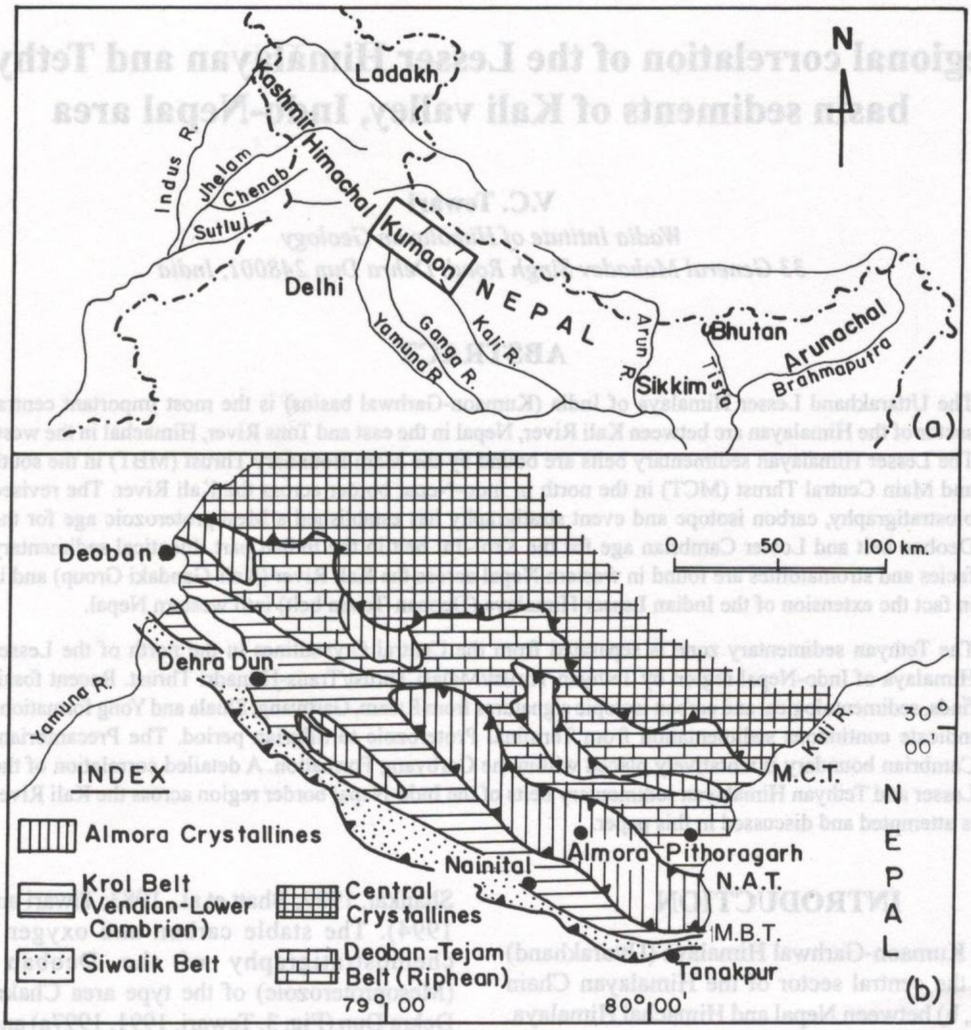


Fig. 1: (a) Map of Himalaya showing location of Kumaon and Nepal Himalaya, (b) Simplified geological map of Kumaon Lesser Himalaya (simplified after Valdiya, 1980)

are well developed in Indo-Nepal region, across the Kali River (Fig. 2). These sediments also represent the distal continental margin of the Indian Shield (Valdiya, 1988, 1995). A detailed revised correlation of the Terminal Proterozoic and Lower Cambrian sedimentary sequences of the Tethys and Lesser Himalaya, India (Fig. 4) has been proposed on the basis of author's observations and the published work of Heim and Gansser (1939), Valdiya and Gupta (1972), Powar (1972), Shah et al. (1974), Kumar et al. (1977), Kumar et al. (1984) and Garzanti et al. (1986). The Precambrian-Cambrian boundary is placed between the Upper Krol and Lower Tal formations in the Lesser Himalaya, within the Garbyang Formation in the Kali valley and Girthi/ Dhauli Valley Tethys Himalaya, within the Kunzam La Formation in the Spiti valley and between the Phe Formation and Karsha Formation in the Zanskar valley (Fig. 4).

The Lesser Himalayan Mesoproterozoic to Neoproterozoic/Cambrian sediments (Damta-Rautgara, Deoban-Gangolihat, Simla-Jaunsar, and Blaini-Krol-Tal belts) bear considerable facies similarity with the Mesoproterozoic-Cambrian

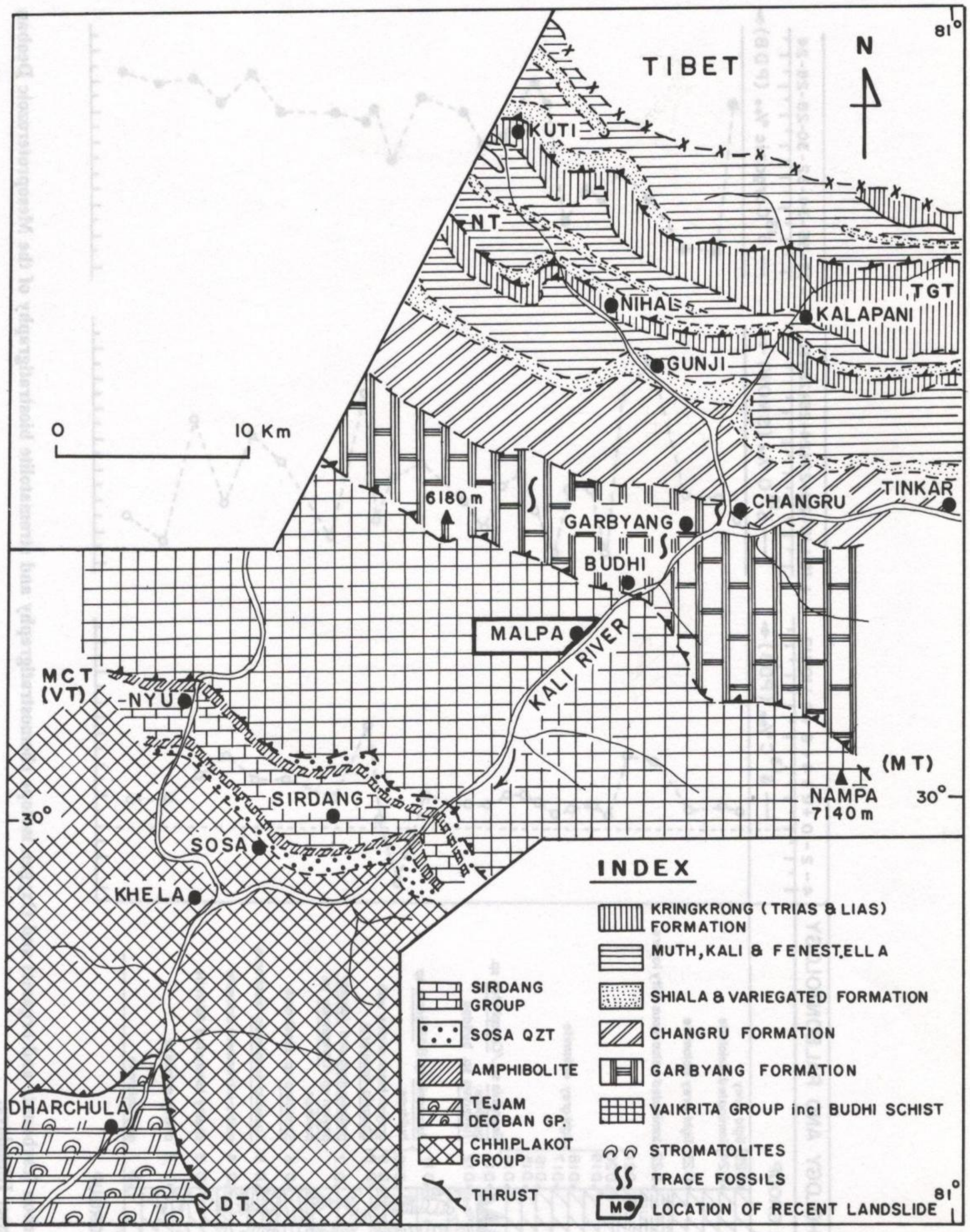


Fig. 2: Geological map of north eastern Kumaon (modified after Heim and Gansser, 1939; Valdiya and Gupta, 1972). Legend: DT - Dharchula Thrust; MCVT - Main Central (Vaikrita) Thrust; MT - Malari (Trans Himadri) Thrust; NT - Nihal Thrust; TGT - Thumka Gad Thrust.

