DISCOVERY OF LOWER CAMBRIAN SMALL SHELLY FOSSILS AND BRACHIOPODS FROM THE LOWER VINDHYAN OF SON VALLEY CENTRAL INDIA, by R.J. Azmi, Jour. Geol. Soc. India, v.52, pp.381-389, 1998

(1)

V.C. Tewari, Wadia Institute of Himalayan Geology, Dehra Dun comments:

The paper reports doubtful Lower Cambrian small shelly fossils and brachiopods from the Lower Vindhyan (Mesoproterozoic or Lower to Middle Riphean age) from Maihar and Rohtas areas in the Son valley. I wish to offer the following comments on the paper:

1. The reported microfossils have been compared with the Lower Cambrian assemblage of 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. It is quite surprising that the newly reported forms have not been described systematically, whereas *Taliella* n. gen. is described from Chert-Phosphorite Member of the Lesser Himalaya.
2. Some of the reported microfossils (Plate 1, Figs. 2, 10,11, 17, 18) have affinities to *Stoibostrombus crenulatus* Conway Morris and Bengston gen. et. sp. nov. and "*Ornamented Cones*" described from South Australia. The correlation of Semri Group with basal Meischucunian/Tommotian to Early Atdabananian is not acceptable on the basis of present finds. These structures could be inorganic in origin and organic geochemical studies may resolve this problem.
3. The author's conclusion that Vindhyan basin forms a Terminal Proterozoic to Early Palaeozoic basin of the Indian shield is not acceptable since there is no definite record so far of Terminal Proterozoic fossils like Ediacaran biota, body fossils like trilobites and the trace fossil *Phycodes pedum* in the Vindhyan. The record of Middle Proterozoic (Mesoproterozoic/ Riphean) fossils like cyanophytes, acritarchs etc. (Mc Menamin et al. 1983; Maithy and Shulka, 1984; Kumar and Srivastava, 1995; Venkatachala et al. 1990) from the Vindhyan is indisputable and indicates a diversified biota at 1200-1000 m.y. The occurrence of typical Riphean stromatolite taxa from the Lower and Upper Vindhyan like *Kussiella kussiensis*, *Colonella columnaris*, *Tungussia* sp. and *Gymnosolen* sp. are identical to those of southern Urals which is the type area in Russia/former USSR (Valdiya, 1989; Raha and Das, 1989; Tewari, 1989). It is important to mention here that no Vendian or Lower Cambrian stromatolite taxa described from Krol-Tal of the Lesser Himalaya or Serbian platform is present in the Vindhyan (Tewari, 1989, 1993).
4. The Lower Vindhyan (Glauconitic Sandstone) has been radiometrically dated at 1110±60 m.y. (Vinogradov et al. 1964). The Fawn Limestone underlying the Glauconitic Sandstone thus confirms the Lower Riphean age based on stromatolites. 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). Crawford and Compston (1970) based on Rb/Sr ratio of phlogopite from kimberlite which is intrusive into the Kaimur Group assigned 1150 m.y. age and suggested that the Lower Vindhyan may be 1200 m.y. or older.
5. Small shelly fossils have not so far been recorded from any Riphean sequence of the world and according to the currently accepted evolution of life on the Earth, SSF's appeared after

the Ediacaran fossils in the Late Vendian-Early Cambrian. The Lower Vindhyan sedimentary facies is also not suitable for the preservation of the Ediacaran biota and phosphatic SSF's. Therefore, there is no question of delineating precise PЄ/Є boundary in the uppermost strata of Rohtasgarh Limestone as proposed by the author (PЄ/Є boundary according to the decision of IUGS/IGCP is based on the first appearance of *Phycodes pedum*). Moreover, the PЄ/Є boundary in most of the Asian sections (China, Lesser Himalaya-Krol-Tal, Mongolia and Iran) is in phosophorites.

6. The biostratigraphic correlation between Mussoorie Group of the Lesser Himalaya and the Semri Group of the Lower Vindhyan is also not tenable since 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; Mathur and Ravi Shanker, 1989, among others). There is no strong evidence to believe that the Basal Conglomerate of Lower Vindhyan could be the equivalent of the Blaini Conglomerate in sedimentary facies, depositional environment and isotopic age. The author has not mentioned anything about the pre-Blaini Conglomerate succession of the Lesser Himalaya. Raha and Das (1989), Tewari (1993, 1996) and Kumar and Srivastava (1995) have correlated the Jammu-Shali-Deoban-Pithoragarh belt (Meso-Neoproterozoic) with the Lower Vindhyan on the basis of identical stromatolite taxa, microbiota and isotopic age, which is accepted worldwide and cannot be ignored. The Precambrian-Cambrian boundary carbon isotope curve of the Krol-Tal sequence is also different from the Upper Vindhyan (Friedman and Chakraborty, 1997). Tewari (1996, 1997) has further established that Deoban belt (Meso-Neoproterozoic, pre-Blaini) is entirely different from the Krol Belt (Terminal Proterozoic-Cambrian, post Blaini) in biota, sedimentary facies and isotopic signature. The Deoban belt is correlatable with Lower Vindhyan on the basis of identical occurrence of stromatolite assemblages *Kussiella kussiensis*, *Conophyton garganicum*, *Colonella 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* (Mc Menamin et al. 1983; Tewari, 1989; Kumar and Srivastava, 1995). This assemblage is globally distributed, but for a few long ranging forms, around 1200-1000 m.y.

7. The author has questioned stromatolite biostratigraphy and its biogenic nature. Stromatolites and their microstructures are still being used world over for biostratigraphic correlation of Proterozoic rocks from Siberian platform, Canada, South Africa, Australia, China and elsewhere. Stromatolites (microbialites) are the most convincing evidence of microbial activity in Precambrian sequences (Schopf, 1993). However, occasionally the biogenicity of some stratified structures is questioned from mathematical modelling (Grotzinger and Rothman, 1996) but in nature, the influence of biologic activity, presence of micro-organisms and the biomolecules in the Proterozoic stromatolites are generally accepted by the 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. (ii) some stromatolites contain microfossils arranged in patterns indicating that they are responsible for the contribution of the laminae 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 of the hot spring vents, New Zealand. All these examples clearly indicate that stromatolites are not abiogenic.

Stromatolite biozones of the Lesser Himalaya (Zone I, II, III) found in the Deoban and equivalent carbonates are also recorded from Lower Vindhyan Semri Group (Tewari, 1989). The Zone IV is common in 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 Vindhyan. This clearly shows that Termial Proterozoic-Lower Cambrian sedimentation of the Lesser Himalaya is absent in the Vindhyan basin.

8. There is urgent need to constitute a multi-institutional team of experts to study the Vindhyan Group of Son valley and a workshop may be organised under the aegis of the Geological Society of India to discuss the present state-of-the-art and future line of action for Vindhyan stratigraphy.

(2)

P.K. Maithy, Birbal Sahni Institute of Palaeobotany, Lucknow - 226 007 comments:

The evidences from the Vindhyan are discussed below with remarks on Azmi's fossil finds.

Stromatolite Evidences

Two distinct assemblage zones have been identified. The older Semri Group is recognised by the assemblage of *Kussiella- Colonella-Conophyton* and the younger Bhander Group by *Tungussia-Gymnosolen* and *Baicalia*. On the basis of stromatolites, the Semri assemblage was considered to be early to middle Riphean and the Bhander assemblage to be late Riphean. So far, the linked stromatolite *Conophyton* (*Thysagectean*), a late Cambrian marker, is not known from Vindhyan (Ravi Shanker et al. 1998).

