Discovery of silicified microfossils from the Khatpul Formation, Shali Group (Neoproterozoic), H.P., India

Vibhuti Rai* and Rajita Gautam
Department of Geology, University of Lucknow, Lucknow 226 007, India

Well-developed organic walled microfossils of cyanobacterial affinity are recorded for the first time from the bedded and stromatolitic chalk units of the Shali Group (Neoproterozoic). The present discovery enhances our knowledge of the palaeobiology of the Shali Belt which has so far yielded only stromatolites. The association of these silicified microfossils with columnar stromatolites signifies the close ecological relationship between the two. A correlation of the Shali Belt with adjacent belts of the Lesser Himalayan Inner

The Proterozoic time span represents major events related with diversification of life that later gave rise to the Phanerozoic explosion of life. The Mesoproterozoic to Neoproterozoic span characterizes the initial diversification amongst the microbial community. However, due to limited number of fossiliferous horizons, a comprehensive picture of the biologic evolution across this time interval is yet to emerge. In the light of this, all such records that can provide us additional data, bear significance in order to testify the various evolutionary models specially those from widely-spaced basins and those which can strongly support the regional correlation. The focus of the present report is, therefore, on the discovery and significance of organic-walled microfossils from the silicified calcareous horizons of the lower part of the Shali Group in the Mandi district of Himachal Pradesh. An attempt has also been made to describe the biota and discuss its utility in correlating widely-spaced coeval basins.

In the Himalayan range, a number of structural belts exist all along its regional E–W trend, several of which show deposition during the Proterozoic time span. Amongst the important belts, the Shali, Larji, Deoban and Garhwal represent the Inner Sedimentary Belt while the Krol Belt represents the Outer Sedimentary Belt. The Shali Belt succession (Shali Group) (Figure 1a; Table 1) represents an important part of the Lesser Himalayan Inner

![Figure 1. Map of the fossil-yielding locality. a. Distribution of Shali Belt; b. Geological map of the area showing microfossil-yielding locality (marked by star).](image)

![Figure 2. Lithocolumn of the Khatpul Formation showing different sedimentary features along with chalk-bearing horizons: 1. Thin band of red shale and orthoquartzite; 2. Sandy dolomite; 3. Laminated dolomite with chertified stromatolite bands and quartzite; 4. Massive structureless dolomite with columnar stromatolites and cryptalgalaminites; 5. Intraformational dolomite breccia; 6. Laminated dololutites and grey to pale-pink quartzite; 7. Grey bedded dolomitic limestone with sporadic grey shale partings. Star indicates fossiliferous chalk-bearing horizon.](image)

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Table 1. The lithostratigraphy of the Shali succession

<table>
<thead>
<tr>
<th>Shali Group</th>
<th>Basantpur Formation</th>
<th>Tattapani Formation</th>
<th>Sorgarh Formation</th>
<th>Khatpul Formation</th>
<th>Khaira Formation</th>
<th>Repri Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandla Formation</td>
<td>250 m (ref. 2)</td>
<td>250 m (ref. 10)</td>
<td>610 m</td>
<td>300 m</td>
<td>380 m</td>
<td>400 m</td>
</tr>
<tr>
<td>Parnali Formation</td>
<td>700 m</td>
<td>608 m</td>
<td>460 m</td>
<td>390 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Makri Formation</td>
<td>180 m</td>
<td>140 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sundernagar Group</td>
<td>1,830 m</td>
<td></td>
<td></td>
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*For correspondence. (e-mail: vibhutirai@hotmail.com.)
Sedimentary Belt with its deposition taking place during the early part of Neoproterozoic time span. The succession, which is developed in calcareous and terrigenous clastic facies, shows strong facies resemblance with adjacent belts of Larji, Deoban and Garhwal. On account of undisturbed nature of the sequence with well-preserved sedimentary features, an attempt was made to understand the bio-sedimentology of the succession. Although preliminary work related with the lithostratigraphy, geological mapping and broad depositional framework was available\(^1\),\(^2\) no further detailed work has so far been carried out in the area.