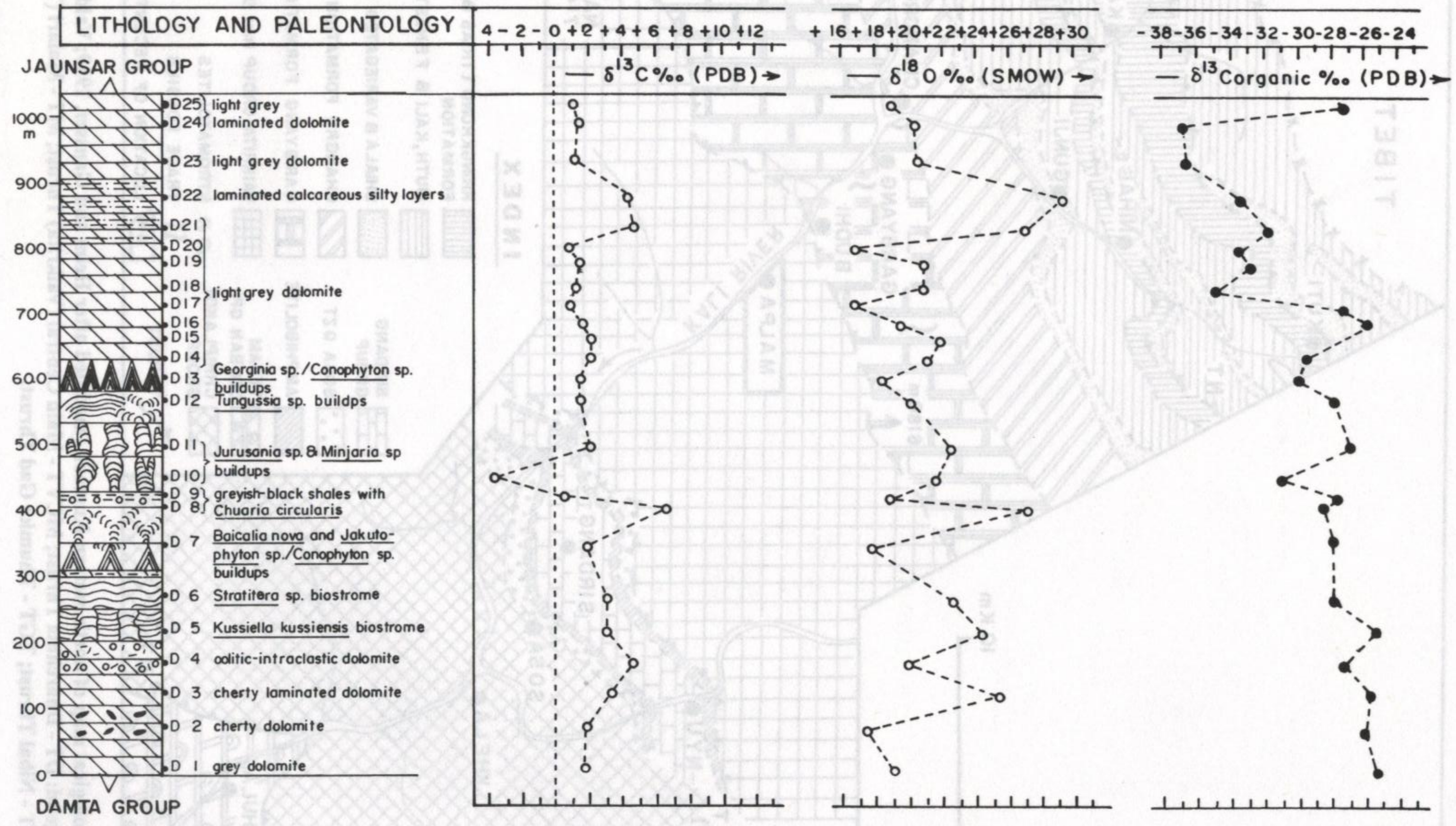


Fig. 3: Carbon (carbonate and organic) and Oxygen isotope chemostratigraphy and stromatolite biostratigraphy of the Mesoproterozoic Deoban Group, Lesser Himalaya.

sediments (Martoli-Ralam-Garbyang) of the Tethys Himalaya in Uttarakhand basin and Kali Gandaki Group of Nepal (Valdiya, 1988; Tewari, 1981, 1984c, 1994a, 1995, 1997b, Table 1, Fig. 4). The recent carbon isotopic signatures of the Ralam-Garbyang Carbonates from the Girthi valley further supports this correlation (Kumar and Tiwari, 1995; Tewari, 1997a, b).

In this paper, an attempt is made to establish a revised regional correlation based on recent findings from the Lesser Himalayan and Tethyan basin sediments of Girthi and Kali River Valley in Indo-Nepal area. The paper is not aimed to review the extensive research done by earlier workers (Arita et al, 1986; Bashyal, 1986; Heim and Gansser, 1939; Gansser, 1964; Fuchs and Frank, 1970; Hagen, 1969; Shah and Sinha, 1974; Sinha, 1989; Valdiya, 1969, 1980, 1986; Powar, 1972; Sakai, 1983, 1985; Upreti, 1990) but to summarise the author's observations in more than last two decades in the Lesser Himalaya and two recent expeditions to Tethys Himalaya (Kumaon and Garhwal) in 1995 and 1996.

MESOPROTEROZOIC-NEOPROTEROZOIC SEDIMENTATION IN THE KUMAON LESSER HIMALAYA

In the eastern Kumaon Lesser Himalaya (Pithoragarh-Dharchula area, Fig. 1 and 2, Kali valley), the sedimentation initiated by deposition of the Rautgara Formation, a clastic facies (tidal flat) comprising protoquartzite, conglomerate, slates and volcanics. The Rautgara clastic facies is succeeded by a dominantly carbonate facies of the Tejam Group (Valdiya, 1980) known as the Deoban (Gangolihat) Formation and represented by Mesoproterozoic stromatolitic (Riphean) carbonates, oolitic, intraclastic-cherty-phosphatic dolomite, magnesite, and slates. This facies was mainly deposited in carbonate tidal flats (subtidal-intertidal zone) of a shallow sea (Tewari, 1994a). The Mandhali Formation in this area is represented by Sor Slates and Thalkedar Limestone (Valdiya, 1980) and is made up of black pyritous carbonaceous phyllites and slates with greyish black (organic) limestone and conglomerate. It is characterised by the Upper

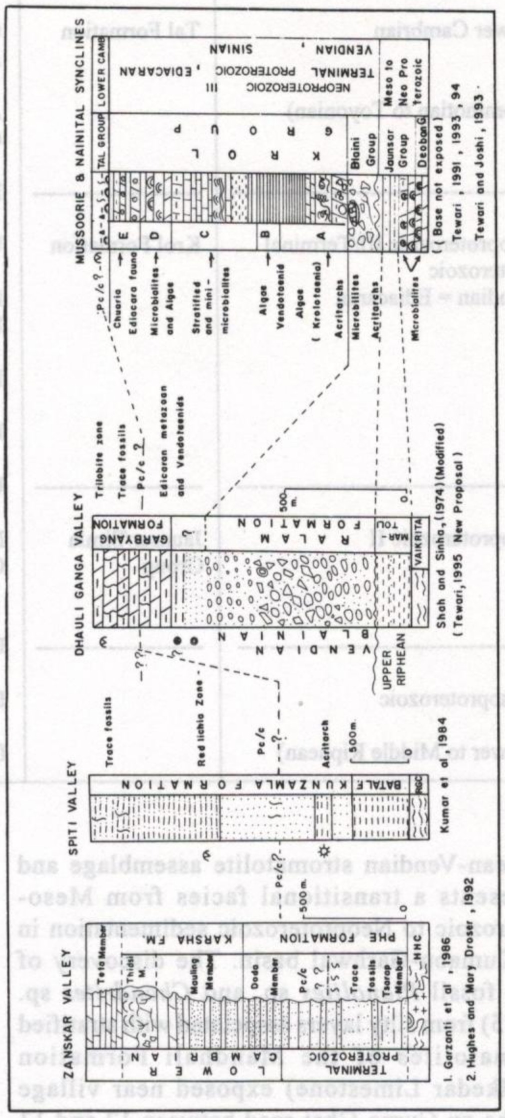


Fig. 4: The regional correlation of the Terminal Proterozoic-Lower Cambrian sedimentary sequences of the Tethys and the Lesser Himalaya of India.

Table 1: Terminal Proterozoic and Lower Cambrian stratigraphy of the Lesser Himalaya of India and Nepal.

Age	INDIA		NEPAL
Lower Cambrian (Tommotian to Toyonian)	Tal Formation	Quartzite Member (Phulchatti Member) Calcareous Member Arenaceous Member Argillaceous Member Chert-Phosphate Member	Upper Kali Gandaki Group
		Diastem	
Neoproterozoic III/Terminal Proterozoic Vendian = Ediacaran	Krol Formation	Upper (Krol C,D, E) Middle (Krol B) Lower (Krol A) Infra Krol Formation Blaini Formation	Kerabari Formation Riri Member Ramdighat Formation
		Unconformity	
Neoproterozoic II	Jaunsar/Simla Group	Nagthat, Chandpur Mandhali	Saidikhola Beds
		Unconformity	
Mesoproterozoic (Lower to Middle Riphean)		Deoban/Garhwal Group Damta Group	Middle Kali Gandaki Group (Baitadi Group) Lower Kali Gandaki Group

Riphean-Vendian stromatolite assemblage and represents a transitional facies from Mesoproterozoic to Neoproterozoic sedimentation in the Kumaon-Garhwal basin. The discovery of trace fossil *Planolites* sp. and *Chondrites* sp. (Fig. 5) from silty layers associated with stratified stromatolites of the Mandhali Formation (Thalkedar Limestone) exposed near village Kantha on Gurna-Ghat road between 12 and 13 kilometre stone by Tewari (1998) is quite significant since this is first strong evidence in favour of a Neoproterozoic (early Vendian) age of the Mandhali Formation in absence of any biotic record except stromatolites.

The Berinag Formation in entire eastern Kumaon is direct lateral continuation of the arenaceous facies exposed at Berinag type locality in the Pithoragarh district. This formation is made up of white, pink, purple and green colour, medium to coarse grained pebbly and bedded quartzite and interbedded chlorite schists, phyllites, amphibolite and boulder beds (Valdiya, 1980, Tewari, 1994a). The Berinag Formation is thrust over the Mandhali or Deoban Formation and also overthrust by the Munsiari Formation in the Kali Valley (Fig. 2, Valdiya and Gupta, 1972; Valdiya, 1980). Valdiya (1980) interpreted a littoral or beach depositional environment for the Berinag Quartzite. Tewari (1994a) has suggested a sandy intertidal flat-coastal beach (shallow water) environment of deposition for Berinag Formation on the basis of sedimentary structures, facies variations and petrography. The pebbly quartzite beds in the Berinag Formation indicate fluvial channel deposits (Tewari, 1994a). There is no definite radiometric age for the Berinag Quartzite from Kumaon Himalaya, however, a Sm-Nd date of 2510 Ma for a mafic metavolcanic from the Rampur Formation in Himachal Himalaya which is correlated with Berinag Formation (Valdiya, 1995; Tewari, 1994a) suggest the beginning of clastic sedimentation of the Berinag Quartzite in Palaeoproterozoic time. This Sm-Nd isotopic date needs reconfirmation from other parts of the Lesser Himalaya to evolve a sedimentological evolutionary model.