Megafossils

The megascopic carbonaceous macrofossils, viz., *Chuaria* and *Tawuia* are well known in the Vindhyan sequence from Rohtas Limestone (Semri Group) to the youngest bed Bhavpura Formation of Bhander Group. The assemblage of Rohtas Limestone (=Suket) is characterised in addition to *Chuaria-Tawuia* by *Sinosabellidites*, *Protoarenicola*, *Grypania*, *Tyrostenia*, *Daltenia* and *Krishnania* (Maithy, 1992). Similar assemblage is also known from the Mid-Proterozoic of Mackenzie Mountains, northwest Canada and China. *Chuaria-Tawuia* are now well known from Rewa and Bhander Groups, but other carbonaceous forms known from the Rohtas Limestone are so far not reported from younger sediments. According to Hofmann (1992) "the absence of *Chuaria* in post-Proterozoic geologic record needs explanation." Maithy and Babu (1997) reported *Sekwia excentrica* from Lower Bhander Limestone, a cocoon of annelida, previously reported from Neoproterozoic of Canada.

Organic walled microfossils

Acritarch

Acritarch distribution in geological sequence is now well known and stratigraphical marker forms are well distinguished. According to Maithy (1991) the Semri Group is dominated by non-ornamented acritarch Sphaeromorphida belonging to Leiosphaeridia sensu Jankauskas. In the Bhander, the acritarchs, Leiosphaeridia and Sphaeromorphida show considerable increase in their size. In addition, sculptured forms, viz., *Cymastosphaeroides*, *Favosphaeridium* and a few Palygonomorphitae appear (Maithy and Babu, 1997). The Cambrian is characterised by the dominance of 'Acanthomorphs' which are rarely known from the Vindhyan.

Cyanophyceae

Cyanophycean algae belonging to Chroococaceae, Entophysalidaceae and Oscillatociaceae are reported from Semri Group. These forms are well known from Bhander Group along with Neoproterozoic marker forms, endosporluting algae, Sphaerocongregus and tubular form, Polythrichoides.

Radiometric dating and S13C value

Recent dating of glauconite in Vindhyan sediments indicates that the total span of Vindhyan ranges from 1400 to 570 Ma (Srivastava and Rajagopalan, 1985, 1988).

Preliminary result of carbon isotopic studies indicate positive incursion of +2.9 to +4.0 of S13C value which is comparable to that recorded from Precambrian sequences elsewhere in world (Kumar et al. 1997). According to them, in the absence of imprints of Varnagian glaciation and Cadomian orogeny from Upper Vindhyan succession, it appears that sedimentation terminated before the onset of the Cadomian orogeny in Early Neoproterozoic itself, i.e., before 650 Ma. Kumar (1998) also supports a Riphean age for Vindhyan.

Summary

All the data enumerated here constitute the evidence for non-deposition of Cambrian in Vindhyan. Azmi has claimed the discovery of Lower Cambrian shelly fossils and brachiopods from Lower Vindhyan of Son valley, central India, and on this basis he has suggested Cambrian to younger age for the Vindhyan. This paper has several gaps which are detailed below:

i) The paper gives no information regarding isolation of biota from rock, which is important because similar structures can be seen if the rocks are treated with hydrofluoric acid and then allowed to dry out after digestion.

ii) According to current stratigraphic nomenclature the bed is Rohtas Limestone Formation not Rohtasgarh.

iii) The Cambrian microbiota cited by author on p.385 item 6 has now proved to be contamination and Salujha's acritarch data have been revised as Neoproterozoic in age, as no typical Cambrian acritarch was present.

iv) Lower Cambrian assemblage is characterised by the presence of *Anabarites-Protohertzina-Circotheca*. There is no evidence of these biota in the reported assemblage.

The assemblages figured by Azmi in Plate 1 Figs.1-7, 8 and 12 are based on latex cast. The original specimens have not been photographed. Therefore, their claim of finding shelly fauna remains doubtful. The reported specimens appear to be cone-in-cone structures. Therefore, any attempt to do stratigraphy and age fixation on basis of these structures is erroneous.

(3)

Vibhuti Rai, Department of Geology, Unversity of Lucknow -226 007 comments:

Azmi's evidences for the Proterozoic to Cambrian age of the Vindhyan basin are at variance with all other palaeobiological and geochronometric data that support a Meso-proterozoic to Neoproterozoic (Riphean to Vendian) age for the entire Vindhyan succession. The discovery of small shelly fossils and brachiopods from the lower Vindhyan succession has been carefully examined in light of our observations and experience in Proterozoic palaeobiology. A few recently published papers (Conway Morris et al. 1998; Kerr, 1998a, b) commenting on Azmi's discovery, invalidate it and are supportive of the comments made in the following paragraphs.

A critical examination of the contents of the paper suggests that the illustrated fossil material need to be tested for its biogenecity 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), the conical structures resemble the diagenetically generated cone-in-cone structure 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 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 photomicrographs are from the latex cast, much fine details are missing for comparison. Reasons have also not been given for not providing the SEM of original brachiopod "shell" material.

Small Shelly Fossils:

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

Younger assemblage: In Plate 1 (9-11, 13-23), the so-called sclerites and scleritomes (belonging to tommotiids and halkieriids, *sensu* Azmi) have faint resemblance to small shelly fossils of early Cambrian age. However, since the mineralogical composition of tommotiids and halkieriids should essentially be phosphatic and calcareous respectively (Bengston et al. 1990), the present material does not seem to represent either of the groups. At best, these can be grouped under the pseudo-fossil (Hofmann, 1972) category.

Older assemblage: In Plate 2 (24-28), the specimens appear to be convincing as far as their biogenicity is concerned. Similar morphotaxa have earlier been recorded from Mesoproterozoic to Neoproterozoic horizons of the world. 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 *Talliella himalayaica* is an invalid taxa and a *nomen nudum*. The taxonomy appended at the end of the article by Azmi 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 himalayaica*. 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 himalayaica*).

The following point to point comments relate to the "conclusion/suggestions" of Azmi where he proposes regional stratigraphic modifications.

1. Azmi's 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 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).
2. 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 paper has, however, erroneously demarcated the "PЄ/Є boundary" using the so-called small shelly fossils and brachiopods in the Rohtasgarh Limestone of the Semri Group without considering the international stratigraphic norms.

3. The correlation of the Blaini Conglomerate of the Mussoorie Group (Lesser Himalaya) with the Basal Conglomerate of the Vindhyan Basin is not understood because mere lithological similarities can create complications in stratigraphic correlation. For example, 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.
4. So far no definitive Ediacaran soft-bodied fossils have been recorded from the entire Vindhyan succession. A few reports from the sequence do not appear to be quite reliable (Singh and Chandra, 1987; Maithy, 1990).
5. Most of the Vindhyan succession is developed in a shallow marine setting under the influence of wave and currents (Bhattacharyya, 1996). Exceptionally well developed stromatolites in the lower and upper Vindhyan succession (Soni et al. 1987 and references therein) with the record of microbial mats with well preserved silicified microbial fossils (in bedded cherts) (McMenamin et al. 1983) and carbonaceous mega-remains viz. *Chuaria-Tawuia-Grypania* etc. (Kumar 1995; Rai et al. 1997; Rai and Gautam, 1998) support the occurrence of glauconites in all the four groups, i.e., Semri, Kaimur, Rewa and Bhander, which again supports the dominance of marine influence in the depositional basin.
6. 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). The fossil occurrences of the supposedly younger ages (younger than Proterozoic) were either modern contaminants and artefacts (Schopf and Klein, 1992) or were not available for subsequent study.
7. Author has misquoted the ages of the strata yielding *Chuaria-Tawuia* occurrence from Spain and India. Contrary to the statement that this assemblage "is long ranging and is reported to occur up to or above the PЄ/Є boundary", the authors of the references cited by Dr. Azmi, clearly illustrate (1) in Spain, the *Chuaria* (note that *Tawuia* has not been cited by them) bearing horizons belong to the "Pusa Shales" (Brasier et al. 1979, Fig.1, p.380) which are restricted to the Vendian time span only and (2) in Iran, the Chopoghlu Shale (Lower Shale Member) of the Soltanich 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.
8. Regarding the consideration of the radiometric dates for the Vindhyan sedimentaries and the intrusives there does not appear to be any anomalous situation. The maxima for the lower Kaimur sediments by fission tract (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 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 region.