The Shali Group has been assigned an age on the basis of its position above the Sundernagar Group (a sequence of quartzites, slates, phyllites and volcanics, that has been dated as $1190 \pm 35$ Ma by K/Ar method\(^3\)). On a biostratigraphic scheme\(^4\), the calcareous units of the Shali Group have shown the development of well-preserved stromatolites with two distinct assemblages. The lower zone is represented by <i>Collenia columnaris</i>, ...
C. buriatica, C. baicalica and C. symmetrica, whereas the upper zone is represented by Jurusania5-7. On the basis of this assemblage, Valdiya suggested an age ranging from Middle Riphean to Upper Riphean for the entire sequence8. In another study9, the stromatolite form genera Tungussia, Conophyton cylindricus, Colonella and Newlandia were recorded from Shali and Larji successions and an age assignment of Middle Riphean was deduced for the sequence. Lately, an age assignment of Lower to Middle Riphean was suggested9 on the basis of stromatolite assemblage for the Shali succession.

During the course of the preliminary study of the columnar stromatolites, it was observed that these are represented by a host of morphologies. Amongst the predominating morphologies, 10–20 cm high, 7–10 cm wide cylindrical forms are common. These can be compared with form genus Colonella. A few conical-shaped forms show faintly developed central columnar region with peripheral conical lamination and can be ascribed to stromatolite form genus Conophyton. A few forms show elongated columns with smooth surface and simple branching pattern. These occur as parallel columns growing perpendicular to the bedding. These structures are comparable to Kussiella kussiensis. Large 10–20 cm high and 20–35 cm wide ‘cabbage-shaped’ algal mounds with convex lamination pattern are commonly found within these horizons. They are similar in morphology to form genus Cryptozoon. Some of the stromatolitic horizons as well as cryptagalaminites are partially silicified. The silicified microbiontic fossils are mainly recorded from the Colonella type stromatolites as well as cryptagalaminites.

Apart from the above biotic evidences, no other palaeontological data has so far been reported from the Shali succession. During a recent visit to the Bilaspur–Sundernagar area, we collected a few partially silicified stromatolites besides a few bedded black chert samples. These samples have shown the preservation of well-developed micro-floristic fossils. Since the silicified specimens are considered to represent the best possible preservation (specially in comparison with macerated specimens) by way of their syn-sedimentary fossilization, their record bears much significance. The newly-discovered microfossils are represented by filamentous, cocoidal, cylindrical and spindle-shaped forms and show close similarity with a few other Neoproterozoic successions around the world.

As a preliminary investigation, a small stretch of the terrain was selected in the Mandi district of Himachal Pradesh where the lower part of the Shali Group (Figure 1 b) was well exposed on the National Highway No. 21 between Bilaspur and Sundernagar in the vicinity of Harkhar Bari and Slapper bridge. Steeply dipping beds with occasional exposures of bedding planes show abundant sedimentary features. These features include ripple-marks, cross-bedding, mud-cracks, lobate rillmarks and herring-bone cross-stratification. In the carbonate sequence, the beds are cream to grey with occasional presence of oolitic and intraclastic horizons. Well-developed domal stromatolites are observed in various horizons. A few fenestral-algal laminated horizons are also observed. On the basis of these structures, a shallow marine environment is inferred for the lower part of the sequence with its domain within the intertidal realm.

The lithostratigraphy of the Shali succession2,10 is shown in Table 1. The microfossil-bearing cherts have been recorded from the Khatpul Formation which conformably overlies the Khaira Formation (pink orthozoitite) and underlies the Sorghwarwari Formation (a thinly-bedded sequence of pink limestone and shales). The Khatpul Formation (Figure 2) is a thick sequence of grey dolomite with characteristic red shales at its base. These dolomites show well-developed oolitic horizons, intraclastic layers and algal-fenestral facies indicating towards intertidal to supratidal depositional environment. The stromatolitic horizons are characterized by domal columnar structures with their cross-section showing circular to elliptical shape.