PALAEOBIOLOGY AND PALAEO-ECOLOGY OF TEJAM GROUP

Stromatolites/Microbial Buildups

The Deoban-Gangolihat Carbonate belt is characterised by occurrence of the Mesoproterozoic (Lower and Middle Riphean) stromatolite taxa *Kussiella kussiensis*, *Colonnella columnaris*, *Conophyton cylindricus*, *C. garganium*, *C. misrai*, *Plicatina antiqua*, *Stratifera* sp., *Baicalia nova*, *Jacutophyton*, *Minjaria uralica*, *Tungussia* sp. and *Georginia* sp. The Mandhali Limestone in the type area in the Garhwal and Thalkedar Limestone near Gurna on the Pithoragarh-Ghat section shows prolific development of stratified microbial buildups of taxa *Stratifera undata* and *Gongylina differentiata*. The cyclicity of stratified stromatolites has been observed in which 10-12 cm thick sequences have been repeated with oolitic, oncolitic, cherty brecciated and vuggy fenestral layers. *Conophyton* sp. is also developed with elliptical transverse sections. The silty layers contain trace fossils *Planolites* and *Chondrites* in ripple bedded units (Fig. 1, 2, 3, 4 and 5). The Upper Riphean-early Vendian age is suggested to the Thalkedar Limestone and Mandhali Limestone of the Tejam Group.

In the Kali valley, mostly stratified microbial buildups have been recorded near Jhulaghat and smaller buildups of *Kussiella* sp., *Colonnella* sp. and *Conophyton* have been recorded from the Deoban greyish white limestone, which is deformed (schistose limestone) at the contact with the Munsiari Formation (Chhiplakot Group, Fig. 2).

Organic Walled Microfossils (OWM), Acritarchs and Vase Shaped Microfossils (VSM)

Well-preserved organic walled microfossils acritarchs and vase shaped microfossils (Tewari, 1995; Shukla, Tewari and Yadav, 1986) in Deoban Cherts and stromatolitic beds reveal a highly diversified life in the Deoban sea during the Mesoproterozoic time. However, in the Gangolihat Dolomite in eastern Kumaon area, only vase shaped microfossils have been recovered from stromatolitic-phosphatic-pelletal facies in Pithoragarh (Fig. 1, 2 and 6) and Gangolihat areas near the Jarmal village. (Tewari, 1995). The OWM recorded so far incorporate *Eomycetopsis robusta*, *Siphonophycus kestron*, *Oscillatoriopsis media*, *Cyanonema* sp., *Gunflintia minuta*, *Animikiea septata*, *Myxococcoides minor*, *Sphaerophycus parvam*, *Melasmatosphaera*, *Glenobotrydion aenigmatis*, *G. Majorinum*, *Globophycus* sp., *Archaeotrichion* sp., *Biocatenoides* and *Kildinosphaera* sp. Tewari (1996) discovered acritarch genus *Chuaria circularis* from black shales associated with microbial buildups in the Deoban area (Fig. 3). Vase shaped microfossils of genus *Melanocyrillium* and *spicules* resembling sponges in fenestral fabric have been identified in the Gangolihat Dolomite.

Palaeoecology

The occurrence of prolifically developed microbial buildups in the Gangolihat and Deoban areas of Uttarakhand region (Tejam Group) suggest that during Mesoproterozoic (1350±50-950±50 Ma) a large carbonate platform facies developed in shallow marine (tidal flat photic zone) sea in which conditions were very favourable for growth of benthic microbial communities which were responsible for development of large stromatolitic buildups. These carbonate banks were dominated by cyanobacterial spheroids and filaments, acritarchs, vase shaped microorganisms and *incertae sedis* microfossils. The carbon and oxygen isotope values of the Gangolihat and Deoban

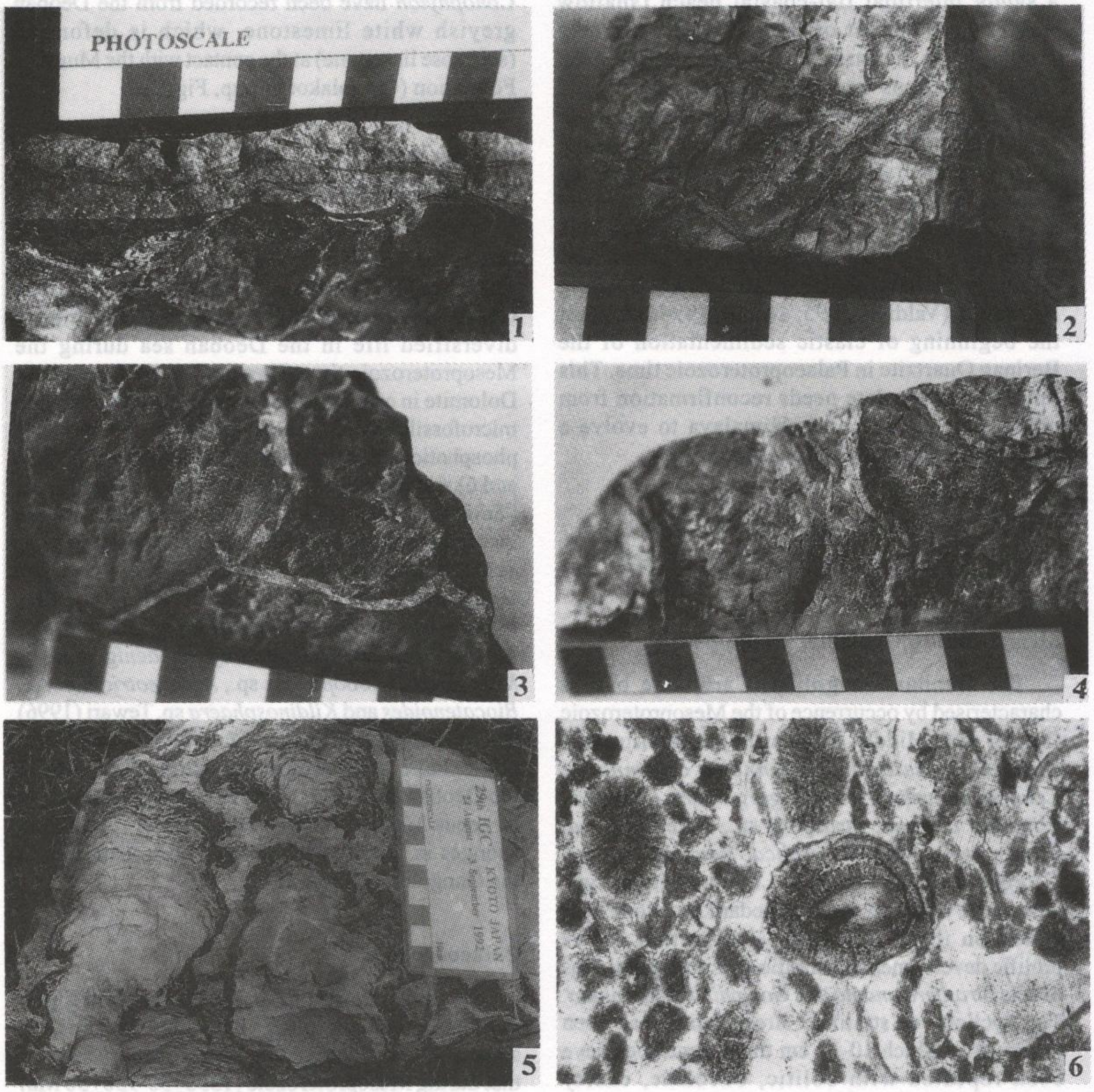


Fig. 5: 1) Wave ripple bedded silty layer of the Thalkedar Dolomite (Mandhali Formation) containing Neoproterozoic trace fossils, 2) Ichnogenus Planolites in the Thalkedar (Mandhali), Locality: near village Kantha on Gurna-Ghat Motor road, Pithoragarh. (Specimen No. WIF/VCT/TF1), 3) Ichnogenus Chondrites in Thalkedar; showing Y shaped junctions. Locality same as Planolites (Specimen No. WIF/VCT/TF2), 4) Ichnogenus Planolites showing curved cylindrical burrows with convex hyporelief in Thalkedar, Locality same as TF1 and TF2, 5) The branching stromatolite Baicalia sp from Gangolihat Dolomite showing more concentration of phosphorite on outer margins and less distribution in microbial laminae Chandak-Bans motor road, Pithoragarh, 6) Microphotograph of Thalkedar cherty oolitic, intraclastic stromatolitic (*Conophyton-Stratifera* assemblage) dolomite showing oosparite microfacies. Locality near trace fossil bearing beds, Kantha village, Gurna-Ghat motor road, Pithoragarh. Scale bar each black and white division = 1 cm.

