INdian Precambrian Algae

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Remains of algae from the Indian Precambrian sedimentary sediments, both Archaean and Proterozoic are surveyed. The Precambrian algal forms are preserved either in form of structural biological remains or their exogenous activities, the stromatolites. The structural biological remains are preserved in form of macrofossils and microfossils. Microfossils are referable to Cyanophyceae and Acritarchs. The evidences of algae indicate that cyanophytes are biostratigraphically significant in the Precambrians.

Key words: Precambrian, India, Algae, Acritarch and Stromatolites.

Precambrian Algal remains are known to occur in the sedimentary rocks as old as 3500 million years. They are preserved in form of structural biological remains and their exogenous activities, the stromatolites. The structural biological forms are preserved as macrofossils and microfossils. Macrofossils occur as impressions, cast and moulds. Microfossils are organic walled and are commonly preserved in shales and cherts. They have been studied both in thin sections and by digestion of rocks, i.e., maceration method. Stromatolites, the organo-sedimentary structures, are formed by the carbonate precipitation and sediment binding activities of the successive mats of algae. It has been noted that during the periods of non-deposition a thin algal mat is formed and as the sediments are deposited, the algae premate them and bind them together. Lamination due to mechanical deposition is accentuated to alternation of these organic layers. They have distinct forms externally and show in cross section thin and curval lamellae. Using a set of characters, systematic distinctions are made to establish taxa with binomial nomenclature.

Precambrian sequences in India (text-fig. 1) are extensively developed and widely distributed over the peninsular as well as the Himalayan regions. The ages of the Precambrian rocks range from 3800 million years to 570 million years. The stratigraphy of the Indian Precambrian is detailed below (after Sarkar, 1973):

<table>
<thead>
<tr>
<th>Period</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archaean</td>
<td>3800-2500 Ma</td>
</tr>
<tr>
<td>Early  Proterozoic</td>
<td>2500-1600 Ma</td>
</tr>
<tr>
<td>Middle Proterozoic</td>
<td>1600-900 Ma</td>
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<tr>
<td>Late  Proterozoic</td>
<td>900-570 Ma</td>
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The Archaean rocks show medium to high metamorphism with extensive tectonic disturbance while the Proterozoic rocks are of low to medium grade metamorphism, in which the sedimentary nature of the rock is still recognisable. The late Proterozoic rocks are best preserved, more or less undisturbed and have the least effect of metamorphism.

The earliest accepted record of algal fossil is from the Iron Ore Supergroup of Keonjhar district, Orissa, dated ca. 3100 Ma (Maithy & Avasthy, 1982). Thereafter, they have been reported and described from various horizons in the early, middle and late Proterozoic sequences (Maithy, 1984). The significant records of Precambrian algal forms and their exogenous activities are being dealt here.

Archaean

Microfossils: Maithy and Avasthy (1982) reported Cyanophyceae from the black cherts associated with stromatolites of Keonjhar district, Orissa. No radiometric age is available for these rocks. However, the Singhbhum Granite which has intruded the Supergroup has been dated as ca. 2950 ± 20 Ma by Rb/Sr Method and the Gneisses which unconformably underlie the Iron Ore Supergroup gives an age...
3200 ± 85 Ma. Thus the tentative age of Iron Ore Supergroup has been taken as ca. 3100 Ma. The recorded forms have been identified as Chroococcales and Nostocales. The Chroococcales forms are Coccolid, either solitary - *Sphaerophycus* and colonial - *Aphanocapsiopsis* and *Nanococcus*. The Nostocales has linearly arranged elongated cell-like unit comparable to *Gunflintia*. However, Kumar and Srivastava (1989) opined that the arrangement of cells in chain-like manner is more likely to be *Eosynechococcus moorei*.

