ABSTRACTS

WORKSHOP
ON
VINDHYAN STRATIGRAPHY AND PALAEOBIOLOGY

March 19-20, 1999

The Department of Geology, University of Lucknow
Lucknow

The Palaeontological Society of India
Lucknow

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Organised by

The Department of Geology, University of Lucknow, Lucknow
The Palaeontological Society of India, Lucknow

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S. Kumar, A.K. Jauhri,
Vibhuti Rai and A.K. Kulshreshtha

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Technical Programme

March 19, 1999

08.30 – 09.30	Registration
09.30 – 10.30	Inauguration
10.30 – 11.00	Tea Break
11.00 – 12.00	Technical Session I
12.00 – 13.30	Technical Session II
13.30 – 14.30	Lunch Break
14.30 – 16.30	Technical Session III
16.30 – 17.00	Tea Break
17.00 – 18.30	Technical Session IV

March 20, 1999

09.00 – 11.00	Technical Session V
11.00 – 11.30	Tea Break
11.30 – 13.30	Technical Session VI
13.30 – 14.30	Lunch Break
14.30 – 15.15	Display of Material and Exhibits
15.15 – 16.15	Technical Session VII
16.15 – 17.00	Valedictory Function
17.00 – 17.30	Tea

Field Programme

March 21, 1999

8.00	Departure for Field

Contents

1. VINDHYANS VIEWED UNHURRIEDLY AT AN INDIAN STRATIGRAPHIC CROSSROAD

A.D. AHLUWALIA

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Cambrian seems to be the sudden destination of some crucial lithostratigraphic units of Indian stratigraphy. Nearly two decades after resolution of the Tal Tangle, equally surprising was the outcome from the Vindhyans that had given a fund of isotope data as well as microbiota and stromatolites supporting an older age. Paradoxically, the discovery of Early Cambrian Small Shelly Fauna from the Lower Vindhyans came almost simultaneously with the report of supposedly 1.1 billion year old worm trails/tunnels from only slightly below the SSF yielding horizon. The claim of older multicellular Vindhyan fossils, drew support from the isotope ages and questioned the very theory of evolution. The report of Early Cambrian Small Shelly Fauna, however, virtually pulled the carpet from under the feet of all stromatophiles and geochronologists swearing by a Proterozoic age for the Vindhyans. Geological conventions and common sense make it imperative that a horizon cannot be any older than the youngest *in situ* fossils found in it. For evolution of multicellular organisms to have commenced nearly 550 million years before and that too selectively in the Vindhyan Basin alone, was rather odd. The supportive isotope and palaeobiological data ostensibly provided some support though fragile. An older evolution of multicellular life might have carried currency for some more time but for the report of Early Cambrian SSF from Lower Vindhyans. Once all the heat and dust is settled, the alternatives would be:

i) the Early Cambrian SSF is not coming from Lower Vindhyans but is actually coming from a transgressive Cambrian sequence overlying the Vindhyans and ignored in mapping so far. This would still leave scope for tiny fossil trails/tunnels from the Churhat Sandstone to be corroborated as older and interpreted the way these were; or

ii) the proponents of older age for the Vindhyans as well as tiny tunneling structures goofed, lacked objectivity and drew confidence from extraneous sources and not the rocks or data at hand.

Life from Vindhyans is obviously going to be in sharp focus for a long time as would be the relevance of stromatolites in stratigraphy in general.

Curiously, unlike the Tals where discoverers of younger fossils had been embarrassed, from Vindhyans it is the turn of older discoveries and isotope dates. Presumptions no doubt seem to be hazardous unless checked and cross checked frequently.

2. AGE OF THE VINDHYAN SUPERGROUP: A DISCUSSION

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Controversy on the age of the Vindhyan Supergroup has been an over-impending problem of the Indian Stratigraphy ever since the early work carried out about 150 years ago. In recent decades, however, the Vindhyan age problem apparently got settled as there appeared to be some consistency (but with inherent contradictions) in the stromatolite and geochronological data, leading to a general consensus that the Vindhyan Supergroup is largely of Late Precambrian age (~1400 - 600 Ma, mainly Riphean). This age notion got so much entrenched that even a recent suggestion, based on the carbon isotope excursion, that the uppermost Vindhyan could extend up to the Precambrian-Cambrian boundary interval (Friedman and Chakraborty, 1997), was refuted (Kumar, 1997). Further, there were even some very convincing recent records of Vendian to early Cambrian metazoa (including trace fossils) and metaphytes both from the Lower as well as the Upper Vindhyans which could have been easily used to revise the Precambrian age of the Vindhyan succession but instead were generally claimed (except a few, e.g. Chakrabarti, 1990; Chakraborty and Friedman, 1998) to have evolved deep into the Precambrian (e.g. Maithy and Shukla, 1984; Shukla and Sharma, 1990; Kulkarni and Borkar, 1996; Sarkar *et al.*, 1996; Seilacher *et al.*, 1998). However, I have not followed the latter option for my discovery of 91 Small Shelly Fossils 92 from the Rohtasgarh Formation (Azmi, 1998a) as I was fully convinced that these shelly fossils clearly signalize for the global skeletonization event which occurred only near the Precambrian-Cambrian Boundary. This discovery, therefore, necessitated me to propose a major revision of the widely held Precambrian age for the Vindhyan succession (see also Azmi, 1998b). Now these Vindhyan small shelly fossils are before the geological fraternity to decide whether I was correct in my judgement suggesting a Vendian to early Palaeozoic age for the Vindhyan Supergroup or I should also have pulled back the skeletonization event deep into the Precambrian, about more than 1 billion years ago.

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3. PRELIMINARY $^{40}Ar/^{39}Ar$ DATES OF PORCELLANITE AND DETRITAL MICA FROM THE VINDHYAN OF CENTRAL INDIA

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[1] Department of Geology, University of Delhi, Delhi

[2] Geochronology Laboratories, University of Vienna, Vienna

Prompted by the sensational report in SCIENCE about the triploblastic animal burrows in the supposedly 1.2 b.y. old Lower Vindhyan shales of Churhat and still more controversial record of Early Cambrian small shelly fauna from the Rohtas Limestone, a collaborative study of dating the Vindhyan sequence has been initiated between the University of Delhi and University of Vienna. The first set of hurriedly collected samples in November 1998 from the Maihar-Rewa-Panna-Churhat sectors in central India and Chittorgarh in Rajasthan have been dated by $^{40}Ar/^{39}Ar$ method. We have for the first time dated the porcellanite rocks from the sections south of Churhat and from Pandav Falls region. The plateau age for the porcellanite at lower temperature is 617 ± 3.5 Ma. However, at higher temperature steps, higher ages from 920 to 1073 Ma have been measured. Tentatively, we believe in interpreting that ca. 617 Ma corresponds to the depositional age in view of the fact that at low temperatures argon was released only from the fine grained volcanic matrix and, therefore, produced a more or less stable plateau. At higher temperatures other detrital constituents released argon gas causing increment in the age values. On the other hand, detrital mica from the Churhat shale and clay layers in the porcellanite give ages in the range of 932 and 1127 Ma. Detrital clay from the basal Vindhyan sandstones at Chittorgarh give an age of 938.5 ± 3.9 Ma. This, therefore, suggests that Lower Vindhyan sediments were primarily derived from rocks ranging in age from 850 to 1200 Ma, while the depositional age (atleast for the porcellanite) was ca. 617 Ma. Implications of such lower ages will be discussed in this presentation. We hope to suggest a modified geotectonic scenario for the development of the Vindhyan basin.

Some additional dates of the detrital micas and separated feldspars from the porcellanite (kindly supplied by P.K. Bose and Shantanu Banerjee of Jadavpur University) will be made available before the beginning of the Conference.

4. IMPRINT OF METAZOAN ACTIVITY: EXAMPLES FROM THE LOWER BHANDER SANDSTONE FORMATION AROUND MAIHAR, DISTRICT SATNA., M.P.

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Numerous studies have shown that metazoan activity in the form of trace fossils predates the traditionally recognized Precambrian-Cambrian boundary. It has been noted that trace fossils are relatively diverse in the shallow-water clastic seas in the Late Proterozoic times. Since the shallow water mud-dominated tidal flat niche of the Lower Bhander Sandstone appears to be a suitable site for animals to meander or tunnel close to the surface, one can very well expect metazoan activity during that period, particularly when coccoid and filamentous microfossils are found in the limestones older than 1100 Ma. While working on the depositional events of the Lower Bhander Sandstones, the author came across certain features which suggest burrowing activity of worm-like animals during that period.

The burrows represent vertical sac-like bodies with a well defined circular knobby appearance on the surface. Thin section study of burrowed samples displays clay lining on the burrow wall. Distinct contrast between burrow-fill and the surrounding sediments has also been recorded. In samples where bioturbation is intense, the early-formed sedimentary structures are shattered, This, in turn, suggests that the trace makers during the Lower Bhander Sandstone period were probably deposit feeders. Proper radiometric age for the Lower Bhander Formation might sharpen our concept of early metazoan evolution.

5. A CRITICAL REVIEW OF THE GEOCHRONOLOGIC DATA ON LOWER VINDHYAN FORMATIONS

K. GOPALAN

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The surprisingly simultaneous and exciting discoveries of fossil burrows of worm-like organisms within the Chorhat Sandstone by Seilacher and others (Science, 1998, 282, 80-83) and small shelly fossils and brachiopods in the overlying Rohtasgarh limestone by Azmi (J. Geol. Soc. India, 1998, 52, 381-389) have led to two drastically different conclusions. Relying on the general concordance of K-Ar and Fission Track ages at about 1100 Ma for Lower Vindhyan rocks, Seilacher and others argue for metazaon evolution prior to 1000 Ma. Azmi, on the other hand, drastically revises up the age of Vindhyan to about 600 Ma based on the biochronologic correlation of small shelly fossils in the Rohtasgarh limestone with the early Cambrian. Crucial to both the conclusion is the absolute age of the lower Vindhyan rocks. A critical assessment of the existing geochronologic data will be presented, together with suggestions for modern and reliable methods of dating Vindhyan sedimentation.

6. DEPOSITIONAL ENVIRONMENT INFLUENCED BY TECTONISM DURING SEMRI AND KAIMUR TIMES, VINDHYAN BASIN, SOUTH UTTAR PRADESH

SUMANT GUPTA, K.C. JAIN, V.C. SRIVASTAVA and R.D. MEHROTRA

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The rocks of the Vindhyan Supergroup represented by the Semri and Kaimur Groups are very well exposed in southern Uttar Pradesh in the classical Son Valley area (Fig. 1). These rocks have been studied by several earth scientists in the past, which has resulted in generating a wealth of data on sedimentary geology, tectonics, palaeoenvironment, fossil record and age determinations.

The Bundelkhand Granitoid complex in the north and pre-Vindhyan Sidhi/ Mahakoshal Group along with the granitoid batholithic association towards south, with the upthrown and downward rifted blocks controlled by the geometry of major lineament zones, provide the earliest Mid-Proterozoic basin for the deposition of thick sedimentary sequences. The Narmada-Son and Amsi-Jiawan lineaments, limiting the Vindhyan Basin to the South, are ancient suture zones which have witnessed repeated rejuvenations in the geological past and shows continued reactivation till date.

The southern part of the basin comprises a thick and well developed sequence of rudaceous argillaceous and chemogenic sedimentary pile belonging to the Semri Group and a predominantly arenaceous and argillaceous sedimentary sequence belonging to the Kaimur Group.

The lithological, sedimentological and palaeontological attributes of these sequences show marked facies changes both laterally and vertically, exhibiting a variety of depositional environments and ecological set up influenced by syndepositional tectonism and biotic elements. Bathymetric considerations are a rule in defining the facies variations, overlapping and basinal conditions during the Semri and early Kaimur times.

Measurement of sections and studies on lithological variations, sedimentological, structural and palaeontological parameters of the Semri Group of rocks of South U.P. indicate a periodically fluctuating palaeoenvironmental domain restricted mainly

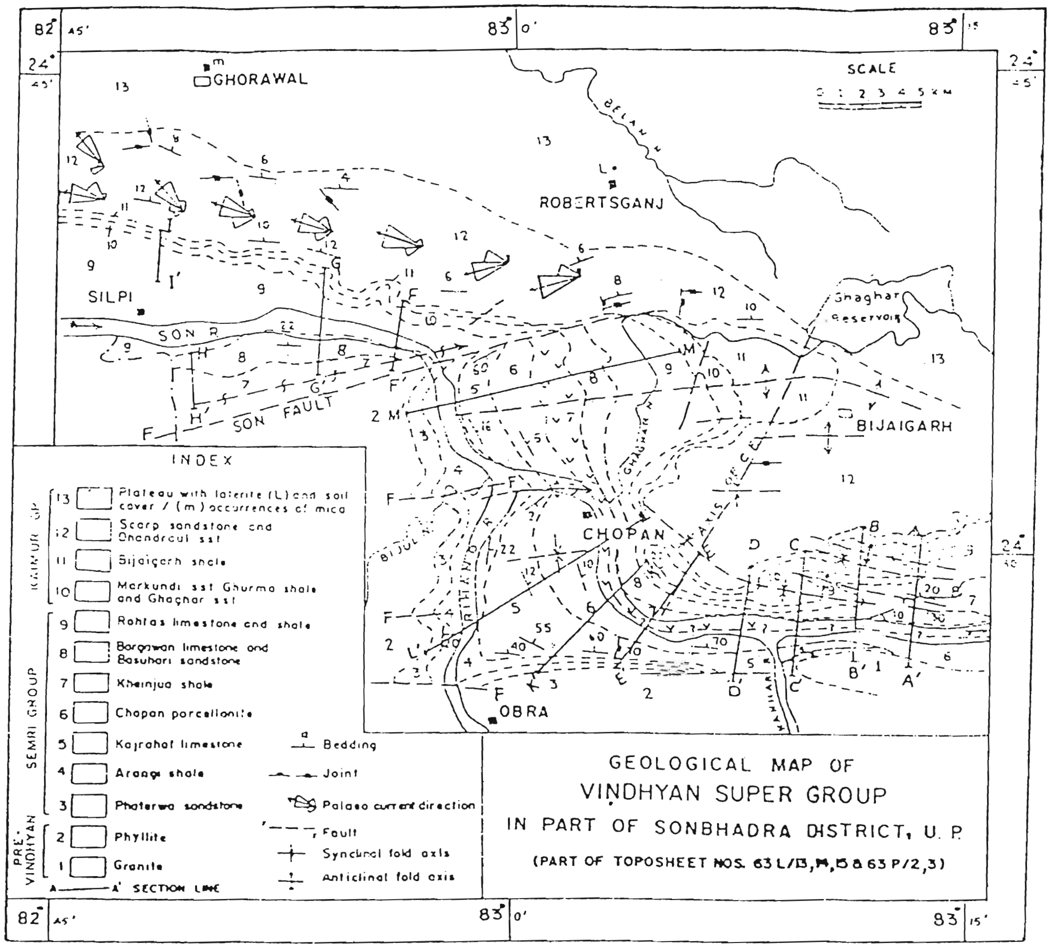

Fig. 1

within the limits of shallow to moderately deep marine coastal shelf, tidal mud-flat to euxinic lagoonal conditions of deposition.

