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Neoproterozoic stromatolites from the Dharwar Supergroup, India

Chethan Kumar¹, Yogmaya Shukla^{2,*},
Mukund Sharma², S. B. Harish Kumar³,
N. Malarkodi¹ and Saleem Ahmed Khan⁴

¹Department of Geology, Bangalore University, Bengaluru 560 056, India

²Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226 007, India

³Bhogarbhudhama, No. 19, 1st Main, 4th Cross Road, New Maruthi Nagar Extension, Near MEI International School, Kempapura Road, Chikkabanavara, Bengaluru 560 090, India

⁴No. 291, JHBCS Layout, Near Dayanand Sagar College, Bengaluru 560 111, India

A new occurrence of Neoproterozoic stromatolite, older than 2600 Ma, has been found in the dolomite beds of Aleshpur Formation of the Chitradurga Group in the Shimoga Schist Belt, western Dharwar Craton. The occurrence is near Shanti Sagara lake (Sulekere) in the Davangere district of Karnataka. Stratiform, laminated, columnar with some showing branching forms indicate an advanced stage of evolution of stromatolites. The newly found stromatolite occurrence is an important addition to the inventory of Archaean stromatolites.

Keywords: Archaean, Dharwar Craton, Shimoga Schist Belt, stromatolite.

GLOBALLY, Neoproterozoic carbonate rocks with palaeobiological signatures such as stromatolites are rare. Any report of such an occurrence of Archaean stromatolites from a new geographical locality or stratigraphic level is therefore important to the global inventory^{1–4}. In 2008, two of us (S.B.H.K. and S.A.K.), while prospecting for minerals in the Archaean Dharwar Schist Belts, noted an outcrop of

*For correspondence. (e-mail: yogmayashukla@bsip.res.in)

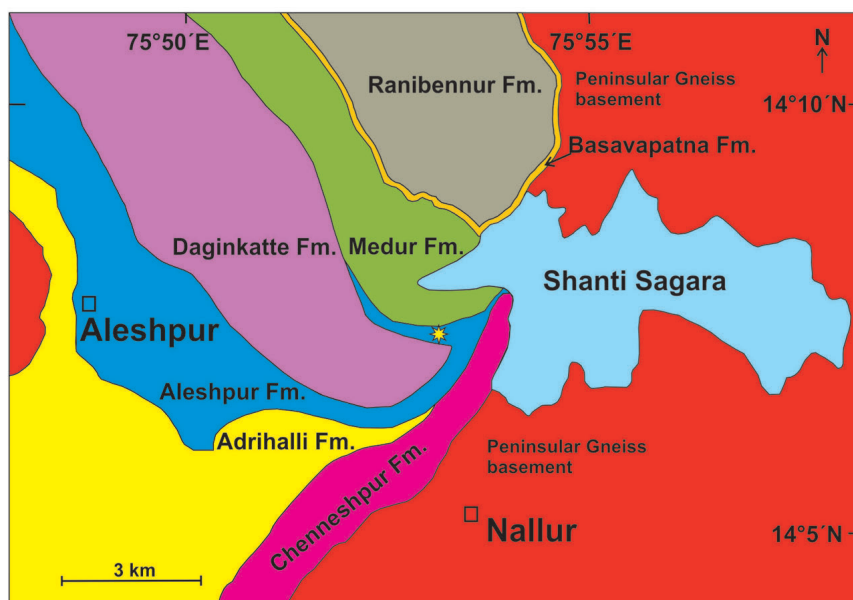


Figure 1. Regional geological map of a part of the Shimoga schist belt, Western Dharwar Craton, after Chadwick *et al.*²⁵. The map is slightly modified to indicate the interpreted stratigraphic position of the stromatolitic biostrome.

