

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

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Well-developed organic walled microfossils of cyanobacterial affinity are recorded for the first time from the bedded and stromatolitic chert 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 Himalaya has been discussed in the light of the present discovery.

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

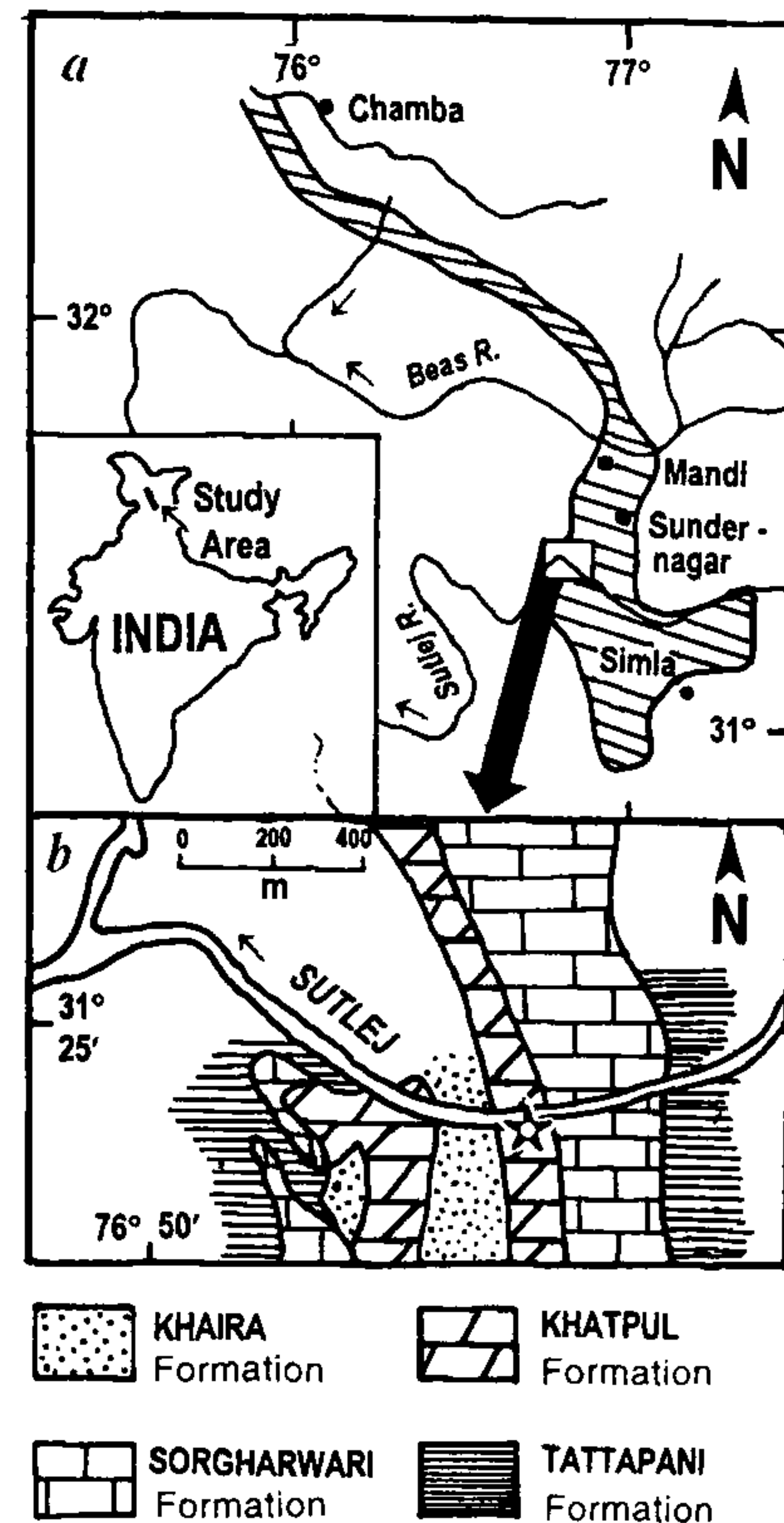


Figure 1. Map of the fossil-yielding locality. *a*, Distribution of Shali Belt; *b*, Geological map of the area showing microfossil-yielding locality* (marked by star).