Naqvi *et al.*, (1987) reported two filamentous forms interpreted as silicified Cyanobacteria which they compared to modern *Lyngbya* and *Scytonema* in a 15-22 cm thick chert band occurring in the Donimali Formation in the Bellary district of Karnataka. Direct radiometric data are not available but these rocks have been correlated with the other schist belts, whose age has been suggested as 3000 Ma, i.e. the time of its Cratonisation (Naqvi & Rogers, 1986). Kumar (1988) pointed out that the forms mentioned by Naqvi *et al.*, (1987) show very high optical relief with respect to surrounding silica and thus questioned the silicified Cyanobacterial interpretation. Further in 1989, Kumar and Srivastava (p. 70) expressed since no organic matter has been reported from the slides, there is possibility that these forms may represent non-biotic mineralic threads.

**STROMATOLITE**

Grant, Murthy and Sengupta (1978) reported stromatolites in the Koira Group, Iron Ore Series of Bihar and Orissa dated to be less than 2.7 Ma. Four main forms of stromatolites-domal, laminar, oncolite and clavate have been recognised. Stromatolites have been recorded from the chert horizon which is a part of Iron Ore Formation of Bonai-Keonjhar (Avasthy, 1978) district of Orissa, (± 3100 Ma). The form is LLH-type. Beside this, the dolomites associated with greenstone sequence of the 2900 Ma old Sandur Belt (Murthy & Reddi, 1984), Chitardurga Group (2600 Ma), Dodguni (Baral, 1986) and Old Shimoga Schist Belt (2600 Ma), Kumsi (Vasudeva *et al.*, 1989) in the Karnataka craton contain vertically stacked columnar stromatolites.

**PROTEROZOIC**

Macrofossils: Diversified algal macrofossils are well known from the upper part of Middle Proterozoic (± 1000 Ma). Affinities of many of the forms are still debatable. The recorded types are categorised baseing on their external morphology.

**Disc form:**

*Chuaria* Walcott 1899 - It is now considered to be encystment structures of eucaryotic algae (Maithy, 1990) due to their large size (P1.1, Fig. 1). The forms are carbonaceous, platyspermic circular, measuring 2 to 5 mm, surface smooth or with concentric wrinkles on the margin. It is globally known in between 1000-800 Ma.

*Ramapuraea* Maithy & Shukla, 1984 - This is known to occur commonly in association of *Chuaria*. Carbonaceous impressions, circular (8-10 mm) with a distinct central circular area, which is occupied with compactly packed numerous small globular structures; outer area with fine dichotomising radial thickenings, occasionally branched. The form in gross organisation compares to the extant genus *Chlorococum* and *Neochloris* of the family Chlorococcales.

**Ovoid forms:**

*Tawuia* Hofmann, 1979 - Sausage shaped (P1.1, Fig. 1) specimens isolated as well as clustered. They are commonly found as black carbonaceous impressions or compressions closely associated with *Chuaria*. This form was considered by Hofmann (1985) to represent a distinct group probably of eucaryotic algae that constituted part of a widespread mid to late Proterozoic marine macroplankton.

*Katnia* Tandon & Kumar, 1977 - Carbonaceous sausage shaped, measuring 25-50 mm in length and 1.5-3 mm in width with distinct narrow transverse markings, equally spaced 2-4 mm apart. Glaesener (1987) considered it to be large oscilatorean cyanobacteria. Maithy (1990) opined that *Katnia* may be episodic remains of plankton blooms or mass encystment structures, algal in nature.
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**Ribbon-like Carbonaceous films:**

Walter et al., (1976) opined the Ribbon-like carbonaceous films to be eucaryotic organisms, possibly algae due to their megascoporic nature. They further suggested that these fossils most likely represent plant material, perhaps from a type of algae unknown in modern biota.

**Grypania** Walter, Oehler & Oehler, 1976 - Carbonised impressions of linear unbranched filament, evenly curved, ends broken, ribbons upto 1.0 mm wide (P1.1, Fig. 2); occasionally some of the specimens exhibit faint regular segmentation along a portion of their lengths.