The lithofacies and isopach maps (Fig. 2) suggest a tectonically unstable southern block, whereas the northern part remained a potentially stable platform area, during the Mid-Proterozoic time. The deposition of the Semri Group was punctuated by frequent and recurrent pulsating tectonism. At least, three major

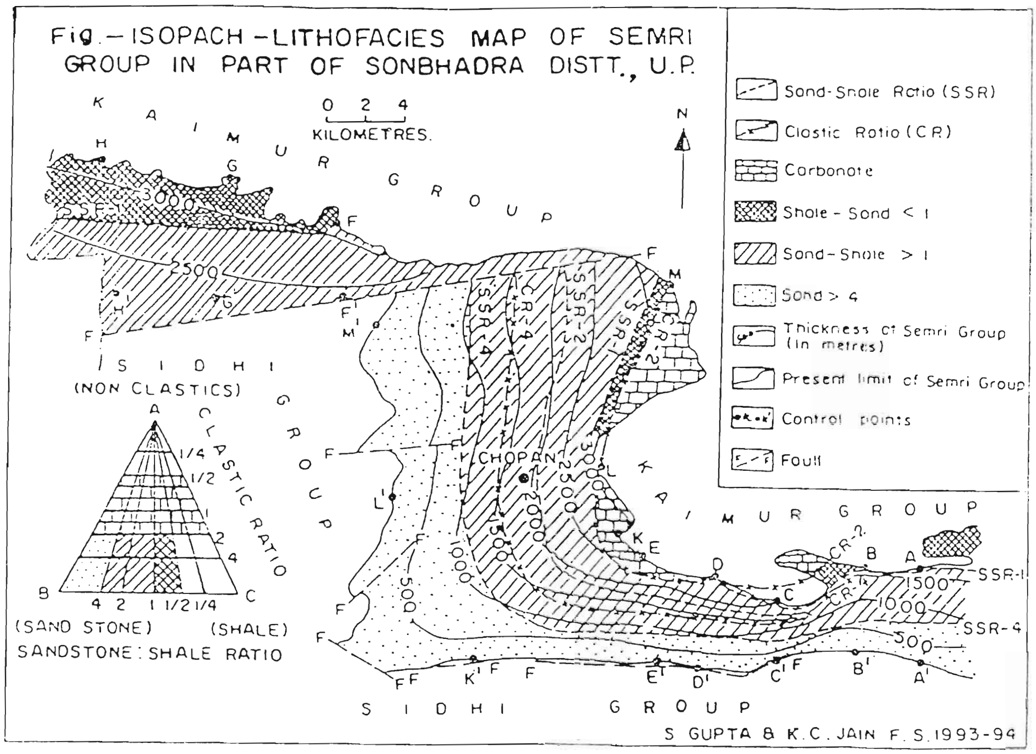

Fig. 2

arenite-shale-carbonate cycles of sedimentation exists, each culminated by tectono-magmatic activity. Tectonism, and volcanicity after the first major cycle of sedimentation resulted in the deposition of a thick sequence of volcaniclastic sediments represented by Chopan Porcellanites in the Son Valley area. This was also probably responsible for the transgression of the sea northwards over the Bundelkhand region and widespread accumulation of glauconite- bearing sediments in the upper part of the Semri.

The present studies suggest a depositional environment wherein recurrent sea-level fluctuations continued throughout the deposition due to the upliftment of the southern marginal parts of the Vindhyan basin corresponding to periodic pulsating tectonism, instead of a gradual and periodic sinking and subsiding basin *pari pasu* deposition, under a uniformly shallow marine environment, postulated by many earlier workers (Auden, 1933). The water body continued to move northwards transgressing

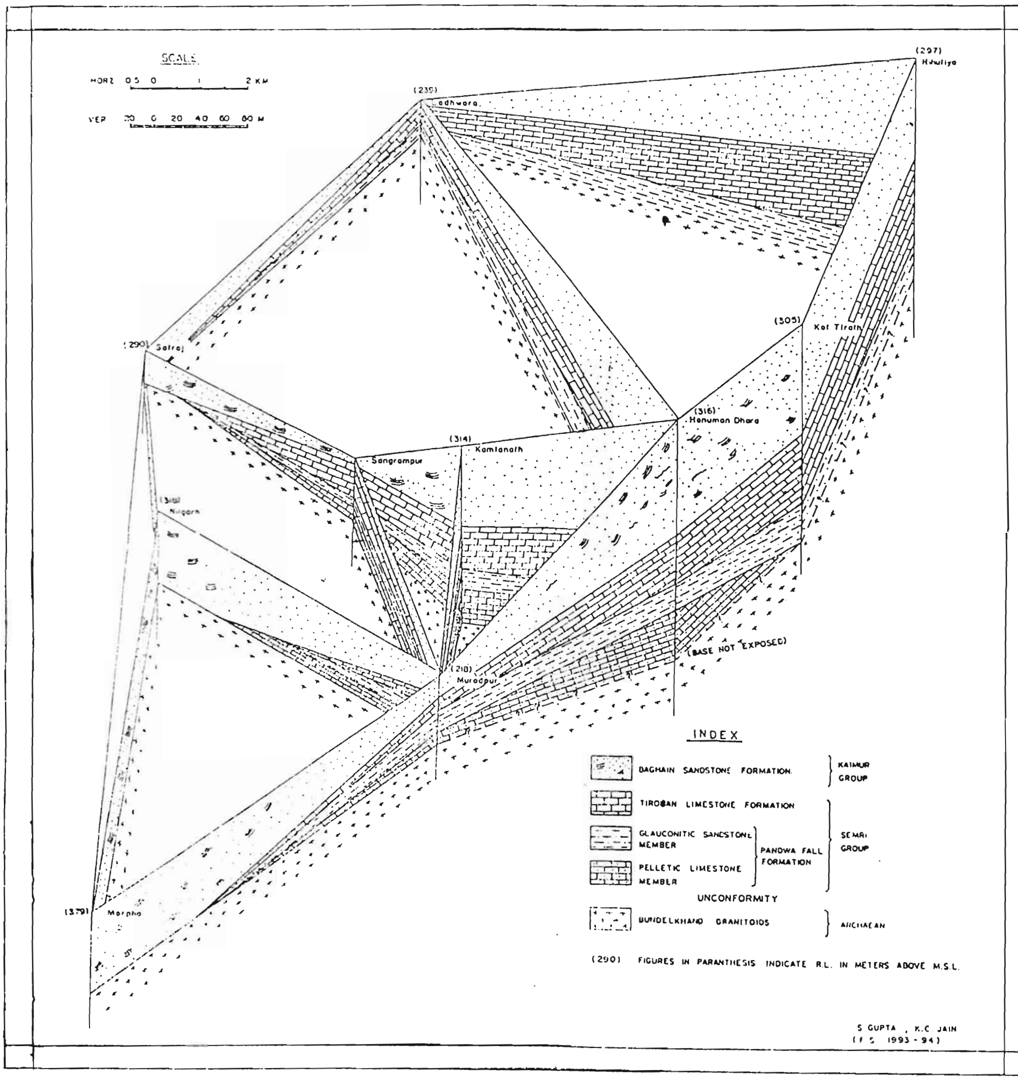

Fig. 3 : Fence diagram showing Semri - Kaimur Lithofacies variation in the Chitrakoot - Karvi Area U.P.

the Bundelkhand basement rocks under the influence of tectonism and sediment fill leading to northward shifting of southern strand line and successive overlapping of younger formational units in the northern parts of the basin.

7. LITHO-, BIO-, CHEMO- AND CHRONO-STRATIGRAPHY AT CROSSROADS: THE VINDHYAN-LESSER HIMALAYAN CORRELATION DILEMMA

M.N. JOSHI

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The stratigraphic contemporaneity of the Vindhyans and the autochthonous/ parautochthonous, sedimentary formations of the Lesser Himalaya, generally considered to be unfossiliferous has been accepted for long, although with differences about details. The watershed breakthrough came when Valdiya (1969) correlated the Fawn and the Bhander with the Shali-Deoban-Gangolihat-Thalkedar limestone formations, assigning them the Riphean age on the basis of stromatolites. Within Himalaya also, on the same basis, the Jammu, Shali, Sataun-Tundapathar, Naldera-Kakarhatti, Deoban, Gangolihat and Buxa Carbonate formations were considered to be Riphean. Since the stromatolites of the Krol-Tal sequence did not tally with these formations that was not considered to be correlatable. On the contrary a number of litho-stratigraphic evidences were put forth to disprove the Krol-Deoban correlation, even if advocated by some. However, lately the stratigraphic reliability of the stromatolites has been doubted even by some stromatophiles.

The biostratigraphy has brought the Krols to Precambrian leading to the general notion of considering other carbonates as the Riphean and the Krols as the Vendian. However, many recent fossil findings have suggested that the Deoban can also extend up to Early Cambrian (references cited by Srivastava and Kumar, 1997). Their report of forms comparable to Nematoda and Annelida phyla also corroborates this better than the conclusion drawn by them. In fact, Rai *et al.* (1997) reported discovery of clusters of *Skolithos* from the Dharagad Group (underlying the Deoban Group) and visualized a late Vendian to early Cambrian age for it. Similarly Vaishnodevi (Jammu) limestone has yielded a distinctive Phanerozoic acritarch *Veryhachium* extending that also to Cambrian (Venkatachala and Kumar, 1998). This suggests that the Deoban and Krol sequences are quite correlatable being deposited in two distinct basins in inner and outer Lesser Himalaya.

In this background, the so far not seriously taken notion of the presence of Phanerozoic elements in Vindhyans got momentum with the recent fossil findings of

Precambrian-Cambrian boundary age from the Rohtas Formation (Azmi, 1998). Interestingly, Kumar (1995) had noticed carbon isotope evidences favouring strong biotic activity at Rohtas level. Azmi's discovery implies that the Deoban-Krol carbonate sequence can be coeval to the Kajarhat-Fawn sequence.

A marked positive excursion of $\delta^{13}C$ within Bhander Group led Friedman and Chakraborti (1997) to believe the initiation of Cambrian at that level. Importantly, their data are quite consistent with those presented twenty eight years ago by Pandey *et al.* (1969), although, at that time their age significance was not known. However, as Kumar (1998) pointed out, the isotopic data must have strong bio- or chronostratigraphic support, which is at present not there. Azmi's findings will, however, prove that the positive $\delta^{13}C$ excursion at Bhander is indicative of a later biotic activity explosion. A comprehensive plot of $\delta^{13}C$ values of Vindhyans and Lesser Himalayan carbonates shows that the Deoban Group compares well with the Vindhyans.

The radiometric dates are very meagre, at times self contradictory and in general inconsistent with biological evidences. For example, the glauconitic sandstone of Kheinjua Formation is 1080±40 Ma, the glauconites of Lower Kaimur are 940±30 Ma, the lead isotope age of Kaimur is 725 Ma and the kimberlite intrusive into it is dated to be 1067±31 Ma (Vishwakarma, 1998). From Himalaya except the galena age of Jammu limestone (967 Ma), no data is available. Hence, at this stage they cannot be of much use for correlation purposes.

Therefore, the problem can be resolved only by generating more and more data of interdisciplinary and unbiased approach.

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8. PROTEROZOIC SEA-LEVEL VARIATIONS AND THEIR POSSIBLE IMPLICATIONS OF SEDIMENTARY HISTORY OF THE VINDHYAN SUPERGROUP

VIVEK S. KALE

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Recent studies across the world have indicated that there were at least two major phases of sea-level high-stands on a global scale, during the Proterozoic preceding the Terminal Proterozoic rise in the eustatic sea-level. They have contributed to the evolution of the large platform systems, which characterise the Mesoproterozoic and Neoproterozoic deposits of the world.

Studies in the contemporary sequences in the Dharwar craton of south have shown that they preserve an excellent record of the Mesoproterozoic with a transgressive cycle beginning around 1.8 Ga. This is manifested as the Papaghni Group in the Cuddapah Basin and the Bagalkot Group in the Kaladgi Basin. The peak transgression in this cycle occurred around 1.6 Ga. The Dharwar craton has an ambiguous record of the early Neoproterozoic high-stand, but appears to have preserved the record of the Terminal Proterozoic transgressive event (estimated to have been initiated around 0.7 Ga) in the Kurnool, Bhima and Badami Groups of sediments. Traditionally, the sequences in the Dharwar Craton have been correlated with the Vindhyanchal Basin on the basis of lithological similarities. The developments in the stromatolite biostratigraphy strengthened some of the earlier correlations while others were revised. Findings "fossilised" organic records in the past decade from the 'Purana' sediments added significantly to the knowledge on their ages. However, all Precambrian biology is and should be open to doubts and, unlike Phanerozoic palaeontology, will remain a matter of debate as to whether or not a particular fossil find (compared with the standards' established globally) should be taken as an index of the sediment age, or, whether it should be taken as a record of evolution, which was hitherto unknown. This problem does not have an easy solution till reliable radiometric ages are available. Due to the nature of the sediments of the Purana Basins, such dates are not likely to become available easily and in great numbers, in the near future.

In the background of recent reports of such findings from the Vindhyan Supergroup, and given the inherent limitations on the possibilities of dating these sediments, their examination in the perspective of regional and global sea-level fluctuations may provide an additional framework for defining broad periods of time in which they were deposited. An attempt to define this framework is presented.

9. ISOTOPE EVENT STRATIGRAPHY OF PROTEROZOIC SUCCESSION OF THE VINDHYAN BASIN, INDIA

B. KUMAR[1], S. DAS SHARMA[1], A.M. DAYAL[1], R. R. KUMAR[1], H. KAUR[1], M.N. RAO[1] and M. MATHUR[2]

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Extensive carbon, oxygen and selected Sr-isotopic work on the Lower (Semri Group) and Upper (Bhander Group) Vindhyan sedimentary succession from three different sections, viz., Jabera-Satna-Maihar; Robertsganj-Chopan; and Kota-Jhalawar have yielded the following:

The Kajrahat, Kheinjua and Lower Rohtas Formation carbonates are characterised by $\delta^{13}C$ and $\delta^{18}O$ signatures of –2.00 to +0.3 ‰ (PDB) and +15.3 to + 26.2 ‰ (V-SMOW), respectively, while, the Upper Rohtas (Nimbahera) carbonates of the Semri Group exhibit an $\delta^{13}C$ and $\delta^{18}O$ values of +0.3 to + 2.8 ‰ and +19.5 to 23.3 ‰ respectively.

The Lower Bhander Group carbonates have $\delta^{13}C$ and $\delta^{18}O$ composition ranging between + 2.6 to 5.7 ‰ and +21.3 to 25.6 ‰, respectively, on the other hand, Upper Bhander Group carbonates have values in the range of -3.3 to -5.2 ‰ for $\delta^{13}C$ and +19.5 to 21.7 ‰ for $\delta^{18}O$.

$^{87}Sr/^{86}Sr$ ratios of the Semri Group carbonates vary from 0.7051 to 0.7066 and that for the Bhander Group carbonates range from 0.7060 to 0.7089.

A comparision of our data with that from world wide Proterozoic successions suggests a Mesoproterozoic-Terminal Proterozoic age for the Vindhyan sediments. The mark positive $\delta^{13}C$ values for the Bhander Group carbonates from the Jabera-Satna-Maihar section indicate an interval of increased organic carbon burial, which may have a bearing on hydrocarbon resource potential.

10. STROMATOLITE BIOSTRATIGRAPHY OF THE VINDHYAN BASIN: UTILITY AND SIGNIFICANCE

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The recent stromatolites are well known and their study gave important clues regarding the genesis of most ancient fossil stromatolites on earth. It is now established that stromatolite morphology is environment senstive and same microbial assemblage can give rise to different morphologies in different environmental settings. However, in comparison to Precambrian stromatolites the recent stromatolites are very simple and only a few morphologies are recorded. In the Precambrian stromatolites, more than seven hundred different morphologies have been described from the different Precambrain successions from the different parts of the world. Out of these, many morphologies are non-repetitive with respect to time and have been successfully used for intrabasinal and interbasinal correlation. Attempts have also been made to use them for intercontinental correlation. In the light of the above mentioned facts, the Vindhyan stromatolites are evaluated for their stratgraphic testimony and usefulness.

