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Microbially induced sedimentary structures (MISS) from the Ediacaran Jodhpur Sandstone, Marwar Supergroup, western Rajasthan

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ABSTRACT

Fourteen microbially induced sedimentary structures (MISS) have been described from the middle part of the Jodhpur Sandstone. They have been subdivided under three headings; (A) those microbially induced structures which could be compared with the structures also produced by the inorganic processes, (B) those structures which have unique morphologies and could not have produced by inorganic processes alone and (C) those structures which could not acquire specific morphologies and can be referred to as 'textured morphological surfaces' in the sense of Gehling and Droser (2009). These forms are described and their stratigraphic significance discussed. There are some morphologies like *Arumberia banksi*, *Rameshia rampurensis* and *Jodhpuria circularis* which have been restricted to latest Neoproterozoic sediments.

1. Introduction

Microbial mats and their related structures in siliciclastic sediments have only recently attracted the attention of the scientists, though these were well recorded in the calcareous rocks as 'stromatolites' since more than a century from the different stratigraphic horizons ranging in age from the Archean to Recent. In the Precambrian, the stromatolites show varied morphologies with size ranging from microscopic dimensions to the size measurable in meters (Grey, 1989). Many of them are non-repetitive in stratigraphic sequences and appear to have a restricted time frame (Cloud and Semikhatov, 1969; Raaben, 1969; Vlasov, 1977; Grey, 1984). Because of this reason they have been used with a reasonable success in intrabasinal and interbasinal correlations when age marker fossils are absent (Valdiya, 1969; Bertrand-Serfati and Trompette, 1976; Serebryakov, 1976; Preiss, 1976; Vlasov, 1977; Kumar, 1980; Misra and Kumar, 2005). In the Precambrian, the stromatolites representing microbial mats in the calcareous rocks were studied and documented in detail as they were conspicuously visible in them, but in the siliciclastic rocks the microbial mats being less conspicuous and generally poorly preserved could not draw the attention of the field geologists. As such, the siliciclastic rocks were seldom searched for their presence. They were given attention in recent years only when the modern siliciclastic sediments yielded imprints of microbial mat formation both in the field as well in the laboratory experiments (Castenholz et al., 1992; Noffke et al., 1996; Schieber et al., 2007). The presence of these structures in the modern sediments prompted and encouraged their search in the ancient sediments especially in the Precambrian where the microbial life flourished unhindered in the absence of benthic animal life covering a period of more than 3 billion years from 3500 Ma to the base of the Cambrian at 541 Ma. The rise of metazoa near the beginning of the Cambrian period affected the role of microbial mats in the Phanerozoic as they browsed upon them (see Awarmik, 1971; Walter and Heys, 1985). Now, with the available information from the modern sediments, the siliciclastic rocks are also being searched for microbial mats and their signatures in the ancient sediments with considerable success (Schieber et al., 2007; Chakrabarti and Shome, 2010; Chakraborty et al., 2012; Sarkar et al., 2006; Banerjee and Jeevankumar, 2005; Parizot et al., 2005; Banerjee et al., 2010; Banerjee, 2012). These structures are also termed as microbially induced sedimentary structures abbreviated as 'MISS' (Noffke et al., 1996; Noffke, 2009, 2010).

In the Indian context, currently, the maximum types of microbially related morphologies from the siliciclastic rocks have been described from the Ediacaran Jodhpur Group of the Marwar Supergroup by Sarkar et al. (2008). Here the "Ediacaran" term is used in purely stratigraphic sense as suggested by McGabhann (2013).

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They treated them as sedimentary structures without attaching any stratigraphic significance. The abundance of the microbial mats in the Jodhpur Sandstone can be linked to the Ediacaran age on the basis of the available palaeontological data like the presence of *Hiemalora Aspidella*, *Arumberia banski* and *Marsonia artiyansis* (Raghav et al., 2005; Kumar and Pandey, 2009). This adds stratigraphic significance to the microbial mats as has been given to the stromatolites in the calcareous rocks in the Precambrian. Gehling (1999) has noted that certain structures which are particularly common in the terminal Proterozoic and early Palaeozoic record have no apparent analogues in the modern environment and these structures, like fossils, may reflect evolutionary changes in the Earth System during the Precambrian-Cambrian transition. In the present paper, the microbially induced sedimentary structures (MISS) in the siliciclastic rocks are considered as organo-sedimentary structures produced by the interaction of microbial community with the siliciclastic sediments. These structures can be compared with the stromatolites of the carbonate rocks which have both stratigraphic and environmental significance. The stratigraphic significance is given to these structures on the basis of the fact that the microbial community in the siliciclastic sediments must have evolved with time. This evolution is bound to have manifested in producing varied morphological features in the microbial mats as it is expected that the microbial community evolved with passage of time in the long Precambrian eon of more than 3 billion years. This microbial community could have produced unique morphologies in association with the mineralogy of the sediments and specific hydrodynamic conditions. For evaluating MISS in the siliciclastic sediments in similar looking environmental settings only microbial community and the hydrodynamic conditions have been taken as two parameters important for their genesis as the grain size of the sediments is linked to the hydrodynamic conditions. The mineralogy might have played a significant role but in quartz arenite depositional environmental setting its role should have been minimum as it is made up dominantly of quartz only. Thus, MISS can also have stratigraphic significance with microbial community evolving with time in long Precambrian eon and itself in producing some unique microbially induced morphologies in the siliciclastic sediments. Disc described by Srivastava (2013) as medusoids have also been considered as microbially produced sedimentary structures. The paper describes fourteen microbially induced sedimentary structures (MISS) from the Jodhpur Sandstone of the Marwar Supergroup.