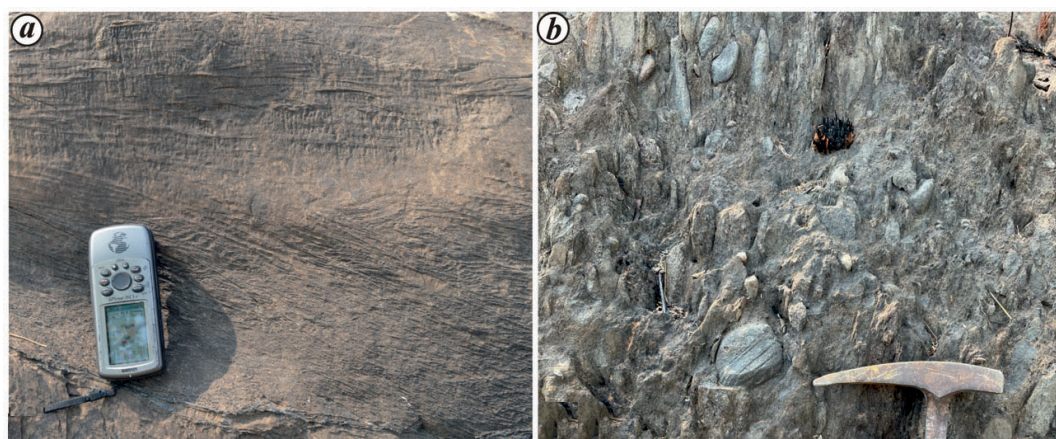


Figure 2. Sedimentary features observed in the Aleshpur Formation showing the shallow marine depositional environment. *a*, Cross-bedding in the calcarenite bed. *b*, Pebbles noted in phyllite surrounding the stromatolitic outcrop. Phyllite occurs below and above the stromatolite-bearing carbonate layers. However, pebbles are found in patches in the overlying phyllite beds (GPS reading N14°07'25.8", E75°52'31.0").

Neoproterozoic carbonate rocks in the area near Shanti Sagara Dam (also known as Sulekere) in Davanagere district, Karnataka, India, with peculiar surface markings. A restudy of this outcrop in 2022 revealed that these peculiar structures are well-preserved stromatolites. This unknown occurrence of Archaean stromatolite from the Dharwar Craton is reported here.

The Archaean Dharwar Craton is divided into western and eastern Dharwar cratons (WDC and EDC respectively)^{5,6}. The lithostratigraphy of the region has been extensively studied earlier^{7–12}. The rock sequences in the schist belts of WDC are grouped into the older Sargur Group

and younger Dharwar Supergroup. The supracrustal belts of the Sargur Group are composed dominantly of mafic and ultramafic volcanic and plutonic rocks and minor sedimentary sequences. The younger Dharwar Supergroup constituting the major Dharwar schist belts comprises rock formations of two major groups: the Bababudan and the Chitradurga. These consist of large accumulations of detrital and non-detrital sedimentary rocks and metabasaltic and felsic volcanic rocks, which constitute the Dharwar Supergroup^{8,13–16}. The Dharwar Supergroup is a 3000–2500 Ma old Neoproterozoic succession which occurs in several schist belts. Prominent among them are the Sandur,

Table 1. A comparison and correlation chart of lithostratigraphic units of the Shimoga Schist Belts (proposed by Harinadha Babu *et al.*²¹) and northeast, east and southeast of the Honnali Dome (proposed by Chadwick *et al.*²³). Using this correlation, the Aleshpur Formation (proposed by Chadwick *et al.*²³) of Dharwar Supergroup, flanking northeast, east and southeast of the Honnali Dome, is equivalent to the Joldhal Formation following the standard scheme proposed by Harinadha Babu *et al.*²¹

	Group	Shimoga Schist Belt (Harinadha Babu <i>et al.</i> ²¹)	Lithostratigraphy northeast, east and southeast of the Honnali Dome (Chadwick <i>et al.</i> ²³)	Radiometric ages	
		Laterite basic and ultrabasic intrusives, granite, pegmatite and quartz veins	Chitradurga and Closepet Granite	2605 ± 18 Ma (ref. 20) 2603 ± 28 Ma (ref. 39) 2452 ± 50 Ma (ref. 39)	
D H A R W A R S U P E R G R O U P	Chitradurga Group	~~~~~Unconformity~~~~~			
		Ranibennur Formation	Ranibennur Formation Basavapatna Formation		
			Medur Formation		2614.6 ± 1.9 Ma (ref. 25) 2602.0 ± 1.5 Ma (ref. 25)
			Daginakatte Formation ~~~~~		2565 ± 28 Ma (ref. 20) 2614 ± 18 Ma (ref. 40) 2616 ± 34 Ma (ref. 40)
			Joldhal Formation* Jhandimatti Formation	Aleshpur Formation* Adrihalli Formation Devara Betta Formation Kur Gudda Formation	2601 ± 6 Ma (ref. 24) 2606 ± 6 Ma (ref. 24)
		~~~~~Unconformity~~~~~			
	Bababudan Group	Amphibolite, garnet schist, quartzite (unclassified)	Mulaingiri Formation  Kudrekonda Formation	2720 ± 07 Ma (ref. 41)  2718 ± 06 Ma (ref. 41)	
	~~~~~Unconformity~~~~~				
	Peninsular Gneiss	Gneissic complex (unclassified)	Peninsular gneiss of the Honnali Dome	3035 ± 60 Ma (ref. 42) 3030 ± 30 Ma (ref. 19) 3020 ± 230 Ma (ref. 19) 3080 ± 110 Ma (ref. 20) 3175 ± 45 Ma (ref. 20)	
	Sargur Group				