The stromatolites are recorded from the Semri and Bhander Groups. The Semri Group shows good development in the Son Valley area, Bihar and Uttar Pradesh, and in Chittorgarh area, Rajasthan. In the Semri Group of the Son Valley area, there are three carbonate horizons ; in the stratigraphic order these are the Kajrahat Limestone, the Fawn Limestone and the Rohtas Formation/Tirohan Limestone. The Kajrahat Limestone and the Fawn Limestone display profuse development of stromatolites, while the Rohtas Formation shows poor develoment. In Rajasthan, the well preserved stromatolites have been recorded from the Bhagwanpura Limestone. But the Nimbahera Limestone is devoid of stromatolites. The Semri Group is charactersied by an abundance of *Conophton*, *Colonnella*, and *Kussiella* and other columnar forms which show very passive branching. The conophytons are extensively developed and display varied morphologies. *Thassagates, Ephyaltes, Calypso, Cyathotes* and *Siren* are recorded. The assemblage suggests the Lower to Middle Riphean age.

The Bhander Group is developed in the Maihar area, Madhya Pradesh and the Kota-Bundi area, Rajasthan. In both the areas, the Bhander carbonates are characterised by the complete absence of Conophytons, though the environmental setting is well comparable to the environmental setting of the *Conophyton*-bearing carbonates of the Semri Group. The characteristic forms of the Bhander Group are *Baicalia, Tungussia, Inzeria* and other columnar forms but all the forms show very active branching. However, in the Kota-Bundi area, the Lakheri Limestone, the oldest carbonate horizon of the Bhander Group, has not yielded the stromatolites and at the same time it gives a very negative $\delta^{13}C$ carb values (-5.4 ‰ PDB, N=5), while the overlying Sirbu Shale carbonates and the Balwan Limestone, the youngest carbonate horizon of the Bhander Group of Rajasthan, give $\delta^{13}C$ carb values as 0.5 ‰ (N=5) and 1.72 ‰ (N=4), respectively. In the Maihar-Satna area, the Bhander Limestone gives $\delta^{13}C$ carb values as 4.3 ‰ (N= 8, Kumar, 1991). The Lakheri Limestone cannot be correlated on the basis of stromatolites as well as on the basis of carbon isotope values with the Bhander Limestone. The Bhander Limestone is correlatable with the carbonates of the Sirbu Shale and /or the Balwan Limestone. In Rajasthan, the carbonates of the Bhander Group show very strong negative excursion which may indicate a very cold climate at the time of deposition of the Lakheri Limestone or deposition in the deeper part where methogenesis played a significant role.

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11. CARBONACEOUS MEGAFOSSILS FROM THE SUKET SHALE, RAMPURA AREA, NEEMUCH DISTRICT, MADHYA PRADESH

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Seven megafossils are described from the Suket Shale of the Semri Group, Rampura area, Neemuch district, Madhya Pradesh. These megafossils represent seven species belonging to five genera. All the forms show chlorophycean affinity. The megafossils are *Chuaria circularis* Walcott, *Chuaria vindhyanensis* sp. nov. , *Tawuia dalensis* Hofmann, *Tawuia indica* sp. nov., *Suketia rampuraensis* gen. *et* sp. nov., *Tilsoia khoripensis* gen. *et* sp. nov., and *Chambalia minor* gen. *et* sp. nov. There is a definite relationship between *Chuaria circularis, Tawuia* and *Tilsoia.* They appear to constitute different parts of a multicellular chlorophycean plant. *Chuaria circularis* represents a cyst-like body which was attached to *Tawuia*, a siphonaceous thallus or a vegetative filamentous cell. *Chuaria vindhyanensis* represents spore-like bodies which were released by the *Chuaria circularis* on maturation. *Tawuia* was attached to a substrate by a holdfast apparatus represented by *Tilsoia. Suketia rampuraensis* appears to be a compressed *Tilsoia. Grypania* reported from the Rohtas Formation of Son Valley and *Chuaria* and *Tawuia* reported from the Suket Shale occur more or less at the same stratigraphic level and hence constitute a single biozone.

12. CARBON AND OXYGEN ISOTOPES OF THE ROHTAS FORMATION, SON VALLEY- MAIHAR AREA, CENTRAL INDIA: A PRELIMINARY REPORT

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Precambrian-Cambrian boundary has been suggested between the Bhander Limestone and the Sirbu Shale of the Bhander Group on the basis of carbon isotope values by Friedman and Chakraborty (1997). However, the same boundary has also been proposed within the Rohtas Formation by Azmi (1998) on the basis of shelly fauna. As there is a well marked global $\delta^{13}C$ excursion near Precambrian-

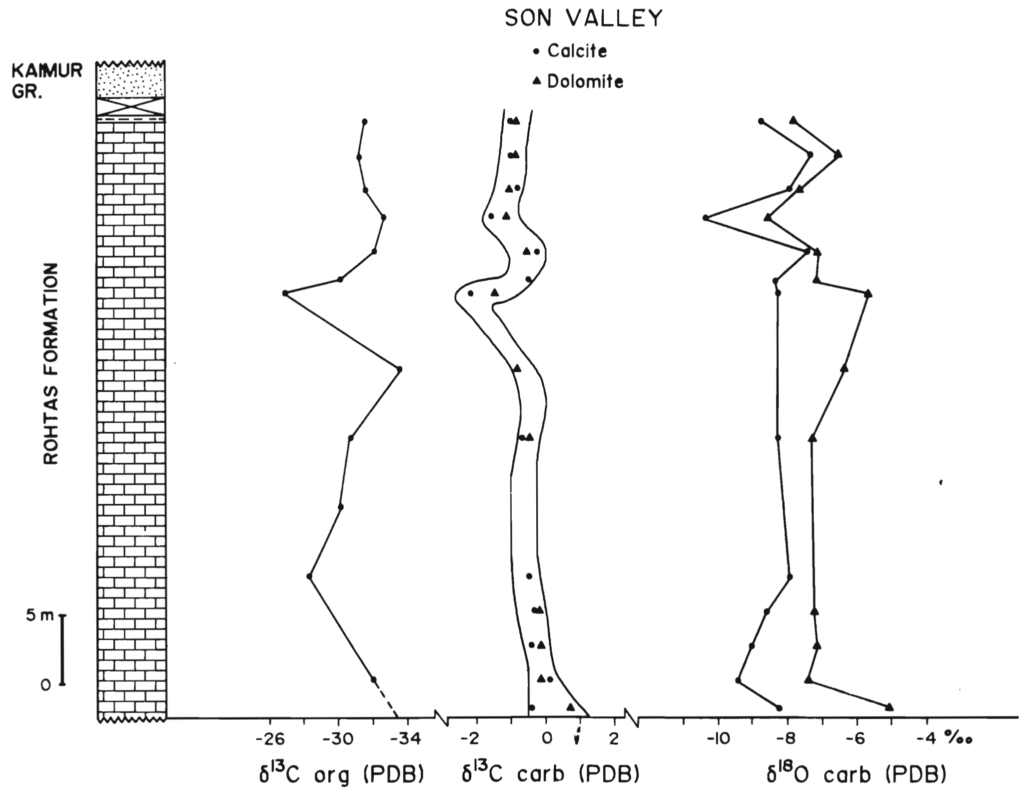

Fig. 1: $\delta^{13}C$ and $\delta^{18}O$ variation in the Rohtas Formation in Son Valley, Ghurma area, U.P.

Table 1: Son Valley area, Uttar Pradesh

S. No.	Sample No.	$\delta^{13}C$ organic (‰ PDB)	$\delta^{13}C$ calcite (‰ PDB)	$\delta^{13}C$ dolomite (‰ PDB)	$\delta^{18}O$ calcite (‰ PDB)	$\delta^{18}O$ dolomite (‰ PDB)
1.	Rh1	-31.7	-1.0	-1.2	-8.7	-7.8
2.	Rh 2	-31.2	-1.0	-0.9	-7.3	-6.5
3.	Rh3	-31.6	-0.8	-1.0	-7.9	-7.6
4.	Rh4	-32.6	-1.6	-1.1	-10.3	-8.5
5.	Rh5	-32.1	-0.2	-0.5	-7.4	-7.1
6.	Rh6	-30.9	-0.5	-0.6	-8.3	-7.1
7.	Rh7	-26.9	-2.3	-1.4	-8.2	-5.6
8.	C1	-33.5	—	-.08	—	-6.3
9.	C2	-30.7	-0.7	-0.4	-8.2	-7.2
10.	C3	-30.1	—	—	—	—
11.	C5	-28.2	-0.5	—	-7.9	—
12.	C6	—	-0.3	-0.2	-8.6	-7.2
13.	C7	—	-0.4	-0.1	-9.0	-7.1
14.	C8	-32.0	+0.7	-0.4	-8.2	-5.0
15.	C9	—	-0.4	-0.7	-8.2	-5.0
	Mean	**-31.0**	**-0.8**	**-0.7**	**-8.3**	**-6.9**

Table 2. Maihar area, Madhya Pradesh

S. No.	Sample No.	$\delta^{13}C$ organic (‰ PDB)	$\delta^{13}C$ calcite (‰ PDB)	$\delta^{13}C$ dolomite (‰ PDB)	$\delta^{18}O$ calcite (‰ PDB)	$\delta^{18}O$ dolomite (‰ PDB)
1.	M1	—	—	-0.2	—	—7.2
2.	M2	-30.8	-1.4	-0.8	-7.2	-4.7
3.	M3	-29.6	-1.6	-1.4	-7.2	-6.2
4.	M5	-39.7	-1.9	-1.6	-7.2	-5.9
5.	M6	-30.4	-1.6	-1.4	-7.3	-6.0
6.	M8	-30.1	-1.6	-1.4	-7.3	-6.0
	Mean	**-30.1**	**-1.6**	**-1.1**	**-7.2**	**-5.4**

Cambrian boundary and is also well recorded in the Krol-Tal Succession of the Lesser Himalaya, an attempt has been made to identify this excursion in the Rohtas Formation. For this, two sections were selected for carbon isotope analyses; one is in the Son Valley - Ghurma area, Sonbhadra district, Uttar Pradesh where about 170 m thick succession of Rohtas Formation is well developed; and the other section is in the Maihar area where about 30 m thick succession of the upper part of the Rohtas Formation is exposed in the mines of the Maihar Cement Factory. The carbon and oxygen isotope values for the Son Valley and Maihar areas are given in Table 1 and 2.

When the data is plotted in a stratigraphic order for both the areas, no perceptible variation is recorded in $\delta^{13}C$ values (Figs. 1 and 2) and thus on the basis of $\delta^{13}C$ values no Precambrian-Cambrian boundary can be suggested in the Rohtas Formation.

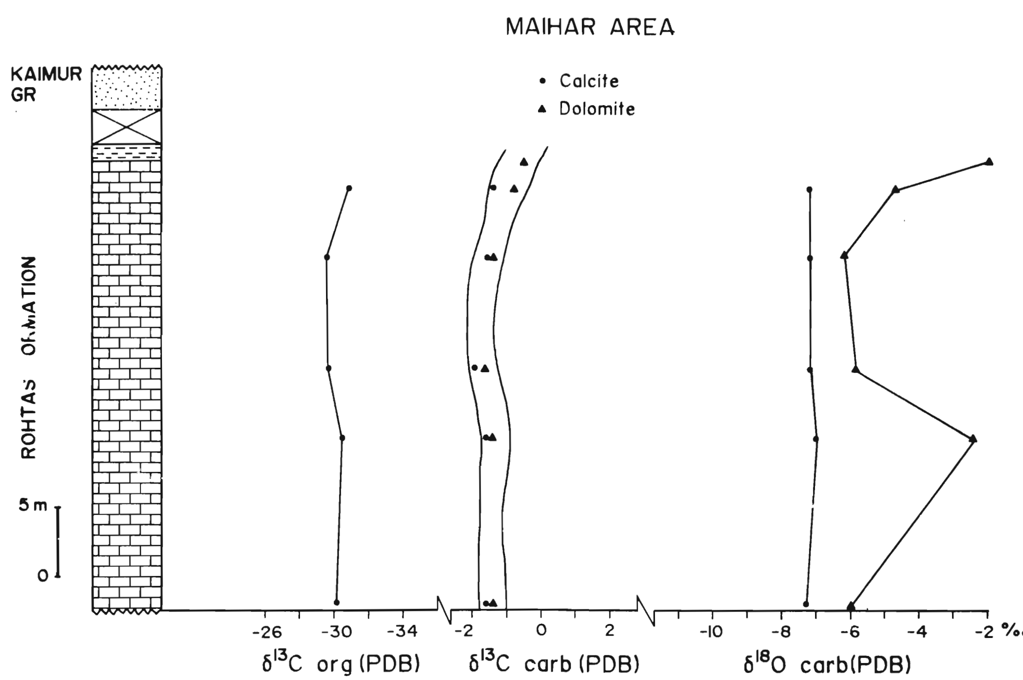

Fig. 2 : $\delta^{13}C$ and $\delta^{18}O$ variation in the Rohtas Formation, Marihar area, M.P.

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13. VINDHYAN ORGANIC-WALLED MICROFOSSILS: A TYRO'S VIEW

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Organic-walled microfossil records are well known from the different formations of the Vindhyan Supergroup. The remains of microfossils have been studied either in petrographic thin sections or by releasing the organic-walled microfossils after dissolving the fine-grained clastic rocks by acid. The latter method of study helps in understanding the morphological details, though doubts have been posed from time to time regarding their syngenicity.

The organic-walled microfossils now known from the Vindhyan Supergroup are grouped as follows:

(i) Solitary and colonial coccoidal forms

(ii) Non-septate filamentous forms

(iii) Septate filamentous forms

(iv) Acritarchs

(v) Vase-shaped microfossils

The forms of the groups (i) to (iii) resemble the modern members of the Cyanobacteria in their gross morphology. The morphometric similarity of the Vindhyan microfossils to living taxa supports the hypothesis that prokaryotes are "hypobradytelis" which have exhibited little morphological evolution over exceptionally long periods of geologic time. Thus, such fossils cannot be expected to provide a basis for a meaningful biostratigraphic work. Still some forms like, *Sphaerocongregus,* and *Polythricoides* are important age markers of Neoproterozoic.

The most important organic-walled microfossils for the Vindhyan biostratigraphy are Acritarch. Acritarchs are "small microfossils of unknown and probably varied affinities, consisting of a central cavity enclosed by a wall of single or multiple layers of chiefly organic composition". Most acritarchs probably represent a resting stage or cyst in the life cycle of planktonic eucaryotic algae. The Vindhyan acritarchs show the dominant presence of sphaeromorphids and nonsphaeromorphs are rare.

Amongst nonsphaeromorphs, only Acanthomorphs with small processes are present. The forms of Acanthomorphs with large processes - Diacrodiod forms, Netromorphs and Oomorphs are so far the remains unrecorded from the Vindhyan. Recently, Prismatomorphs, enigmatic polyhedral acritarch and vase-shape acritarch - *Melanocyrillium* have been reported from the Bhander Group. The stratigraphic distribution of Acritarch from Mesoproterozoic to Lower Palaeozoic is well documented by the work of Timofeev (1966), Jankauskas (1990) and Vidal (1981). Comparative analyses show that the Vindhyan acritarch assemblage comprise Meso-Neoproterozoic forms.

In the past, the organic-walled microfossils from the Rohtas Formation and its equivalents have been worked out in details at the Birbal Sahni Institute of Palaeobotany. The analysis of Acritarch shows that the assemblage is dominated by Sphaeromorphida - Leiosphaerids commonly known from 1000-800 Ma. Old. The assemblage is devoid of Acanthomorphs with small processes and a Prismatomorphs known from the Bhander succession. Considering the available data, the Rohtas Formation can best be bracketed in the age ranging between 1000 and 850 Ma.