2. Geological setting

The Marwar Supergroup, earlier referred to as the Trans-Aravalli Vindhyan occupies large area in the western Rajasthan (Fig. 1). The exposures lie in the west of Aravalli mountain range which separates the rocks of the Vindhyan Supergroup of the Chambal Valley Section (Kumar, 2012) from the rocks of the Marwar Supergroup. The Marwar Supergroup unconformably overlies the Malani Igneous Suite and the Older Metamorphics (Pareek, 1981, 1984). Recently, the Malani rocks have been dated as 779 ± 5 Ma by U-Pb method (Gregory et al., 2009). The Marwar Supergroup has been subdivided into three groups; in stratigraphic order these are the Jodhpur Group, the Bilara Group and the Nagaur Group. Each group has been further subdivided into formations (Table 1). The rocks are unmetamorphosed and undeformed. In general, the rocks are horizontal or show very low dips. Pareek (1981, 1984) has subdivided the Jodhpur Group into three formations; in stratigraphic order these are the Pokaran Boulder-Bed, the Sonia Sandstone and Girbhakar Sandstone. However, Chauhan et al. (2004) have merged the Sonia Sandstone and Girbhakar Sandstone under the Jodhpur Sandstone. The Pokaran Boulder-Bed is developed only at Pokaran and adjoining areas where it attains a thickness of only up to 4 m. In rest of the area, the Jodhpur Sandstone directly overlies the Malani Igneous Suite and/or the basement metamorphic rocks (Fig. 2). The Jodhpur Sandstone is represented by the arenaceous facies made up of fine to coarse grained sandstone, pebbly sandstone, siltstones and shales. The sandstones are brick red, light yellowish brown to light grey in color. In general, the dominant lithology is fine to medium grained sandstone with almost negligible shale bands which are very rarely seen at only few places. The maximum development of microbial mats and related structures are seen in the middle part of the Jodhpur Sandstone. The microbial mat bearing horizon shows excellent preservation of sedimentary structures dominated by trough and planar cross bedding, wave and current ripples, interference ripples, parallel bedding and mud cracks etc. which suggest a shallow water environment of deposition with moderate energy. The sandstones are quartz arenite.

3. Description of microbially induced sedimentary structures (MISS)

Sarkar et al. (2008) have described a number of mat related morphologies which are preserved in the Jodhpur Sandstone and considered them simply as mat-influenced sedimentary structures. But in the present work, these structures are described under three headings: (A) those microbially induced structures which could be compared with the structures also produced by the inorganic processes; (B) those structures which have unique morphologies and could not have produced by inorganic processes alone and (C) those structures which could not acquire specific morphologies and can be referred to as 'textured morphological surfaces' in the sensu Gehling and Droser (2009).

Six structures have been described by using binomial nomenclature which are described as 'group' and 'form' as used for the stromatolites instead of 'genus' and 'species'. It is done for the ease of communication, conceding the fact that these morphologies are not true fossils but are the product of a collective interaction of a community of micro-organisms with the sediments. It is emphasized that the form and group are not species and genus in the traditional sense of palaeontology; for example the nomenclature is used for describing siliciclastic mat structure *Arumberia banksi* from the Arumberia Sandstone, Australia reported originally by Glaessner and Walter (1975) but is now considered a mat structure (McIlroy and Walter, 1997) and it is not a species but a 'form'.

In all 12 microbial forms and 2 types of textured morphological surfaces have been described from the Jodhpur Sandstone which owe their origin to the microbial activity at the time of the formation of the sandstones. These have been reported from two areas; one is the Sursagar area near Jodhpur and the other is the Khatu area, about 60 km from Nagaur Township in the western Rajasthan. The samples have been deposited in the museum of the Centre of Advanced Study in Geology, University of Lucknow, Lucknow, Uttar Pradesh.

3.1. Microbially induced sedimentary structures which also show similarity with the inorganically produced sedimentary structures

3.1.1. Microbial flat laminated beds

In the Sursagar area, there are many sandstone beds in the Jodhpur Sandstone on whose bedding surfaces incomplete or isolated ripples are preserved (Fig. 3A). The thickness of such beds varies from a few centimeters to tens of centimeters and they are massive looking. The height of the ripple crest is up to about 4 mm and the distance between the two crests varies from 1.4 to 3 cm. In most of the cases the ripples are wave ripples. The two ripple crests are