

Indian Precambrian palaeobiology : goals and gaps

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Palaeobiological evidences from Precambrian basins of India and related problems, viz., advent of prokaryotes, prokaryote- eukaryote transitions and attainment of multicellularity are discussed. The usefulness of these evidences as biostratigraphic markers has been assessed. The gaps in the knowledge have been identified and suggestions are put forward on how to bridge them. The paucity of data on the distribution of acritarchs through time and space does not permit establishment of acritarch based fine resolution stratigraphy. Further lack of uniformity in approach towards stromatolite taxonomy which has often created more confusion than offering solutions to the problem and the need to assess authenticity of persistent reports of metazoan and metaphytes from sediments older than 600 Ma in India have also been discussed. A multidisciplinary approach has been advocated to resolve the persistent problems of Precambrian palaeobiology in India.

Key-words –Precambrian, palaeobiology, India.

INTRODUCTION

ARCHAEOAN and Proterozoic Eons cover three fourth period of the total history of the earth. Palaeobiology of this time spanning from 4.5 Ga to nearly 0.6 Ga is relatively unexplored. During this period major events were defined to set the trends of evolution of the biosphere which include advent of life, origin and evolution of prokaryote, prokaryote-eukaryote transition and attainment of multicellularity. The prokaryotes which dominated the earth's biosphere during the first 3 Ga show evolutionary conservatism with great ability to adapt to extreme changes in environmental conditions. In fact, the ecological tolerance of these organisms defined the environmental limits of the primitive earth. The ability of the prokaryotic organisms to adapt to extreme environmental conditions led to an evolutionary process. The trend in evolution at this time was more of additive in nature than of replacing or substitution. It also helped them to exploit new environments. This led Knoll and Bauld (1989) to postulate that rates and patterns of prokaryotic evolution reflect developmental history of earth's surface environment.

The earliest palaeobiological records from 3.5 Ga old sediments, although debatable, (Awramik *et al.*, 1983, 1988; Buick, 1984, 1988) indicate that the living system had already evolved from the primordial—cell to a photosynthetic organism passing through chemotrophic (both auto & heterotrophic) mode for synthesising food.

The basic difficulty in deciphering the entire history is the nonavailability of unmetamorphosed or less metamorphosed sediments deposited prior to 3.5 Ga, which could contain signatures of earliest life. The palaeobiological information available from the sediments deposited prior to 2.5 Ga is incomplete and fragmentary. It is difficult to comprehend early biogenic processes in the absence of sedimentological, geochemical and isotopic data, hence the need for a multidisciplinary approach to trace the advent of life and early biogenic processes is imperative.

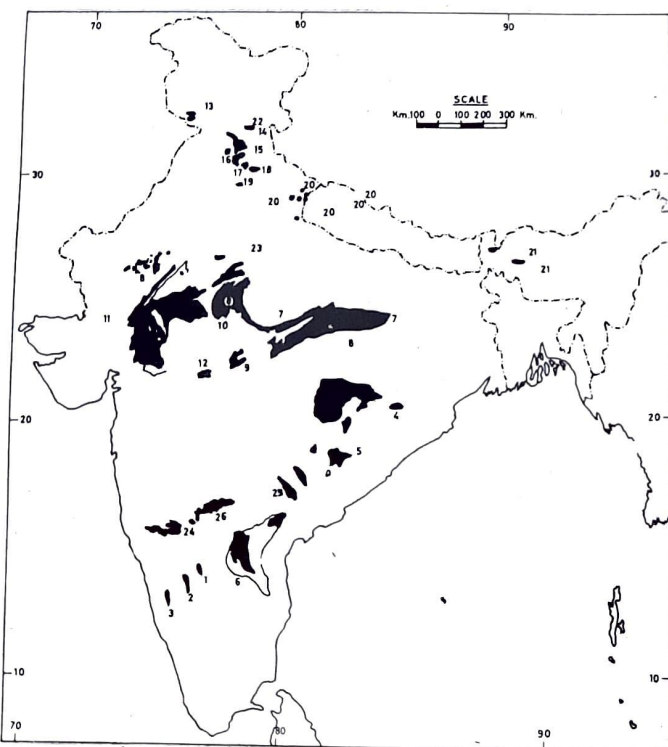
India has large expanse of exposed Archaean and Proterozoic sediments. The remnants of the Archaean sediments occur in Dharwar, Singhbhum and Jaipur-Baster Craton (Radhakrishna & Naqvi, 1986). The Proterozoic sediments are exposed in Cuddapah, Kurnool, Bijawar, Aravalli, Vindhya, Koirā, Bonai-Keonjhar, Pakhal, Albaka, Indravati, Chattisgarh, Kaladgi, Bhima, Inner and Outer sedimentary belts of Himalaya.

