Available online at www.sciencedirect.com

SCIENCE DIRECT®

Sedimentary Geology 176 (2005) 195–209

Sedimentary Geology

www.elsevier.com/locate/sedgeo

Research paper

Microbial mat control on siliciclastic Precambrian sequence stratigraphic architecture: Examples from India

S. Sarkar[a,*], S. Banerjee[b], P.G. Eriksson[c], O. Catuneanu[d]

[a] *Department of Geological Sciences, Jadavpur University, Kolkata 700 032, India*
[b] *Department of Earth Sciences, IIT Bombay, Powai, Mumbai 400 076, India*
[c] *Department of Geology, University of Pretoria, Pretoria 0002, South Africa*
[d] *Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E3*

Received 10 April 2004; received in revised form 5 November 2004; accepted 20 December 2004

Abstract

An attempt has been made to understand, within a cause-and-effect framework, the sequence-building pattern in Proterozoic time that witnessed non-uniformiteranean microbial mat growth and epeiric sea development. Marine or marginal marine successions in three Neoproterozoic formations, the Sonia Sandstone in western India, and the Sirbu Shale and Upper Bhander Sandstone in central India have been examined here for this purpose. The strikingly common feature of all three formations is vertical stacking of highstand systems tracts without intervention of any significant transgressive deposits. In one instance only, the transgressive systems tract is represented by a thin granular transgressive lag, and in all other cases the evidence of transgression is simply marked by the presence of marine flooding surfaces. The absence of transgressive strata relates to the low sea floor gradients, which facilitated rapid transgressions, combined with a generally low sediment supply. Aggradation under normal regressive highstand conditions, in spite of the low sediment supply, was promoted by the prolific growth of microbial mats, which reduced the effects of wave and current reworking by organic binding of clastic particles.

Keywords: Microbial mat; Neoproterozoic siliciclastics; High net sedimentation; Stacking of highstand systems tracts; India

---

1. Introduction

The Precambrian biosphere belonged almost exclusively to microbiota (Schopf, 1999). The oldest fossils known, recorded in 3.5 Ga rocks of marine origin in Australia include cyanobacteria of rather advanced forms (Schopf, 1993); this implies an advent of microbiota quite early in the history of the Earth. The earliest direct evidence for terrestrial microbial mats affecting siliciclastic sediments is, as far as we are aware, from 1.8 Ga palaeodesert deposits of the Waterberg Group, South Africa (Eriksson et al., 2000). However, indirect evidence for microbial mats can be traced back to at least 2.6–2.7 Ga (Watanabe et al., 2000), with the earliest evidence of mat formation

---

* Corresponding author. Fax: +91 33 4731484.
E-mail address: jugeoss@vsnl.net (S. Sarkar).

0037-0738/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.sedgeo.2004.12.012

within siliciclastic sediments being cited from the 2.9 Ga, predominantly marine sedimentary rocks of the Mozaan Group, Pongola Supergroup, South Africa (Noffke et al., 2003). Nonetheless, the record of atmospheric oxygen build-up suggests proliferation of microbiota during the Mesoproterozoic (Eriksson et al., 2000; see also, Schopf, 2004; Altermann, 2004). Pflüger and Sarkar (1996), Seilacher (1999) and Sarkar et al. (2004, submitted for publication) reported a large spectrum of microbial mat-induced structures within siliciclastic lithologies from the Chorhat Sandstone in central India, that was later dated accurately (SHRIMP) to be 1.6 Ga (Rasmussen et al., 2002; Ray et al., 2002). This apparent Mesoproterozoic mat proliferation most likely decreased at the Precambrian–Cambrian transition, as the microbial community suffered a severe decline because of rapid growth of grazing metazoan communities (e.g., Grotzinger, 1990).

It is thought that microbial communities colonized most surfaces within Precambrian environments, where their minimal needs of moisture, light, and nutrients were met, including not just carbonate-forming settings but also most siliciclastic sediment surfaces as well (e.g., Hagadorn et al., 1999; Schieber, 1999). Microbial mats have an entire spectrum of influences (physical, biological, and chemical) on the depositional fabrics of sedimentary rocks, and a large number of features indicating their influence upon clastic deposits have recently been summarized by Schieber (2004; see also, Sarkar et al., 2004, submitted for publication). Such mats tend to stimulate processes such as binding, trapping, and baffling (Gerdes et al., 2000), and thin biofilms of intermingled sediment grains and filaments will stabilize sediment surfaces after physical reworking episodes (Schieber, 2004). The overall effect of such mat growth is thus to lessen erosive removal of clastic sediment, although a host of preserved features is known, related to metabolic effects, physical mat destruction, mat decay, and diagenesis as well (cf. Schieber, 2004, and references therein). The effects of microbial mats on sediment accumulation and preservation are still active today, although lessened by the deleterious effects of grazing metazoans.

We thus postulate here that prolific mat growth, an intrabasinal factor, could have influenced Proterozoic depositional systems significantly and in an essentially non-uniformitarian way, possibly more emphatically from the Mesoproterozoic to the end of the Proterozoic. Mat growth, with its implicit impedance (at least to a certain degree) of erosion, would have promoted a long-term high rate of effective net sedimentation, even where the short-term rate of sedimentation had been low. This influence, in conjunction with another common intrabasinal factor, namely the low gradients of the floors to the frequently developed epeiric seas related to Meso- to Neoproterozoic supercontinental cyclicity, could have dictated a distinctive sequence-building pattern for the geological time interval concerned.

Precambrian epeiric seas were commonly associated with low continental freeboard (e.g., Eriksson, 1999; Eriksson et al., 1999), implying low sediment yield and low sedimentation rate. Furthermore, the sediments would have been characterised by high mineralogical maturity, due to weathering dominating over erosion in the source terrains. The low gradient of the epeiric depositional surfaces ensured rapid coastline transgressions and forced regressions with only moderate sea level changes. Rapid transgression combined with low sedimentation rate possibly hindered the formation and/or preservation of transgressive systems tracts (TSTs; Posamentier et al., 1988; Van Wagoner et al., 1988). However, during normal regression conditions, progradation and aggradation could have taken place because of lessened erosion under the influence of prolific microbial mat growth in shallow, warm seas, ensuring a relatively high rate of net sedimentation, despite the generally low sediment supply. A succession of stacked highstand systems tracts (HSTs), instead of the TST-HST alternations typically found in the Phanerozoic record, may thus have developed (at least in certain cases) between unconformities formed during episodes of forced regression during base level fall. This paper aims to describe several examples of such inferred stacked HST successions, from the Indian subcontinent, which may represent a distinctive Proterozoic sequence architecture which may also be found in other regions.

2. Indian Neoproterozoic epeiric successions

Three examples of Neoproterozoic Indian epeiric marine successions are detailed in this paper. The