Figure 3. Scale in all forms equals 10 μm (bar given in f). a, S. No. Shali 2 (E. F. No.-K 26/2, co-ord.-10.8 x 57.1), Cross-section of a filament with inner tube showing a notch at one end. b, S. No. Shali 1 (E. F. No.-J 22/1, co-ord.-15.3 x 58.2), Cocoidal form comparable to Gloeoindopsis showing two layers with a dark body occurring on the left side of the vesicle cavity. c, S. No. Shali 2 (E. F. No.-J 27/1, co-ord.-10.4 x 56.5), Ring-shaped cocoidal form comparable to Globophycus. d, S. No. Shali 2 (E. F. No.-K 27/0, co-ord.-10.3 x 56.9), Two overlapping spheres with irregular, crenulated margins resembling Xenolitha. e, S. No. Shali 2 (E. F. No.-N 25/3, co-ord.-12.5 x 54.2), Oval-shaped solitary cells of Myxococceoides. f, S. No. Shali 1 (E. F. No.-T 23/1, co-ord.-14.3 x 48.7), Myxococceoides with granular surface texture. g, S. No. Shali 1 (E. F. No.-J 29/3, co-ord.-8.9 x 57.2), Myxococceoides with thick wall. h, S. No. Shali 1 (E. F. No.-H 21/4, co-ord.-16.0 x 58.6), A cluster of five cocoidal cells with thick dark walls and centrally located intracellular mass. i, S. No. Shali 1 (E. F. No. K 21/4, co-ord.-14.9 x 56.8), Archaeotrichion. The illustrated length of the filament is partial, the actual length of the specimen is 200 μm, j. S. No. Shali 1 (E. F. No.-J 22/0, co-ord.-14.9 x 57.9), Conical vase-shaped form with terminal aperture clearly seen (marked by arrow). k, S. No. Shali 1 (E. F. No.-J 28/0, co-ord.-9.3 x 58.4). Specimen comparable to genus Xenolitha with a central curved tube connecting two spherical ends. l. S. No. Shali 1 (E. F. No.-F 200, co-ord.-17.1 x 48.5), U-shaped form with the upper part showing clearly rounded end. m, S. No. Shali 2 (E. F. No.-P 26/4, co-ord.-11.1 x 51.9), Triangular specimen with two large adjacent cells and a terminal triangular cell. n, S. No. Shali 2 (E. F. No.-P 20/4, co-ord.-16.4 x 51.8), Cylindrical filament showing network of cells. o, S. No. Shali 2 (E. F. No.-K 26/4, co-ord.-11.1 x 56.7), Part of a filament with trichome preserved within the sheath. p, S. No. Shali 2 (E. F. No.-M 19/0, co-ord.-18.1 x 55.3), Spindle-shaped filament comparable to Bacthropycus, showing some organic inclusions. q, S. No. Shali 2 (E. F. No.-J 24/1, co-ord.-13.5 x 58.5), Dark cylindrical filament of Eumycocceida, r, S. No. Shali 1 (E. F. No.-L 22/1, co-ord.-15.0 x 56.5), Septate filament (cortex marked by arrow) with a terminal cell seen on the right side. s, S. No. Shali 2 (E. F. No.-L 27/1, co-ord.-10.3 x 55.9), Spindle-shaped Bacthropycus with granular walls and some organic inclusions. t, S. No. Shali 1 (E. F. No.-K 23/1, co-ord.-14.4 x 57.4), Large rod like filament with tapering ends, comparable to Archaeoellipsoides. u, S. No. Shali 2 (E. F. No.-H 27/3, co-ord.-10.7 x 58.6), Part of Eumycocceida sheath.