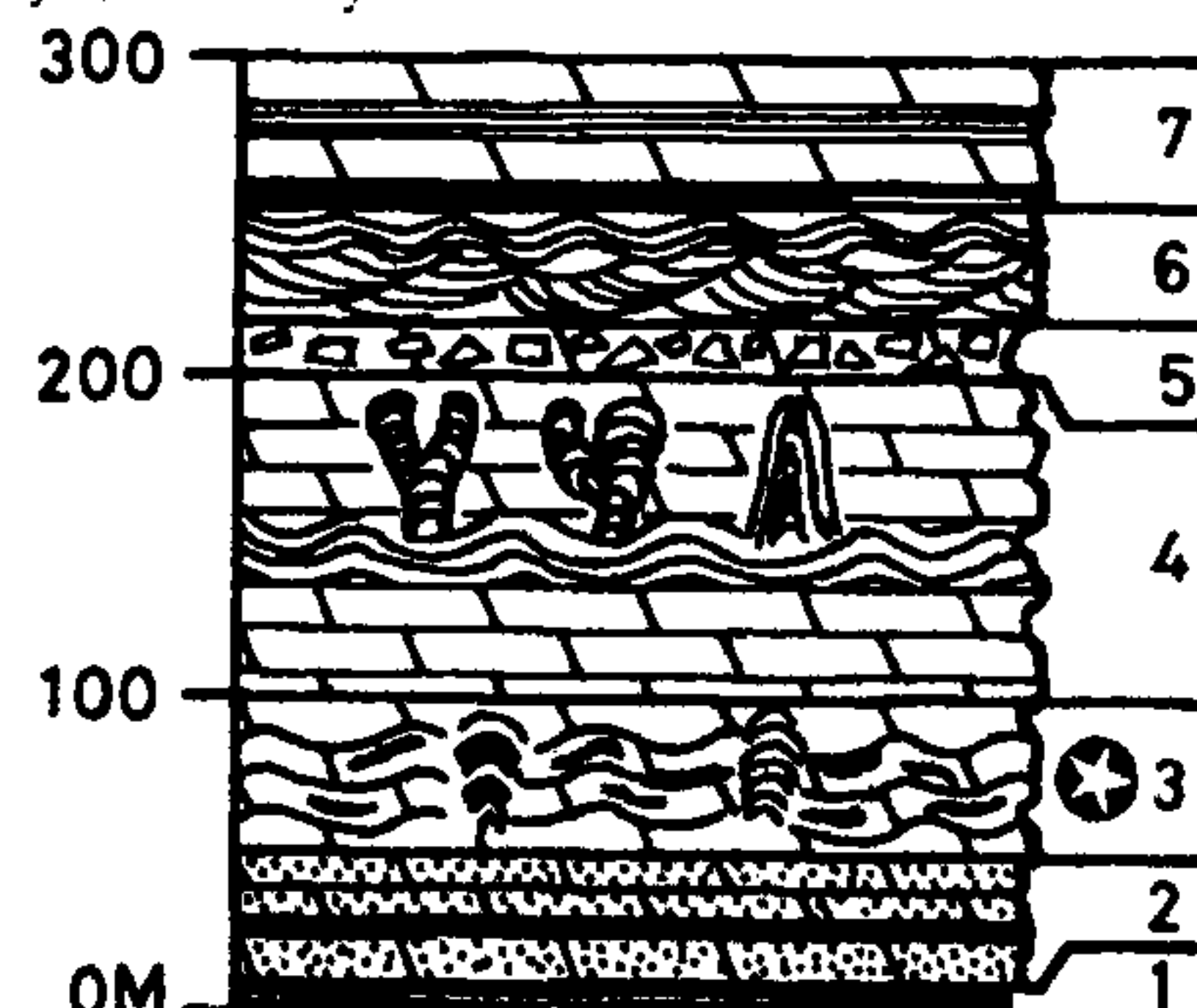


Figure 2. Lithocolumn of the Khatpul Formation showing different sedimentary features along with chert-bearing horizons²; 1, Thin band of red shale and orthoquartzite; 2, Sandy dolomite; 3, Laminated dolomite with chertified stromatolitic bands and quartzite; 4, Massive structureless dolomite with columnar stromatolites and cryptogalaminites; 5, Intraformational dolomite breccia; 6, Laminated dololutes and grey to pale-pink quartzite; 7, Grey bedded dolomitic limestone with sporadic grey shale partings. Star indicates fossiliferous chert-bearing horizon.