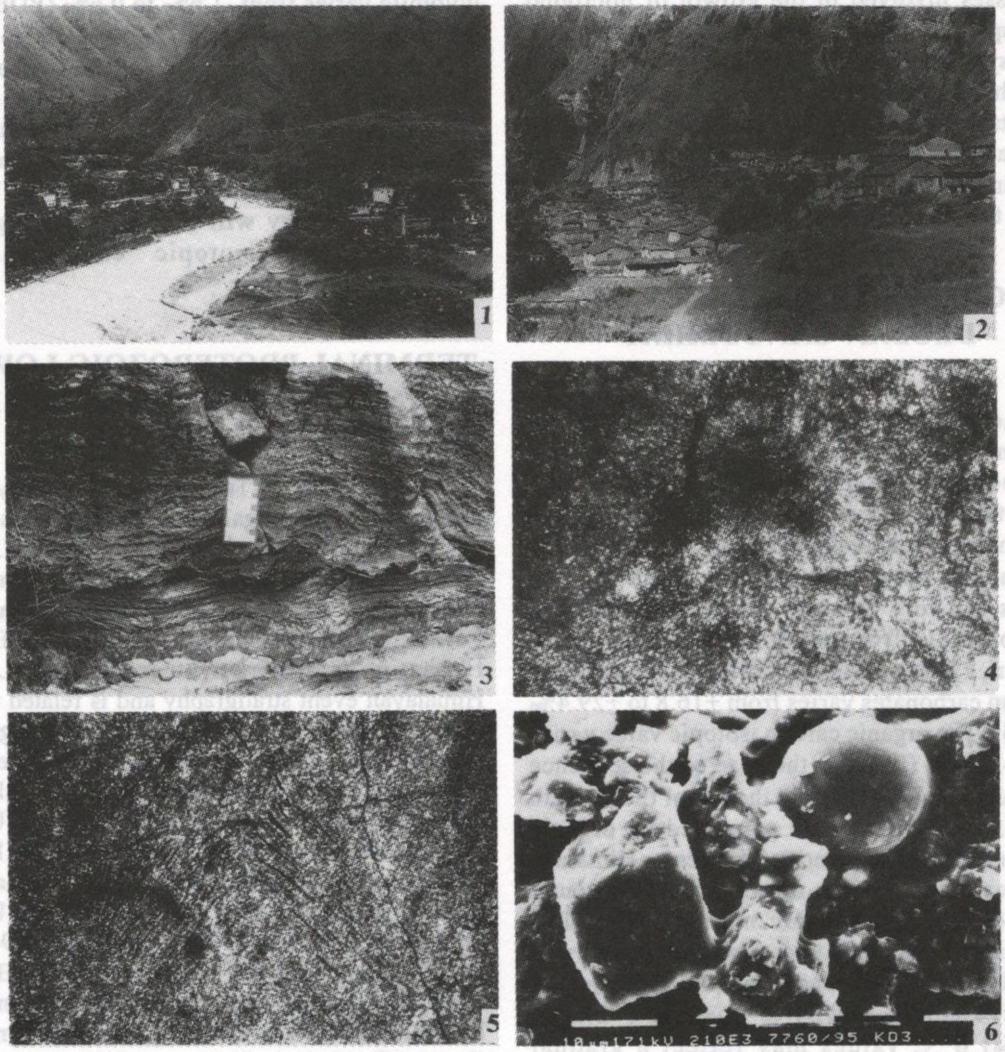


Fig. 6: 1) Photograph showing Dharchula town on the left separated by Kali River in Indo-Nepal border area. DT- Dharchula Thrust (DT), a low dipping thrust that separates the Tejam-Deoban Group sediments from Chhiplakot Group crystallines a few km north of Dharchula (Fig. 2). These lithotectonic units continue in western Nepal (Darchula), 2) Photograph of Garbyang Village situated on lake deposits and the rocks around are type area of Garbyang Formation. Trace fossils and Ediacaran biota have been recorded from here (Fig. 7 and 8), 3) A stratified microbial buildup in Garbyang Formation, Malari-Sumna track oolitic facies, Girthi valley Garhwal Tethys Himalaya, 4) Microphotograph of Garbyang Dolomite showing enlarged radial oolite, partially recrystallised. Garbyang, Kumaon Tethys Himalaya Kali valley, 5) Microphotograph of axial zone of a new conical stromatolite *Valdiyaphyton* sp. showing dark (organic) layers containing *Eomycetopsis* (*filamentous cyanobacteria*). Locality: Buraskhanda village, Mussoorie-Tehri Road in Upper Krol Dolomite Garhwal Lesser Himalaya (Slide No. KD4), 6) Scanning Electron Microscope photograph of Krol D stromatolitic dolomite showing presence of spheroidol cells, filaments and dolorhomb as microbial sedimentation. (Slide No. KD3), Locality: Mussoorie–Tehri Road.

stromatolitic carbonates also support photosynthetic processes involved in the growth of microbial buildups. The stromatolites use CO_2 of seawater for photosynthesis is believed to have a direct control over the pH value of the environment, which is an important factor in carbonate sedimentation. Modern stromatolites in Shark Bay in wesytern Australia grow in hypersaline conditions with a salinity range of 5.6 to 6.5%.

CHEMOSTRATIGRAPHY OF DEOBAN-GANGOLIHAT CARBONATES

The carbon isotope variation in carbonate carbon ^{13}C and reduced or organic carbon $\delta^{13}C$ in Deoban carbonates of Chakrata-Deoban mountain is shown in Fig. 3. The $\delta^{13}C$ for carbonate carbon ranges from -3.7 to 6.6‰ (PDB) and mostly between 0 and 2‰ (PDB). These values are very close to the Mesoproterozoic isotopic data from other parts of the world (Tewari, 1997a). The $\delta^{18}O$ (SMOW) values of the Deoban carbonates varies from $\pm$16.8 to $\pm$29.4‰ (Fig. 3). The organic carbon isotopic value varies from -25.4‰ (PDB) at the base of the sequence (D1) and -36.8‰ (PDB) at the top of the Deoban (D24). This is first data generated on organic carbon from this sequence of the Lesser Himalaya and has an important implication on organic productivity and organic matter burial. The Deoban carbonates are microbial, and organic rich biota has been recorded from the sequence. A negative (-3.7‰ PDB) to positive (+2‰ to +4.8‰) $\delta^{13}C$ values may reflect a gradual increase in the biomass productivity (Tewari, 1997a). The organic carbon is biologically produced and highly reduced in Deoban carbonates (Fig. 3) as supported by prolific growth of stromatolitic buildups formed by interaction of prokaryotic microbiota or benthic microbial communities and sediments. Kumar (1998) has also analysed nine carbonate and magnesite samples from the Gangolihat Dolomite of the Chandak area in Pithoragarh district (the eastern continuation of the Deoban belt in Kumaon). $\delta^{18}O$ for dolomite varies from -10.8‰ to -9.0‰ (SMOW) and for magnesite it varies from -16.8‰ to -11.8‰ (SMOW). $\delta^{13}C$ for dolomite varies from -1.6‰ to 0.6‰ (PDB) and for magnesite it varies from -2.2‰ (PDB) to 0.1‰ (PDB). The carbonate carbon of the Deoban and Gangolihat Dolomite does not show much variation in $\delta^{13}C$ values. A detailed chemostratigraphy of the Gangolihat Dolomite in Kumaun and Kali Gandaki Carbonates of Nepal in the Kali valley will be useful for regional correlation of isotopic excursions in Mesoproterozoic time.

TERMINAL PROTEROZOIC-LOWER CAMBRIAN SEDIMENTATION IN THE LESSER HIMALAYA

The Blaini-Krol-Tal succession is very well developed in the Nigalidhar, Korgai, Mussoorie, Garhwal and Nainital synclines of the Lesser Himalaya. The Blaini Formation unconformably overlies the siliciclastic sediments (Nagthat Formation of the Jaunsar Group). The Blaini Formation is a marker horizon in the Lesser Himalayan event stratigraphy and is related to the global Terminal Proterozoic glaciation (Varangerian) event (Tewari, 1993a). It has two main facies, the diamictite and the pink limestone with shales. Microfossils and stratified stromatolites of Upper Proterozoic age have been recorded from the Blaini Formation. The Infra Krol grey shales and quartzite sequence with black chert nodules containing Upper Proterozoic acritrachs (Tiwari and Knoll, 1994) are interbedded between the underlying Blaini Formation and the overlying Krol Formation. The Krol Formation is overlain by the Tal Formation (Lower Cambrian). It is essentially a peritidal carbonate deposit with development of evaporites in the middle part. Total thickness of the Krol Formation is about 2000 m. The Krol succession is a shallow marine carbonate, showing good development of Vendian stromatolites. A new stromatolite form *Valdiyaphyton* has been recorded (Fig. 6 and 7). Spheroidal and filamentous microbiota is found in organic laminae of *Valdiyaphyton* (Fig. 6 and 8). The other palaeobiological records include algae, acritarchs, *Vendotaenides*, trace fossils, Ediacaran fossils and phytoplankton *Chuaria* in black shales (Tewari, 1984b, 1993a,b; Mathur and Shankar, 1989; Shankar

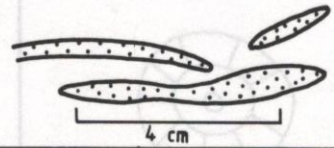
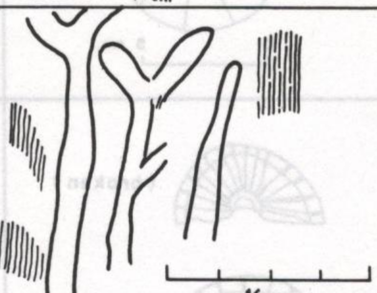
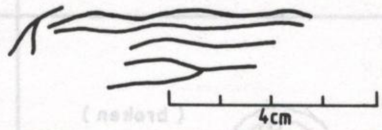
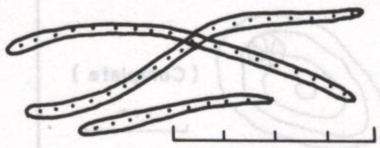
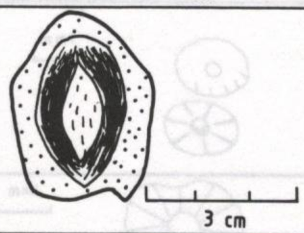
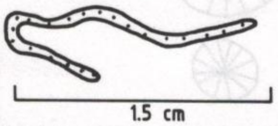
ICHNO-GENUS	DIAGRAMATIC SKETCHES	CHARACTERISTIC FEATURES
Phycodes aff. *palmatum*		Cylindrical burrows, convex hyporelief
Chondrites		Tunnels of uniform diameter, branching off from side tunnels Y shaped junctions
Planolites		Straight to gently curved burrows convex hyporelief
Monomorphicnus, M. bilinearis		Long narrow ridges, gently curved, forming fan shaped sets
Planolites		Curved cylindrical burrows, cross cutting, unbranched
Rusophycus		Bilobate traces 3cm wide, 3-4cm long
Meandering trail		Irregularly meandering trail

Fig. 7: Diagramatic sketches of Ediacaran biota from the Garbyang Formation, Tethys Himalaya, Kali valley (Specimen numbers: WIF/VCT/E1, and WIF/VCT/E2)

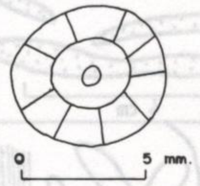
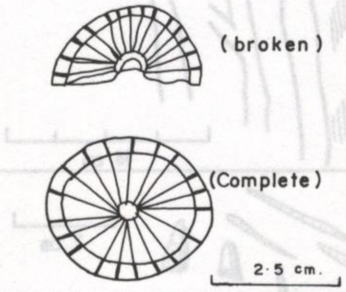
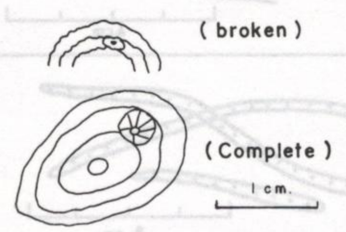
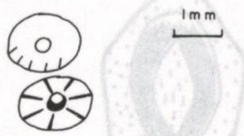
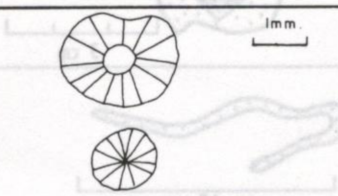
GENUS	DIAGRAMATIC SKETCH	MORPHOLOGY
Cyclomedusa radiata Sprigg, 1947		Having Concentric and radial markings smaller in size,
Irridinites multiradiatus Fedonkin, 1983		Having radial markings originating from centre, 2mm. thick, outer rim larger in size
Ovaloscutum concentricum ? Glaessner et Wade, 1966		Having wrinkled Concentric markings
Tirasiana disciformis Palij, 1975 T. coniformis		Disc shaped, small in size, radial marking, hyporelief,
Dickinsonia D. costata ? Sprigg, 1947 Dickinsonia sp.		Having radial markings, smaller in size,

Fig. 8: Diagramatic sketches of ichno fossils from the Garbyang Formation, Girthi Valley, Garhwal, Tethys Himalaya except Chondrites reported from Kali Valley, Kumaon Tethys Himalaya. (Specimen numbers : WIF/VCT/I1 to I7).

et al., 1997). The carbon, strontium and oxygen isotope data are also available from the Blaini-Krol-Tal carbonates and consistent with the global peaks (Aharon et al, 1987; Tewari, 1991; Kumar and Tewari, 1995).

