Journal of Palaeogeography, 2016, 5(3): 278–291 (00101)

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.journals.elsevier.com/journal-of-palaeogeography/

JOURNAL OF PALAEOGEOGRAPHY

Biopalaeogeography and palaeoecology

Microbial mat-related structures shared by both siliciclastic and carbonate formations

Subir Sarkar [a,*], *Adrita Choudhuri* [a], *Sunipa Mandal* [a], *Patrick G. Eriksson* [b]

[a] Department of Geological Sciences, Jadavpur University, Kolkata 700032, India
[b] Department of Geology, University of Pretoria, Pretoria 0002, South Africa

Abstract Microbiota has always been the dominant life form, records of which are preserved in delicate forms within siliciclastic rocks. More pronounced record in the form of stromatolites possibly obscured the fact that many of the same delicate structures may be recognizable within carbonate rocks too. The Neoproterozoic Bhander Limestone in central India bears many such structures that are quintessentially similar to microbial mat-related structures reported from the Paleoproterozoic Chorhat Sandstone preserved within the same, Vindhyan Basin. Extensive microscopic, ultramicroscopic, and geochemical studies address the apprehension that such bedding plane structures in carbonate rocks could be merely weathering products. Trapping, binding and stabilitization of sediment by microbial mats are all evident. Preferred pyritization along the inferred, predefined microbial mats confirmed on the basis of EPMA (Electron Probe Microanalysis) results, and the enhanced carbon content along these mats layers and within suspected mat chips associated with them, are revealing. Raman spectroscopy, indeed, evinces enhanced kerogen content within both mats and mat chips.

Interestingly, these microbial mat layers are recognized selectively within the lower of the two tiers of the Bhander Limestone. The lagoonal carbonate of the lower tier of the Bhander Limestone is muddy and contains a substantial proportion of silt-sized quartz grains that possibly impeded stromatolite growth. Stromatolites abound in the wave agitated upper tier of the Bhander Limestone which is dominated by oosparite. This paper provides evidence that the delicate microbial mat-related structures reported so far only from siliciclastic rocks can also be recognized within carbonate formations, and hopes to stimulate the search for additional such features, more preferably within carbonates originated in shallow and quiet water.

Keywords Microbial mat-related structures, Bhander limestone, Chorhat sandstone, Kerogen, Preferred pyritization, Impeded stromatolite growth

Received 9 September 2015; accepted 28 December 2015; available online 10 May 2016

* Corresponding author.
E-mail address: jugeoss@gmail.com (S. Sarkar).
Peer review under responsibility of China University of Petroleum (Beijing).
http://dx.doi.org/10.1016/j.jop.2016.05.001

1. Introduction

Among all the life forms on the Earth, microbiota is present in the largest numbers and the widest spectral variation (Schopf, 1999). They leave a detectable signature within the sedimentary pile, especially in form of mats grown at the sediment—water interface and the delicate features that may be preserved. Although restricted now to stressful environments only, before the advent of grazers and bioturbators, microbial mats almost certainly dominated the biosphere of the Earth. Mat growth presumably exerts severe constraints on sedimentary systems. The physical, chemical and biotic ambience of sedimentary environments undergoes substantial alterations in the presence of profuse mat growth. Recognition of mat-related features within sedimentary rocks thus has huge potential. In the Precambrian era, such mats probably colonized most surfaces where their life cycle requirements were met (*e.g.*, Banerjee *et al.*, 2014; Schieber, 1999). Microbial mat-related structures (MRS; commonly termed MISS, *i.e.*, microbially-induced sedimentary structures) have recently been studied in detail within the siliciclastic rocks (*e.g.*, Banerjee *et al.*, 2014; Eriksson *et al.*, 2000, 2010; Gehling, 1999; Gerdes *et al.*, 2000; Hagadorn and Bottjer, 1999; Noffke *et al.*, 2001, 2003, 2013; Pflüger, 1999; Prave, 2002; Sarkar *et al.*, 2004, 2006, 2008, 2014a; Schieber, 1998, 1999; Schieber *et al.*, 2007), but reports of such features from carbonate deposits are rare and limited in MRS variety (Luo *et al.*, 2013; Shi *et al.*, 2008). The presence of stromatolites in profusion within carbonate rocks has possibly obscured the presence of the MRS in the carbonate sedimentary record. The precipitation of carbonates in extracellular polymeric substance (EPS) in a repetitive manner may be the dominant cause for common stromatolite buildups within carbonate deposits and this may help ultimately to produce these three-dimensional structures which are more common, often larger and more visible over the two-dimensional and delicate MRS structures, commonly recognized in siliciclastic rocks (Noffke and Awramik, 2013). The present paper describes a similar set of microbial mat-related structures from the Proterozoic Bhander Limestone of the Vindhyan Supergroup, central India, mostly present on the freshly exposed bed surfaces (Fig. 1a). A comparative study has also been made to show their similarity to that of the MRS features present in a siliciclastic Chorhat Sandstone of the Vindhyan Supergroup (Fig. 1b). Given that the record of the MRS is best known in clastic rocks, we assess the evidence for such two-dimensional structures within carbonate deposits and explore the constraints on their development.

2. Geological setting

The microbial mat-related structures studied here are present profusely on the bed surfaces of the Bhander Limestone Member (~90 m thick) of the Bhander Formation, and within the Chorhat Sandstone of the Kheinjua Formation, both forming part of the Vindhyan Supergroup, central India.

The Bhander Limestone Member of the Bhander Formation is the only carbonate deposit within the Upper Vindhyan Group. Previous consensus was that the Bhander Formation is less than 600 Ma old (Bose *et al.*, 2001; Ray, 2006; Ray *et al.*, 2002), but recent studies (Basu and Bickford, 2014; Gopalan *et al.*, 2013; Malone *et al.*, 2008; Venkateshwarlu and Rao, 2013) have recommended a *ca.* 1000 Ma age for the Bhander Formation. The Ganurgarh Shale and the Lower Bhander Sandstone Members bound the Bhander Limestone, respectively below and above; they are of marginal marine origin and show gradational contacts with the Bhander Limestone (Bose *et al.*, 2001; Sarkar *et al.*, 1996). The Bhander Limestone, having an abundance of wave-induced structures, is considered to be a product of shallow marine environment, tentatively. In-depth study (both facies and isotope analyses) shows that deposition of the Bhander Limestone first took place in a low-energy marginal marine or lagoonal environment which later changed into an open, agitated shelf environment because of either the rapid sea-level rise or the rapid basin subsidence (Sarkar *et al.*, 2014b; Fig. 1b). This transition is reflected through sharply increased ripple heights and differently directed palaeocurrent trends between the lower lagoonal part and the upper inferred open shelf environment (Banerjee *et al.*, 2010, 2014; Sarkar *et al.*, 2014b). In addition, petrographic analysis shows distinct differences between these two inferred palaeogeographies. The lower lagoonal part is characterized by the common presence of detrital silt-sized quartz grains in between carbonate mud layers while the overlying open shelf portion is characterized by oomicrite and fewer siliciclastic inputs (Fig. 1b). The structures resembling siliciclastic MRS formed within the lower lagoonal part only.

The ~1.6 Ga Chorhat Sandstone (Rasmussen *et al.*, 2002; Ray *et al.*, 2002; Fig. 1b) belongs to the Kheinjua Formation of the Lower Vindhyan/Semri Group, and shows excellent preservation of a variety of delicate structures of microbial mat origin (Sarkar *et al.*, 2006,