LIMITATIONS

The sediments deposited between 4 Ga to 2.5 Ga, are generally classified as Archaean. These have been subjected to many cycles of tectonic, igneous and metamorphic deformations, which led to mutilation and disintegration of the preserved signatures of early life. It is due to this reason that the norms set, to authentically describe a Proterozoic microfossil from less metamorphosed sediments, is difficult to adhere to in the Ar-

chaean. The well defined original morphologies of these micro-organisms are generally not preserved in these older sediments. Evaluation of other indirect evidences from other disciplines, viz., isotopic geology, organic and inorganic geochemistry and sedimentology in conjunction with structural evidences helps to prove the authenticity of biogenic structures. The other major constraint of Archaean palaeobiology in India is the non-availability of geochronological data. Concerted efforts are therefore required to date the sediments from which important palaeobiological discoveries have been made. Dating of stromatolitic limestones and cherts should be the major target.

The study of microbial mats from Proterozoic sediments has traditionally drawn support from the studies conducted on extant microbial systems. Sedimentological data can provide broad environmental parameters such as marine or non-marine; and also depositional regimes, e.g. supratidal, intertidal, subtidal, etc. The study of microbial communities inhabiting these broad environ-



Map 1. showing Precambrian stromatolites and microfossil localities in India (modified after Sastry, 1980).

1 - Deogiri Formation, 2 - Vanivilas Formation, 3 - Joldhal Formation, 4 - Iron Ore Group, 5 - Indravati Group, 6 - Vempalli Limestone Formation, 7 - Fawn Limestone Formation, 8 - Bhandar Limestone Formation, 9 - Bijawar Group, 10 - Bhagwanpura Limestone Formation, 11, 12 - Aravalli Group, 13 - Jammu Limestone Formation, 14 - Shali Formation, 15 - Naldera Formation, 16 - Kakarhatti Limestone Formation, 17 - Tundapathar Limestone Formation, 18 - Deoban Limestone Formation, 19 - Krol Group, 20 - Calc-zone of Pithoragarh and Tejam, 21 - Buxa Dolostone, 22 - Larji Formation, 23 - Delhi Group, 24 - Kaladgi Supergroup, 25 - Pakhal Group, 26 - Bhima Supergroup.

mental regimes for their relative preservational potentials, is helpful in interpreting the interaction and evolution of Proterozoic biosphere and lithosphere.

One of the major difficulties in the study of Precambrian microfossils is to prove their authenticity. In thin sections of chert the relationship between microfossils and sediments can be clearly observed and hence it is comparatively easier to prove the authenticity of these microfossils. However, in case of acid resistant microfossils derived from sediments it is difficult to study the relationship. This had led many workers to describe extant contaminants as Precambrian microfossils. Many cautionary notes are available where this constraint is discussed in detail suggesting methods to overcome them (see Fuxing & Luo, 1982; Hofmann & Schopf, 1983; Venkatachala, 1987; Manoharachary *et al.*, 1990; Shukla *et al.*, 1992).

GAPS IN KNOWLEDGE

Since the discovery of Gunflint microfossils (Tyler & Barghoon, 1954) considerable data has been added on the morphology and distribution of the Precambrian micro-organic communities. Schopf (1983) while discussing the earth's earliest ecosystem concluded that anaerobic chemotrophs and phototrophs were already in existence by 3.5 Ga. Aerobic phototrophs and amphiaerobes had also probably appeared by 2.8 Ga. If these interpretations are true then a palaeobiologist, constrained by the availability of suitable sediments older than 3.5 Ga can only discuss the distribution of chemotrophs in sediments later than 3.5 Ga. It is not possible to understand the evolutionary stresses responsible for the evolution of anaerobic autotrophs from anaerobic chemoautotrophs. This part of the understanding of evolutionary pathway has to be done by scientists working on simulation/gene cloning studies as suggested by (Fox *et al.*, 1980; Woese, 1982, 1983). Most of the data on the early biogenic processes has been derived through organic geochemical studies and isotope geology. Very little data is available on the structural remains. Concerted efforts are required to search for structural remains in sediments where organic geochemical and isotopic data have indicated the existence of life. The relationship between ancient mineral deposits *vis-a-vis* biogenic processes is another important area of study.