The Blaini-Infra Krol-Krol sections of the Nigalidhar, Korgai Mussoorie, Garhwal and Nainital synclines of the Lesser Himalaya, India are recommended as one of the candidate for the Global Strato Type and Section Point (I.G.C., 1992 Kyoto, Japan). Following the subdivisions of the Precambrian suggested by the International Commission on Precambrian Stratigraphy and the decision on the Precambrian-Cambrian boundary stratotype (Brasier et al., 1994), the base of the Terminal Proterozoic is proposed to be placed at the base of the Blaini Formation in the Lesser Himalaya. In the light of this event, the possible revised correlation of the Upper Proterozoic and Lower Cambrian sedimentary rocks between the Lesser Himalaya of India and adjoining western Nepal is quite significant and summarised in Table 1 and 2.

CARBON AND OXYGEN ISOTOPE GEOCHEMISTRY OF THE KROL-TAL SEQUENCE

The integrated studies of carbon, oxygen, strontium isotopes and trace elements including REE in Krol-Tal carbonates from the Mussoorie Syncline have helped to demarcate Precambrian-Cambrian transition in the Lesser Himalaya. The PC/C transition is tentatively placed between Upper Krol and Lower Tal formations or within Lower Tal Formation based on palaeobiological records. The $\delta^{13}C$ signatures are positive for the Krol C and D carbonates reaching a $\delta^{13}C$ maxima of +6.3‰ (PDB) which is followed by a near zero $\delta^{13}C$ value for Krol E and a $\delta^{13}C$ minima of -2.9‰ (PDB) in the Lower Tal. The $\delta^{18}O$ lies in a range of +20.1 to 28.4‰ (SMOW). The enriched $\delta^{18}O$ values for the Krol C and D carbonates may be associated with intervals of high environmental oxygen levels similar to or higher than the present atmospheric level (PAL). The Sr-isotope value of 0.7088 for the Upper Krol carbonates of the Mussoorie syncline (Neoproterozoic) may be taken as near pristine sea water value. The trace element abundance of Krol E have high concentration of transition metals (Co, Ni, Cu and Zn), lithophile elements (Cs, Rb, Ba and Pb) and high field strength cations (Y, Th, U, Zr and Nb), but are depleted in vanadium. Rare Earth Element (REE) content of carbonates show high concentration of total LREE and HREE for Krol E. REE patterns show negative Ce and positive Eu anomaly in carbonates. Isotopic and geochemical evidences together with the already available palaeobiological record confirm that PC/C transition in Mussoorie syncline is between the Upper Krol and Lower Tal Formation.

CARBONATE SEDIMENTATION IN THE TETHYAN BASIN

Garbyang Carbonates: Palaeobiology and Age

Heim and Gansser (1939) introduced the name *"Garbyang Series"* from Bhotia village in the type area, Kali River valley in Kumaon Tethys Himalaya (Fig. 2 and 6). They assigned Cambrian age to this carbonate series on the basis of presence of flat gastropods *Eccliopteris kushanensis* Grabau (Valdiya and Gupta, 1972) and crinoidal limestone. This age for the Garbyang Formation (Gansser, 1964) was accepted since the conformably overlying Shiala Formation has yielded typical Ordovician brachiopods *Refinesquina aranea*, *R. alternate*, *Orthis and Monotrypa* (Shah and Sinha, 1974). The shales and quartzites of the upper part of the Ralam Formation transitionally passes to calcareous facies of the Garbyang Formation (Kumar et al., 1977; Sinha, 1989). However, in the Girthi Ganga Valley, Garhwal Tethys basin, the contact between the Ralam Quartzite and Garbyang Formation is faulted (Shah and Sinha, 1974). There is no fossil record from the Ralam Formation so far and a Terminal Proterozoic age is tenable since the overlying Garbyang Formation has yielded early Cambrian trace fossils *Phycodes* off. *palmatum*, *Chondrites*, *Planolites*, *Monomorphicnus*, *Monomorphicnus bilinearis*, *Rusophycus* and Meandering trail (Fig. 8) These trace fossils are abundantly found between Km 16 and 20 from Malari to Sumna along the road section. A sample yielding cluster of flat gastropods *Eccliopteris*? has been recorded from this section. Fragmentary trilobites and lingulids have been recorded earlier by Shah and Sinha (1974) from the same section along the mule path.

Table 2: Regional correlation of the Precambrian and Lower Cambrian sedimentary sequence of the Lesser Himalaya in South Asia (Pakistan, India, Nepal and Bhutan)

Age/Stage	Period/Group	Western Lesser Himalaya India Formation	Pakistan Formation		Nepal Group/Formation	Eastern Lesser Himalaya Bhutan (including Sikkim and Arunachal
	Lower Cambrian (Aldanian/*Talian*) Tal Group 570 (624±10 Ma)	Lower Tal Formation (with Shelly microfossils and stromatolites of tommotian/ Meischucunian age/*Talian*)	Hazira Formation (with shelly microfossils of Tommotian age)		Upper Nawakot Group/ Upper Kali Gandaki Group/Upper Midland Metasediments	Mirl Group (with Lower Cambrian ichnofossils)
PROTEROZOIC TERMINAL VENDIAN	Krol Group (650-570 Ma)	Krol Formation (with Vendian stromatolites, algae, metaphytes, metazoans) (Ediacaran/*Krolian*)	Abbottabad Formation (stromatolites in Sirban limestone)	KALI GANDAKI SUPER GROUP	Kerabari Formation (stromatolites) Rirl Member	Buxa Group (Carbonates with stromatolites of Kudashian-Vendian affinity Tatapani Formation
		Blaini Formation (Varangar/*Blainian*)	Tannakki Formation (Conglomarate)		Ramdighat Formation	
		Unconformity	Unconformity		Unconformity	Unconformity
	Neoproterozoic Jaunsar/ Simla Group (950-650 Ma)	Nagthat Formation Chandpur Formation Mandhali Formation Simla Formation (Upper Riphean/*Jaunsarian*)	Tanawal (Tanol) Formation Hazara Formation		Saldikhola Beds	Phuntsholing Group
UPPER TO MIDDLE MESOPROTEROZOIC RIPHEAN	Deoban Group (1300-950 Ma)	Jammu (Great) Limestone Dharamkot/Larji/Shali/ Deoban/Gangolihat/Tejam Dolomite (with abundant Riphean stromatolites, microbiota, *Chuariasi*) (Lower to Middle) Riphean/*Deobanian*	Salkhala Formation Stromatolitic carbonates equivalent to Jammu/ Great Limestone ?		Middle Kali Gandaki Group/Baitadi and Darchula Groups (Darsing Dolomite) Khoraidi Dolomite) Dhading Dolomite) (with abundant Riphean stromatolites)	
	Damta Group (1600-1300 Ma)	Rautgara Formation Chakrata Formation (Lower Riphean)			Lower Kali Gandaki Group Lower Nawakot Group Lower Midland Metasediments	Jainti Formation Sinohula Formation
		Tectonic/Thrust ? Contact				
	Almora Jutogh Group	Crystallines	Basement Crystallines		Kathmandu Complex Dadeldhura Group Crystallines	Daling Formation

Ediacaran metazoans have been reported recently from the lower part of the Garbyang Formation in the Kali valley (Tewari, 1997b). The medusoids are well preserved in dark grey micaceous calcareous siltstone on the mule track near the Garbyang village. The assemblage is comparable to medusoid genus *Cyclomedusa radiata* Sprigg, 1947, *Irridinites multiradiatus* Fedonkin, 1983, *Ovaloscutum concentricum?* Glaessner et Wade, 1966, *Tirasiana disciformis* Palij, 1975, *Tirasiana coniformis*, *Dickinsonia* sp., *D. costata* Sprigg, 1947 (Fig. 7). Some spheroids (*?Beltanelliformis*) are also found in light grey calcareous siltstone. This assemblage seems radiated just after the Neoproterozoic or Varanger glacial event in the Tethys Himalaya. The ichnogenus *Chondrites* (Fig. 8) is also well developed near the Village Garbyang. The Precambrian-Cambrian boundary seems to lie between the Lower and Middle Garbyang Formation. The Upper Garbyang may extend upto Cambrian or Cambro-Ordovician since flat gastropods and abundant stromatoporoids have been recorded from the upper part. In the Spiti Valley, the Kunzam la Formation is correlated with the Middle and Upper Garbyang Formation on the basis of occurrence of identical trace and body fossils (Tewari, 1997b, Fig. 4).

The lithostratigraphic classification of the Garbyang Formation by Kumar et al. (1977) and Sinha (1989) has been followed. The generalised lithostratigraphic framework of the Garbyang Formation in the Girthi Ganga Valley is given below (Table 3).

Petrography of Garbyang oolitic carbonates from the type area near Garbyang village (Fig. 4 and 6) reveals presence of dark zoned dolomite, radial and concentric oolites, sometimes deformed and elongated in chain like fashion (Slide No. VG1/96). The important feature recorded in some slides are completely altered circular structures with dolorhoms in the core and an outer thick margin with radial septate structure (Slide No. GB/9/96) which could be remnant of either a coral or archaeocyatha? Stromatoporoids, algae, coated grains, oolites, sponge spicule like structures have been recorded (Slide No. GB 4/96). These petrographic studies suggest a Precambrian/Cambrian boundary-Cambrian age for the Garbyang Formation.