Table 1. The lithostratigraphy of the Shali succession

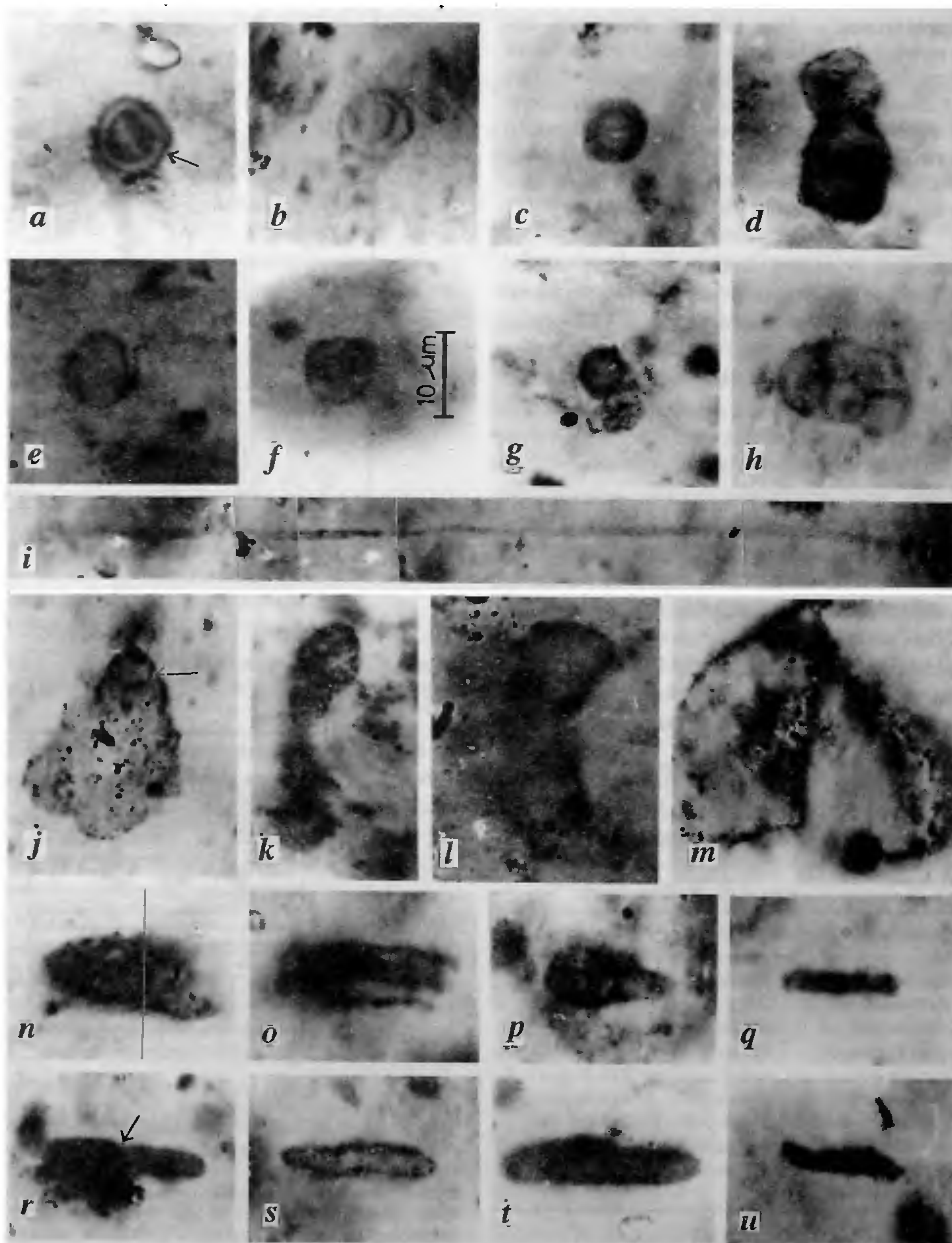
Basantpur Formation			
	Bandla Formation	250 m (ref. 2)	250 m (ref. 10)
	Parnali Formation	700 m	608 m
	Makri Formation	180 m	140 m
Shali Group	Tattapani Formation	610 m	630 m
	Sorgharwari Formation	460 m	390 m
	Khatpul Formation	300 m	250 m
	Khaira Formation	380 m	390 m
	Ropri Formation	400 m	77 m
---Unconformity/ Tectonic-----			
	Sundernagar Group		1,830 m

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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 ± 35 Ma by K/Ar method³). On a biostratigraphic scheme⁴, 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 *Collenia columnaris*,



C. buriatica, *C. baicalica* and *C. symmetrica*, whereas the upper zone is represented by *Jurusania*⁵⁻⁷. On the basis of this assemblage, Valdiya suggested an age ranging from Middle Riphean to Upper Riphean for the entire sequence⁷. In another study^{4,8}, the stromatolite form genera *Tungussia*, *Conophyton cylindricus*, *Colonnella* 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 *Colonnella*. 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 cryptalgalaminites are partially silicified. The silicified microbiotic fossils are mainly recorded from the *Colonnella* type stromatolites as well as cryptalgalaminites.

