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Discussion

Comment on the paper by Davies et al. "Resolving MISS conceptions and misconceptions: A geological approach to sedimentary surface textures generated by microbial and abiotic processes" (Earth Science Reviews, 154 (2016), 210–246)

Nora Noffke

Old Dominion University, Norfolk, VA 23529, USA

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ABSTRACT

The article by Davies et al. discusses scientific studies on microbially induced sedimentary structures (MISS). The sedimentary structures are caused by benthic microbes in clastic deposits and have the potential to fossilize. In the opinion of Davies et al., it may be problematic to distinguish MISS-like structures (e.g., 'wrinkle structures') from similar, but abiotic structures. Therefore, their article argues, there exists a need for an umbrella classification summarizing both biological and abiotic sedimentary structures. However, Davies et al.'s paper does not reflect a thorough understanding of the formation and preservation of MISS. More so, while the authors appreciate the benefit of geological field work, and petrological as well as geochemical laboratory sample analyses, their article appears to widely disregard that this scientific rigor is presented in studies on MISS. The lack of data make the classification by Davies et al. unsupported and difficult to use. It potentially confuses by producing multiple classification possibilities rather than a pragmatic organization, and it contributes an unnecessary terminological ballast to a research area that has progressed far beyond to the concepts that the paper by Davies et al. presents.

1. Introduction

The article by Davies et al. (2016) presents a discussion on the use of terminology in the description of possible MISS, and on perceived 'common misconceptions' by the geological community. The proposed classification is based on the opinion of Davies et al., that distinguishing MISS-like structures (e.g., 'wrinkle structures') from abiotic structures of similar morphologies but different formation is difficult; that not always analytical work can be performed; or that some material may be of poor preservation. Pointing out perceived issues in a research field or suggesting a novel scientific approach always is welcomed. However, Davies et al.'s paper, while eloquently written, is self-contradicting in essential points and reflects an inaccurate understanding of MISS. In consequence, the proposed 'umbrella classification' is flawed. Here a brief correction of some of the article's misconceptions. For a thorough introduction into the field of MISS, the well-illustrated atlas edited by Schieber et al. (2007), the contributions in Noffke and Chafetz (2012), the textbook by Noffke (2010), and other review articles may be helpful.

2. Mat-forming microorganisms

Biofilms are organic coatings that cover substrates such as the surfaces of sand grains (e.g., Decho, 2000). They are composed of single celled organisms (prokaryotes and eukaryotes) plus their extracellular polymeric substances (EPS). In nature, biofilms occur everywhere on a substrate as long as water molecules are present. Krumbein (1994) described biofilms picturesquely as 'organized water'. Under favorable conditions, the organic envelope around each sedimentary particle continues to grow until all particles of a sedimentary surface are embedded in a laterally continuous organic layer: a microbial mat (Neu, 1994). Microbial mats are dense organic layers of millimeter to decimeter thickness that cover entire sedimentary surfaces (e.g., Visscher and Stolz, 2005; Stal, 2012). Modern tidal flats are the classical sites for microbial mat studies in clastic settings (e.g., Black, 1933; Hardie and Garrett, 1977; Cameron et al., 1985; Gerdes and Krumbein, 1987). Microbial mats here are commonly dominated by cyanobacteria and may extend to square kilometers. The microbial mats interact with the physical sediment dynamics. This interaction generates various MISS. Microbial mats have also been reported from modern and ancient fluvial, lagoonal, and lacustrine settings, where they record, low-energy

E-mail address: nnoffke@odu.edu.