In the light of these para-wise observations, it would be apparent that the inferences drawn by the learned author suffer from inadequacy of 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 serious scientific attention.

(4)

S. Kumar, Department of Geology, University of Lucknow - 226 007 comments

The author has discovered small shelly fossils and brachiopods from the Rohtas Formation of Son valley, central India, and on this basis has suggested that the sedimentation in the Vindhyan basin started in early Vendian time (~650 Ma) and was disrupted in Atdabanian time of early Cambrian (~528 Ma). I have personally examined the material under discussion in Dr. Azmi's Laboratory in WIHG, Dehra Dun on 24th July 1998. In the light of the above mentioned discovery I have to submit the following:

1. The brachipods are nothing but depressions seen on the surface of a small slab which is made up of fibrous calcite. The small slab appears to represent a secondary calcite vein. In the published photographs nothing is seen which can be even remotely related to brachiopods. The author has not published photographs of the original material but of latex cast. The photographs of latex cast give an impression of cone-in-cone like structure, which must have been present on the surface of the limestone as a positive relief which ultimately produced a depression like feature in the secondary calcite vein.
2. The so-called sclerites are also comparable to cone-in-cone like structure and perhaps represent a diagenetic feature. Only *Spirellus shankari* (Plate 1 - 24) looks like a fossil. It may be a pseudomorph after a spirally coiled algal filament. Spirally coiled algal filament *Grypania circularis* has already been described from the Rohtas Formation (Kumar, 1995).
3. The so-called shelly fauna should have been studied under petrographic thin section to confirm the syngenecity and indigenous nature of the fossils as well as their relationship with the host rock. Moreover, the phosphatic nature of the acrotretid has not been confirmed but simply inferred (verbal communication with Dr. Azmi).
4. The author has suggested Precambrian-Cambrian boundary in the uppermost strata of the Rohtas Formation. Even if his suggestion is accepted the following points need clarification:

   a) There is a complete absence of typical Cambrian and other Phanerozoic fossils including trace fossils from the Kaimur, Rewa and Bhander Groups. Azmi has explained this absence due to fluviatile nature of the Upper Vindhyan. But there are large number of papers which have suggested a marine origin to the Upper Vindhyan sediments (Soni, 1987 and references therein).

   b) There is complete absence of carbonate build ups produced by Archaeocyathids, calcareous shells, echinoderms, brachiopods, trilobites and molluscs etc. At the same time carbonate build ups produced by columnar stromatolites are abundantly common in both the Semri and Bhander Groups. There is a global decline in the stromatolites in the Cambrian and this decline is attributed to evolution of skeletal metazonas which are so conspicuously absent in Vindhyan sediments. There is no record of biological evolution in the Vindhyan sediments which appears to have a beginning in early Vendian (Tucker, 1992).

   c) Hamdi (1989) has assigned Vendian age to Soltanyeh Formation on the basis of *Chuaria* and acritarchs and not up to or above PЄ/Є boundary as quoted by the author. Brasier et al. (1979) have specifically mentioned that the coexistence of Precambrian and Cambrian elements in Spain serves to blur the picture of an abrupt biotic turnover at the start of the Cambrian. According to Zang and Walter (1992) *Chuaria-Tawuia* assemblage in the northern Anhui, China have been considered to indicate, a pre-Sinian age but their occurrence in upper Sinian Shiyca Formation and probably lower Cambrian Gouhou Formation suggests a younger age to this assemblage. However, in all the above mentioned reports the Vendian and Lower Cambrian fossils are abundantly recorded whereas no such fossil has been reported from the Vindhyan Supergroup.

   d) In support of younger age for the Vindhyan sediments the author has referred to the works of many authors e.g., Salujha, 1973, but these are based on fossils recovered by maceration techniques where the indigenousness and syngenecity of the recovered fossils are always a matter of doubt (*see* Schopf and Walter, 1983; McMenamin et al. 1983). Since last two decades only those microfossils from the Precambrian successions are considered reliable which have been reported from the thin section of black bedded cherts. Thus no conclusion should be drawn on the basis of the above mentioned works.

In the light of the foregoing comments, it is suggested that unless the syngenecity, indigenousness and biogenecity of the fossils are established beyond doubt, no conclusion should be drawn on the basis of shelly fossils and brachiopods reported by Azmi. To change the well established Precambrian age assignment to the Vindhyan Supergroup, one has to produce unambiguous and indisputable evidences for its support. The reported fossils are of very doubtful nature, possibly structures produced by diagenesis.

(5)

T.M. Mahadevan, Kochi, comments:

The discovery of *Tommotian* fossils in the Rohtas limestones exposed near Maihar and Rohtas overlain by the Semri sediments in both the areas is indeed an achievement that deserves scientific recognition. Dr. Azmi deserves our felicitations. The discussion on Dr. Azmi's paper that appeared in the January 1999 issue of the Society's Journal further highlights the importance of this find. It is however, disconcerting that the author, as also some of the contributors to the discussion, tend to undervalue the available geochronological data on Vindhyan rocks and even doubt their utility by the weight of the evidence from fossils, which unfortunately may not have the same status as well established "index fossils" of the Phanerozoic.

The Rb-Sr dates of 1090 Ma of the Panna kimberlite are based on precise isochrons (Anil Kumar et al. 1991) and set a younger limit to the age of the Lower Semri beds they intrude. If the Semri beds of Maihar and Rohtas are homotaxial and have a physical continuity with those of Panna, as is believed today, based on fairly reliable geological mapping, it raises the question whether the life forms the fossils are supposed to represent did not evolve in this part of the world much earlier than in other parts. Geologically such a possibility is not unreasonable. On the other hand, careful modern structural and lithological mapping of the Vindhyan, taking into consideration facies changes, rates of sedimentation and seidmentological parameters may perhaps modify the present correlations. But it is unlikely that the age of the Semri fixed by the Rb-Sr isochron would get modified drastically. It, therefore, seems that there is no justification to ignore the mid-Proterozoic ancestry of the Vindhyan basin.

Recent publications in the Journal of the Society have highlighted the chronostratigraphic significance of the oxygen and carbon isotopic data. Future studies should aim at an integration of data from geological, palaeontological and isotope studies, if possible, in the same selected areas so that data generated are comparable. A high priority for such programmes is needed.

R.J. Azmi, Wadia Institute of Himalayan Geology, Dehra Dun 248 001 replies:

An extended discussion on the controversial age of the Vindhyan stratigraphy has now become more important than ever, as this problem has attracted world-wide attention due to recent claim of the startling > one billion year old origin of multicellular animals from the Vindhyan Basin (Seilacher et al. 1998). In this connection the views which recently appeared in *Science* (Kerr, 1998 a,b; Azmi, 1998b; Conway Morris et al. 1998), *Nature* (Brasier, 1998) and *Current Science* (Sankaran, 1999) need special attention, and more so since Prof. Simon Conway Morris and his colleagues have made some cursory observations on some of my published and unpublished material under discussion.