14. ON CONUNDRUM REMAINS FROM THE ROHTAS LIMESTONE FORMATION, SEMRI GROUP, VINDHYAN SUPERGROUP, EXPOSED AROUND AKBARPUR, BIHAR

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Rich megafossils comprising *Chuaria-Tawuia-Krishnania* are well known from the Rohtas Limestone Formation, Semri Group, Vindhyan Supergroup. The biogenicity of these remains is undisputed today, but still their systematic position is not certain. Sometime ago, while carrying an investigation in the Akbarpur area, four distinct types of fossils were collected. They are being detailed here for their biogenicity and possible affinities.

(All specimens are displayed in the exhibition hall for examination)

15. THE DIVISION OF THE VINDHYAN SUPERGROUP INTO "LOWER" AND "UPPER" : HOW VALID IS THIS CLASSIFICATION?

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Although it has been demonstrated in several sections throughout the vast Vindhyan Basin that the transition of the uppermost beds of the so-called "Lower Vindhyan" (the Semri Group) into the immediately overlying bottom beds of the Kymore Group (the lower-most group of the so-called "Upper Vindhyan") is conformable, i.e. without a hiatus, most workers continue to use the two-fold classification. Conformable transition between the Semri and the Kymore can be observed in many parts of the basin, including the classical Son Valley of Auden. To begin with, T. Oldham saw only three major units - namely, the Kymore, Rewah and Bundair -when he newly created the Vindhyan "Series" in 1856. Later, H. B. Medlicott identified the "Sub-Kymore" group of rocks in the same stratigraphic succession, which he named "Semri" in 1860. He rightly considered these as the downward continuation of the Oldham's "Vindhyan" and grouped them all together. Mallet in 1869 banded the original three divisions of Oldham into "Upper Vindhyan" and put the single Semri group of rocks into "Lower Vindhyan". Apparently, Mallet made this distinction only in view of the fact that the upper three divisions were created originally and the lower fourth was added later, and not on any geological grounds as the perusal of his comprehensive Memoir on the Vindhyan shows amply. Some workers have justified this division on the ground that in some sections a hiatus is observed between the Semri and the Kymore Groups. Such hiatuses occur in some sections of the basin between the three upper Groups too; and not only between the groups but locally within the formations themselves. Such local breaks in sedimentation are common in all sequences the world over as sedimentation is never continuous, and the geologist uses many criteria for creating formations and groups and to assemble them into a major stratigraphic unit. Mallet's two-fold classification, unfortunately, has persisted since his time, and in spite of all evidence that all the four divisions of the Vindhyan are of equal status and form a unitary stratigraphic succession, the use of the terms "Upper" and "Lower" continues to be used. It is high time that all the investigators of the Vindhyan Supergroup recognise the unitary character of the Vindhyan succession and abandon the two-fold division, which, from all evidences, is stratigraphically arbitrary.

16. EVAPORITE CYCLOTHEMS AND SABKHA SEDIMENTATION OF SIMARAWAL SHALE, BHANDER GROUP OF THE REWA PLATEAU AREA, MADHYA PRADESH

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"Evaporite Cyclothems" of Simarawal Shale (Bhander Group) have been exposed during geotechnical explorations and foundation excavations for Tons Barrage - an appurtenant of Bansagar Project, in Satna district, Madhya Pradesh (Fig. 1). This finding reveals a new aspect of sedimentation history of the Vindhyan Epeiric Sea. A model with Sabkha set on margin of the great epeiric sea has been invoked to explain the sedimentation of the Simrawal Evaporite Cyclothems; the paper also reviews the model of sedimentation for the Bhander Group.

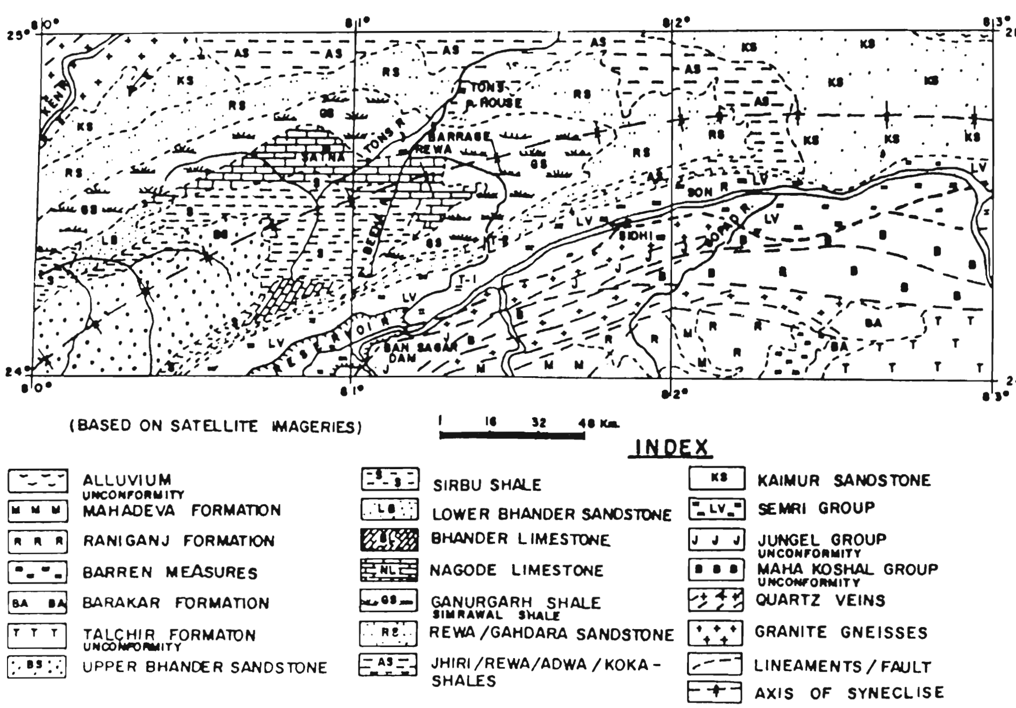

Fig. 1. Geological map of Rewa Plateau and part of Son Valley.

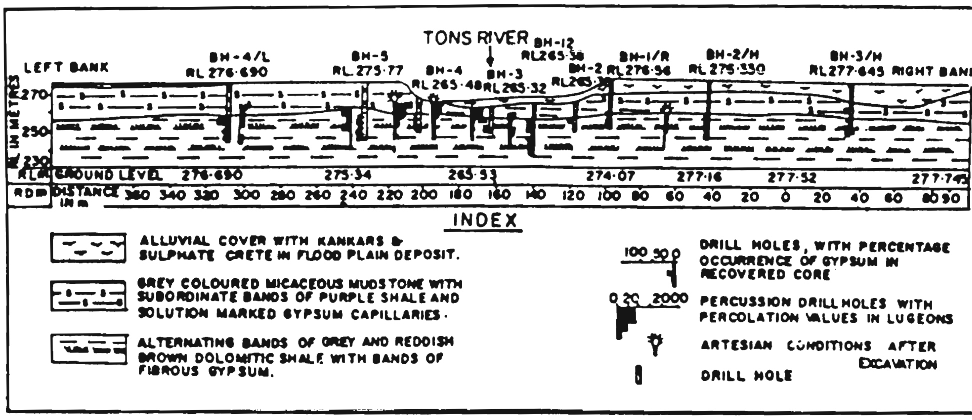

Fig. 2. Geological section along Dam axis, Tons Barrage, Satna, M.P. showing Gypsum bands and lithotypes.

LITHOSTRATIGRAPHY, MICROFACIES AND EVAPORITE CYCLOTHEMS

Lithostratigraphy of the Simrawal Shale Formation at depth was hitherto unknown. Revelation from the exploratory drill holes down to RL 220 m (Fig. 2) and exposed foundations for cut-off trench of Tons Barrage (Fig. 3) confirmed the occurrence of low order evaporite with Gypsum in the Simrawal shale sequence (Mishra and Chhibber, 1980). Added information from explorations facilitates grouping of the lithostratigraphy of the Simrawal Shale into two units namely (a) Upper flat bedded mudstone, shale and limestone and (b) lower unit with evaporite cyclothems. The upper flat bedded sequence contains capillaries of gypsum, whereas the lower sequence consists of fibrous gypsum bands (max. thickness 19 cm) interlaminated within grey and reddish brown shale. The occurrence of gypsum bands and pattern of variation in their thickness manifest cyclicity in the sedimentation of the evaporite sequence. Three such cycles of gypseous sedimentation are noted in the cut-off trench of the Tons Barrage (Fig. 3).

The Simrawal evaporites are exclusively calcium sulphate type; the gypsum occurs in five different fabric forms (Mishra and Dutta, 1985) namely - (a) Clear elongate crystals, with herringbone twins having swallow tail upright (G-1 type microfacies), (b) spherulitic gypsum with radial arrangements culminating into polygonal patterns with remnants of anhydrite and ghost fabric (G-II type microfacies)., (c) turbid xenomorphic gypsum occurring as cavity infillings in

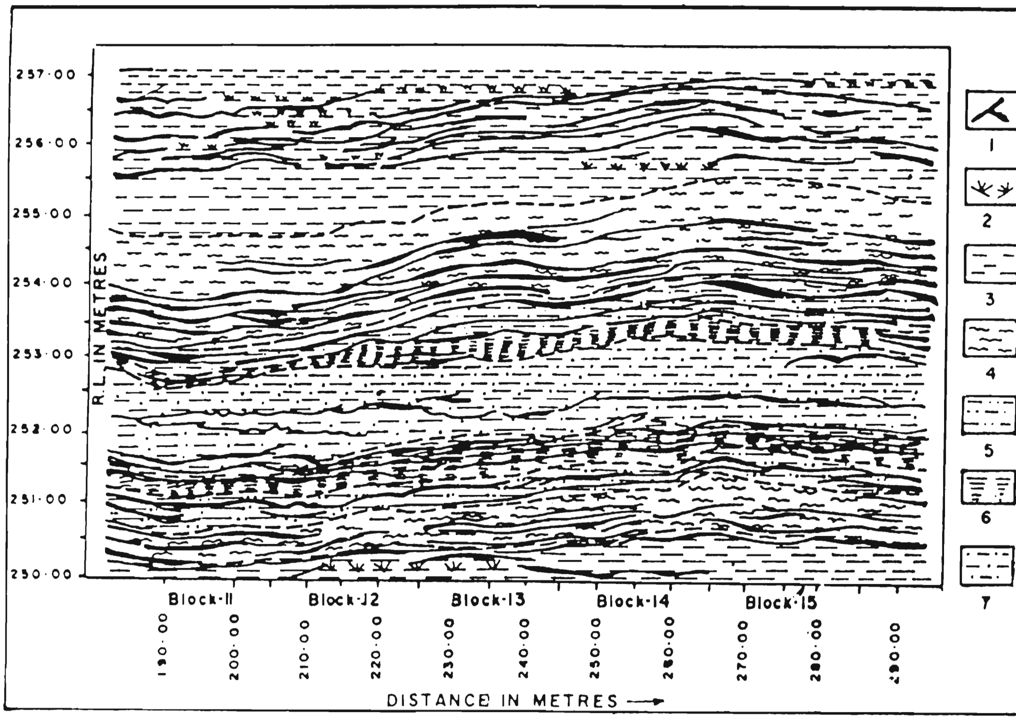

Fig. 3. Geological log of U/S wall of cut-off trench, Tons Barrage showing Gypsum bands and lithotypes.

1, Grey and honey coloured single/twin fibrous gypsum (satinspar) band. Fibres are arranged vertically to bedding. 2, Capillary fibrous gypsum single layers. 3, Hard compact, moderately bedded reddish brown dolomitic/ferruginous shale. 4, Dark grey, well-laminated shale. 5, Light grey, well-laminated shale with occasional clay pockets at the contact zone. 6, well-laminated shale with alternating bands of light grey and reddish brown colour. 7, Well-laminated shale

spherulitic gypsum (G-II type microfacies), (d) Poikilotopic cement in dolomicrite (G-III type microfacies) and (e) detrital gypsum shreds in dolomicrite (G-IV and V type microfacies). The fabric types A and B are devoid of terrigenous contaminations whereas microfacies with C, D and E fabric types are associated with dolomicrite and terrigenous eluviations. The close association of gypsum fabric of A, C and E type, i.e. elongate crystals formed under slow evaporation (Braitsch, 1967) in restricted waters such as brine-pan, poikilotopic cement with dolomicritic inclusions having formed by evaporation of ground water (Shearman, 1966) and gypsum shreds

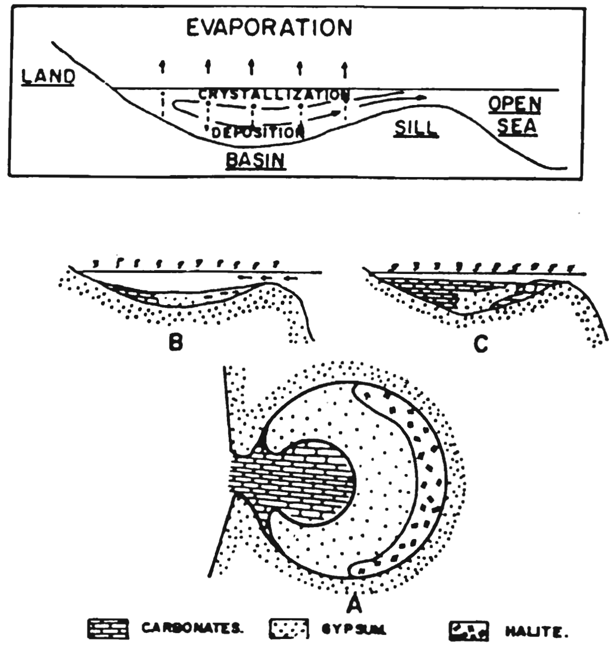

Fig. 4 A. Simplified open system model of an evaporite basin (adapted from King *et al.*, 1947). Flow directions are indicated by solid arrows.

Fig. 4B. Idealised teardrop pattern of evaporite distribution typical of partially restricted basins (modified after Hsü *et al.*, 1973).

formed as incipient crystal during dolomitization on tidal mud flats (Shinn *et al.*, 1969), is unique.

SEDIMENTATION OF SIMRAWAL EVAPORITES

Primary structure-associations in the Simrawal shale enumerated earlier by Rao *et al.* (1981) reveal that sedimentation took place in shallow basins. Occurrence of evaporite suggests that the basin was characterized by restricted circulation combined with high rate of net evaporation. The unique association of mono-mineralic gypsum bands with periodically precipitated alternating dolomicrite, extraclastic dolomicrite and poikilotopic gypseous dolomicrite could have generated in a hypersaline milieu of evaporite precipitation alternating with rhythmic influx of sea water of lower salinity from open sea.

Thus, the facies assemblage and association of the Simrawal evaporite cyclothems suggest that their sedimentation took place in supratidal mud-flats of sabkhas in a way similar to modern examples of Trucial Coast of Arabia on the Persian Gulf (Kinsman, 1966) and North-western margin of California (Shinn *et al.,* 1969).

After sedimentation of the Rewa Group in a shallow epeiric sea margin, the marine waters were left standing as shallow 'pans' resulting into marginal 'Sabkhas', frequently visited by high rhythmic tides across barrier or sill (Fig.4). The sedimentation of the Simrawal shale with evaporite cyclothems took place in this sabkha domain. This enunciated model explains periodic association of gypsum with dolomicrite. The elongate crystals of gypsum growing perpendicular to bedding represent 'brine pans' (Kinsman, 1969). Gypsum occurring as poikilotpic cement, precipitated within pervious carbonate sediments during early diagenesis in Sabkha mud-flat domain (Shearman, 1966).

Lithofabric association in the Simrawal evaporite necessitates co-ordinated function of barrier across which periodic influxes of sea water could occur. Organic reefs of stromatolites of the associated Nagod Limestone offered plausible barrier. Lateral relations of the Simrawal Shale and Nagod Limestone units (Ghosh, 1981) corroborate such an assumption. However, precipitation of substantially thick gypsum bands (5 mm to 190 mm) would warrant a slow and repeated influx of sea water across reefal barrier.