*Denotes the level of stromatolite occurrence²³. In the last column geochronological ages of the respective formations are provided.

Shimoga and Chitradurga schist belts in WDC^{17,18}. These schist belts are composed of the Bababudan and Chitradurga Group of rocks, which were deposited on a gneissic basement older than 3000 Ma (refs 19, 20).

A part of the Chitradurga Group overlies the 3000 Ma Honnali Gneiss in the Shimoga schist belt in Davangere district, Karnataka, India (Figure 1 and Table 1). This area was mapped in detail by Harinadha Babu *et al.*²¹ and Chadwick *et al.*^{22,23}, who proposed the stratigraphic succession for rock formations (Table 1). Stromatolite-bearing carbonate rocks in the Shanti Sagara (Sulekere) area, reported in the present study, are part of the Joldhal Formation according to Harinadha Babu *et al.*²¹ or Aleshpur Formation

according to Chadwick *et al.*²³. The Aleshpur Formation consists of orthoquartzites, phyllites, polymictic conglomerates, limestone and dolomite, and banded ferruginous cherts²³ (Figure 2). The shallow marine depositional setting for the carbonate rocks is inferred based on the occurrence of stromatolites in limestone.

The Aleshpur Formation is unconformably overlain by felsic and intermediate volcanic rocks of the Daginakatte Formation (Table 1; dated 2614 ± 1.9 Ma; 2601 ± 6 Ma and 2602 ± 1.5 Ma)^{24,25}. The stromatolite-bearing Aleshpur Formation is, therefore, of proven Neoproterozoic age.

Earlier, stromatolites were recorded from carbonate rock units of different schist belts of the Dharwar Supergroup.