After going through all the comments, I find that they are mainly focussed on the following two points:

1. Biogenicity of the reported Early Cambrian 'conical' small shelly fossils (SSFs) from the Rohtas area of Son valley [please note that the biogenicity of the reported fossils from the Maihar area (Azmi, 1998, Pl.1, figs. 24-28) has not been doubted].
2. The age of the reported SSFs vis-a-vis the age of the Vindhyan Supergroup.

I would like to reply to the comments on these two aspects.

Biogenicity

All are of the opinion that they resemble "cone-in-cone" structures of diagenetic origin (*see* also Conway Morris et al. 1998, p.1265), Curiously enough, Dr. Nicholas Butterfield had earlier given a divergently different explanation in the annual meeting of the Geological Society of America in Toranto in the last week of October, 1998 (immediately after my visit to Cambridge) and there he commented (*in* Kerr, 1998b, p.1020) : ".........they are not fossils at all but artifacts. ....their ribbed structure was simply a reflection of fine layers in the rock itself. The texture of the rock plus the acid treatment Azmi used to extract any fossils apparently created the oddly shaped bits." It is amazing to visualise such a casual explanation which in fact has created more confusion than finding a solution.

However, on receiving the comments it was obvious that I should look the internal details to find if there were any cone-in-cone structures present in these apparent conical fossils (Pl. 1, figs. 1,2). Interestingly, my thin section examination has clearly revealed that the internal cone-in-cone growth arrangement of essentially fibrous calcite crystallites, making a 'solid' cone-in-cone structure, is spectacularly missing (Pl. 1, figs. 3-6). Instead, these are well organised 'hollow' cones of dark carbonaceous colour, essentially made up of a thin fibrous wall (Pl. 1, fig. 2) of a siliceous composition (confirmed by EDAX). This dense fibrous wall is covered by somewhat smooth but discontinuous transverse bands of brownish black colour of possible organic composition (Pl. 1, figs. 4-6). Further, these thin walled conical bodies are filled with primary sediments, often shaly matter, which occasionally preserve brownish black irregular tubular patches (possibly also organic) such as those in one of the cones (Pl. 1, fig. 5). Primary origin of the conical bodies is apparent from the fact that the secondary calcite vein having calcite fibres perpendicular to the bedding plane and emplaced within the shale layer, never penetrated the originally existing shelly conical body unless the wall was broken/collapsed (see right cone in Pl. 1, fig. 3 and detail in fig. 4). In the latter case the fibre orientations outside and inside the body are in perfect conformity. These observations thus make it very clear that the conical bodies under discussion are principally primary features and certainly not "cone-in-cone" structures. Their well-organised walls linking the adjoining cones thus make a larger skeletal structure – the scleritome (the protective armour coat for the animal). In fact, the regularity in orientation with characteristic smooth bending of the apices of the articulated conical organic bodies are suggestive of a part of a real metazoan seleritome, architecturally very close to the one recently proposed for the armoured *Lapworthella* animal (McMenamin, 1989).

Age implications

Since there is no disagreement as to the biogenecity of the Maihar fossil material is concerned (see also Conway Morris et al. 1998), it would be useful to discuss their age implications. Further, in order to clear the doubts on the discovery of small shelly fossils from the Lower Vindhyan and also to strengthen my view that they are indeed of earliest Cambrian age, I supplement here additional illustrations of the SSF material (Plates 2-5) from the same locality and horizon of the Maihar area (*see* locality in Azmi, 1999, figs. 1-3).

Established world biostratigraphic record indicates that the major skeletonization event occurred only near the Precambrian-Cambrian boundary (~ 545 Ma), succeeding the soft-bodied Ediacaran metazoa and metaphytes. From the illustrations (Pl. 2 to 5) one can judge that the stage of skeletonization has clearly reached during the deposition of the uppermost Rohtasgarh Limestone Formation. Among the fossils recovered, *Spirellus shankari* (tube diameter >60 µm), *Olivooides multisulcatus* (recently interpreted as metazoan embryos, see Bengtson and Yue, 1997, and Shuhai et al. 1998 for comparison), and high cone and cap shaped fossils referable to *Codonoconus* dominate along with rare specimens of *Taliella himalayaica* and a new genus possibly related to *Taliella*, *Hyolithellus*, agglutinated tubes of *Platysolenites antiquissimus* and cf. *Volborthella*. While all these taxa occur in the early Cambrian in different parts of the world, *S. shankari*, *O. multisulcatus*, *Hyolithellus* and *Taliella* are the important common elements of the SSF assemblages of the earliest Cambrian Lower Tal Phosphorites of the Garhwal Lesser Himalaya (Azmi, 1998a; Brasier and Singh, 1987) and the earliest Cambrian Meishucunian Zone I of South China. This age assignment is further strengthened because agglutinated foraminifera(?) *Platysolenites antiquissimus* consistently occurs only in the early Cambrian strata across the northern hemisphere from California to China through Baltic Platform (Lipps, 1990; Brasier, 1986) and even in the basal early Cambrian part of the global Precambrian-Cambrian boundary stratotype section in southeastern Newfoundland (Landing et al. 1989). Interestingly, the metaphyte *Tyrasotaenia* Gnilovskaya (identified by Gnilovskaya, *in* Shukla and Sharma, 1990) which occurs in the Suket Shale (= topmost Rohtasgarh Formation) is also recorded in the global stratotype section at approximately the same level as *Platysolenites*. It should be further noted that a glaring Cambrian type, advanced horizontal winding trace fossil was also recorded by Shukla and Sharma (1990, Pl. 2, figs. 8 and 9) from the lower beds of the Kaimur Sandstone in Mandsaur district of Madhya Pradesh. I, therefore, have no hesitation in assigning an earliest Cambrian age to the uppermost strata of the Rohtasgarh Limestone Formation. I am sure that my Indian colleagues and the Cambridge experts would also agree with me at least for the age I assigned to the Maihar small shelly fossils.

Further, in view of this age deduction, the occurrence of *Chuaria-Tawuia* assemblage in the shales of Semri, Rewa and Bhander Groups do not seem to be anomalous so long as the upper Vindhyan formations are also considered to occur within the early Cambrian. In Elburz Mountains, Iran, '*Chuaria* gp'., occurs in the Chopoglu Shale which overlies the Lower Dolomite Member containing typical earliest Cambrian SSFs (*Olivooides multisulcatus*, *Protohertzina*, *Hyolithellus*, *Rugatotheca*, *Spihogonuchitids*, *Monoplacophorans*; *see* Hamdi et al. 1989). Similarly in Spain, *Chuaria* also occurs with trace fossils and early skeletal fossils of early Cambrian aspect (Brasier et al. 1979). For Chinese occurrence of *Chuaria* - *Tawuia* assemblage in the early Cambrian, I concur with Zang and Walter (1992). Dr. Maithy's drawing my attention to Hofmann's statement (*in* Schopf and Klein, 1992, p. 356) is important but it cannot be understood unless its full context is mentioned . Further, Sun (1987) and others regarded *Chuaria* as probable colonies of filamentous cyanobacteria, comparable to modern *Nostoc* colonies. If this interpretation was

