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Lakshanhatti stromatolite, India: Biogenic or abiogenic?

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Abstract The extraordinary lateral continuity of isopachous stromatolite laminae in the ~87 m-thick Mesoproterozoic Lakshanhatti Dolomite (India) evinces chemical precipitation. Fan-shaped crystals grown on lamina surfaces further corroborate this contention; growth of fan-shaped crystals under the overhanging stromatolite column-margin indicates direct carbonate precipitation from ambient waters. The fan-shaped crystals are stacked up, separated only by thin dark micritic laminae. In a relatively upper stratigraphic interval of the formation, lighter laminae characterized by a clotted texture and traversed by numerous winding tubular voids change gradually upwards into dark micritic laminae. Some sporadically distributed lenticular intraclastic beds also have the similarly dark micritic coatings.

Clear carbonate cement crusts also occur between laminae and between successive dark micritic coats around intraclasts. Dull cathodoluminescence (CL) characterizes this cement as well as the cement lining within early diagenetic voids. In contrast, the laminae with clotted textures show dirty orange luminescence, while the dark micritic laminae and the dark micritic grain-coats display clear bright orange luminescence. Pyrite and its pseudomorphs are preferably concentrated along the dark micritic laminae. Carbon content in these dark micritic components, whether laminae or coats, is much higher than in the lighter components, exceeding what can be accounted for their $CaMg(CO_3)_2$ composition. A large part of this carbon is kerogen, plausibly biogenic. The dark components are, therefore, reasonably, though not unequivocally, assumed to be microbial mats. Degradation of the mats might have given rise to the light laminae with clotted textures. The fuzzy-margin tubes within the light laminae probably manifest the escape of gases generated during organic matter decomposition.

Si—Al-rich terrigenous fines thinly draping the dark carbonaceous laminae was possibly the result of baffling and trapping of terrigenous fines by filamentous microbiota. Dark carbonaceous laminae encasing intraclasts was considered to be the result of binding and stabilization by microbiota. Spike-like growth of discrete laminae strongly suggests an occasional breakdown of colonial homeostasis of phototrophic microbiota. The microbial community thus appears to have played an active role in stromatolite-building in the Lakshanhatti Dolomite Member, even though the simultaneous existence of direct carbonate precipitates from sea water indicates a hybrid origin of these stromatolites.

Resting on shelf sandstone and being capped by dark offshore shale, the Lakshanhatti Dolomite had been deposited in distal offshore, but not at the great depth, perhaps in an epeiric sea. Progressive deepening

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inhibited direct carbonate precipitation. $\delta^{13}C$ and $\delta^{18}O$ values suggest normal open marine salinity during deposition.

Keywords Stromatolite, Lamina continuity, Mesoproterozoic Lakshanhatti Dolomite Member, Inorganic precipitation, Kerogen enrichment, Filamentous microbiota

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1. Introduction

Almost all stromatolites are interpreted as archetypal colonies of bacteria, especially cyanobacteria (Altermann, 2002, 2007; Awramik and Margulis, 1974; Burne and Moore, 1987; Chen *et al.*, 2010). Notwithstanding structurally similar to modern microbial stromatolites, some ancient stromatolites are, however, considered as abiotic (Grotzinger, 1990; Hladil, 2005; Lowe, 1994; Reis, 1908). These authors argued that even in the presence of microbiotic remains, it is impossible to comprehend what role microbiota played in the morphogenesis of ancient stromatolites (Grotzinger and Rothman, 1996). Power spectral analysis of traced and digitized stromatolite laminae led Walter (1996) to assume that fall-out of suspended sediment, downslide of sediment surface, chemical precipitation and various random effects can account for stromatolite morphogenesis. A number of researchers took various mathematical approaches to arrive at the same conclusion that physical and chemical depositional processes can entirely account for stromatolite morphogenesis and there is no need to invoke the biomediation (Batchelor *et al.*, 2004, 2005; Corsetti and Storrie-Lombardi, 2003; Grotzinger and Rothman, 1996; Jogi and Runegar, 2005). Synthetic columnar and sometimes branching stromatolites have also been generated with help of colloid spreading beam (McLaughlin *et al.*, 2008). Awramik and Grey (2005) did not find any single feature in their Archean examples that could unequivocally be attributed to biomediation. Kerans (1982) and Grotzinger and Reed (1983), presented persuasive arguments that some Precambrian stromatolites are misnomers and essentially abiogenic crusts on sea floor. Pope *et al.* (2000) and Sumner (2002) suspected prolific growth of sea-floor cement crust during much of the Precambrian period. Awramik and Grey (2005), therefore, opined that significant contribution of a component whose biogenecity is beyond any reasonable doubt should only warrant the name "stromatolite" for any such structure. Hofmann (1973, 2000) advocated the inclusion of abiogenic precipitation into the definition of "stromatolite". Riding (2008) classified stromatolites according to different origins of biogenic, abiogenic and hybrid. It is, therefore, important to identify biogenic components within ancient stromatolites, in their form, layering, microfabric, chemical composition variation, mineral concentration or magnetic susceptibility (Miller *et al.*, 2011; Petryshyn *et al.*, 2012).

In the above context, stromatolites of the Mesoproterozoic Lakshanhatti Dolomite Member (LDM) in India yield a significant record of such biogenic and/or abiogenic processes, because the continuation of isopachous laminae across tens of columns (Fig. 1) simulates abiogenic chemical precipitation (Pope and

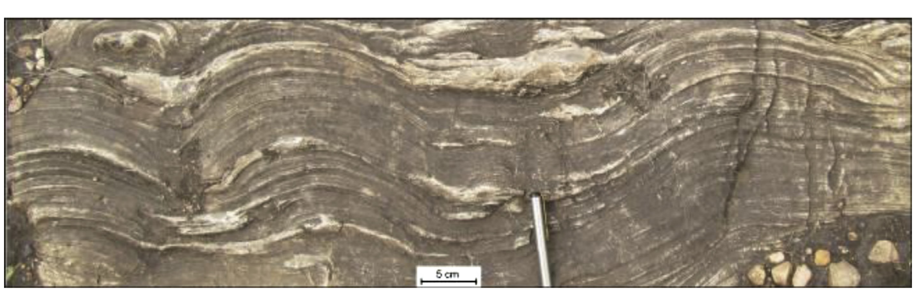

Fig. 1 Laterally persistent, continuous, isopachous laminae runs across stromatolite columns within the Mesoproterozoic Lakshanhatti Dolomite Member (LDM), India.