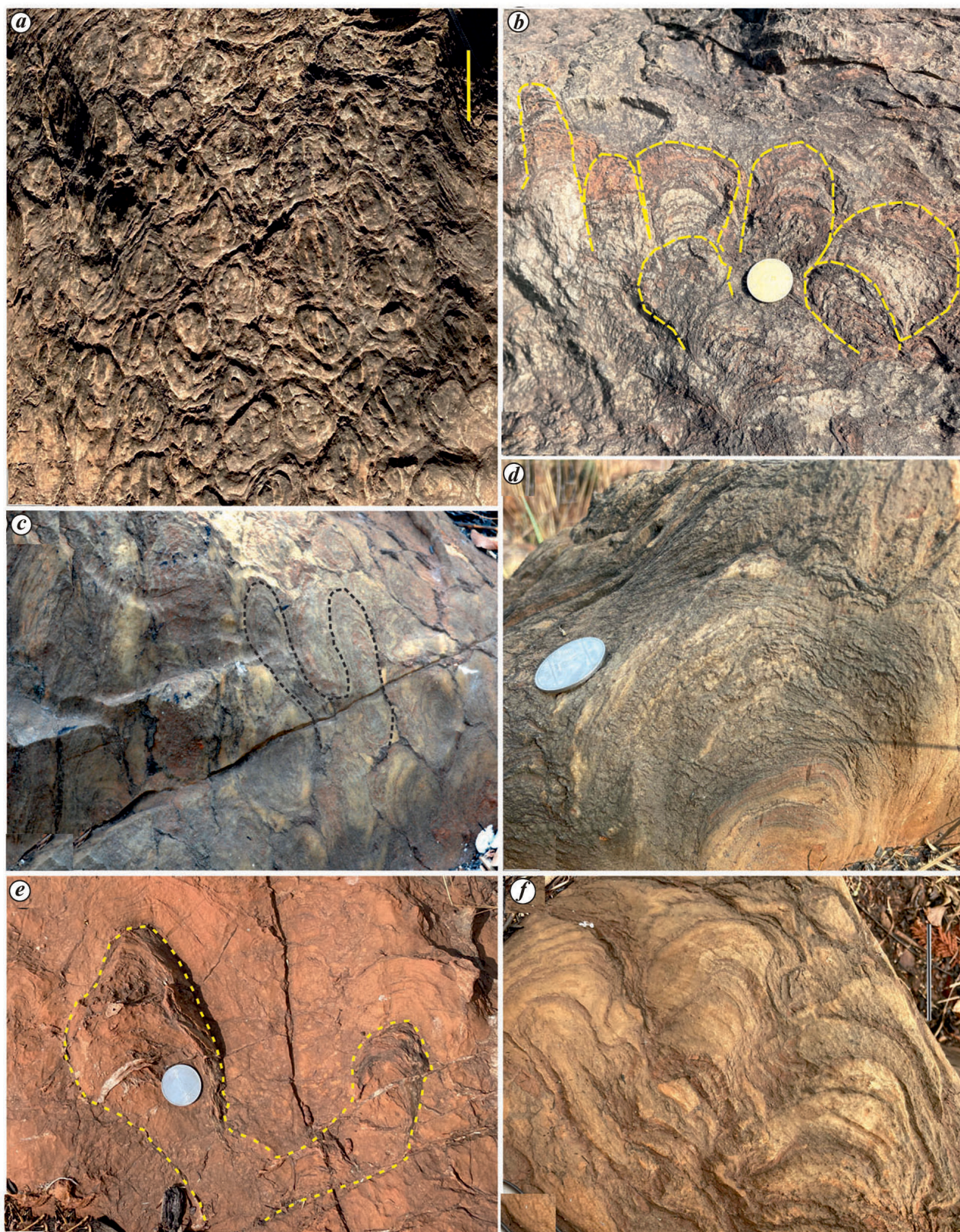


Figure 3. *a*, Circular to oval (transverse) cross-section of stromatolitic columns. *b*, Columnar non-branching (turbinate), small cumulate to columnar stromatolites seen in the longitudinal section of the biostrome. *c*, Longitudinal cross-section of stromatolite having unified base that divides upward into columns, showing parallel branching highlighted by the broken line. *d, f*, Longitudinal section of non-branching bulbous to nodular stromatolites. *e*, Longitudinal section of stromatolite showing lateral branching highlighted by the broken line. Scale bar = 10 cm for Figure 3 *a* and 5 cm for Figure 3 *f*; coin diameter = 2.5 cm.

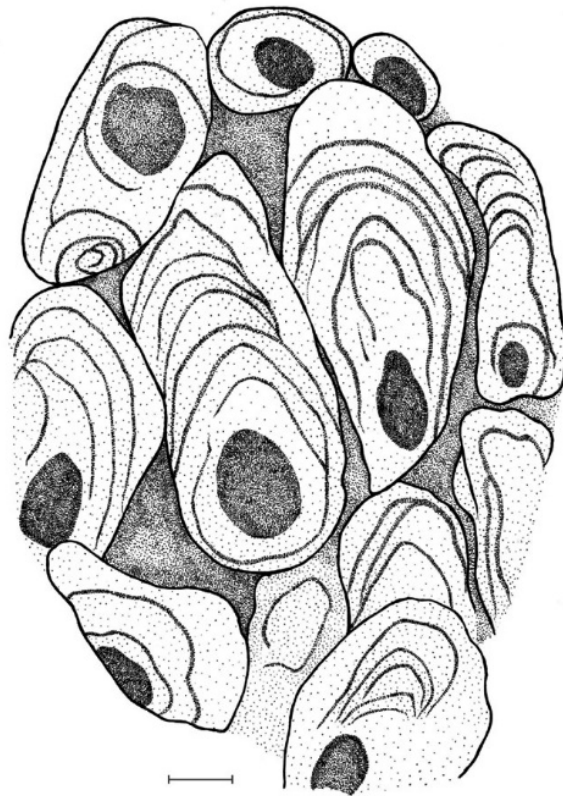


Figure 4. Three-dimensional reconstruction of columnar stromatolite based on the sample collected from the Aleshpur Formation. Bar scale = 2 cm.

Simple to complex (branched) stromatolites were documented in the Deogiri Formation of the Sandur Schist Belt, the Vanivilas Formation of the Chitradurga Schist Belt and the Joldhal Formation of the Shimoga Schist Belt^{26–31}. Branching was noted in some stromatolites of the Dharwar Supergroup^{26,28}.