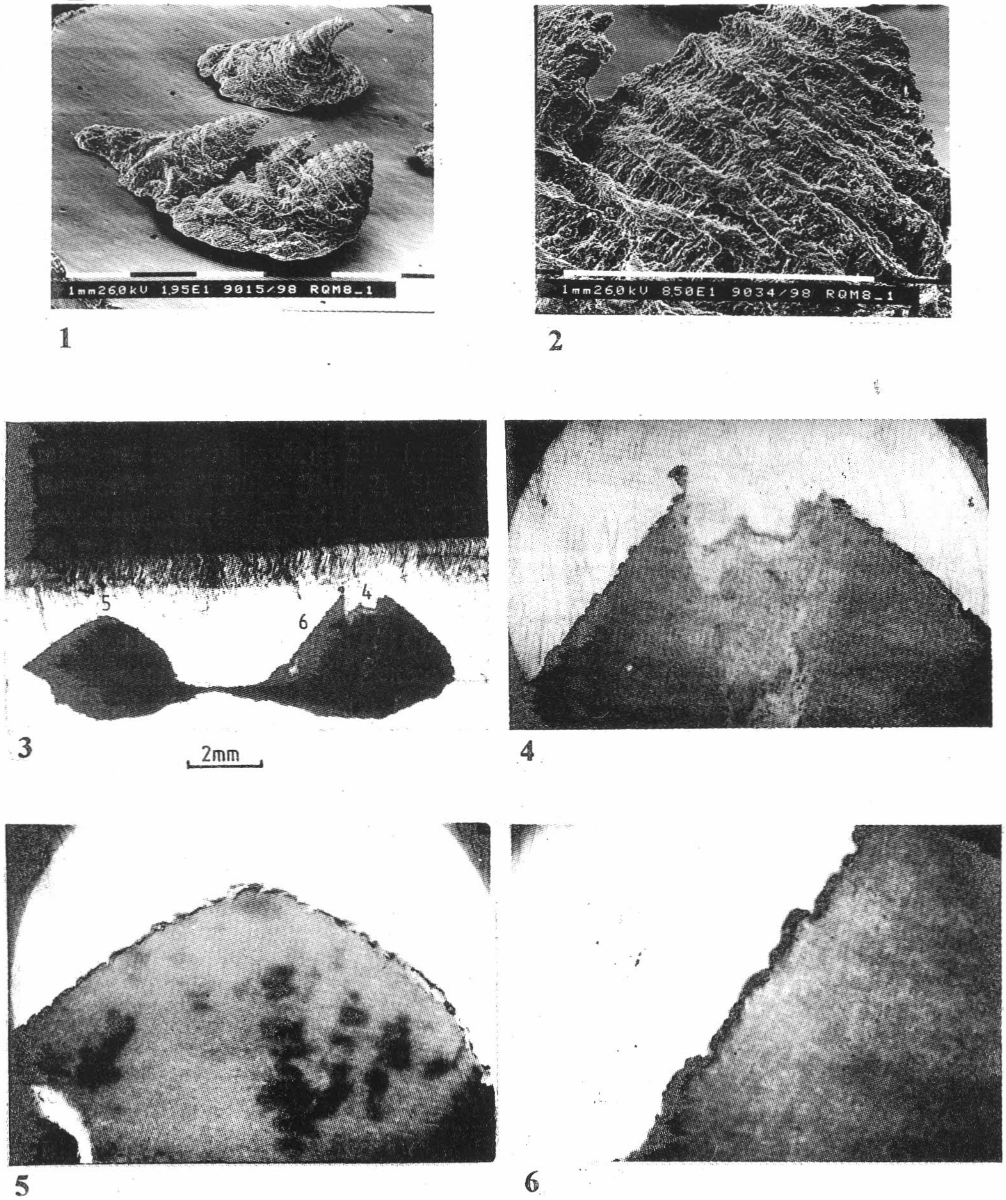

Plate 1. SEM and thin section photomicrographs of early Cambrian small shelly fossils from the lower Vindhyan of Rohtas area, Son valley, central India. **1.** Isolated individual and partial scleritome of *Lapwarthella* sp. Note the characteristic orientation of apices, possibly posteriorward (partial scleritome WIMF/A 177, sample RQM 8-1; isolated individual sclerite WIMF/A 178, sample RQM 8-2); **2.** detail of apical area of partial scleritome in 1, showing discontinuous transverse bands of brownish black colour and longitudinally oriented crystallites in fibrous wall; **3-5**, *Lapworthella*-like laterally linked conical bodies in longitudinal thin section parpendicular to bedding plane. Note that sections do not pass through the apices. The secondary fibrous calcite crystallites abut the conical bodies and penetrate only at the collapsed wall positions as seen in the right cone in **3** and details in **4**; **4-6**. details of thin wall consisting of outermost transverse bands of brownish black colour (black in print), compare to that shown in SEM micrographs **1** and **2**. Cones filled with primary shale often preserving brownish black (possibly organic) tubular patches as in **5** (WIMF/A 193, sample RMD-TS1).