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The microfossil assemblage is represented by filamentous, coccolidal and irregular, vesicle-shaped forms showing a wide variation in morphology. However, a few forms amongst all the taxa recorded have not been illustrated. The most abundant forms are filamentous, showing variation in shape from simple tubular to cylindrical, spindle-shaped and rod-shaped. They occur mainly as solitary forms but a few poorly-preserved broken clusters are also seen. The most commonly occurring filamentous forms include species of Archaeotrichion (Figure 3 i), Eomycteotis (Figure 3 g, u) and Siphonophyscus with the filament width being < 1 µm, between 2-3 µm and > 4 µm respectively. Archaeotrichion with broken ends, measuring up to 200 µm in length is the longest recorded form from this assemblage (Figure 3 i). The next most abundant form is cylindrical in shape with tapering ends, comparable to Bactrophyicus (Figure 3 p, s). A few of these specimens show some organic inclusions while most are smooth and empty. Another type of filamentous form is represented by large-sized ellipsoidal envelope with a broad rounded ends, containing some clotted inclusions and ranging in length from 22 to 28 µm and in width from 7 to 9 µm. These forms are comparable to Archaeoellipsoides (Figure 3 i). A few specimens of genus Eosynechococcus with small rod-like bodies, 3-4 µm long and ~1 µm wide are also recorded. In one of these specimens, three such bodies are linked together forming a chain. Another interesting form is represented by non-septate, dumb-bell shaped microfossil with spherical ends connected by a curved tube. The surface texture is finely reticulate to granular (Figure 3 d, k). These forms can be ascribed to genus Xenothrix. Two U-shaped filamentous forms with sharp tapering ends are also recorded (Figure 3 f). For a few morphotypes, only a single specimen has been observed. One of such forms is spatula-shaped with one end broad and flat and the other tapering and narrow. Another partly-preserved specimen shows a non-septate trichome preserved within a thick outer sheath (Figure 3 e). Cross-section of filament showing inner ring depicting trichome is also recorded (Figure 3 a). In another specimen, cylindrical filament shows a network of cells within the main body (Figure 3 n). In yet another specimen, a septate filament (septa marked by arrow) with a well developed terminal cell is seen with smooth margins (Figure 3 r).

The coccolidal forms comprise the next most abundant group of microfossil assemblage from Shali. These occur mostly as small solitary spheres, ~6 µm in diameter, referable to well-known taxa like Myxococcioides (Figure 3 e, f, g), Gloeodiniopsis (Figure 3 b) and Globophycus (Figure 3 c). Colonial forms are rare but a partly-preserved colony with five cells preserved in two rows is recorded (Figure 3 h). This form is comparable to genus Gloeodiniopsis. Large coccolidal bodies occurring embedded within a mucilaginous sheath also form a component of the microbial assemblage as is evident from spongy mat-like structures with circular to semi-circular empty spaces (indicating possible position of coccolids), scattered randomly within the thin section.

The irregular vesicle-shaped forms comprise a rare component of the assemblage with individual specimens showing varied shapes and sizes. A very distinctive form is pear-shaped in which two large cells occur adjacent to each other and a third smaller triangular cell protrudes from behind and above the two (Figure 3 m). This form is large in size, measuring 30 µm at base and ~30 µm in height. Another conical vase-shaped form with a terminal aperture is also characteristic of the assemblage (Figure 3 j). Apart from this, a few vesicles ~20 µm in diameter and with undulating curved edges also occur in the assemblage.

Such diverse assemblage of microfossils from the Shali Group compares with the Middle Proterozoic to Early Neoproterozoic assemblages from Wumishan Formation of Jixian Group in China (11), the Bitter Springs Formation of Central Australia (12) and Vindhyan Supergroup of Central India (13).