Standard terminology has been followed in describing the morphology of the Aleshpur stromatolites^{32–36}. The stromatolitic carbonate rock outcrop of the Aleshpur Formation occurs at the GPS coordinates 14°07'30.6"N, 75°52'9.7"E (Figure 1). It can be easily approached via a bridge across an irrigation canal on the southern side of the Shanti Sagara barrage. Stromatolitic dolomite here is in contact with ferruginous phyllites (Figure 2). It is underlain by polymictic conglomerates and phyllites and overlain by felsic volcanic rocks of the Dagainakatte Formation. Uranium–lead zircon geochronology of the Dagainakatte volcanics is in the range 2565–2616 Ma (Table 1), indicating that stromatolites of the Aleshpur Formation are of Neoproterozoic age.

The tabular stromatolitic biostrome can be traced for more than half a kilometre in this locality. The thickness of the stromatolite-bearing carbonate bed is ~50 m.

Mode of occurrence: Circular/oval-shaped features are observed on the surface transverse to the stromatolite columns (Figure 3 a). In longitudinal sections, some stromatolites are columnar, non-branching (turbinate, bulbous,

nodular) (Figure 3 b). Few have a unified base that divides upward into columns (Figure 3 c), while others are non-columnar (cumulate) (Figure 3 d). Few stromatolite columns show branching (lateral to parallel) (Figure 3 e). In some cases, the columns are closely spaced. At other places, isolated bulbous stromatolitic structures are seen (Figure 3 f). Small columns of stromatolites are also seen in a few places. A columnar stromatolite specimen was subjected to serial slab cutting for 3D reconstruction of the morphology of stromatolite (Figure 4).

Habit: Morphologically, stromatolites show varied nature of fascicle. In a single fascicle, one can notice stratiform, bushy and branching stromatolites. Stratiform stromatolites are laminated, undulatory, layered to cumulate and rarely pseudo-columnar. In the case of columnar stromatolites, the columns are simple, cylindrical, bulbous and nodular to hemispherical. Branching stromatolites show only bifurcate nature with equal division.

Column shape: The natural horizontal cross-section of the stromatolites shows the column width. It is circular, elliptical and oval to oblong. The length of the stromatolitic column varies between 5 and 11 cm, and the width varies between 2.5 and 5.0 cm. Column diameter is fairly constant. Columns are inclined.

Features of stromatolites: Laminar profile is gently convex, with a high degree of inheritance, showing enveloping dark laminae. Walls have been noted in most of the columns,

which are formed by the down-turning of the laminae. The walls are smooth, complex and multilaminar. Some columns show interconnection. In such cases, bridging is massive.

Inter-space filling: Between the columns, fragmented parts of stromatolites are noted.

Secondary alteration: In thin sections of stromatolite, a few pockets of recrystallization of carbonate minerals and secondary silicification are seen.

In the Indian Archaean cratonic successions, stromatolites are recorded from the Dharwar and Singhbhum Cratons^{26-31,37}. In the last two decades, no new Archaean stromatolite-bearing stratigraphic unit or geographical locality has been added to the Dharwar Supergroup inventory. Therefore, the present finding of a well-preserved Archaean stromatolite of the Shanti Sagara Dam area is an important addition to our knowledge. Earlier, Vasudev *et al.*²⁶ had reported stromatolites in the cherty dolomites exposed near the Kumsi area in the Shimoga Schist Belt. Srinivasan *et al.*³¹ reported the occurrence of stromatolites from the Kalche area in North Kanara in the northern extension of the Shimoga Schist Belt. Detailed stratigraphic correlation of these stromatolitic horizons with that reported in the present study requires further work.

Although stromatolites are considered to have been formed by the interaction of microbes and their binding and trapping activity³⁸, the microbes are seldom found preserved in the Archaean stromatolites. Their absence in the Archaean rocks is attributed to invariable post-deposition diagenetic alteration, metamorphism, tectonic activity and age. Despite these limitations, stromatolites are considered unequivocal evidence of early biosphere. Recording the occurrence of the Archaean stromatolites and establishing them as built by microbiota is important for understanding the early biosphere³⁸.

This record of stromatolites near the Shanti Sagara Dam provides further evidence for possible palaeobiological activity during the Archaean. Further, multi-proxy studies are likely to reveal the role of stromatolite-forming microbes in the transformation of the Archaean-age biosphere and atmosphere.

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