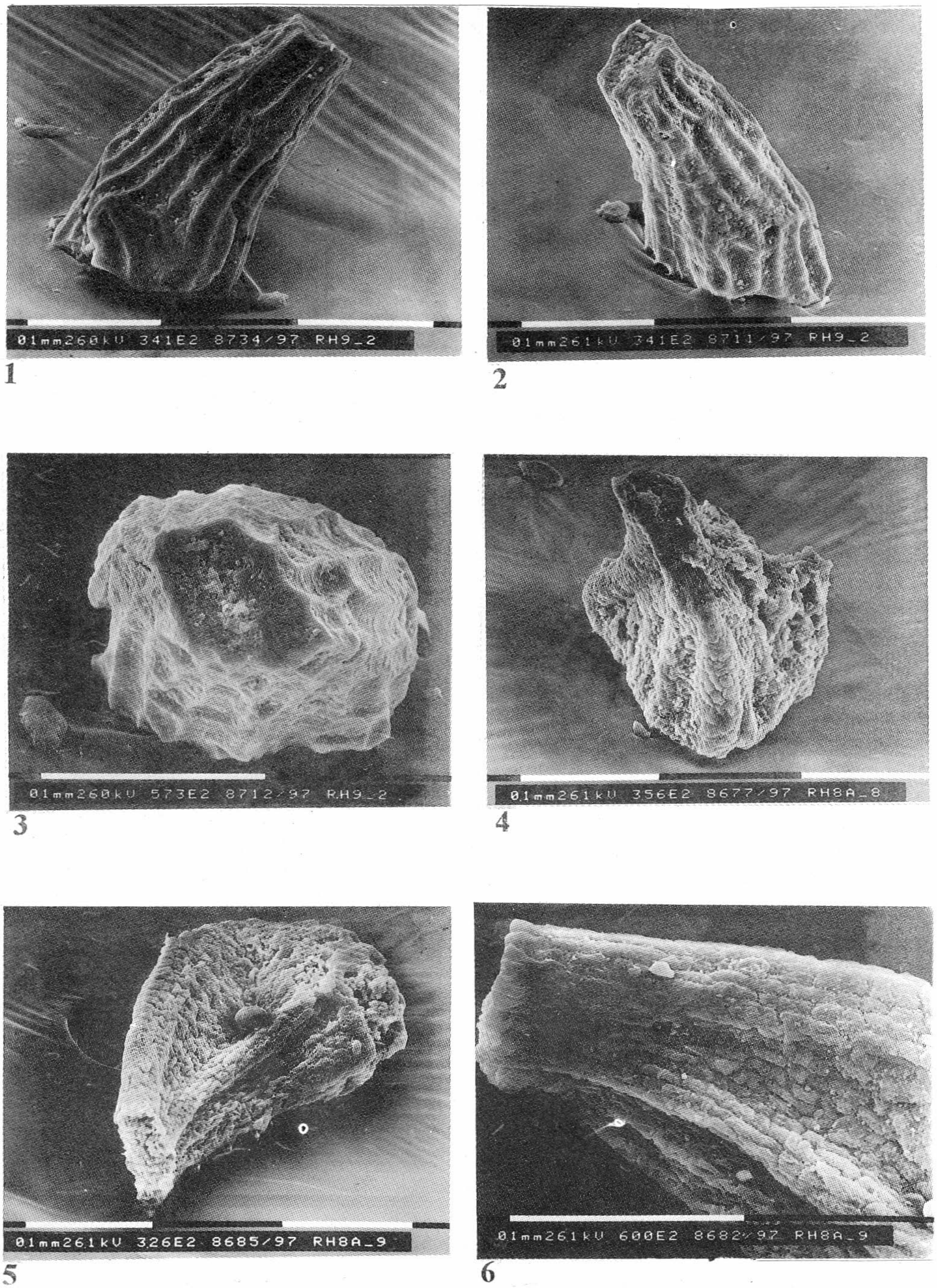

Plate 2. SEM photomicrographs of early Cambrian SSFs from the lower Vindhyan of Maihar area, central India. All scale bars = 100 mm. **1-3**, *Taliella himalayaica* Azmi (WIMF/A 188, sample RH 9-2); **4-6**, n.gen. et n.sp. (4, WIMF/A 194, sample RH 8A-9; **5-6**, WIMF/A 195, sample RH 8A-8).

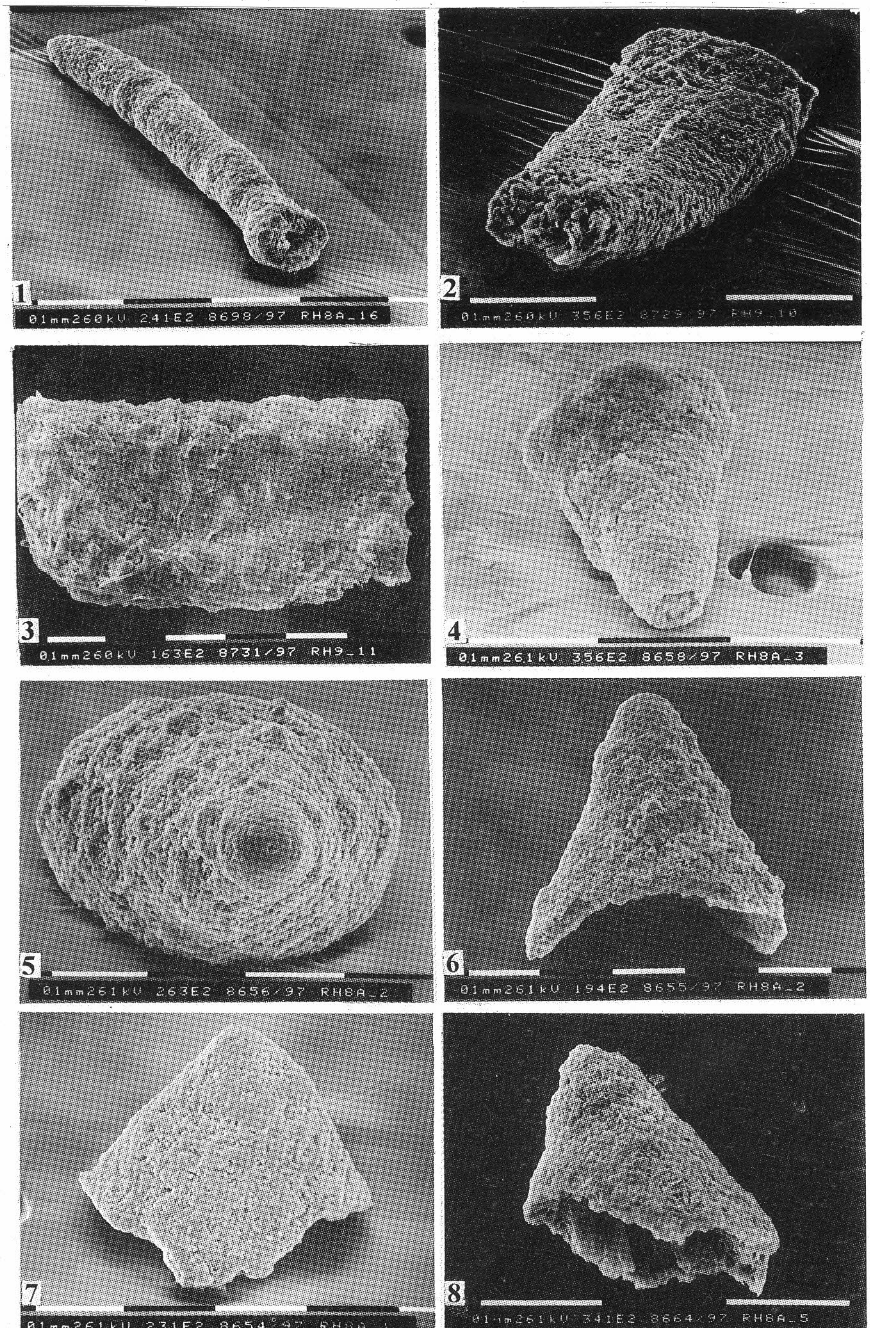

Plate 3. SEM photomicrographs of early Cambrian SSFs from the lower Vindhyan of Maihar area, central India. All scale bars = 100 mm. **1**, cf. *Volborthella* sp. (WIMF/A 196, sample RH 8A-16); **2**, *Hyolithellus* sp. (WIMF/A 197, sample RH 9-10); **3**, *Platysolenites antiquissimus* Eichwald (WIMF/A 198, sample RH 9-11); **4-8**, *Codonoconus* sp.(**4**, WIMF/A 186, sample RH 8A-3; **5-6**, WIMF/A 199, sample RH 8A-2; **7**, WIMF/A 200, sample RH 8A-1; **8**, WIMF/A 201, sample RH 8A-5).