**Body with a filament:**

**Krishnania** Sahni & Srivastava emend. Maithy 1991 - It is the oldest benthic algal form (Maithy, 1991). The bilateral flat fossil consisting a foliate part, abruptly constricting towards one end into a narrow stipe-like structure attached to soil by a rounded holdfast (P1.1, Fig. 3). Foliate part 6-10 mm in length and ovate shape. Du and Tian (1985) suggested it to be algal in nature belonging to Phaeophyta or Chlorophyta. According to them the apical foliate part being used for photosynthesis and the basal part parastem for support attached to rhizome. Hofmann (1985) due to its clusted appearance and subradial arrangement expressed that the taxon represents a colony of rather complex organisms of its age possibly an algae, phaeophytic or rhodophytic affinities.

**CALCAREOUS ALGAE**

**Nuia** Maslov, 1954: According to Maslov, 1954 (in Johnson, 1966; p. 73) the thalli of Nuia develops calcareous cylinders with a distinct central duct. Numerous very fine calcareous plates or needles radiate in all directions from the central duct giving a radial structure to the cylinders in cross section (P1.1, Fig. 4). The thalli may be straight or sinuous.

The systematic position of the genus is quite uncertain, superficially it suggests small primitive dasyclad algae. However, the supposed primary branches consists of flattened blad-like plate of calcite instead of rounded needle like or thread-like elements preservation are not characteristic of Dasycladaceae. Being this character, Johnson (1966) suggested its structural closeness to *Microcystidium* Gluck 1914, possibly a blue-green algae. *Nuia* is known to occur from middle to late Proterozoic of Vindhyan succession.

**MICROFOSSILS**

**Chroococcaceae:** Precambrian remains of Chroococcaceae exhibit wide range in their morphology. They are preserved as unicells and large colonies.

Among the unicells *Huronispora* Barghoorn, 1965 is spherical, smooth to micro-reticulate and enveloping sheath absent. *Huronispora* is known to occur in the entire Proterozoic sequence. *Eosynechococcus* Hofmann, 1976, comprises loosely associated group of cells, rod shaped to ellipsoidal, occasionally slightly curved, cells lack individual sheath. *Eosynechococcus* is known to occur in middle Proterozoic. *Sphaerophycus* Schopf, 1969 has cell solitary or in pairs, less frequently arranged in loosely associated group of cells, encompassed by sheath. Its presence is known in the Middle to late Proterozoic.

A large number of forms are known from Proterozoic sequence, which are arranged in groups or forming colonies. *Gloeodiniopsis* Knoll & Golubic, 1979 is characterised by spheroids and ellipsoids with single, double or multiple outline, solitary or in groups of 2, 3, 4 up to 8 and the individuals within a common envelop. It is known from late Proterozoic (Maithy & Mandal, 1983). *Tetrephyicus* Oehler, 1979 comprises of cells spherical, psilate arranged in planar tetrads, cross tetrads, diads and cluster of cells isolated or in groups surrounded by amorphous matrix. It is known from middle Proterozoic (McMenamin et al. 1983).