Sedimentation of the four-tier lithostratigraphy of the Bhander Group, viz. Simrawal Shale, Nagod Limestone, Sirbu Shale and Bhander Sandstone, has been reviewed. As the vertical sequence is the reflection of lateral facies sedimentation in a dynamic domain (Walther's law of facies), it is shown that supratidal Simrawal Shale, overlain by intertidal/subtidal facies of Nagod Limestone, marks prograding shoreline and closing phase of sedimentation of the Bhander Group, i.e. Simrawal Shale (Supra-tidal) overlain by the Bhander Sandstone (Terrestrial/fluvial), represents retrograding phase.

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17. PROTEROZOIC-EARLY PALAEOZOIC DEPOSITIONAL CYCLES OF GANGA BASIN WITH SPECIAL REFERENCE TO SARDA DEPRESSION

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The Proterozoic-Early Palaeozoic sediments concealed beneath the Gangetic alluvium have been under active exploration, albeit in phases, by ONGC consistent with the prevailing concepts and priorities since 1956. Given the large volume of data acquired thus far and notwithstanding the constraints of uneven data spread and inadequate biostratigraphic information, it is nevertheless possible to construct a fairly correlatable sequence stratigraphy based on recognition of mega depositional cycles. The individual sequences with apparent similarity of character and chronology are pieced together across the Ganga Basin to the outcropping Upper Vindhyans in the south.

Our understanding of the evolutionary history of Ganga basin comes from the structural arrangement of the basin floor in the interior Indian craton east of Delhi-Aravalli fold belt as deciphered from gravity-magnetic data. A number of sub-latitudinal and linear structural features characterise the tectonic framework of the basement. North of the Bundelkhand massif, E-W to ENE-WSW trending basement ridge along Lucknow-Faizabad-Tundla alignment divides the basin into Sarda and Gandak depressions. Further east, Zamania-Sitamarhi ridge separates the Madhubani depression from Gandak depression. Monghyr-Saharsa ridge marks the western and eastern boundaries of the Madhubani and Purnea depressions respectively.

Integrated analysis of the information available from 11 deep and 4 shallow subsurface sample points and a large volume of 2D seismic data across the basin has broadly revealed four sedimentation cycles concealed below the alluvial cover representing the bulk of the rock volume of the basin. Of this, Cycles II and III essentially account for the Proterozoic-Early Palaeozoic sequence correlatable to Lower Vindhyan and Upper Vindhyan group of rocks unconformably overlying the metasediments (Cycle-I). Miocene mollasse (Cycle-IV) represents the Tertiaries in Ganga basin. Except for Madhubani depression, Lower Vindhyans (Cycle II) have not been encountered anywhere in Ganga basin. Similarily, the Upper Vindhyans (Cycle III) are confined only to the Sarda and Gandak depression. West of Delhi-Aravalli fold belt, right through the Punjab plains, the Miocene mollasse rests directly over the Delhi-Aravalli group of rocks.

A fair continuity between the UpperVindhyan sediments exposed in the Chambal Valley to the south and those beneath the alluvial cover in Ganga Basin is apparently established based on the regional seismic profile shot closed to the Bhander outcrops. Attempt has also been made to correlate subunits of the exposed Kaimur, Rewa, and Bhander subgroups with the subsurface succession encountered in the wells of Sarda depression.

In Sarda and Gandak depressions three distinct lithounits have been identified unconformably overlying the metamorphosed sequence (Cycle-I). In Sarda depression the lithological differentiation is more pronounced than in Gandak depression. The lower unit essentially consists of siltstones and shales with minor limestone. The lithological attributes further subdivide this unit into Kaimur and Rewa subgroups. The middle unit is dominantly a limestone and (Bhander subgroup) with intervening shales and siltstones/sandstones. The uppermost unit (Bhander sandstones) is characterised by a sandstone-siltstone unit with shale intercalations. Based on the lithological associations, electrolog motifs, seismic-facies analysis and carbon-oxygen isotope studies, the environment of deposition reflects a transition from fluvial - clastic inner shelf - carbonate shelf - open shelf environment for the Upper Vindhyan sediments.

Even though precisely dated biostratigraphic information on the UpperVindhyans and its equivalents is lacking, they have on the basis of the presence of stromatolites been assigned a Riphean-Vendian age. Recent palynological studies on the core samples of UpperVindhyan sediments in the Sarda and Gandak depressions indicate that the sediments immediately below the pre-Tertiary unconformity are characterised by abundant population of acritarchs of definite Late Riphean-Vendian age represented dominantly by sphaeromorphs. Significantly, core samples from a well in Gandak depression recorded the first appearance of acanthomorphs, sphaeromorphs with developed ornamentation and herkomorphs from the upper part of Upper Vindhyan thereby indicating a Cambrian age to this unit.

The geochronological (Rb-Sr) studies carried out on the core samples have yielded ages of 438 ± 34Ma and 658 ±12 Ma for the Rewa and Kaimur subgroups of the UpperVindhyans.These ages represent the age of diagenesis of these sediments. Ages of around 1600 Ma and beyond have been recorded for the metamorphics encountered below the Vindhyans in Sarda depression.

18. STROMATOLITE-BASED BIOSTRATIGRAPHY OF THE CHHATTISGARH BASIN AND ITS POSSIBLE CORRELATION WITH VINDHYAN BASIN

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In the Chhattisgarh basin due to restricted vertical span and scanty exposures separated by huge tracts of soil cover/alluvium, the correlation of stromatolitic beds become difficult. Moreover, though there are three deep bore holes ranging from 380-600 metres, identification of stromatolites in core samples is not possible where many morphological characters are not available.

To overcome these constraints, the author preferred to utilize the geological set up of the basin which is tectonically undisturbed. Accordingly, the vertical distribution of the stromatolites in the 670 m thick Raipur Limestone were computed based on topographical control of the exposures. However, the local disturbances causing minor shifts in sediments seen rarely in this basin, have been carefully avoided for this study.

To minimise the error, the exposures of stromatolite-bearing sediments were studied by taking traverses in various directions and computing their relative topographic levels.

Both surface studies and scrutiny of subsurface data from deep quarries over an extensive area reveal two vertically defined assemblages of stromatolites, with little or no correlatable aspect of facies variation.

Two assemblages which indicate two distinct temporal set up are mainly found at two topographic levels, namely Reduced Level 213-266 m and 270-340 m.

Taking into account the empirically known vertical ranges of stromatolites groups on the basis of findings in various parts of the world, the two assemblages can be assigned the Middle Riphean and the Upper Riphean to the Vendian age respectively. In these two assemblages, there are some groups which are common to both. Close scrutiny of these groups relating to finer details of forms appear to point towards more decisive temporal set. *Baicalia burra, B. constricta, B. bifurcata, B. capricornia* are seen in close association with the Upper Riphean-Vendian set up of *Gymnosolen* and *Linella*. These are never seen to occur with other forms of *Baicalia* having a Middle Riphean association like *Kussiella, Colonnella* and *Anabaria*. Similar observation is made in case of *Tungussia*. The *T. inna* is seen with Upper Riphean-Vendian association but *T.* fm. indet. is seen in association with the Mid-Riphean forms.

Furthermore, it is observed that the varieties of stromatolites in the case of mid-Riphean assemblage are more than those of the Upper Riphean Vendian association.

The final deduction then reads as follows:

Topographic Level	**Assemblage**	**Age**
L. 270-340 m	*Gymnosolen rotandus, G. furcatus, Tungussia inna, Baicalia capricornia, B.* cf. *lacera, B.* cf. *burra, B. constricta, B. bifurcata, Linella avis, Acaceilla augusta, Inzeria tjoumusi.*	Vendian to Upper Riphean
R.L. 23-266 m	*Baicalica prima, B. baicalia, Tungussia* fm. indet., *Kussiella* cf. *kussiensis, K. irregularis, Conophyton* cf. *cylindricus, Jacutophyton* fm. indet., *Anabaria radialis, Omachtenia* fm. indet., *Colonnela discreta, C.* cf. *elongatus, C. conica, C. laminata.*	Mid-Riphean

The *Inzeria-Gymnosolen* combination is seen in the upper part of the Bhander Formation of the Vindhyan Supergroup. The *Baicalia-Tungussia* combination present in the Bhander Formation is also present in the upper biozone described here. However, since the groups are not specified as are done in the Chattisgarh basin, it is only possible to put them tentatively at par.

The lower biozone of the Chattisgarh basin is comparable to the assemblage of stromatolites in the Semri Group of the Vindhyan basin. Here, an assemblage of

Kussiella, Conophyton and *Colonnella* have been observed and given an early Riphean to Mid-Riphean status. In the Chattisgarh basin, in addition, three groups namely, *Anabaria, Baicalia* and *Tungussia* are seen where *Anabaria* is characteristic of the Mid-Riphean age.

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19. TECTONO-SEDIMENTATION MODEL OF PROTEROZOIC SEDIMENTS IN SON VALLEY, VINDHYAN BASIN AND ITS IMPLICATION FOR PROBABLE HYDROCARBON HABITAT

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The Proterozoic Vindhyan Basin of north-central India has attracted the attention of petroleum explorationists for over decades because of its shear size and huge pile (5500+m) of unmetamorphosed sediments. Discovery of gas in the sub-economic quantities from the first exploratory well drilled by Oil And Natural Gas Corporation Ltd. (ONGC) further rejuvenated the interest of geoscientific community in Hydrocarbon exploration in this basin.

ONGC has acquired good amount of geological, geophysical and geochemical data in this basin so far, which has been integrated to bring out a tectono-sedimentation model of the basin for deciphering the possible source-reservoir-cap rock facies relationship.

Initial field data contemplated simple saucer-shaped syncline model on the basis of observation of homoclinal dips, simple outcrop pattern and little deformation of the exposed sediments. The interpretation of new geophysical data, however, has revealed complex extensional fault system in the sub-surface in the Lower Vindhyan Group diagnostic of rift-basin geometry. Initial development of this basin was in the form of sag created by extensional forces from the Son-Narmada-Lineament from the southern side. The greater thickness of Lower Vindhyans in the southern side was perhaps due to active southern margin along which continuous rifting was responsible for accommodation of huge pile of sediments. The bottom most lithounit of the Basal Kharaundi Arenite was deposited in the high energy continental environment in the initial irregularities (Lows) of the basement. Transgression of the sea led to development of lagoon-tidal flat complex in which limestone dominated lithounits of the rest of the Semri Group were deposited. At the end of the deposition of the Semri Group, the basin was completely drained out as evidenced by an unconformable surface elsewhere, however, in Son Valley the contact between the Lower Vindhyan and the Upper Vindhyans is gradational at places. The three sub-groups Kaimur, Rewa and Bhander, which, conformably overlain in ascending order, are dominated by clastics and are characterised by near-shore depositional environment. The entire Vindhyan sequence, in general, thus, appears to have been deposited in cycles of recurring transgressive and regressive sea. Development of good source rock facies, because of such a favourable environment of deposition in a restricted shallow marine condition within a rifted (half graben) part of a stable craton, is quite likely.

In the sole exploratory well drilled in the Vindhyan Basin to date, hydrocarbon occurrence is associated with porcellanite layer of the Deonar Formation. However, because of lack of adequate primary porosity its commercial potential is severely limited.

Present study has brought out presence of important inverted anticlinal structures in the sub-surface in the Lower Vindhyan, which may have resulted in adequate maturity and good amount of secondary fractured porosity. This is important from hydrocarbon exploration viewpoint in the deeper part of the Lower Vindhyan where sediments are overmatured with meager amount of primary porosity development. As these structures are inverted and have formed due to differential block movement along the oblique fault system and Son-Narmada-Lineament, they are likely to be potential targets of hydrocarbon exploration.

Moreover, origin of porcellanite in Vindhyans is generally attributed to pyroclastic sedimentation. However, cyclic interstratification of porcellanite layer with siliceous shale and marl bands can originate because of biogenic silica sedimentation also. Changing detrital silica percentage may lead to diagenetic transformation of silica into porcellanite preferentially in a layer of higher biogenic silica content. Similar phenomenon has been reported from San Joaquin Basin, California, USA where brecciated porcellanite layers interstratified with siliceous shale have acted as commercial hydrocarbon reservoir. Horizontal fractures in the core sample from porcellanite are observed in Vindhyans as well. They may have developed because of mechanical properties of porcellanite, and as such can substantially improve the reservoir potential of the Deonar Formation.

20. VINDHYAN STRATIGRAPHY IN INTER-REGIONAL PERSPECTIVE

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The Vindhyan Supergroup of Central India represents a major geological event in the Indian subcontinent. Its equivalent sedimentary deposits are spread in peninsular and extrapeninsular India. Of these, the Cuddapah and the Kurnool basins of south India and the Shali-Deoban-Krol-Tal sequences of the extrapeninsular India form major sedimentary sequences of the Indian subcontinent. To consider the Precambrian-Cambrian boundary in broad inter-regional perspective along with the palaeobiological evidences, other geological signatures like those of lithostratigraphy, and geochronology need to be taken into account. A review of these evidences towards correlation is presented to assess the problem of Precambrian-Cambrian boundary.

21. DISCOVERY OF ENIGMATIC MICROBIAL MAT TEXTURES AND PROBABLE EDIACARAN FOSSILS FROM THE UPPER BHANDER SANDSTONE FORMATION, VINDHYAN SUPERGROUP , MAIHAR AREA, CENTRAL INDIA

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Several palaeobiological evidences supported by geochronometric data from the Vindhyan Supergroup have generated a well-constrained biostratigraphic scheme for the entire succession. Records of stromatolites, organic-walled microfossils from the bedded cherts and shale facies and carbonaceous compressions, (?) trace fossils, etc. from different lithounits have provided the exceptional database to recognize the various evolutionary parameters of the Proterozoic biosphere.

The lower division of the Vindhyan Supergroup (the Semri Group) has so far been known for its various palaeobiological evidences. Lately, the upper part (the Rewa and Bhander groups), apart from stromatolites, has been demarcated by a number of horizons which have exceptional fossil content in them.

Although a host of geochronometric dates for the various horizons of the Vindhyan succession provide a broad geochronological frame-work, the youngest lithounits (*i.e.* the Bhander Group) have not yet provided any definite age-diagnostic evidences that could help in dating the terminal Vindhyan depositional event. The paper discusses the occurrence of certain palaeobiological evidences that could help in ascertaining the geological age of the youngest part of the Vindhyan sequence.

I herewith report, for the first time, the discovery of algal mat covered bedding surfaces of the sandstone, where pristine mat fabric (mat texture) is preserved in its varied forms. Such mat fabric was earlier recorded from the Ediacaran fossil bearing horizons of Australia and Russia (Fendonkin, 1992) where bedding surfaces show warty, pustular textures, referred to by Russian palaeontologists as "old elephant skin", a good lead to hunt for Ediacaran fossils. These textures were rarely found in horizons that do not contain Ediacaran fossils and these fossils were almost never found in beds that lack such fabrics. Gehling (1986), perhaps for the first time, recognized the similarity between these surfaces and modern microbial mats and concluded that these mats were instrumental in stabilizing the mud surface and perhaps providing a "death mask" on the organism itself. Later, Gehling (1987) also suggested that impressions of partly rolled-up and distorted membranous mats suggest algal mantling of these (clayey substrates with tiny Ediacaran organisms) surfaces during fair weather, as a mechanism for protection of clayey surfaces by storm events.