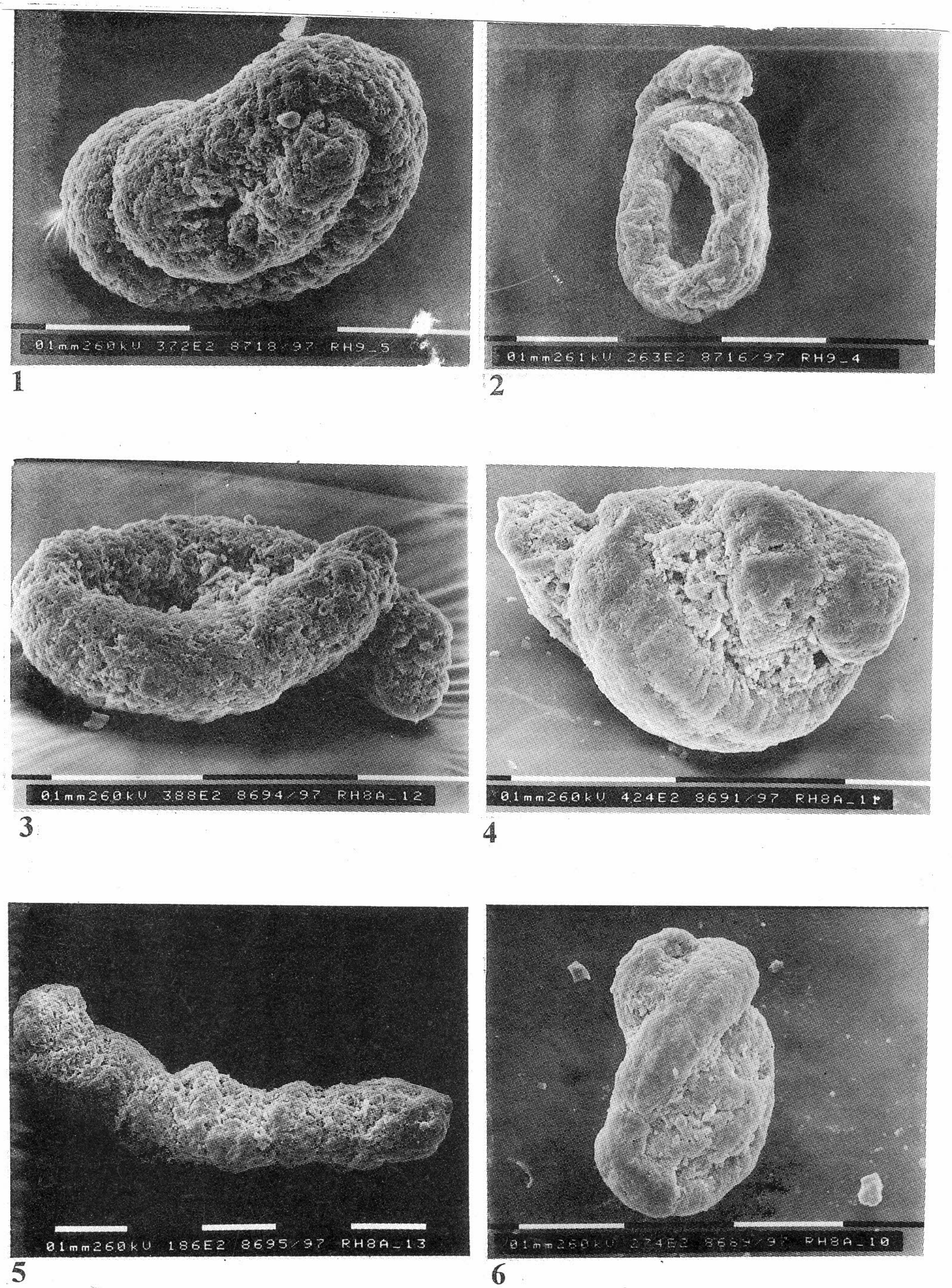

Plate 4. SEM photomicrographs of early Cambrian SSFs from the lower Vindhyan of Maihar area, central India. All scale bars = 100 mm. **1-6**, *Spirellus shankari* (Singh and Shukla) (**1**, WIMF/A 185, sample RH 9-5; **2**, WIMF/A 202, sample RH 9-4; **3**, WIMF/A 203, sample RH 8A-12; **4**, WIMF/A 204, RH 8A-11; **5**, WIMF/A 205, sample RH 8A-13; **6**, WIMF/A 206, RH 8A-10).

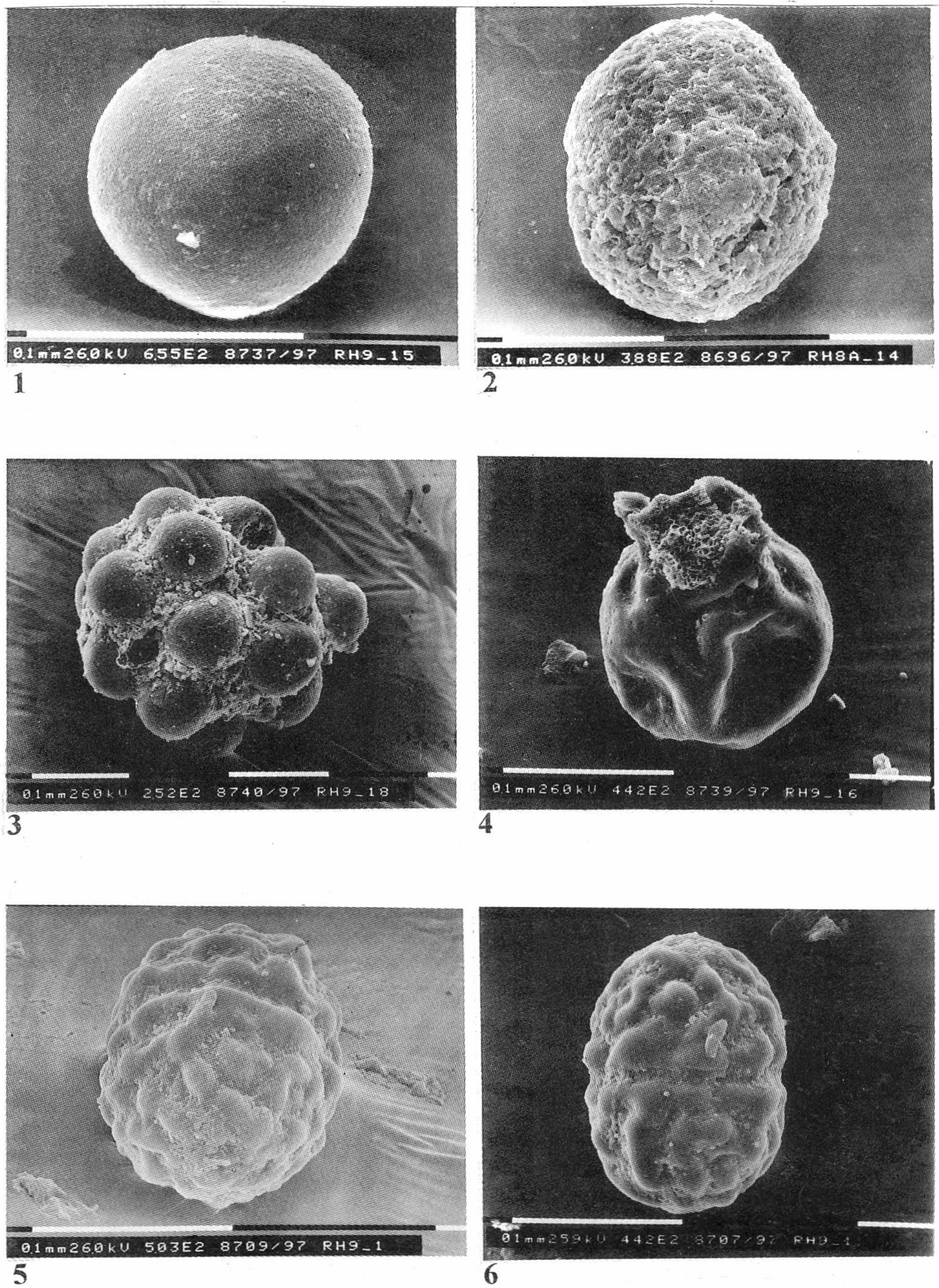

Plate 5. SEM photomicrographs of early Cambrian SSFs from the lower Vindhyan of Maihar area, central India. All scale bars = 100 mm. **1-2,4**, *Olivooides multisulcatus* Qian; fossilized metazoan embryos *sensu* Bengtson and Yue, 1997 (**1**, WIMF/A 187, sample RH 9-15; **2**, WIMF/A 207, sample RH 8A-14; **4**, WIMF/A 208, sample RH 9-16); **3,5-6**, fossilized metazoan embryos *sensu* Shuhai *et al*., 1998; **3**, multiple - cell stage (WIMF/A 209, sample RH 9-18); **5-6**, two - cell stage (WIMF/A 210, sample RH 9-1).

true then, according to Hofmann "the absence of *Chuaria* in the post-Proterozoic geologic record needs explanation, in as much as one would expect it to be present, given the existence of the modern analogue." In this context the recent reports of *Chuaria* and *Tawuia* from the upper Vindhyan sediments (Rai et al. 1997; Kumar and Srivastava, 1997) may throw some light on its continuity at least into the higher early Cambrian, probably younger than the levels recorded from China, Iran and Spain. Also, the occurrence of helicoidal carbonaceous megafilaments of *Grypania* in Suket Shale (Kumar, 1995) appears significant as its upper stratigraphic range is questionable (*see* Hofmann and Bengtson in Schopf and Klein, 1992, p. 503). Its upper range may also extend up to Late Vendian or earliest Cambrian (*see* also Burzin,1995).