The large colonial forms show varied organisation. *Myxococcoides* Schopf, 1969 shows spheroidal cells clumped together in a globular colony. Both individual cells and the entire colony are encompassed by a commonly well developed amorphous non-lamellated organic matrix.
Fig. 1. *Chuaria* (circular form) and *Tawuia* (oval form) associated together. B.S.I.P. No. 36105; Locality: junction of Ghagar river with Ghagar nala, Cho-
chan; Horizon: Rohtas Formation, Vindhyan Supergroup, x Natural size. Fig. 2. *Crystania*, C-shaped carbonaceous filament. B.S.I.P. No. 36515; Locality: Anjohre Pyrite Mine; Horizon: Rohtas Formation Vindhyan Supergroup, scale one division equal to one millimeter. Fig. 3. *Krishnania acuminata*, note the apical foliate part with narrow stalk; B.S.I.P. No. 36516; Locality: Murlipahar; Horizon: Rohtas Formation, Vindhyan Supergroup, x Natural size. Fig. 4. *Nuita* sp.; B.S.I.P. slide No. 5950; Locality: 1.5 km. N. 51W of Mhow; Horizon: Hinaoti Limestone Formation, Semri Group, Vindhyan, x 50. Fig. 5. *Myxococcales globosa* Maithy & Shukla, a colonial algae belonging to Chroococaceae; B.S.I.P. slide No. 4929; Locality: Talsoi River near Ramapura; Horizon: Suket Shale, Vindhyan, x 500. Fig. 6. *Glauccapsomorpha karauliensis* Maithy & Mandal, a chroococcean colonial algae with daughter colonies; B.S.I.P. slide No. 5993 Locality: Ranipura, S.E. of Karauli, Rajasthan; Horizon: Semri Shale Formation, Bhandar Group, x 1000. Fig. 7. *Palaecocystis ghoshii* Maithy & Mandal; B.S.I.P. Slide No. 5992; Locality: 1 km north of Karauli; Horizon: Maihar Sandstone, Vindhyan Supergroup, x 1000. Fig. 8. *Bavlinella foveolata* Shepeleva; B.S.I.P. Slide No. 9791; Locality: Lijja nala, Maihar; Horizon: Suket Shale Upper Vindhyan, x 1000. Fig. 9. *Oscillatoriaopsis pusilata* Maithy & Shukla, B.S.I.P. Slide No. 4929; Locality: Talsoi River bed near Ramapura; Horizon: Suket Shale, Semri Group, x 500. Fig. 10. *Emocystis pusilata* Maithy & Shukla, empty tubular filaments; B.S.I.P. No. 4931; Locality: Talsoi River bed near Ramapura; Horizon: Suket Shale, Semri Group, x 500. Fig. 11. *Acetarch, Kildinosphaera* sp.; B.S.I.P. No. 6257; Locality: Bapori village, north of Sapota; Horizon: Panna Shale, Rewa Group, Upper Vindhyan, x 1000. Fig. 12. *Tungusia*, a columnar branched stromatolite; B.S.I.P. No. 36350; Locality: Pali Ghat, Sawai Madhopur District; Horizon: Slrshu Shale Formation, Upper Vindhyan Supergroup, x 1.
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(P1.1, Fig. 5). Occurrence is well known from middle to late Proterozoic. *Palaeoanacystis* Schopf, 1968 which looks similar to *Myxococoides* differs in the absence of enveloping sheath around individual cells. It also shows same geological distribution like *Myxococoides*. *Gloeocapsamorpha* Zalessky, 1916 has large colonies alongwith daughter colonies (P1.1, Fig. 6). Individual cells and daughter colonies and entire colony are unsheathed by non-lamellated amorphous sheath. Division of cells common and occurs in two directions. It is known from late Proterozoic.

Beside this, the form *Nanococcus* Oehler, 1977 shows spheroidal to ellipsoidal cells loosely arranged in a colony, individual cells ensheathed, colony enclosed in a large formless organic matrix. *Corynhoboccus* Awramik & Barghoorn, 1977 is organisationally similar to *Nanococcus* but differs as the individual cells do not have enveloping sheath. Both the forms are known from late Proterozoic (Maithy & Mandal, 1983).

*Glenobotrydion* Schopf, 1968 has a prominent circular small organic structure on inner surface of cell walls, cells loosely associated groups of many hundred cells in pseudofilamentous organisation enclosed in a sheath, sheath non-lamellated. It is known from middle to late Proterozoic. *Aphanocapsaopsis* Maithy & Shukla, 1977 agrees to *Glenobotrydion* in the organisation of colony, but differs in the absence of organic structure inside individual cells. Its occurrence is known from middle Proterozoic.