Shiala and Variegated Formations

The Shiala and Variegated Formations (Yong microbial Limestone in Yong Gad) is of Ordovician-Silurian in age and conformably overlying the Garbying Formation in the Uttarakhand basin. Petrographic study of the Shiala Formation show presence of large shell fragments, bioclastic limestone, oolitic limestone, quartzwacke, calcarenite, sparry dolomite and intraclasts. Oolitic fabric is well preserved and concentric, radial, concentric cum radial oolites are very common. Zoned dolomite, stylolites and diagenetic replacement of oolites has been observed. Thin section study of the Yong (nodular) Limestone also reveals presence of recrystallised oolites, dolosparites, oncolites, fragments of algae, Scolecodonts, sponge spicules, dark conoidal bodies, ferron dolomite and organic rich microbial laminites. A well developed microbial reef in Yong Limestone is recorded on the mule track to Rimkhim from Yong village.

DEPOSITIONAL ENVIRONMENT OF GARBYANG, SHIALA AND YONG FORMATIONS

The gradational contact between the Upper Garbyang Formation and Lower Shiala Formation is exposed along Malari-Sumna mule track near 20.25 km stone. In the contact zone, 40 m thick sequence of the Garbyang Formation is represented by biohermal grey limestone with large scale cross-laminations, grey limestone with herringbone cross laminations and cross bedded oolitic limestone and dark bluish grey limestone with microbial buildups (Fig. 3 and 6). The presence of trace fossils, sedimentary structures like cross-laminations, herringbone cross-laminations, wavy bedding, and oolitic cross-bedding units suggest a high energy shallow marine depositional environment mainly in intertidal zone of a carbonate tidal flat. The petrographic study of carbonates and carbon isotopic values of the Garbyang Formation also supports a shallow marine depositional environment.

The silty shales, shelly limestone dark black cross-bedded calcareous quartzite with trace fossils and brachiopod fossils of Shiala Formation over lies

Table 3: Lithostratigraphy of the Garbang Formation.

Lithounit	Time Unit	Thickness	Lithology
		Upper 550 m	Oolitic limestone Crinoidal limestone Calcareous quartzite and siltstones with trace fossils and body fossils
	Cambrian	Middle 200 m	Grey dolomitic limestone with marl, barite and pyrite
PC/C Boundary			
-------------------------	-------------------------	Garbyang Formation ---	-------------------------
	Terminal Proterozoic	Lower 250 m	Shaly dolomitic limestone, Calcareous phyllites and quartzites

the Garbyang Formation. A thick sequence of green calcareous shales with ripple marks and purple, pink and grey quartzite and siltstones are found interbedded. Cross-laminated and wavy bedded, laminated crinoidal limestone with shell fragments and greyish-bluish calcareous quartzite with clusters of small brachiopods and corals are found in the upper part. All these features indicate a shallow marine depositional environment for the Shiala Formation. The nodular limestone of Variegated Formation (Yong Limestone) is also a tidal flat deposit as supported by petrographic microfacies. The early Palaeozoic sequence of the Uttarakhand basin (Kumaon-Garhwal) was also part of a large shallow *Prototethys* as in Spiti-Zanskar and Kashmir basins of the western Himalayas.

CARBON AND OXYGEN ISOTOPE VALUES OF GARBYANG, SHIALA AND YONG CARBONATES AND PRECAMBRIAN-CAMBRIAN BOUNDARY

Kumar, Tewari and Rao (1995) analysed ten carbonate samples of the Garbyang Formation from the Malari-Sumna section for carbon and oxygen isotope data. The carbon and oxygen isotopic signatures of carbonates varies in the range of -7.8 and -1.4‰ (PDB) for $\delta^{13}C$ and +13.5 to 17.4‰ (SMOW) for $\delta^{18}O$ respectively. Two of the Lower/Middle Garbyang carbonates have largely depleted $\delta^{13}C$ values of -6.7 and -7.8‰ (PDB) similar to the early Cambrian Tal carbonates of the Lesser Himalaya. The Upper Garbyang carbonates have comparatively enriched $\delta^{13}C$ values (-3.6 to -1.4‰ vs PDB). It is interpreted on the basis of these isotopic values that the Precambrian/Cambrian boundary may lie within Garbyang Formation. The $\delta^{13}C$ values of Shaila and Yong Carbonates lie in the range of –2 to +2‰ (PDB) and oxygen isotopic values varies from +16 to +20.8‰ (SMOW). These isotopic excursions indicate marine conditions. The isotopic analysis of the Garbyang carbonates from the type area *'Garbyang'* in the Kali valley (Fig. 2) is being carried out and will shed more light on the regional correlation of isotopic signatures. The inferences derived from the isotopic data substantiates the palaeobiological interpretation that PC-C boundary may lie in the Garbyang Formation. It is important to mention here that Kackar and Srivastava (1993) have reported *Redlichia* cf. *noetlingi* from the Martoli Group in the Gori valley and suggest that PC/C boundary lies in the Martoli Group. However, the present author also visited the trilobite fossil locality in the Gori valley, 1 km NNW of Milam at the upstream of the Lilam Gara during his 1996 expedition and no trilobite fossil was found.

The upper part of the Garbyang Formation yielding gastropod *Ecclіopteris kushanensis* in the Kali valley was designated as the Changru Series (Formation) by Valdiya and Gupta (1972) in Indo-Nepal region. It has been done since the age of the *E. kushanensis* is Ordovician and the Garbyang Formation is basically a Cambrian carbonate deposit.

UPPER PALAEOZOIC MICROBIAL BUILDUP IN KALI VALLEY

Stromatolitic (microbial) buildup of Carboniferous age is developed in bluish grey limestone exposed between 3 and 2.5 km from Gunji on Gunji-Kalapani mule path. The limestone of Kali Series (Formation) show good development of Columnar forms 8-10 cm in height (Type A) comparable to enveloping convex upward laminae of *Colonnella* type morphology. The columns vary in height upto 20 cm and in breadth up 16 cm. in some forms. Another passively branching form (Type B) having overhanging laminae similar to *Kussiella* morphology and ranging in height upto 15 cm and 10 cm wide columns have been recorded for the first time. These stromatolite forms have been described systematically elsewhere. Oncolitic and fenestral grey limestone is also found associated with these stromatolitic buildups. A shallow marine depositional environment is suggested for microbial facies. Similar stromatolitic facies is also developed in Spiti near Guling Village in Pin Valley (Tewari, 1998 in press). In Kashmir basin, at the same stratigraphic level, Singh (1984) has also reported algal structures.

DISCUSSION AND CONCLUSIONS

Regional mapping of eastern Kumaon and western Nepal of the Kali valley by earlier workers has shown that the major lithotectonic units of the Uttarakhand basin (Kumaon-Garhwal) very well extend into western Nepal (Heim and Gansser 1939; Valdiya, 1969, 1980, 1986, 1988, 1995; Valdiya and Gupta, 1972; Gansser, 1964; Hagen, 1969; Fuchs and Frank, 1970; Arita et al., 1986; Upreti, 1990). Author's own work in the eastern Kumaon has suggested that the Mesoproterozoic sedimentation (Deoban-Tejam belt) in the Lesser Himalaya was continuous in western Nepal based on major sedimentary facies and stromatolites (Tewari, 1981, 1984a, 1993a,b, 1994a, 1996). The correlation between Neoproterozoic-Cambrian sedimentation facies (Blaini-Krol-Tal sediments) of the Lesser Himalaya of India and Nepal is still tentative since the defenite fossil records of Ediacaran biota, organic walled microfossils and small shelly fossils, trilobites, etc. have not been reported from Nepalese counter part so far. The earlier correlations attempted by a number of workers between the Blaini-Krol-Tal sequence and Tansen Group of Nepal Lesser Himalaya (Fuchs and Frank, 1970; Sakai, 1983, 1985; Valdiya, 1986) suggesting a Upper Palaeozoic to Mesozoic age needs revision since, in the Indian part, the Blaini-Krol-Tal sequence has been firmly established as a Terminal Proterozoic-Lower Cambrian sedimentary sequence based on new fossil finds and strongly supported by the stable isotopic chemostratigraphy. The revised correlation of the Indo-Nepal region attempted by the author is summarised in Table 1 and a more detailed correlation of the Precambrian-Cambrian sequences of South Asian Himalayan region is given in Table 2.

The recent work of Upreti (1990), Kaphle (1994) and Arita et al (1984) and Bashyal (1986) in western Nepal Himalaya and its comparison with Kumaon Himalaya is quite useful for regional correlation.

The direct continuation of Almora nappe rocks of Kumaon (Fig. 1) in Nepal is designated as Dadeldhura Group (Hagen, 1969, Upreti, 1990). The Baitadi Group rocks of western Nepal (Dhikgad Dolomite, Anarikhola and Patan Slate) is continuation of Gangolihat Dolomite (Tejam Group and Mandhali Sor Slates and Thalkedar, Limestone) Formation of the eastern Kumaon. The Rautgara Formation is not continuing in western Nepal. The Dhikgad Dolomite of Nepal is identical with Gangolihat Dolomite of Kumaon in its cherty nature and identical stromatolitic assemblages (*Conophyton, C. garganicus, Kussiella kussiensis, Baicalia* msp). It is also characterised by development of huge magnesite lenses and phosphoritic stromatolitic dolomite as in the Chandaak area of the Pithoragarh district. (Fig. 5 and 7) A precise and high resolution stratigraphic correlation is further possible if microbiota is recovered from the Baitadi and Darchula groups and its equivalents in Nepal and stromatolites are systematically studied with microstructures and three dimensional reconstructions-together with stable isotope chemostratigraphy is attempted for these carbonates as already established in the Deoban-Tejam Group in India (Tewari, 1981, 1984b, 1991, 1993a, 1994a, 1996, 1997a, 1998b; Tewari and Joshi, 1993; Kumar and Tewari, 1978a, b).