The spirally coiled cyanobacterial filament *Obruchevella* is reported recently from the Upper Vindhyan Sirbu Shale of the Bhander Group. Although the genus has a long stratigraphical range (Middle Riphean to Devonian), it is most common in Vendian to Early Cambrian rocks world over. Like China (Song, 1984), *Obruchevella* also occurs abundantly along with *Spirellus columnaris* and *S. shankari* in the earliest Cambrian Lower Tal Chert-Phosphorite (Ahluwalia, 1985) and rarely in the Vendian Infra-Krol (Tiwari and Azmi, 1992). Recently the genus has also been recorded by Srivastava and Kumar (1997) from the Lesser Himalayan Deoban chert along with two worm remains of annelid and nematodean affinities and a third one as probable back filled burrow (Srivastava and Kumar, 1997, fig. 4c) which, in my view, appears like *Cloudina*. Very significant are also the findings of definite *Veryhachium* (early Paleozoic marker) and *Obruchevella* from the lower part of the Vaishnodevi Limestone (Jammu Limestone) by Venkatachala and Kumar (1996, 1998) and *Veryhachium* from the earliest Cambrian Lower Tal Chert-Phosphorite beds of Korgai Syncline (Himachal Pradesh) by Tiwari (1996). It is also significant to note that Brunel et al. (1985) had recorded early Cambrian paleobasidiospores from the magnesites of eastern Nepal which is broadly considered equivalent to the Gangolihat Magnesite of Inner Kumaun Lesser Himalaya. All these evidences thus clearly suggest that the Deoban and its equivalent carbonate formations of the Inner Lesser Himalaya have positively reached at least the early Cambrian time. This is quite relevant in the present context because the Semri Group, with its Kheinjua microbiota and stromatolites, is usually considered to be of early to middle Riphean age and correlated with the Deoban Formation. As I have suggested in my paper under discussion and elsewhere (Azmi, 1998b; *see also* Brasier, 1998) that with the new evidences of multicellular triploblastic animal tracks (Seilacher et al. 1998) from the Chorhat Sandstone (upper Kheinjua) and earliest Cambrian SSFs from the overlying Rohtasgarh Limestone, it is almost certain that the Semri Group is of Vendian-earliest Cambrian age and, in turn, is correlatable with the Mussoorie Group comprising the Blaini - Krol - Tal (basal) Formations. Obviously, the 'Blaini Conglomerate' and the 'Basal Conglomerate' should also be equivalent as Vendian markers which were possibly developed in response to a common paleo-tectonism and/or environment. In effect, the Semri Group of the Vindhyan and the Mussoorie and Deoban Groups along with other carbonates of the Inner Lesser Himalaya appear to form a much larger Vendian to early Cambrian carbonate platform of the Paleotethys on the northern margin of the Indian Peninsula.

It must be recalled that at number of times in the past several typical Vendian and Cambrian fossils were recorded from the Vindhyan sediments (for example, *see* Chakrabarti, 1990; Shukla et al. 1991; Maithy, 1992; Sharma et al. 1992) but their age interpretations were seriously hampered due to ill-conceived Mesoproterozoic age of the Vindhyan Supergroup, mainly based on stromatolites and radiometric dates. Now it is becoming clear that neither the stromatolites nor the radiometric dates seem to be reliable to constrain the age of the Vindhyan sediments. Prof. Mahadevan's concern at least on the reliability of the Panna kimberlite dates appears justified, but in view of the fossil data presented here, his proposal does not necessarily push down the global skeletonization event deep into the Precambrian. One such exercise has been done by Vishwakarma (1998). Instead, it is desirable to re-ascertain the Vindhyan radiometric dates, particularly of the kimberlites, by more modern geochronological techniques.

The following are my replies to other specific comments.

To Dr. Vibhuti Rai:

1. *Taliella himalayaica* Azmi, 1998 cannot be a *nomen nudum* because it is a formally described taxon. Further, there is no justification to synonymise *Taliella* Azmi, 1998 with *Tumuliolynthus* Yang and He, 1984 (*see discussion in* Azmi, 1999).
2. My suggestion of 'early Paleozoic' upper age limit for the Vindhyan succession was intended to broadly accommodate the age range anywhere between Cambrian to Silurian, pending further scrutiny of Salujha's (1973) palynological data.
3. The general absence of marine megafossils in the upper Vindhyan-early Paleozoic succession is most likely due to environmental factors. Bhattacharyya et al. (1986) and Bhattacharyya and Morad (1993) have even considered the possibility of misidentifying fluvial deposits as shallow marine in the Vindhyan sequence.
4. I agree with Dr. Rai that mere lithological similarities can create complications in the stratigraphic correlation. Rather, it has already created a lot of confusion. But then how can lithological correlation of the Jodhpur Group of the Marwar Supergroup with the Upper Bhander Sandstone Formation of the Vindhyan Supergroup by Dr. Rai be justified? I would like to reiterate that my correlation of 'Blaini Conglomerate' 'Basal Conglomerate' and 'Pokhran Boulder Bed' is not merely lithological but has primarily a Vendian connotation.
5. Although the Precambrian-Cambrian boundary has been ratified by the IUGS-IC$\d{S}$ on the basis of the initial appearance of the ichnofossil *Phycodes pedum* in the siliciclastic-dominated Global Stratotype Section of the southeastern Newfoundand, this criterion may not be always applicable to the small shelly fossil-rich platformal carbonate dominated sections (e.g., Krol Belt, India; Iran, China, Mongolia, Siberia etc.). The absence of *P. pedum* at boundary level in such sections does not mean that the Precambrian-Cambrian boundary is not there. Undoubtedly, the SSFs have already been potentially used for demarcating this important boundary. Therefore, there is no justification for stating that I have erroneously demarcated the Precambrian - Cambrian boundary in the uppermost Rohtasgarh Limestone by using small shelly fossils without considering the international stratigraphic norms. In addition, other supporting criteria such as chemostratigraphy and magnetostratigraphy are being invoked and effectively utilised for various boundary delineations.

To Dr. P.K. Maithy:

1. I am aware of the enumerated evidences of Vindhyan stromatolites, organic-walled microfossils, radiometric dates and isotopic excursions which have been used until now to assign a Precambrian age to the Vindhyan Supergroup. My only submission is that all these may be re-evaluated in the light of my discovery of earliest Cambrian small shelly fossils.
2. I am convinced that future discoveries should also reveal the occurrences of not only *Protohertzina*, *Anabarites*, *Circotheca* but also many more early Cambrian SSF elements approximately in the same level of the Semri Group. The reported SSFs are just the beginning towards resolving the problem of age of the Vindhyan succession. Let us be optimistic and positive in our interpretations.

3. The SSFs were recovered through the standard glacial acetic acid etching technique.
4. I have followed 'Rohtasgarh Limestone Formation' as suggested in Bhattacharyya (1996, Table 1).

In addition to the above there are a few points raised by the commentators which have been already covered in my previous reply (*see in* Azmi 1999), hence not replied again. My original SSF material housed in the Wadia Institute Repository is available for examination by interested persons.

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