*Palaeoglaucocystis* Maithy & Mandal, 1982 is characterised by cells spherical, isolated or in loose groups, outer layer of cells uniform in thickness lamellated and occasionally with vertical thickenings may extend beyond outer layer, giving a sinuous margin, inner portion of cell thick with many short or long vertical parallel running thickenings giving reticulate appearance and cells not enclosed within a sheath (P1.1, Fig. 7). Reproduction by fission and budding (?) and cells division in single plane.

*Bavinella* Shepeleva, 1962 occurs commonly in the late Proterozoic-Vendian rocks i.e. 650-570 Ma. They are spheroidal aggregates of dark brown organic material, 4-16 μm across containing tightly packed, isodiametric globular to subpolyhedral globular cell-like units 0.3-1.0 μm in diameter (P1.1, Fig. 8). They are in great abundance at certain levels probably being attributable to explosive blooms in a stressed habitat, such as a glacially influenced marine environment or hot drying condition.

**Entophysalidaceae**

*Eoentophysalis* Hofmann 1976 is known from the middle Proterozoic, cell-like units spheroidal, ellipsoidal or subpolyhedral; solitary, in pairs, planar tetrads, characteristically crowded in luxurious palmelloid colony. Some cell-like units with dark inclusions. Occurrence is known from middle Proterozoic. (McMenamin et al., 1983).

**Pleurocapsaceae**

*Vindhaycapsiopsis* Maithy & Mandal, 1983 has cells clumped together in rectangular colony, ensheathed within a gelatinous mass; 4-6 cells in each vertical row, arranged in opposite pairs, cells spherical non-ensheathed. It is known to occur from middle Proterozoic sequence.

**Oscillatoriaceae**

*Eomyce topsis* Schopf, 1968 has cylindrical tubular filament, unbranched predominantly non-septate, either solitary or gregariously sometimes entangled in small groups (P1.1, Fig. 10). Another form *Animikea* Barghoorn, 1965 resembles *Eomyce topsis* but differs in the presence of finely arranged grana in parallel row indicating fine transverse septa. *Archaeoresis* Barghoorn, 1965 known in the late Proterozoic (Maithy & Mandal, 1983) has a slender trichome non-septate, non-tubular and branched.
**Nostocaceae**

Representatives are known from middle to late Proterozoic sequence. *Gunnflintia* Barghoorn, 1965 is a unbranched multicellular filament, straight or curved cells, rectangular, arranged end to end and septa distinct. Cells equidimensional or longer than wide, Licari and Cloud (1968) reported heterocyst and akinete. A multicellular unbranched filaments with heterocyst has been described by Sastri et al., (1972) under *Palaeonostoc*. *Vetronostocale* Schopf & Blacic 1971 is unbranched multicellular filament, cells beaded in appearance, septa distinctly constricted, cells circular or ellipsoidal in shape. Maithy and Meena, (1989) reported it from the rocks ± 1000 Ma old.

**Palaeoscytonema** Edhoorn is a filamentous alga, trichome multicellular, uniseriate, septa almost equidimensional, trichome straight showing false branching, hormogone-like structures, three to several cells long at intervals along trichome. The form was recorded from Ajabgarh Group, probably middle Proterozoic (Mandal et al., 1983).

**Rivulariaceae**

**Primorivularia** Edhoorn is known from middle Proterozoic (Mandal et al., 1983). It has solitary filament, uniseriate, multicellular, unbranched, en-sheathed, fully constricted at septa, basally, sheath non-lamellated, basal cells spherical, broader than...
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long, median cells rectangular, closely placed, septa faint, heterocyst basal, single and hemispherical.