It is believed that in the evolution of living system, appearance of aerobic photoautotrophs created a crisis which ultimately led to the evolution of eukaryotes. The oldest acceptable record of planktonic eukaryote, is from 1.8 Ga old sediments of China (Walter *et al.*, 1990). Reports of bizarre forms from the close of 2.5 Ga (Archaean) to 1.8 Ga indicate the natural experimentation of prokaryotes under stress due to attaining higher

levels of Oxygen in the atmosphere. As Oxygen was lethal for the early micro-organisms they adopted various physiological and morphological variabilities which have been observed in the sediments of Palaeoproterozoic (Hofmann, 1971). These experiments ultimately culminated in the evolution of eukaryotes. The early prokaryotes and eukaryotes had simple morphology. Therefore, it is difficult to differentiate one from the other in the fossil state. However, it is now prokaryotic organisms (Tappan, 1984). It is, therefore, likely that these early eukaryotes might have been larger in size as compared to contemporary prokaryotic communities. Thus, the only criterion available today to differentiate a prokaryote from eukaryote in fossil record is the size parameter. More efforts are required to find out criteria to differentiate the fossil eukaryotes and prokaryotes. The data from other disciplines, viz., organic geochemical studies, help in substantiating the evidences to prove the presence of eukaryote in early fossil records. Sterane, a derivative of sterol, which is confined to eukaryote has been detected from 1600 Ma old sediments (Walter, personal communication in Conway Morris, 1989). Another course of action could be to study primitive eukaryotic organisms in different habitats. This can be achieved through a close interaction between extant biologists and palaeobiologists.

When and why the living system chose to attain multicellularity is still not known. It is believed that the Neoproterozoic glaciations at 1000 Ma and between 700 to 640 Ma resulted in mass extinction. The warming up of climate occurred between 800 and 600 Ma in different areas. The ecology rebounded and gave rise to the multicellular organisms. The attainment of multicellularity and advent of metazoa has also been attributed to changes in Oxygen levels and ultraviolet radiations. The sudden appearance of metazoans and metaphytes with wide diversity of forms in the Terminal Proterozoic definitely indicates towards the availability of precursors which had less advanced organization. The presence of Ediacaran biota in geographically widely distributed locales indicates that by 680 Ma multicellular organisms had already started colonizing the commonly available ecological niches. The precursors of these advanced forms should be searched in the older strata specially of those countries which were equatorial in position during that period and show development of stabilized crust and platforms, ideal locales for presence of these early multicellular organisms like the cratonic part of India, Africa and Australia. In the Indian subcontinent large scale development of ortho-quartzite-carbonate shelf type association in Dharwar sediments and presence of stromatolitic dolomite indicate that well developed platforms were available for early colonization by these organisms.