In the Maihar area, the Upper Bhander Sandstone Formation constitutes a sequence of thick sandy units intercalated with siltstone and minor shale horizons. A few bedding plane surfaces show different types of ripples, syneresis cracks, load casts besides planar cross bedding in vertical sections. The underlying sequence of the Sirbu Shale Formation shows a shale dominated litho-succession with occassional thin sandy horizons. The sequence is quite well exposed in the vicinity of Maihar township. A few of the bedding planes of the Upper Bhander Sandstone Formation show well developed microbial mat textures and a number of blobby structures on the top as well as under surfaces. These mat structures are tentatively categorised into following six types:

(a) Type 'A' – Parallel but smoothly laminated (Plate 1 - a)

(b) Type 'B – Intensely wrinkled but laminated (Plate 1 - b)

(c) Type 'C' – Anastomosing (Plate 1 - c)

(d) Type 'D' – Network (Plate 1 - d)

(e) Type 'E' – Branching (Plate 2 - a)

(f) Type 'F' – Pitted and wrinkled (Plate 2 - b)

(In all figures, one division is equal to 1 cm)

It is believed that the grain size of sediments, type of microbial mat community and environmental conditions controlled the texture of these mat laden surfaces. Further work on these mat textures is in progress.

PROBABLE EDIACARAN FOSSILS

Apart from these microbial mat textured surfaces, a number of blobby (circular to elliptical) structures occur as hyporelief on the under surface of these mat laden beds . They are also recorded from the Sirbu Shale Formation. These are 2 mm to 2 cm in diameter, have occassional concentric markings with a central tubercle structure and occur either in clusters or as a solitary form (Plate 2 - c). These are closely comparable to the Ediacaran forms - *Beltanelliformis* and *Nemiana*. One of the specimens shows a faintly developed disc-like structure with an inner ring and a number of spindle-shaped bodies filled between inner and outer rings (Plate 2 - d). This structure is closely comparable with the Ediacaran taxa *Irridinites multiradiates*. These circular and few other structures coexist with surface scratch marks and irregular meandering trace like features.

A close scrutiny of the recently discovered material from the Upper Bhander Sandstone Formation suggests that there possibly existed a series of palaeobiological evolutionary events that occured very close to the Ediacaran time (mid to late Vendian) when the microbial mat textured surfaces developed along with the evolution of the elementary members of Edicaran animals. In a recent personal communication, J. G. Gehling (Australia) has clarified that *"Mat textures should have been around on bedding surfaces for the whole Proterozoic, but they seem only to be apparent on the Terminal Proterozoic siliciclastic surfaces."* It is therefore concluded that the existence of these mat textures, along with possible Ediacaran fossils, support the author's contention of a Vendian age (~570 Ma) for the Bhander Group which is at variance with the age proposed by Kumar and Srivastava (1997) supporting a 700-650 Ma (Riphean) for the Bhander Group.

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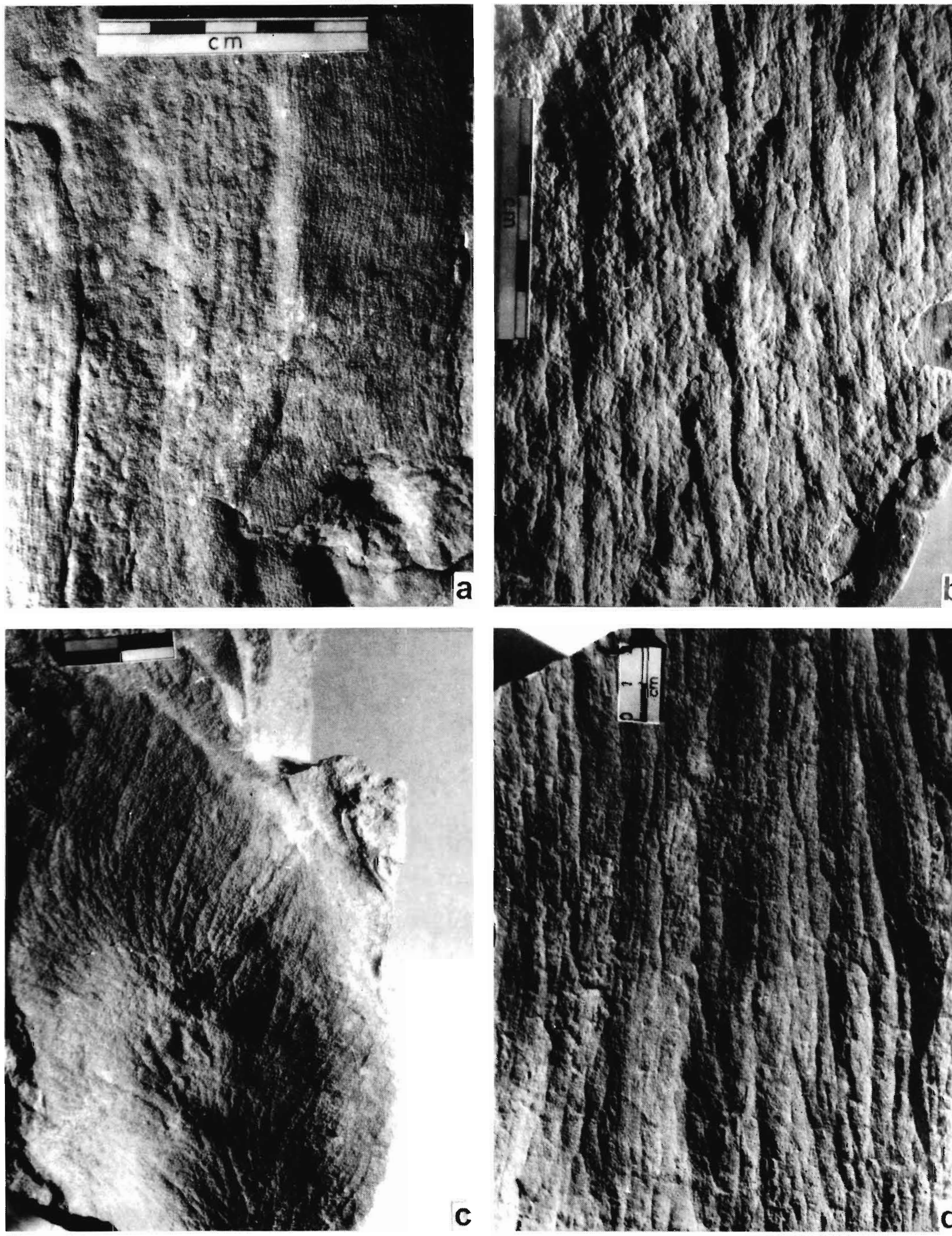

Plate 1 : Microbial mat textures from the upper Bhander Sandstone Formation (a-d).

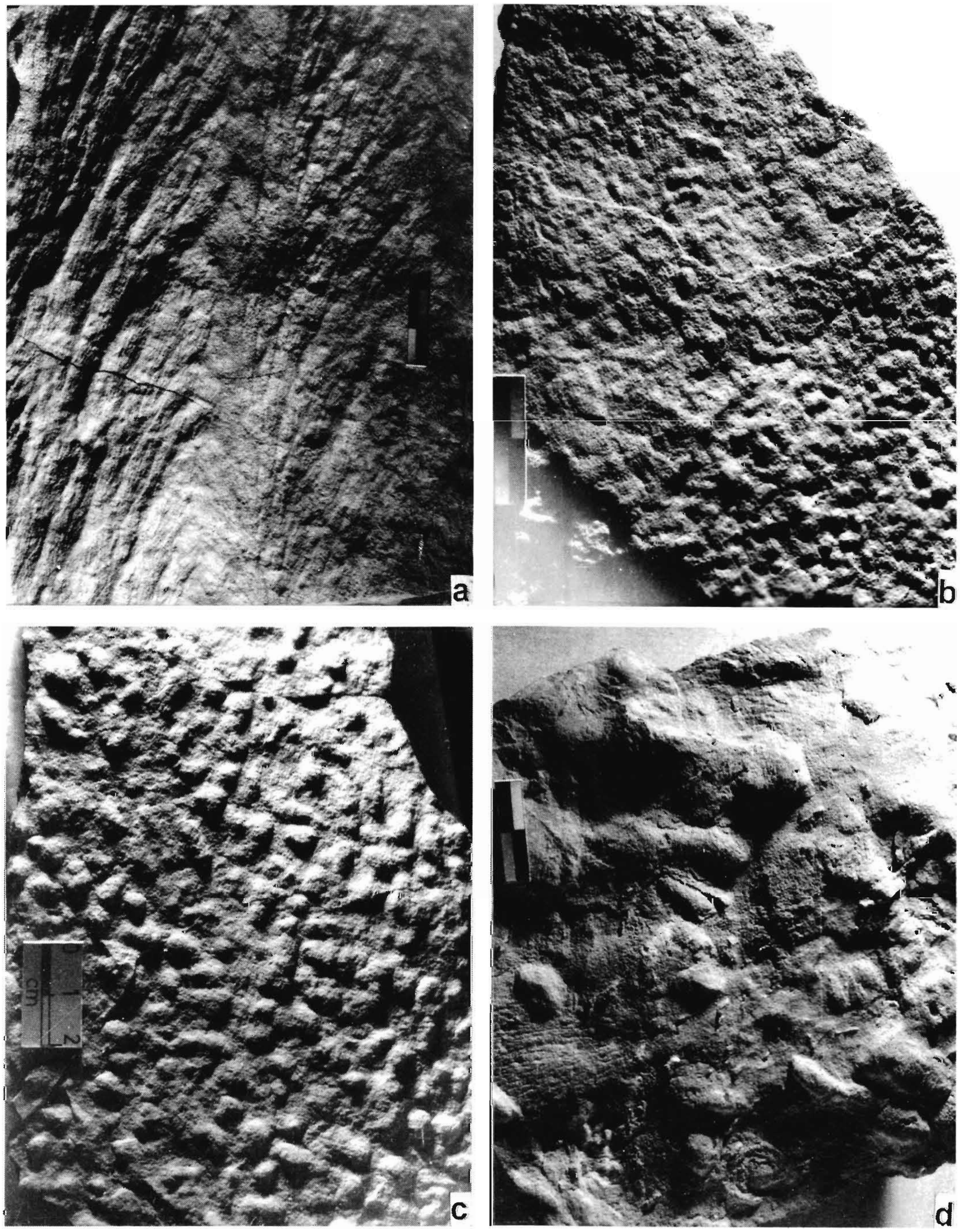

Plate 2 : Microbial mat textures from the Upper Bhander Sandstone Formation (a, b), Blobs having Ediacaran fossil affinity from the Sirbu Shale Formation (c), Ediacaran disc (?) from Upper Bhander Sandstone Formation (d).

22. FACTS, ARTIFACTS AND THE VINDHYAN PALAEOBIOLOGY

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The Vindhyan Supergroup, one of the most prominent Proterozoic sedimentary basins of India, has lately been dogged by controversies in recent months. Two palaeontological findings, which curiously enough were published almost simultaneously, from closely spaced stratigraphic horizons within the lower Vindhyan succession (Semri Group), support two distinct time lines with a huge gap of over half a billion years, within the geological time-scale. The first report indicates an early Cambrian (~ 540 Ma) age for the Rohtasgarh Limestone Formation, the youngest lithostratigraphic unit of the Semri Group (Azmi, 1998) and the second report suggests a Mesoproterozoic (~ 1100 Ma/ Mid Riphean) age for the strata underlying the Rohtasgarh Limestone Formation (Seilacher *et al.* 1998), the Churhat Sandstone Formation. Apart from these, few new evidences have also been evaluated in the light of existing biostratigraphic scheme of the Vindhyan Supergroup.

Proterozoic is a time span that represents the part of the earliest biosphere when major evolutionary changes set the pattern for future diversification of life on the planet earth which experienced the explosion of life forms with the beginning of Phanerozoic. The Vindhyan succession in central India remains the key stratigraphic succession in the world that provided, perhaps the first glimpse of some of the megascopic fossil remains of Proterozoic Eon (Rai and Gautam, 1998). The sound biostratigraphic scheme of a time span ranging from ~1400 Ma to ~570 Ma has lately been proposed to be modified on the basis of a couple of new findings. Both these reports are discussed herewith critically in order to lift the veil from existing controversies.

In the first report, Azmi (1998), while pursuing his contention of a Proterozoic to Late Cambrian model for the Peninsular and Extra-peninsular basins (Azmi, 1993), has attempted to support it by providing fossil evidences. These evidences are at variance with all other palaeobiological and geochronometric data that support a Mesoproterozoic to Neoproterozoic (Riphean to Vendian) age for the entire Vindhyan succession. Recently, a few published reports (Convay Morris *et al.*, 1998, Kerr, 1998a,b) commenting on Azmi's (1998) discovery appear to have virtually invalidated it and are supportive of the following comments.

A critical examination of the contents of the paper suggests that the illustrated fossil material needs to be tested for its biogenicity first as most of the illustrated material lack the specific characteristics of brachiopods and small shelly fossils. Assemblage wise, the comments are as follows:

Brachiopods: In Plate 1 (1-8, 12) of Azmi (1998), the conical structures resemble the diagenetically generated sedimentary structure "*cone-in-cone*" which has a pointed apex that flares outward with corrugated undulatory surfaces. Such structures are observed in calc-argillaceous sediments with dimensional range of few mm to few cm. Composite "*cone-in-cones*" are quite common when several cones can generate fused structures. The acrotretid brachiopods are phosphatic and obolellid brachiopods are calcareous in chemical composition. In the absence of any mineralogical details for Azmi's brachiopods, it is improper to compare the specimens with any of the two genera. Since the illustrated SEM photographs are from the latex cast, much finer details are missing for comparison. Reasons have also not been given for avoiding the SEM of original brachiopod "shell" material. Moreover, in a reply to several rejoinders to his discovery, Azmi (1999) himself has disowned these structures as brachiopods. However, he has not commented upon the affinity of his illustrated forms.

Small Shelly Fossils: The entire assemblage has been put under the following two broad categories:

Younger Assemblage – In Plate 1 (9-11, 13-23) of Azmi (1998), the so called sclerites and scleritomes (belonging to tommotiids and halkieriids, *sensu* Azmi) have faint resemblance with small shelly fossils of early Cambrian age. However, since the mineralogical composition of tommotiids and halkieriids should essentially be phosphatic and calcareous respectively (Bengtson *et al.* 1990), the present material does not seem to represent either of the groups (there is no mention about the mineralogical composition of these (?)fossils which have been derived from the limestone and shale lithologies). At best, these can be grouped under the pseudo-fossil (Hofmann, 1972) category.

Older Assemblage – In Plate 1 (24-28) of Azmi (1998), the specimens appear to be quite convincing as far as their biogenicity is concerned. Similar morphotaxa have earlier been recorded from Mesoproterozoic to Neoproterozoic horizons of the world. Cyanobacterial and algal microfossils within the close dimensional range of the illustrated material having variable morphologies are known from China, Australia, India and a few other countries. Coiled cyanobacterial remains (*Obruchevella*) are well known from Russia (Shenfil, 1983) and India (Rai *et al.*1996, Srivastava and Kumar, 1997) from the Riphean sequences. Spherical coccoidal remains with 100 microns or larger diameter are quite commonly recorded (Sergeev *et al.* 1997) besides the conical algal remains (*Polybessurus bipartius*) are well known from Meso-Neoproterozoic sequences (Sergeev, 1994). The Vindhyan specimens, although preserved in the mineralized (skeletal) form, are closely comparable with several microalgal-cyanobacterial fossil remains (Brasier and Singh, 1987).

Azmi's (1998) *Talliella himaliyaica* is an invalid taxa and a *nomen nudum.*The taxonomy appended at the end of the article by Azmi (1998), compares the newly generated taxa with the existing taxa *Tumuliolynthus orthacanthus* Yang and He, 1984 in an "*overall similarity and particularly the apically directed spines*". Since *Tumuliolynthus orthacanthus* is a valid taxa, the newly erected taxa could only be put under its synonymy. Under the circumstances, there would be no validity of the age implications and biostratigraphic significance of *Talliella himaliyaica*. Moreover, the specimen from Vindhyan (Plate 1- 28) does not show any spiny structure on the surface (nodal, surfacial or apical), in order to be considered as *Tumuliolynthus orthacanthus* (*Talliella himaliyaica*).