ACRITARCHS:

Precambrian acritarchs are spherical microfossils with thick and complex organic walls (Pl.1, Fig. 11). They are probably algae that grew thick organic coats in a resting stage of their life cycle and they are large enough to be undoubtedly eukaryotes. The Precambrian acritarchs must have evolved in or near stromatolites in shallow coastal waters. Many of the Proterozoic acritarchs were large in size and to keep themselves floating they evolved buoyancy chambers. The buoyancy chambers had varied organisation and were presumably filled with gas or light oil (?). Acritarch became very abundant in the close of middle to late Proterozoic.

STROMATOLITES:

Occurrences of stromatolite from the entire Proterozoic sequence are well known. The stromatolites from the early Proterozoic sequence i.e. 2500 to 1600 Ma old rocks are large sized, elongate sub-cylindrical column, characterised by a short discontinuous ribs and small elongate niches and projections in which the column breaks up into L-type of slightly divergent branching. The laminae are steeply convex or parabolic and marginally coalesce to form connecting bridges. This assemblage is best known in the Udaipur area, the Aravalli Group, Jhabua area in south-western Madhya Pradesh, Jonga area in Hoshangabad District and in the Bijawar Group exposed in Chatarpur District (Valdiya, 1989). The stromatolites are identical to Patomia and Pilbara reported by Walter (1972) from the 2000 Ma old Duck Creek Dolomite of Wyloo Group, Western Australia. Maithy (1978) has reported solitary, unicalcian cyanobacteria referable to Chroococcaceae and binary fission of cells in the stromatolites deposited at Jhamar Kotra (near Udaipur) belonging to Matoon Formation, Aravalli Supergroup.

The middle Proterozoic stromatolites i.e. between 1000-1600 Ma old contain mainly Canophytonidia and Kussiellida types. The form of Canophytonidias shows monoculmnar stromatolites with almost rectilinear axes. Lamination is either conical, subhemispheroidal or pyramidal but always concentric in transverse section. The Kussiellidia forms are passively branching form (sensu Raaben, 1964) and are characterised by distinctive mode of growth; the cylindroidal vertical columns becoming gradually narrow by branching and this has an effect of reducing the total surface of the stromatolite lamina. The middle Proterozoic stromatolites are known from Ajabgarh (Upper Delhi), Semri (Lower Vindhyan), Pakhal, Kaladgi and Cuddapah.

The late Proterozoic sediments are characterised by stromatolites of small branching type, viz., "Gymnosolenids" and "Tungussids". Both the families show pronounced tendency to widen through branching. The difference between these families lies in the well accentuated parallelism of columns in the Gymnosolenidia structure whereas the Tungussidia display nonparallel columns that form bush-like structure. Gymnosolenidia includes Gymnosolen Strein; Inzeria Krylov, Minjaria Krylov and Lena Doln. Tungussidae is known commonly by Tungussia Semikhatov (Pl.1, Fig. 12), Baicalia Krylov and Anabaria Komar. Late Proterozoic stromatolites are known from Bander Group (Vindhyan), Raipur Group (Chattisgarh), Jamalmaduga Group (Kurnool) and Bhima.

DISCUSSION

The simple morphological nature of the Precambrian macrofossils have largely forced the palaeobiologists to describe them as algal remains, since they are quite common and abundant today. There is every possible chance that some of the algal inferences drawn by may prove wrong in near future with the findings of better preserved materials. In past phycologists have always assumed that the fossil evidence can make no useful contribution to the understanding of Cyanophytic evolution. Fritsch (1965, p. 859) has expressed "even should some of the fossil types referred of structural features or of the evolutionary sequence". This has also been supported by Desikachary (1959). The Precambrian algal records indicates that such views are no more tenable. The Archaean and early Proterozoic shows pres-
ence of Chroococaceae, whereas the middle and late Proterozoic rocks show common occurrence of Nostocaceae and Oscillatoriaceae in addition to Chroococaceae. The fossil evidences indicate that there was a progressive morphological diversification of the Cyanophycean algal life has taken place from Archaean to Proterozoic.

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