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, coccoidal, 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 1b) 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 rill-marks 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 succession^{2,10} is shown in Table 1. The microfossil-bearing cherts have been recorded from the Khatpul Formation which conformably overlies the Khaira Formation (pink ortho-quartzite) and underlies the Sorgharwari 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 μ m (bar given in f). a, S. No. Shali 2 (E. F. No.-K 26/2, co-ord.-10.8 \times 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 \times 58.2), Coccoidal form comparable to *Gloeodiniopsis* showing two layers with a dark body occurring on the left side of the vesicle cavity. c, S. No. Shali 2 (E. F. No.-L 27/1, co-ord.-10.4 \times 56.5), Ring-shaped coccoidal form comparable to *Globophycus*. d, S. No. Shali 2 (E. F. No.-K 27/0, co-ord.-10.3 \times 56.9), Two overlapping spheres with irregular, crenulated margins resembling *Xenothrix*. e, S. No. Shali 2 (E. F. No.-N 25/3, co-ord.-12.5 \times 54.2), Oval-shaped solitary cells of *Myxococcoides*. f, S. No. Shali 1 (E. F. No.-T 23/1, co-ord.-14.3 \times 48.7), *Myxococcoides* with granular surface texture. g, S. No. Shali 1 (E. F. No.-J 29/3, co-ord.-8.9 \times 57.7), *Myxococcoides* with thick wall. h, S. No. Shali 1 (E. F. No.-H 21/4, co-ord.-16.0 \times 58.6), A cluster of five coccoidal 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 \times 56.8), *Archaeotrichion*. The illustrated length of the filament is partial, the actual length of the specimen is 200 μ m. j, S. No. Shali 1 (E. F. No.-J 22/0, co-ord.-14.9 \times 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 \times 58.4), Specimen comparable to genus *Xenothrix* with a central curved tube connecting two spherical ends. l, S. No. Shali 1 (E. F. No.-T 20/0, co-ord.-17.1 \times 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 \times 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 \times 51.8), Cylindrical filament showing network of cells. o, S. No. Shali 2 (E. F. No.-K 26/4, co-ord.-11.1 \times 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 \times 55.3), Spindle-shaped filament comparable to *Bactrophycus*, showing some organic inclusions. q, S. No. Shali 2 (E. F. No.-J 24/1, co-ord.-13.5 \times 58.3), Dark cylindrical filament of *Eomycetopsis*. r, S. No. Shali 1 (E. F. No.-L 22/2, co-ord.-15.0 \times 56.5), Septate filament (septa 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 \times 56.5), Spindle-shaped *Bactrophycus* with granular walls and some organic inclusions. t, S. No. Shali 1 (E. F. No.-K 23/1, co-ord.-14.4 \times 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 \times 58.6), Part of *Eomycetopsis* sheath.

All the thin sections have been housed in the museum of the Department of Geology, University of Lucknow, Lucknow. The photomicrographs have been taken on the Nikon OPTIPHOT-POL microscope using the oil immersion objective – 100 \times . The England Finder Numbers along with the co-ordinates for all the specimens are given in the description of the Figure (Figure 3).

The microbial assemblage is represented by filamentous, coccoidal 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), *Eomycetopsis* (Figure 3 q, u) and *Siphonophycus* with the filament width being < 1 μ m, between 2–3 μ m and > 4 μ m respectively. *Archaeotrichion* with broken ends, measuring up to 200 μ m 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 *Bactrophycus* (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 broad rounded ends, containing some clotted inclusions and ranging in length from 22 to 28 μ m and in width from 7 to 9 μ m. These forms are comparable to *Archaeoellipsoides* (Figure 3 t). A few specimens of genus *Eosynechococcus* with small rod-like bodies, 3–4 μ m long and ~1 μ m 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 l). 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 o). 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 coccoidal forms comprise the next most abundant group of microfossil assemblage from Shali. These oc-

cur mostly as small solitary spheres, <6 μ m in diameter, referable to well-known taxa like *Myxococcoides* (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 coccoidal 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 coccoids), 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 μ m at base and ~30 μ m 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 μ m 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 China¹¹, the Bitter Springs Formation of Central Australia¹² and Vindhyan Supergroup of Central India¹³.

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 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 Limestone¹⁷. This discovery has opened up new vistas of study in the area, specially in the field of biostratigraphy, 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 biostratigraphic 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 stromatolitic 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 Limestone¹⁷ 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

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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 monu-

ment, 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 NO_3^- , SO_4^{2-} , Cl^- , Ca^{2+} , Mg^{2+} , 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 NO_3^- ion is mainly produced from the oxides of nitrogen³. The formation of NO_3^- in the atmosphere indicates clearly the chances of