Azmi's (1998) contention that the Vindhyan Basin represents a Terminal Proterozoic-early Palaeozoic basin merely on the basis of some obscure pseudofossils is at variance with the works of several palaeontologists and a host of other geologists. Moreover, early Palaeozoic is the time interval comprising Cambrian, Ordovician and Silurian (Cowie and Bassett, 1989; Encyclopædia Britannica, 1995) with a total time-span of about 130 million years. No supportive evidences have been given to substantiate the claim that the "Vindhyan Basin" ranges in age up to early Palaeozoic (till Silurian).

According to IUGS-ICS decision of Kyoto, IGC (Landing,1994), the Precambrian-Cambrian boundary is to be based on the first occurrence of ichnozone *Phycodes pedum.* The strata below would be Terminal Proterozoic and the strata above would be earliest Cambrian. Azmi's (1998) paper has, however, erroneously demarcated the "P∈ - ∈ boundary" using the so called small shelly fossils and brachiopods in the Rohtasgarh Limestone of the Semri Group without considering the International stratigraphic norms.

The correlation of the Blaini Conglomerate of the Mussoorie Group (Lesser Himalaya) with the Basal Conglomerate of the Vindhayn Basin is not understood because mere lithological similarities can create complications in the stratigraphic correlations (significant confusion has been created in the past due to similar correlation between the Talchir Boulder Bed of Permian age and the Blaini Boulder Bed/ Conglomerate of Varangerian age).

Most of the Vindhyan succession is developed in a shallow marine setting under the influence of wave and currents (Krishnan and Swaminath, 1959; Srivastava *et al.* 1983; Sastry and Moitra, 1984; Akthar, 1996; Mitra, 1996; Chakraborty and Bhattacharya, 1996a). Exceptionally well developed stromatolites in the lower and upper Vindhyan successions (Kumar, 1980; Mathur, 1981; Barman and Verma, 1982) with the records of microbial mats with well preserved silicified microbial fossils (in bedded cherts) (McMenamin *et al.* 1983; Rai *et al.* 1998) and carbonaceous mega-remains viz. *Chuaria-Tawuia-Grypania,* etc. (Kumar, 1995; Rai *et al.* 1997; Rai and Gautam, 1998) support the marine set-up in most of the sequence. The occurrence of glauconites in all the four groups, i.e. Semri, Kaimur, Rewa and Bhander again supports the dominance of marine influence in the depositional basin. Undoubtedly, there are a few fluviatile horizons in the upper part of the succession, nevertheless they do not constitute the major depositional system (Chakraborty and Bhattacharya, 1996b; Chakraborty, 1996).

The previous reports of the fossil occurrences belonging to a host of animal and plant affinities of the Cambrian age have long been settled and there is now a general consensus that all these fossil remains represent morphotaxa restricted to mega-algal remains only (e.g. *Chuaria* and associated forms) (Sahni, 1977). The fossil occurrences of the supposedly younger ages (younger than Proterozoic) were either modern contaminants or artifacts (Schopf and Klein, 1992) or were not available for subsequent study. Azmi (1998) has misquoted the ages of the strata yielding *Chuaria-Tawuia* occurrence from Spain and Iran. Contrary to the statement that this assemblage *"is long ranging and is reported to occur up to or above the P∈ - ∈ Boundary"*, the authors of the references cited by Azmi, clearly illustrate:

(1) in Spain, the *Chuaria* bearing horizons (note that *Tawuia* has not been cited by them) belong to the "Pusa Shales" (Brasier *et al.* 1979, Fig. 1, p.380) which are restricted to the Vendian only and (2) in Iran, the Chopoghlu Shale (Lower Shale Member) of the Soltanieh Formation (Hamdi, 1989, Fig. 3, p.8) is Vendian in age. In China, the *Chuaria-Tawuia* assemblage is recorded from a number of horizons of the Huaibei Group (Zang and Walter, 1992) which is considered to be of Sinian age on the basis of microfossils, stromatolites, carbonaceous megafossils and K-Ar dating (Yang *et al.* 1980; Yao and Zhang, 1983; Yan Yongkui, 1984; Zhang Shi-en *et al.* 1984; Cao *et al.* 1985). An anomalous record of small shelly fossils (Zhou Benhe *et al.*1984) of the probable lower Cambrian age from the uppermost part of Huaibei Group (Jingshanzhai Formation) needs proper scrutiny and reproducibility as all other data are in favour of a Sinian age for the entire Huaibei Group.

Regarding the consideration of the radiometric dates for the Vindhyan sedimentaries and the intrusives, there does not appear any anomalous situation. The maxima for the lower Kaimur sediments by Fission Track (F-T) method on glauconite samples varies between 1240.9 Ma (Lodhwara) to 1230.9 Ma (Chitrakoot) (Srivastava and Rajagopalan, 1986) that fits well with the intrusive Kimberlite (Rb-Sr) dates of 1140+/-12. The correlation between the Vindhyan Supergroup and the Trans Aravalli Vindhyans (Marwar Supergroup) is not on one-to-one basis. In fact, only the terminal part of the Vindhyan succession correlates with the base of the Trans Aravalli Vindhyan succession. The Marwar Supergroup overlies the Malani rhyolites (~750 Ma) with an unconformity, the basal part of which, the Jodhpur Group has been lithostratigraphically correlated with the Upper Bhander Sandstone Formation of the Vindhyan succession (Sinha-Roy *et al.* 1998, Mishra, 1998). The Bhander Group overlies the Rewa Group which has been dated as ~710+/-120 Ma (Srivastava and Rajagopalan, 1988), which is in tune with the correlation of the Jodhpur Group in the Trans-Aravalli reagion.

In the light of the observations made above, it would be apparent that the inferences drawn by the learned author suffer from inadequacy of the relevant data, and possibly also an error of judgement in arriving at the stated findings. There is therefore, a need for a fresh reappraisal on more objective grounds for the article to merit a serious scientific attention.

In the second report by Seilacher *et al.* (1998) the report on "Triploblastic Animals more than One Billion years ago : Trace fossil evidences from India" needs urgent scrutiny as the discovery may prove to be misleading in the light of following aspects not given due importance in their published study:

In the Churhat Sandstone (Semri Group of the Vindhyan Supergroup), the reported occurrence of the burrows in the form of meandering, linear markings, considered to be made by peristaltic movements of some worm-like animals, can only be categorised at best as pseudo-trace fossils or cast of some megascopic algae. The above deduction is based on the following observations- (i) the author's explanation for the absence of any backfill (spreite) structure in the burrow tunnel is not supported by any evidence and is dubiously assumed by the authors to have collapsed, (ii) absence of any algal-mat impression (mat texture) on the bedding surface (what to say of its fossilized form !) makes their findings speculative, (iii) the rippled nature of the bedding indicating consistent supply of silt/sand under agitated energy conditions suggests a non-congenial environment for the delicate triploblastic animals (worm-like) to survive and to mine underneath the algal-mat, (iv) the absence of any faecal structures (coprolite) which naturally occur along with these burrows, as is seen in all present-day worms that produce such features in abundance after excretion, also creates doubt about these structures referred to as trace-fossils in the article in question. Moreover, the use of the term *"triploblastic "* is also inappropriate as authors have not given any conclusive evidence to support the triploblastic nature of their supposed animals.

An earlier study (Sarkar *et al.*, 1996), which has the distinction of discovering these trace-fossil like structures for the first time from these horizons (which in fact forms the basis of Seilacher *et al.'s* contribution), has treated the palaeoenvironmental reconstruction of these horizons quite thoroughly. This paper has well demonstrated that many of these trace(?)-bearing rippled horizons represent terrestrial environment with sufficient aeolian influence contrary to what Seilacher *et al.* (1998) have presented in their study. Moreover, even the associated supratidal-aeolian setting (Sarkar *et al.,* 1996) would not be suitable to sustain any delicate worm-like animal and algal-mat system due to very high aridity.

Lastly, the Vindhyan succession has long been reported to contain similar trace fossil occurrences that include worm-burrows as well, but all these reports have been ignored by the authors for the reasons best known to them. Moreover, the intensive survey of literature by us (Rai and Gautam, 1998) revealed that the earliest record of Proterozoic mega-fossils from the world were first noticed from the same Vindhyan Supergroup way back in 1823. Almost 50 records of different fossil findings were published since then, which included many of the exceptionally well preserved mega-fossils. It must be emphasized that if at all these newly discovered trace-fossils (?) are to be attributed to any biologically formed structure, they may best be considered to represent the cast of some large megascopic filamentous algae. One such form with close dimensional range *(Grypania* sp.) has been recorded by us (Rai and Gautam, 1998) from the beds a little higher up in the succession (Rohtasgarh Limestone Member) within the Semri Group itself. Recently, similar organic structures with curved to curvilinear shape have been considered to be trace-fossils made by some benthic eumetazoan organisms from 1400 Ma old Gaoyuzhuang Formation of Jixian, China (Yan and Liu, 1998) which in all probability represents a cluster of *Grypania* specimens.

A recent field trip undertaken in the Maihar and Churhat areas resulted in the discovery of microbial mat textured bedding surfaces in the Upper Bhander Sandstone Formation (Maihar Sandstone) which also shows small blobs of some Ediacaran animal impressions(?). Such mat-covered surfaces are typically recorded from the Terminal Proterozoic strata in Australia and Russia. The underlying Sirbu Shale Formation has also yielded well developed clusters of ***Beltanelliformis*** on the sole of sandy layers (Rai, 1999; this volume). This report also suggests a Terminal Proterozoic (Vendian) affininty to the biota. In one of the open cast limestone quarries at Badanpur near Maihar, the bedded limestone preserves a number of diagenetic and solution structures. A few stylolitized surfaces which incidently were parallel to the bedding planes, show highly crenulated surfaces with conical and clustered blobs spread throughout the bedding planes. These blobs could be mistaken for some fossil-like forms. In the Churhat Sandstone, a few specimens show meandering architecture on the rippled surfaces. However, the occurrence of abundant syneresis cracks and other dewatering structures overshadow the meagre occurrence of these enigmatic features. Further study on the specimens is under progress and detailed observations would be published separately.

* Parts of abstract were sent to the Journal of Geological Society of India as comments on the paper by Azmi (1998).

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23. OCCAMS RAZOR AND THE CURRENT VINDHYAN AGE CONTROVERSY

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The current Vindhyan age controversy awaits resolution. One approach is to examine possible scenarios in the light of Occams Razor which seeks to find the simplest solution for competing hypotheses. In the Seilacher *et al.* model, the antiquity of metazoans has been extended by nearly 400 Ma on the basis of published geochronological ages. This implies that the metazoan origin bio-event (MOB) in the Indian landmass was significantly different from the conditions prevailing globally. This basically contradicts Occams Razor, if the reported occurrences of worm tracks are indeed correct. On the other hand, Azmi reports small shelly fossils known globally at the start of the Cambrian. This report has yet to be authenticated as it contradicts the published radiometric ages. However, the metazoan burrows reported by several authors is concordant with Azmi's report. A possible third (armchair) scenario envisages a large temporal hiatus between the two viewpoints mentioned above and appears untenable in the light of the field data. In the ultimate analysis, the final solution rests on the duplication of Azmi's finds in the field.

24. GEOLOGY OF PARTS OF ALLAHABAD & MIRZAPUR DISTRICTS, UTTAR PRADESH WITH SPECIAL REFERENCE TO ITS MINERAL POTENTIAL

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The geology of the Vindhyan Super Group from the west of Allahabad district to the east of Mirzapur district was done to investigate the geology and mineral potential of the area. The rocks of the Kaimur Group, are represented by the Dhandraul Formation covering on both flanks of the Belan river which are present as a prominent plateau with altitudes varying between 110 to 140m above msl. The plateau is characterised by residual ferricrete with patchy rock exposures and localized lateritic cappings. The southern fringe of this plateau is marked by the narrow linear zone of Mesa and Butte formed after the differential erosion of the Rewa Group of rocks. Immediately south of this zone falls the vast Rewa plateau with altitude varying between 280 to 474m above msl.

The Dhandraul Quartzite represents the oldest rocks, exposed in the area which comprises dirty white, pink and brown coloured orthoquartzite and sandstone. Ferruginous zones on leaching produce residual soil which is 50 to 60cm thick. At places, the quartzite is very friable and has given rise to free sand suitable for manufacturing glass.

The Dhandraul Group of rocks are gradationally overlain by argillo-arenaceous sequence of rocks of the Rewa Group. The Panna Shales form the basal unit of the Rewa Group and are made up of olive green to chocolate brown splintery shales with gritty and conglomeratic bands. At places, it is glauconitic. The Panna Shales are overlain by discontinous bands of dark brown and gray-coloured sandstone-shale alternation with very prominent ichnofossils. Dirty Green and Chocolate Brown splintery shales with inter-bedded sandstone/siltstone bands forming the Jhiri Shale Formation overlie the Lower Rewa Sandstone Formation with a sharp contact. This unit is the thinnest amongst the litho-units of the Rewa Group but it shows roughly uniform thickness throughout the strike. The Upper Rewa Sandstone Formation comprising light gray to pink coloured quartzose, profusely bedded, sandstone with thin shale partings is the youngest unit of the Rewa Group of rocks which stands out as prominent scarps. Because of its fissile nature it is used for making large slabs for building purposes. Isolated patches of laterite varying from 2 to 3 m in thickness and up to 60 cm thick *morum* are found to occur over both the Dhandraul and Rewa plateaus.

25. ASPECTS AND APPRAISAL OF MEGASCOPIC FOSSILS IN VINDHYAN SEDIMENTS

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Megascopic fossils reported from the Precambrian sediments in different parts of the world, including multicellular remains, suggest that unicellular forms attained multicellular status during Terminal Proterozoic. The other major advancement in the biosphere, i.e. skeletogenesis, is normally considered to begin around Cambrian, though the form like *Cloudina* is known from a slightly older sediments of the Nama Group. In the back-drop of these global marker events, the conflicts between the palaeobiological evidences recorded so far and geochronological dating from the Vindhyan sediments are baffling. This inconsistency in the age inferred on the basis of these remains and radiometric dates leads to ambiguous conclusions. If all these evidences are accepted as genuine, we will have to accept early radiation of multicellularity and skeletogenesis in India, or alternatively these reports will have to be are rejected. Therefore, a thorough re-assessment of palaeobiological evidences is called for.

In the present appraisal, the multicellular forms are assessed for their biogenicity, syngenicity and age connotation. There are more than 50 records of megascopic entities including multicellular forms known from different groups of the Vindhyan Supergroup. When these records are assessed in association with the known data of biological evidences the world over, skeleton building processes and trace fossil records, it is found that most of them do not stand the scrutiny. It is noted that out of total 56 records, 27 are non fossils, 10 are dubio-fossils, 14 are fossils and no comments can be offered on the 5 reports. Maximum number of true fossils (8) and non fossils (19) have been recorded from the Semri Group. The carbonaceous megascopic remains that were once considered to be inorganic and later proved to be *Chuaria-Tawuia* assemblage form the major part of the accepted genuine fossils. These forms are generally found in the 600 –1000 Ma old sediments of the world, a time period also referred to as Chuarian age. *Tawuia* is not known from the sediments older than 850 Ma and, therefore, megascopic palaeobiological records indicate a younger age for the Semri Group. Similarly the evidences from the other groups are also indicative of a younger age bracket.