Microfossil records from bedded chert units of early Neoproterozoic age are very rare in the world. Any new discovery provides crucial information about the level and extent of evolution in the biospheric domain. The present discovery from the lower part of the Shali succession of the Inner Sedimentary Belt (LSB) of the Lesser Himalaya is the third record of microbiota from the bedded black chert horizons, the other two being from the Deoban Group of the Garhwal Himalaya (14-16) and from the Jammu Limestone (17). This discovery has opened up new vistas of study in the area, especially in the field of biostatigraphy, as no conclusive fossil evidences were so far recorded from the present sequence. Although the composition of the biota presently recorded during the course of this preliminary study does not necessarily indicate any age diagnostic form, a future study in the area would possibly generate enough data in establishing an age constraint for the biostatigraphic scheme of the Shali Group. However, the absence of acritarchs and any characteristic Vendian taxa suggests an age confined to Riphean only. This contention is also supported by earlier studies being carried out on the stromatolite assemblage of the Shali succession. The record of some of the described forms from the chertified laminae of the columnar stromatolites strongly suggests a common evolutionary niche and palaeoecological setting where the microfossils influenced the stromatolitic growth and development. The chertified
microbiota from the Deoban Group represent a highly diversified assemblage (a record of over twenty-two taxa) whereas the microbiota from the Jammu Limestone although limited in number, represent quite an evolved community. A cursory comparison of all the three assemblages suggests that the Deoban micro-floristic community possibly represents slightly younger elements in comparison to those from the Shali succession, and those from the Jammu Limestone may still go higher up in the evolutionary ladder. It is therefore suggested that amongst the several terrains of the Lesser Himalayan Inner Sedimentary Belt, the coeval nature of the various sequences needs re-examination for their regional correlation which should be based on a firm biostratigraphic scheme.


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The effect of physico-chemical parameters on the erosion of monumental stones of Orissa

J. S. Bhargav, R. C. Mishra and C. R. Das
Department of Chemistry, B.J.B. College, Bhubaneswar 751 014, India

Old stone monuments situated in Bhubaneswar, capital city of Orissa, India, were built during 7th century A.D. to 11th century A.D., using sand stones of Gondwana age. The present study deals with the effects of various physico-chemical parameters on the erosion of a variety of sandstones used in the construction of these monuments. Experiments were carried out to study leaching of these stones under neutral and acidic media and the salt attack tests performed under controlled conditions in the laboratory. The results of these studies will help to provide an effective method of protecting these old stone monuments from environmental deterioration due to various physico-chemical parameters.

The temple city of India, Bhubaneswar abounds with hundreds of temples of cultural heritage. These temples are built up of blocks of sandstone of Gondwana age. All the temples constructed between 7th and 11th century A.D. are built up of varieties of siliceous and ferruginous sandstones. Visual observations showed that different stone blocks on a particular face of a monument, exposed to similar environmental condition, have weathered to varying degrees. This shows that pattern of weathering and resistance of the stones towards weathering conditions, change with the variety of stones used.

A detailed survey carried out on all the stone monuments present at Bhubaneswar revealed that three varieties of stones were predominant: red, white and yellow. While the red and yellow varieties, which were locally known as Rajarania were mostly medium grained, the white variety was found both in coarse and fine grained, of which the fine grained was more widely used.

Mineralogically all the three stones can be classified as sublithic arenites. Petrological studies showed that these stones were dominant in quartz and feldspar. Heavy minerals like zircon were noticed apart from opaque minerals. The cementing material was mostly ferruginous and not calcic1 (the stones failed to give effervescence with concentrated HCl).

Based on the results of this study, three sandstones (red, yellow and white) were identified for carrying out experiments under simulated conditions in the laboratory.

A study conducted2 on the quality of rain water at Bhubaneswar revealed that the ions precipitated from the atmosphere of Bhubaneswar were NO₃⁻, SO₄²⁻, Cl⁻, Ca²⁺, Mg²⁺, Na⁺, K⁺, etc. A well-known source of most of these ions is the Bay of Bengal (about 30 km towards east of Bhubaneswar) while the NO₃⁻ ion is mainly produced from the oxides of nitrogen3. The formation of NO₃⁻ in the atmosphere indicates clearly the chances of

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