Indian records

Widespread availability of surface exposures of the Archaean sediments associated with Banded Iron Formation (BIF) and stromatolitic structures make India an ideal choice for the study of Archaean palaeobiology. Early attempts in this direction were made at the Mysore University (Viswanathiah & Gowda, 1970, 1977; Viswanathiah & Murthy, 1972; Viswanathiah & Sreedhara, 1979; Viswanathiah & Venkatachalapathy, 1980; Viswanathiah *et al.*, 1975, 1976a, 1976b, 1976c, 1976d, 1976e, 1978a, 1978b, 1979a, 1979b, 1980, 1984a, 1984b, 1984c, 1984d). They have reported large number of acritarchs from these sediments. The acritarchs are eukaryotic planktons and are generally believed to have proliferated in Mesoproterozoic. This oldest acceptable records of these forms are from 1800 Ma old sediments. Therefore, the presence of acritarchs in Archaean sediments is quite unlikely and these records cannot be considered infallible till their syngeneity is finally established. Later few attempts were also made on thin section studies by Suresh (1982). He has substantiated his records through organic geochemical studies as well. These finds from Dodguni cherts are from the same locality as were studied by Pichamuthu (1945). During the last five years major efforts have been made to understand early biogenic processes extant at the time of deposition of Dharwar sediments. Recent work brings out that methanogenic and methanotrophic bacteria were extant at >2600 Ma (Venkatachala *et al.*, 1989). This is evidenced both by the high degree of fractionation ($\delta^{13}\text{C} - 23\text{‰} - 35\text{‰}$) of Carbon in the graphite samples of Nagvand (Shimoga Schist Belt) and Ganacharpur (Kolar Schist Belt) and presence of probable bacteria morphologically comparable to methanogens and methanotrophs under the Scanning Electron Microscope. The presence of coccoid and rod shaped bacteria morphologically comparable to members of Siderocapsaceae from Kudremukh Iron Formation provide structural evidence for sulphate reducers from >2.6 Ga old sediments (Venkatachala *et al.*, 1987). Presence of both stratified as well as columnar stromatolites from Dharwar sediments is now already known (Srinivasan *et al.*, 1989, 1990; Vasudev *et al.*, 1989). The study of modern analogues of stratified stromatolites indicate that benthic anaerobic photosynthetic and heterotrophic bacterial communities are responsible for their formation. Similarly, by analogy with modern stromatolites, the presence of columnar stromatolites indicates the existence of filamentous autotrophs. Structurally mineralized filamentous microfossils have also been reported from thin section of the black cherts interbedded in the Banded Iron Formation of Donimalai Formation (Venkatachala *et al.*, 1990). The available geochemical data from these beds

indicate an oxygenated sea water from which these BIF's were precipitated. The existence of oxygenated sea water, presence of columnar stromatolites, and structurally mineralized filamentous microfossils, having morphological similarities with extant *Phormidium*, provide presumptive evidence of presence of filamentous autotrophs earlier than 2600 Ma.

Proterozoic sediments are widely distributed in India. They extend in the extreme north in the outer and inner sedimentary belts of Himalaya and Vindhyan, Chhattisgarh, Aravalli in the central part to Cuddapah, Kurnool, Kaladgi, Bhima and Pakhal in the South. Well developed stromatolitic bioherms are known from these basins but concerted efforts to understand their role in time and space are lacking. The morphotaxonomic approach adopted varies from author to author. Some just mention the general nature of the stromatolitic bioherms, viz., stratified, domal and columnar while others try to follow the binominal nomenclature. It is difficult to judge these taxonomic assignments as they are based on field studies. The accepted method of serial sectioning and three dimensional reconstruction for study of microtexture and microfabric has not been generally used. It is necessary to use uniform methods for the study of these stromatolites. This will help to understand actual vertical and horizontal distribution of the stromatolites towards developing our own stratigraphic picture. The tendency to rush to intercontinental correlation and assigning ages on the basis of these organosedimentary structures whose morphologies are largely dependent on the depositional environment is not correct. Perhaps, the more profitable use of these stromatolitic structure can be made in developing depositional models and intrabasinal biostratigraphy along with planktonic forms, viz., acritarchs.

Microfossil studies of the Proterozoic sediments in India date back to 1953 when Sitholey, Verma & Srivastava reported microfossils from Vindhyan sediments. These studies gained momentum in late sixties and early seventies when a number of papers were published describing microfossils from Proterozoic sediments of India (Maithy, 1968; Salujha & Rehman, 1972; Saluja *et al.*, 1971). As in the case of Archaean microfossil studies, here too, the method employed was acid digestion of sediments which has the same inherent problem, i.e., difficulty in proving the syngeneity of microbiota. It is not possible to comment on most of these records due to the poor quality of published photomicrograph. Their probable morphological similarity with extant pollen, pteridophytic spores and fungal remains creates further doubts about their authenticity.

Abundant reports of microfossils from cherts are known from Proterozoic sediments of India. There is no scope of doubt on their syngeneity and biogeneity,

however, views on their taxonomic treatments vary from person to person (Kumar & Srivastava, 1990). These studies on the microfossils from chert can only help to understand the biota responsible for the formation of stromatolites. It represents a minor constituent of the microbial assemblage present in specialized niches. Therefore to get the complete picture of the early biosphere it is necessary to find out methods for substantiating acid resistant microfossils derived from shales, to develop a more balanced and complete picture of the Precambrian biota. A major part of these microfossils is constituted of planktonic forms which can be profitably used for biostratigraphy. A major gap in our knowledge is sequential appearance of planktonic microfossil through time on well measured sections. An extensive effort is required in this direction.