26. SEDIMENTATION AND DEPOSITIONAL ENVIRONMENT OF THE CHOPAN PORCELLANITE FORMATION, SEMRI GROUP, VINDHYAN SUPERGROUP IN PARTS OF SONBHADRA DISTRICT, UTTAR PRADESH

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The Chopan Porcellanite Formation (CPF) of the Semri Group (Vindhyan Supergroup) represents submarine and terrestrial volcaniclastic and volcanogenic epiclastic sediments. These sediments were deposited in a tidal-flat region of the Vindhyan Epicontinental Sea. Fissure and vent types of acidic-silicic volcanic eruptions (both submarine and terrestrial types) erupted periodically and resulted in the deposition of these sediments by means of the tidal and turbidity currents, which were operating side by side near the continental platform region to give rise to quiet (stable) and agitated (unstable) depositional cycles, preserved in the lithocolumns of the Chopan Porcellanite Formation, which essentially represents a mixed provenance.The study of the primary sedimentary structures, bedding features and lithologic association, supplemented by the grain-size and heavy mineral studies confirm the findings.

27. ADDITIONAL CARBONACEOUS MEGAFOSSILS FROM THE BHANDER GROUP, MAIHAR AREA, MADHYA PRADESH

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Chuaria-Tawuia assemblage along with few ribbon-like filamentous forms has already been reported from the Neoproterozoic Bhander Limestone and the Sirbu Shales exposed at the Maihar area, Madhya Pradesh. An additional carbonaceous megafossil assemblage is being reported. The assemblage is represented by

- Domination of chuarids exhibiting a wide range of diameter from 0.2-6.0 mm.
- Morphological variation among *Chuaria* itself noticed as
    - (a) Circular discs with marginal thickening and folds
    - (b) Circular discs with marginal laminations
    - (c) Circular discs with cracked surfaces
    - (d) Circular discs with thick/thin smooth margins
    - (e) Circular discs with prominent intracellular mass
    - (f) Circular discs with outer sheath
- Sparsely occurring *Tawuia* with or without marginal folding and cracks
- Prominent v-shaped engroovement or opening in a circular disc.
- Most of the forms are sessile whereas in few forms presence of stalk or hold fast has also been noticed.
- Very thin thread-like filaments exhibiting branching.
- Rare presence of branching among thick filaments or sheaths.
- Irregular morphologies exhibiting some resemblance with fungal structures.
- Linear arrangement of circular disc-like structures with a holdfast-like morphology at the tapered end.

- A sinuous semicircular/arched, thick tubular structure with shrinkage in inner margin, smooth outer margin and a slightly tapering end.
- Irregular filamentous sheath-like structure of variable diameters; and globular structure, dilated at one end and tapering at other,
- A perfect ring-like structure of questionable affinity,
- A globular body with incomplete margins, with very small spheroids very close to the damaged margin, can be interpreted as oospores coming out of sporangium-like spheroidal body.

The overall assemblage exhibits relatively more diversification and better preservation of forms in comparison to the other known megafossil assemblages of the Vindhyan Supergroup. Since carbonaceous megafossil assemblage from the youngest lithounit of the Vindhyan Supergroup, i.e. the Dholpura Shales exposed in Rajasthan has already been reported (represented by *Chuaria-Tawuia* and few other forms), diversity of present assemblage supports the long-term decline in global and local diversity of planktic eukaryotes and apparently some prokaryotic groups, through the end of the Proterozoic times. It is evidently reaching a minimum in the Vendian. It can also be inferred that biotic diversity among carbonaceous megafossils is basically facies controlled, preferably low energy lagoonal setting in subtidal zone.

28. PROTEROZOIC-CAMBRIAN STRATIGRAPHY AND SEDIMENTATION IN THE WESTERN LESSER HIMALAYA AND ITS CORRELATION WITH THE EASTERN HIMALAYA AND THE VINDHYANS

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The North-western Lesser Himalaya is characterised by two major sedimentary belts in sequence stratigraphic order. 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 Quartzite and volcanics) (III) Microbial-stromatolitic carbonate-phosphorite (Shali-Larji-Deoban-Lameri-Pipalkoti-Gangolihat-Dharchula) and (IV) Argillo-calcareous (Mandhali-Sor-Thalkedar units with Vendian stromatolites and recently discovered trace fossils). A correlation with Vindhyans is discussed.

The sedimentation initiated with an earliest Proterozoic rifting event (2500 Ma) followed by a shelf cycle of tidal flat sedimentation during Palaeoproterozoic and subsequent rifting events during Mesoproterozoic (1000-1600 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 and stretching over a distance of 350 km showing major facies variations at Solan, Nigalidhar, Korgai, Mussoorie, Garhwal and Nainital synclines. 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 Central part (Nigalidhar-Korgai-Mussoorie and Garhwal synclines). After the early Vendian rifting the 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 cyclic para sequences like 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 eye structure, microbial laminated and stromatolitic build-ups, oncolites indicate that the depositional environment was tidal flat (high energy peritidal).

The Ediacaran metazoan facies of the Krol is finely laminated siltstone and shale with wave ripples. 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. The Precambrian/ Cambrian boundary transitional facies shows upwelling and stratification of sea as revealed by carbon isotope excursions of Krol-Tal basins. The other Lower Cambrian facies of the Tal Formation includes bioturbated purple grey siltstone (trace fossil) facies and channel sandstone, orthoquartzite facies of fluvio-deltaic and marine shelf facies at the top of the sequence. The Krol-Tal basin was possibly obliterated during Lower Cambrian due to Pan African epeirogenic movements around 550 Ma. 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. Tewari (1998a) has attempted a correlation between the Proterozoic and Cambrian sedimentary rocks of NW and NE Himalaya. The Buxa-Miri Group of rocks in Ranjit Valley and Arunachal Pradesh may be equivalents of the Krol-Tal sediments and, therefore, the potential areas for search of Ediacaran biota, stromatolites and trace fossils.

It is quite interesting that identical assemblages of stromatolites, vendotaenides and Ediacaran biota has been recorded from the Deoban, Infra Krol and Krol formations of the Lesser Himalaya of India and the Sinian, Doushantuo and Dengying formations of China (Tewari, 1998b). 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.

29. CORRELATION OF VINDHYAN AND LESSER HIMALAYAN SEQUENCE STRATIGRAPHY AND PALAEOBIOLOGY

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The Vindhyan Basin is traditionally accepted as Meso-Neoproterozoic in age, since 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 *Phycodes pedum.* The records of Middle Proterozoic (Mesoproterozoic/Riphean) micro and mega fossils like cyanophytes, acritarchs *Chuaria* and *Grypania*, etc. (Mc Menamin *et al.*, 1983; Maithy and Shukla, 1984; Kumar and Srivastava, 1992; 1995; Venkatachala *et al.*, 1990) from Vindhyans are undisputable and indicate a diversified biota at 1200- 1000 m.y. The occurrence of typical Riphean stromatolite taxa from Lower and Upper Vindhyans like *Kussiella kussiensis, Colonnella columnaris, Conophyton garganicum, C. cylindricus, Baicalia* Maslov, *B. satnaensis, Tungussia* sp. and *Gymnosolen* sp. are identical to the Southern Urals of type area in Russia /former USSR (Valdiya, 1969, 1989; Raha and Das 1989; Raaben and Tewari, 1987; Tewari, 1989) (Fig. 1). It is important to mention here that no Vendian

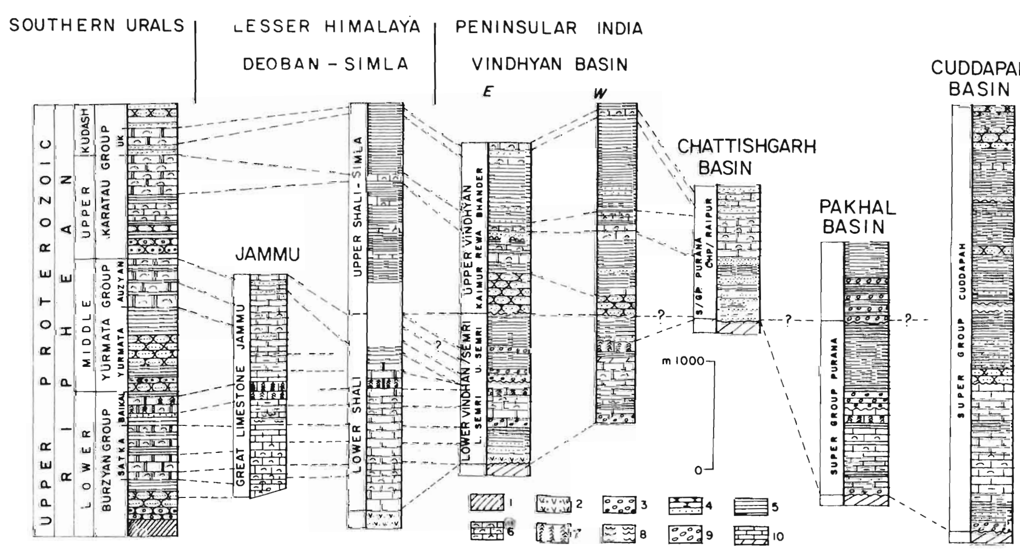

Fig. 1. : A regional correlation of stromatolite assemblages.

or Lower Cambrian stromatolite taxa described from Krol-Tal sequence of the Lesser Himalaya or Siberian platform is present in Vindhyans (Tewari, 1989, 1993).

The Lower Vindhyan (Glauconitic Sandstone) has been radiometrically dated at 1110 ± 60 m.y. (Vinogradov *et al.,* 1964). Underlying the Glauconitic Sandstone the Fawn Limestone, thus confirms the Lower Riphean age based on the stromatolites (Valdiya, 1969; Kumar, 1976). The Rohtas Formation, overlying the Glauconitic Sandstone may be taken as Middle Riphean (1000- 1100 m.y.) for 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 Tugarinov *et al.* (1965), Vinogradov *et al.* (1966) and found to be 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 and suggested that the Lower Vindhyans should be 1200 m.y. or older.

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.F.'s appeared after Ediacaran fossils in 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 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 *Phycodes pedum.* Moreover, the PC/C boundary in most of the Asian sections (China, Lesser Himalaya-Krol, Tal, Mongolia and Iran) is in phosphorites.

Azmi (1998) has reported 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) resemble those with affinities of *Stoibostrombus crenulatus* Conway Morris and *Bengtson* gen. et sp. nov. and "Ornamented Cones" described from South Australia.

The discovery of triploblastic metazoans from the Lower Vindhyans (1.1 billion years) by Seilacher *et al.* (1998) suggests that multicellularity must have existed during Mesoproterozoic and contradicts the Lower Cambrian age of the Lower Vindhyans. The biostratigraphic correlation between the Mussoorie Group of the Lesser Himalaya and the Semri Group of the Lower Vindhyan is also not tenable and unacceptable since the Blaini-Krol-Tal sequence is firmly established as a Terminal Proterozoic-Lower Cambrian succession (~ 650-550 m.y.) based on palaeontological and isotopic signatures (Brasier and Singh; 1989; Bhatt *et al.,* 1983, Kumar *et al.,* 1983; Tewari, 1984; Mathur and Shankar, 1989; Singh and Rai, 1983; Aharon *et al.,* 1987; Kumar and Tewari, 1995). There is no strong evidence to believe that the Basal Conglomerate of Lower Vindhyan could be equivalent of the Blaini Conglomerate in sedimentary facies, depositional environment and isotopic age.

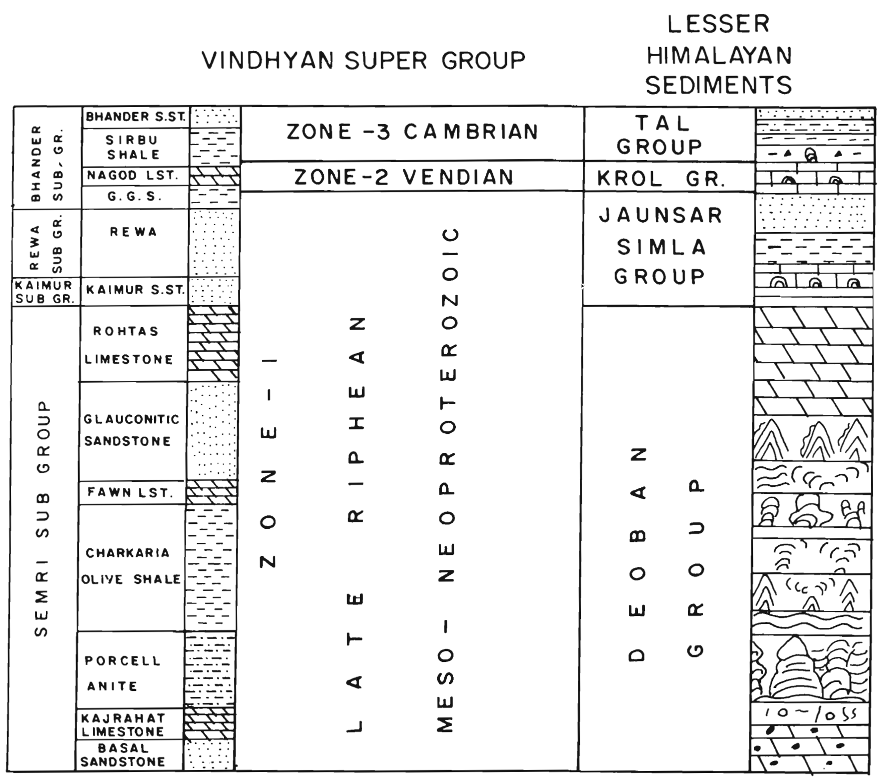

Fig. 2. : Correlation of Vindhayan and Lesser Himalayan sediments.

Valdiya (1969), Kumar and Tewari (1978), Raha and Das (1989), Shukla *et al.* (1986), Tewari (1989, 1993, 1996), Raaben and Tewari (1987), Kumar and Srivastava (1995) have correlatd 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 of the Krol-Tal sequence (Aharon *et al.,* 1987; Kumar and Tewari, 1995) is also different from that of the Upper Vindhyan (Friedman and Chakraborty, 1997). Tewari (1996, 1997) has further established that the Deoban belt (Meso-Neoproterozoic pre-Blaini) is entirely different from the Krol Belt (Terminal Proterozoic-Cambrian post Blaini) in biota, sedimentary facies and isotopic signatures. The Deoban belt is correlatable with the Lower Vindhyan on the basis of identical occurrence of stromatolite assemblages *Kussiela kussiunsis, Conophyton garganicum, Colonnelia columnaris, Jacutophyton, Baicalia nova* and microbial assemblage of *Myxococcoides minor, M. grandis, Huronispora* 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). This assemblage is globally distributed in the rocks dated around 1200-1000 m.y. in age except few long ranging forms.

It is important to mention here also that the stromatolite biozones of the Lesser Himalaya (Zone I, II, III) found in the Deoban and equivalent carbonates are also recorded from the Lower Vindhyan Semri Group (Tewari, 1989). 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 the Vindhyan basin. A tentative correlation chart of the Vindhyan Supergroup with Lesser Himalaya sediments is given in Fig. 2.

Stromatolites and their microstructures are still successfully being used the world over for biostratigraphic correlations of Proterozoic rocks like Siberian platform, Canada, South Africa, Australia, China and elsewhere (Schenfil, 1989; Komar, 1989, Krylov, 1975, Grey, 1982, Hofmann and David, 1998, Tewari and Joshi, 1993, Zhu, S.X., 1982). Stromatolites (microbialites) are 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 micro-organisms 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 namely, (i) there are numerous modern analogues like Shark Bay in Australia, where biological influences in their morphogenesis can be directly observed (Bauld *et al.*, 1992) (ii) some stromatolites contain microfossils arranged in patterns indicating that they are responsible for the construction of the laminae (Walter *et al.*, 1992) and (iii) in the modern world it is difficult to find any stromatolite-like objects that are demonstrably abiotic. Furthermore, Jones *et al.* (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.

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