The Darchula Group (Devthalla Dolomite) in Nepal contains stromatolites in the Kali valley(Upreti, 1990) and between Dharchula and Tawaghat in Kumaon. The author has recorded an assemblage of *Conophyton-Colonnella* near Kulagad and it is similar to the Gangolihat Dolomite. Valdiya (1980) has correctly interpreted that the Baitadi Group and Darchula Group carbonates of western Nepal join together in further west in eastern Kumaon and constitute one single carbonate "Tejam Group".

The Central Crystalline rocks of the Kali valley has been studied by Valdiya and Gupta (1972), Valdiya (1980, 1986, 1988), Powar (1972), Kumar et al. (1972), with special emphasis on structural, seismic and tectonic and petrology of metamorphic rocks. Valdiya (1980) divided the Central Crystalline Zone of Heim and Gansser (1939) into two, the Vaikrita Group in north and Munsiari Formation in South separated by Main Central Thrust (Fig. 2). The Munsiari Formation is separated by the Berinag Quartzite or Tejam Group carbonate sediments in the Dharcula area. The Almora-Askot and Baijnath crystallines occurring in the south with sediments of the Tejam Group are considered to have their roots in Central Crystallines (Munsiari Formation). Valdiya (1980) correlated the Munsiari Formation with Lower Crystallines and Midland Formation of western Nepal. Valdiya (1980), Misra and Tewari (1988) and Tewari (1995, Table 2) on a regional scale, correlated Jutogh Group of Himachal Himalaya, the Thimpu Granitoids in Bhutan and the Bomdila Formation in Arunachal Pradesh with Munsiari Formation of eastern Kumaon. The Rb/Sr whole rock isochron age of the Jutogh Group (Wangtu granitic gneiss, Satluj valley) indicate Palaeoproterozoic (approximately 2000 my age; Bhanot et al, 1980 in Misra and Tewari, 1988). The Vaikrita Group high grade crystalline rocks are exposed near Zipti in the Kali valley. A well-bedded white quartizite with interbedded schist is exposed near Malpa on the mule track from Zipti. This quartzite shows very well preserved sedimentary structures like large scale cross bedding and herringbone cross bedding. A tidal flat coastal beach (shallow marine) depositional environment is suggested for Malpa Quartzie (Fig. 2) by the author. The youngest unit of the Vaikrita Group Crystalline (Fig. 2) is called Budhi Schist in Kali Valley and according to Valdiya (1980, 1988), the Budhi Schist is separated from Garbyang Formation of Tethyan Zone by Malari Thrust or Trans Himadri Thrust.

In the Tethyan basin of the Kali valley, the basal units Martoli and Ralam formations pinched in east. The Budhi Schist (Heim and Gansser, 1939) directly comes in contact with Garbyang Formation (Cambrian) in Kumaon (Fig. 2) and Kali Gandaki valley of western Nepal between the Annapurna Gneiss Complex and Larjung Formation. (Valdiya and Gupta, 1972; Valdiya, 1986). The Dhauladhar Limestone (Fuchs and Frank, 1970) in west Nepal is of Cambro(?)-Ordovician age and can be correlated with the Garbyang Formation of Kumaon (Cambrian) but additional data is required from both sides for a precise correlation. The Upper Ordovician Shiala Formation exposed near Gunji (Fig. 2) has been correlated with North Face Quartzite of the Kali Gandaki Valley in western Nepal (Bodenhausen et al., 1964 in Valdiya and Gupta, 1972).

The Muth (Quartzite) Formation is well developed between Gunji and Kalapani (Fig. 2) and characterised by Devonian fossils (Valdiya and Gupta, 1972). The Muth Quartzite is correlated with the Tilicho Pass Formation of western Nepal. The author agrees with the correlation between Kali (Series) Formation of Valdiya and Gupta (1972) and Lipak (Series) Formation of Spiti Valley and the Syringothyris Limestone of Kashmir basin since he has also reported the Lower Carboniferous stromatolites (this paper) from the Kali Formation similar to Lipak and Syringothris algal buildups in morphology (Singh, 1984). The common occurrence of *Linoproductus* from the Ice Lake Formation of western Nepal and the Kali Formation of Kumaun is correlatable and confirms the Lower Carboniferous age. The Fenestella Shale of the Kali Formation may be correlated with the Upper Ice Lake Formation of Western Nepal characterised by *Fenestella* (Bodenhausen et al 1964 in Valdiya and Gupta, 1972). The Kringkrone (Series) Formation of Valdiya and Gupta (1972) conformably overlies the Fenestella Shale northeast of Kalapani. This is correlated with the Thinichu Formation of west Nepal.

Valdiya (1995) has postulated a long sedimentation gap during the Cambro-Ordovician period in the Kali valley section of Kumaon and Dhaulagiri-Nilgiri-Ganesh Himal areas in north central Nepal and also in Sagarmatha region in NE Nepal. It seems that this absence of late Cambrian-early Ordovician life and sedimentation is a major regional or global event in the Tethys Himalaya related with the regression of the sea. The Palaeozoic succession is completely missing in the Lesser Himalaya after regression of the sea in Lower Cambrian (Tewari 1984b, 1994a) and the fossils of Permian, Cretaceous and Eocene represent three major marine transgressions over the Precambrian-early Cambrian sediments of the Lesser Himalaya. In eastern Himalaya also, the Buxa-Miri Group sediments of possible Precambrian-Cambrian age (Tewari, 1995, Table 2) represent similar situation (Tewari, 1998 in press). It is quite important to explain that there is no record or absence of fossils in Nepal till Middle Ordovician.

IMPRINTS OF PAN AFRICAN AND HERCYNIAN OROGENY IN LESSER TETHYS AND EASTERN HIMALAYA

Pan African orogeny as a major granitic intrusion around 500 Ma in India, Nepal and Pakistan is well established and has great Cambro-Ordovician global geodynamic significance (Valdiya, 1995; Kaphle, 1994 and the references therein). Tewari (1994a) has also explained the imprint of Pan African Orogeny in the Lesser Himalaya. Some tectonic events (Rifting) during the late Mesoproterozoic-early Neoproterozoic uplifted the Deoban sea from the inner Lesser Himalaya and the Terminal Proterozoic-early Cambrian sedimentation was confined to the south in Krol basin. The Mesoproterozoic-early Neoproterozoic carbonate-clastic deposits (Damta - Deoban - Jaunsar and Rautgara-Gangolihat-Mandhali (Sor and Thalkedar) were separated from Terminal Proterozoic (Vendian) Blaini Formation by a major unconformity at the base of the Krol Basin. The Nagthat Quartzite/Simla Group formed the foundation for sedimentation. The Krol Basin sedimentation finally terminated in Lower Cambrian because of the withdrawl of sea from the Lesser Himalaya and may be attributed to the early phase of the Pan African Orogeny.

Kumar (1997) has recognised the Pan African Orogeny in Arunachal Himalaya and interpreted that there was no sedimentation in Arunachal from Neoproterozoic to Carboniferous. Mesoproterozoic uplift was a major event in eastern Himalaya. The Hercynian Orogeny was recorded by Valdiya and Gupta (1972) in the Tethyan sequence of the Kali valley and Dhaulagiri region of the western Nepal where the Upper Carboniferous to Lower Permian gap in sedimentation was recognised. In eastern Himalaya, Kumar (1997) has observed the Middle Permian transgression was short lived and soon after continental facies (Gondwana) sedimentation and volcanic activity took place related with continental rifting due to orogenic movements. The birth of *Neotethys* took place with a marine transgression in Upper Permian and a new cycle of marine sedimentation was reported (Kumar, 1997). The regional correlation of the Lesser Himalayan and Tethyan basin sediments of the Uttarakhand area in Kumaon-Garhwal Himalaya and western Nepal shows striking similarities in style of sedimentation, basin architecture, events of short lived pause in sedimentation, global orogenic phases and palaeobiological events.

ACKNOWLEDGEMENTS

The author is grateful to Professor K.S. Valdiya, F.N.A., Chairman, Wadia Institute of Himalayan Geology, Dehra Dun for his encouragement. Dr. V.C. Thakur, Director, W.I.H.G. is thanked for providing facilities and permission to publish the paper. Drs. D.K. Misra, S.K. Paul and anonymous reviewer are thanked for reviewing the manuscript and suggestions. Dr. (Mrs.) Meera Tiwari is thanked for general discussions on early life. Mrs. Prabha Kharbanda is thanked for ably typing the manuscript.

This is a contribution to the International Geological Correlation Program (I.G.C.P.) Project No. 380 on Correlation and Biosedimentology of Stromatolites, Mud Mounds and related microbial buildups in the Precambrian and the Phanerozoic.

REFERENCES

Aharon, P., Schidlowski, M., and Singh, I.B., 1987, Chronostratigraphic carbon isotopic record of the Lesser Himalaya. Nature, v. 327, pp. 699-702.

Arita, K., Shiraishi, K. and Hayasi, D., 1984, Geology of western Nepal a comparison with Kumaun, India. Jour. Fac. Sc. Hokkaido Univ., Ser IV, v. 21(1), pp. 1-20.

Bashyal, R.P., 1986, Geology of Lesser Himalaya, far western Nepal, In: Le Fort, P. Colchen, M. and Montenat, C. (eds.), Memoires Sciences de la Terre, C.N.R.S., Nancy, v. 47, pp. 31-42.

Bhatt, D.K., Mamgain, V.D. Mishra, R.S. and Srivastava, J.P., 1983, Shelly microfossils of Tommotian age (Lower Cambrian) from Chert-Phosphorite Member of Lower Tal Formation, Dehra Dun district, Uttar Pradesh. Geophytology, v. 13, pp. 116-123.

Braiser, Martin, Cowie, J. and Taylor, M., 1994, Decision on the Precambrian-Cambrian boundary strato type. Episodes, v. 17, pp. 308.

Fuchs, G. and Frank, W., 1970, The geology of west Nepal between the rivers Kali Gandaki and Thulo Bheri Jahrb. Geol., v. 18, pp. 1-103.

Gansser, A., 1964, Geology of the Himalayas. Interscience Publishers, London pp. 289.

Garzanti, E., Casnedi, R. and Jadoul, F., 1986, Sedimentary evidence of a Cambro-Ordovician Orogenic event in the north western Himalaya. Sed. Geol., v. 48, pp. 237-265.

Hagen, T., 1969, Report on the geological survey of Nepal: preliminary reconnaissance. Denkschr. Schweiz Naturf. Ges., v. 86, pp. 185.