The antiquity of the metazoa and metaphyte is an another important area in which special efforts are required to understand the advent, size, shape and environment of evolution. It is generally accepted that the advent of metazoans occurred at around 640 Ma and the biota from Ediacaran and other equivalent bed is the first record. However, Indian records showing coiled trace fossils from Bihar (Beer, 1919), hyolithids (Rode, 1946), Dasycladacean algae *Misracyathus* (Volgdin, 1957), *Ramapuraaea*, Jellyfish-like remains (Maithy & Shukla, 1984), *Katania singhi* (Tandon & Kumar, 1978) indicate possibilities of their appearance in Pre-Ediacaran time. Many of these records have been questioned (Sharma *et al.*, in press).

The earliest assemblage of metazoans known from Ediacara and equivalent beds is dominated by coelentrates and while tracing the ontogeny of coelentrates we find that they all pass through a diploblastic stage represented by planula larva. This planula larva is a free swimming form for few days before settling on the substrate to give rise to triploblastic coelentrates. Could the Pre-Ediacarans have a morphology similar to the planula larva which may have been habiting a planktonic habitat? The recent finds of hollow tubular structure with single celled margin from the Infrakrol sediments of Nainital could represent a Pre-Ediacaran element. The flat discoid structures alongwith radial and volcano-like structure described from Suket Shale Member as probable crinoidal holdfasts (Shukla & Sharma, 1990) infact imparts a superficial morphological resemblance of the development of the planula larva on the substrate. These records from the Suket shales and Infra-Krol sediments could perhaps represent the missing link in the evolution of metazoa. It is now necessary to search extensively for similar and comparable fossil from sediments of 1 Ga or sediments older than 640 Ma.

In India, metazoan assemblages and their equivalents have been reported by Mathur and Shankar (1989).

1990). They perhaps represent the first genuine records of Ediacaran assemblage from India. The advent of metazoa is an important step in the evolution of the biological system, and occurred in Neoproterozoic.

This contention is based on the belief that ecological and environmental factors responsible for the growth and advent of metazoa had become conducive by 900 Ma. According to LaBarbera (1978) shoaling of the continental waters had helped to sufficiently increase the biomass to sustainable limits to enable existence of metazoa and metaphytes.

This last phase of the evolution of Precambrian biosphere is important to understand the events leading to the sudden influx of metazoa. Extensive studies of the Krol Formation of Lesser Himalaya and other equivalent beds in both extra peninsular and peninsular regions are necessary where Precambrian-Cambrian boundary is represented.

CONCLUDING REMARKS

It is necessary that we adopt a positive attitude to assess the available records avoiding clouding of our judgement based on internationally accepted scenario.

A new morphotype whether plant or animal evolved first at one place and then migrates to other places where suitable niches were available. Therefore, sudden proliferation of metaphyte - metazoan in other parts of the world after 700 Ma does mean that we cannot have these forms earlier in India or else where.

It is necessary to understand the relevance of the

study of microfossils and stromatolites in the Proterozoic. It is well known that stromatolite morphologies are at least partially controlled by sedimentological or ecological conditions in which they are deposited. They have little stratigraphic control. They may be used as marker horizon for mapping. It would be better to avoid the use of these stromatolites identified only on the basis of field study, as age markers and create false notions of Inter-continental correlation. They can be profitably used to develop depositional models of the basins.

Studies on plankton need to be taken up on measured section to prepare a detailed biostratigraphic picture across the major part of the Proterozoic. They are useful stratigraphic markers. Such biozonation developed on the basis of acritarch and supported by geochemical data can help in solving the problem of stratigraphy of Meso- and Neo-Proterozoic.

The problems and challenges of the Archaean palaeobiology are much different that of Proterozoic. This is a time when living system did not show much organismal evolution. Whatever changes occurred were mostly physiological and biological in nature. It may not be possible for us to trace the origin of chemoheterotrophs and chemoautotrophs as they were already extant by 3.5 Ga ago. But we can definitely study the ecological limits in which these organisms grew. This would be specially important to understand the break even point where they failed to adjust further and ultimately became extinct or evolved into new forms and gave rise to subsequent scenario.

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