Heim, A. and Gansser, A., 1939, Central Himalaya, geological observation of the Swiss expedition, 1939. Mem. Soc. Helv. Sc. Nature, v. 73, pp. 245.

Kackar, A.K. and Srivastava, M.C., 1993, Delineation of Precambrian-Cambrian boundary in Martoli Group, Kumaon Himalaya, U.P. Geol. Surv. Ind. Rec., v. 126(8), pp. 247-250.

Kaphle, K.P., 1994, The Dadeldhura Granite, far western Nepal: a comparison with other Lesser Himalayan granites. Proc. First South Asia Geological Congress, 1992, Islamabad Pakistan, pp. 80-92.

Kumar, B. and Tewari, V.C., 1995, Carbon and oxygen isotope trends in late Precambrian-Cambrian carbonates from the Lesser Himalaya, India. Curr. Sc., v. 69, pp. 929-931.

Kumar, G., 1997, Geology of Arunachal Pradesh. Geol. Soc. Bangalore, p. 217.

Kumar, G., Mehdi, S.H. and Prakash, G., 1972, A review of stratigraphy of parts of Uttar Pradesh Tethys Himalaya. Jour. Pal. Soc. Ind., v. 15, pp. 86-98.

Kumar, G., Joshi, A. and Mathur, V.K., 1987, Redlichid trilobites from the Tal Formation, Lesser Himalaya, India. Curr. Sc., v. 56, pp. 659-663.

Kumar, S., 1998, A note on oxygen and carbon isotopes of magnesite and dolostone of Mesoproterozoic Gangolihat Dolomite (Formation), Pithoragarh district, Uttar Pradesh. Jour. Geol. Soc. India, v. 5(3), pp. 367-370.

Kumar, S. and Tewari, V.C., 1978a, Occurrence of *Conophyton garganicus* from the Gangolihat Dolomites, Kathpuria Chhina area, district Almora. Jour. Geol. Soc. India, v. 19, pp. 174-178.

Kumar, S. and Tewari, V.C., 1978b, A study of oolites from the Gangolihat Dolomite Kathpuria Chhina area, Almora district, U.P. with special reference to diagenetic changes. Him. Geol., v. 8(11), pp. 611-624.

Kumar, S., Singh, I.B. and Singh, S.K., 1977, Lithostratigraphy, structure, depositional environment, palaeocurrent and trace fossils of the Tethyan sediments of Malla Johar area, Pithoragarh-Chamoli Districts, U.P. Jour. Pal. Soc. Ind., v. 20, pp. 396-485.

Mathur, V.K. and Shandar, Ravi, 1989, First record of Ediacaran fossils from the Krol Formation of Nainital syncline. Jour. Geol. Soc. India, v. 34, pp. 245-254.

Misra, D.K. and Tewari, V.C., 1988. Tectonics and sedimentation of the rocks between Mandi and Rohtang, Beas Valley, Himachal Pradesh India. Geoscience Jour., v. IX(2), pp. 153-172.

Powar, K.B., 1972, Petrology and structure of Central Crystalline Zone, northeastern Kumaun. Him. Geol, v. 2, pp. 34-46.

Sahni, A. and Chhabra, N.L., 1974, Middle Triassic conodont from Kalapani Limestone, Malla Johar area, Kumaun Himalaya. Him. Geol. v. 4, pp. 259-295.

Sakai, H., 1983, Geology of the Tansen Group of the Lesser Himalaya in Nepal. Mem. Faculty of Science Kyushu University, Series D. Geology, v. XXV, No. 1, pp. 27-74.

Sakai, H., 1985, Geology of the Kali Gandaki Super Group of the Lesser Himalayas in Nepal. Mem. Of the Faculty of Science, Kyushu University, Series D. Geology, v. XXV, No. 3, pp. 337-397.

Shah, S.K. and Sinha, A.K., 1974, Stratigraphy and tectonics of the Tethyan Zone in a part of western Kumaun Himalaya. Him. Geol., v. 4, pp. 1-27.

Shankar, Ravi, Mathur, V.K., Kumar, G. and Srivastava, M.C., 1997. Additional Ediacaran biota from the Krol Group, Lesser Himalaya, India and their significance Geoscience Jour. v. XVIII (1), pp. 79-94.

Shukla M., Tewari, V.C. and Yadav, V.K., 1986, Late Precambrian microfossils from Deoban Limestone Formation, Lesser Himalaya, India. Palaeobotanist, v. 35 (3), pp. 347-356.

Singh, I.B., 1984, Record of a stromatolite-algal mat horizon in the Syringothyris limestone (Lower Carboniferous), Liddar Valley, Kashmir. Jour. Geol. Soc. India, v. 25 (8), pp. 537-540.

Singh, I.B. and Rai, V., 1983, Fauna and biogenic structures in Krol-Tal succession (Vendian-early Cambrian) their biostratigraphic and palaeoecological significance. Jour. Pal. Soc. Ind., v. 28, pp. 67-90.

Sinha, A.K., 1989, Geology of the Higher Central Himalaya. John Wiley and Sons, Chichester, 129 p.

Tewari, V.C., 1981, The systematic study of Precambrian stromatolites from the Gangolihat Dolomite, Kumaun Himalaya. Him. Geol., v. 11, pp. 119-146.

Tewari, V.C. 1984a, Discovery of the Lower Cambrian stromatolites from the Mussoorie Tal Phosphorite, India. Curr. Sc., v. 53, pp. 319-321.

Tewari, V.C. 1984b, Stromatolites and Precambrian-Lower Cambrian Biostratigraphy of the Lesser Himalaya, India. Proc. Vth Indian Geophytol. Conf. Lucknow, Spec. Publ., v. 71, p. 97.

Tewari, V.C. 1984c, The allochemical constituents and environment of deposition of Gangolihat Dolomite, Kathpuria Chhina area, Almora District, U.P. Geoscience Jour., v. V(1), pp. 43-54.

Tewari, V.C., 1991, The Carbon and Oxygen isotope trend of the Deoban-Blaini-Krol-Tal microbial carbonate from the Lesser Himalaya, India. Geoscience Jour., v. 12(1), pp. 13-16.

Tewari, V.C., 1993a, Precambrian and Lower Cambrian stromatolites of the Lesser Himalaya, India. Geophytology, v. 23 (1), pp. 19-39.

Tewari, V.C., 1993b, Ediacaran metaphytes from the Lower Krol Formation, Lesser Himalaya, India. Geoscience Jour., v. XIV (1-2), pp. 143-148.

Tewari, V.C., 1994a, Sedimentology of the rocks of Deoban basin, Dhuraphat area, Sarju valley, eastern Kumaun Lesser Himalaya. Geoscience Jour., v. XV(2), pp. 117-162.

Tewari, V.C., 1995. Controls of phosphorite formation superimposed on biological activity in the Lesser Himalaya, India. Geoscience Jour., v. XVI (2), pp. 135-153.

Tewari, V.C., 1997a, Carbon and Oxygen isotope stratigraphy of the Deoban Group (Mesoproterozoic) Garhwal Lesser Himalaya, India. Geoscience Jour., v. XVIII (1), pp. 95-101.

Tewari, V.C., 1997b, Terminal Proterozoic-Cambrian stratigraphy and stable isotopic signatures of Tethyan sediments from Girthi, Kali and Gori valley sections of the Garhwal-Kumaun Himalaya, India. Abstract, 12^{th} Himalaya-Karakoram-Tibet International Workshop, Roma, Italy, April 16-18, 1997, p. 225.

Tewari, V.C., 1997c. Discovery of Ediacaran metazoans and carbon isotope stratigraphy of Garbyang Formation, Kumaon-Garhwal Tethys Himalaya, India and its correlation with Spiti basin, Himachal Pradesh. Ist International Field workshop in Spiti Valley, I.G.C.P. 386 Seminar, 17^{th} September at Indian National Science Academy, Delhi pp. 38 (abstract).

Tewari, V.C., 1998, Prospects of delineating Terminal Proterozoic and Precambrian-Cambrian boundary in the North-Eastern Himalaya. Geosci. Jour. (in press).

Tewari, V.C. and Joshi, Manisha, 1993, Stromatolite microstructures: a new tool for biostratigraphic correlation of the Lesser Himalayan carbonates. Him. Geol., v. 4(2), pp. 29-29.

Tiwari, M. and Knoll, A.H., 1994, Large acanthomorphic acritarchs from the Infra Krol Formation of the Lesser Himalaya and their stratigraphic significance. Him. Geol., v. 5 (2), pp. 193-201.

Tripathi, C., Jangpangi, B.S., Bhatt, D.K., Kumar, G. and Raina, B.K., 1984, Early Cambrian brachiopods from Upper Tal, Mussoorie syncline, Dehra Dun district, U.P. Geophytology, v. 14, pp. 221-227.

Upreti, B.N., 1990, An outline geology of far western Nepal. Jour. Him. Geol. v. 1, pp. 93-102.

Valdiya, K.S., 1969, Stromatolites of the Lesser Himalayan Carbonate formations and the Vindhyan, Jour. Geol. Soc. India, v. 10, pp. 1-25.

Valdiya, K.S., 1980, Geology of the Kumaun Lesser Himalaya. Himachal Times Press, Dehra Dun, 291 p.

Valdiya, K.S., 1986, Correlation of Lesser Himalayan Formation of Nepal and Kumaon. In: Le Fort, P., Colchen, M. and Montenat, C. (eds.), Science de la Terre Memoiere, C.N.R.S., Nancy, v. 47, pp. 361-383.

Valdiya, K.S., 1988, Tectonic evolution of the central sector of the Himalaya. Trans. Philos. Royal Soc. London, v. 326, pp. 151-175.

Valdiya, K.S., 1995, Proterozoic sedimentation and Pan-African geodynamic development in the Himalaya. Precamb. Res., v. 74, pp. 35-55.

Valdiya, K.S., Gupta, V.J., Powar, K.B. and Banerjee, D.M., 1971, Palaeozoic biostratigraphy of the Tethys Himalaya in the northwestern Kumaun with special reference to the discovery of Fenestella shale. Nature, v. 235, pp. 152-154.

Valdiya, K.S. and Gupta, V.J., 1972, A contribution to the geology of northeastern Kumaon with special reference to the Hercynian gap in Tethys Himalaya. Him. Geol., v. 2, pp. 1-33.