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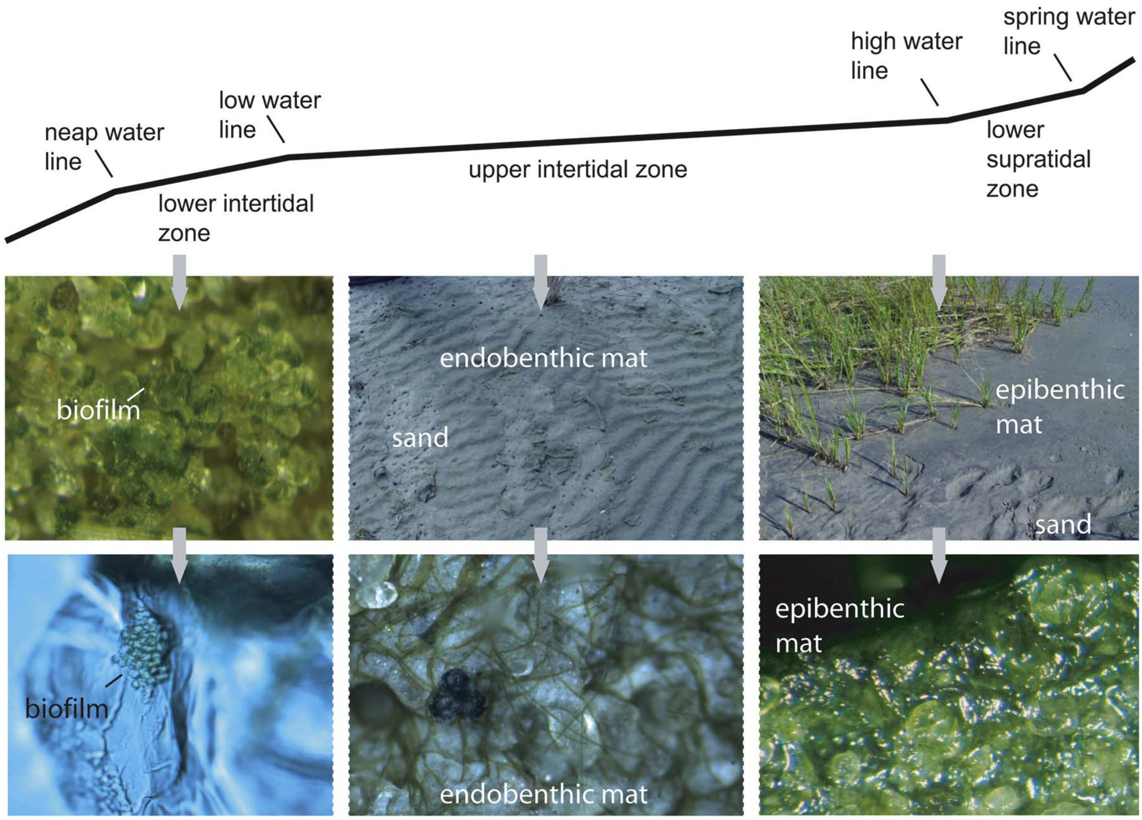

Fig. 1. The biofilm-catena of siliciclastic tidal flats in the temperate clime zone. Microbial mats establish not at random in a given area. They form a lateral succession that is in dependence from the topographic relief. With the change of topography also relevant environmental conditions change. The word 'catena' is according to the term 'soil catena' that was established for the same relation of soils to relief. After: Noffke, 2010.

depositional conditions (e.g., Prave, 2002, Beraldi-Campesi and Garcia-Pichel, 2011; Strother et al., 2011; Noffke, 2010; Wellmann and Strother, 2015). Viewed collectively, microbial mats constitute one of Earth's largest ecosystems.

Like many classical paleontological studies, the paper by Davies et al. tends to regard microbial mats simply as coherent layers that develop at random atop of clastic deposits. That is incorrect. In the study of MISS, it is helpful to understand that microbial mats do not occur at random in a defined environmental setting and, more so, that there are many mat types present (Noffke, 2010). What type of microbial mat develops at which site is a function of parameters such as the local average hydrodynamic situation, the local climate, nutrient availability and/or illumination, and the composition of the substrate. These parameters are influenced to a great degree by the morphological surface relief. In response to the laterally variable environmental parameter, a lateral succession of different mat types is typically established. For such mat successions, the term "biofilm-catena" was introduced (Fig. 1).

Due to the morphological resemblance of filamentous cyanobacteria with 'algae', such microbial mats have been referred to in older literature as 'algal mats'. Microbial communities made up of very different prokaryotic groups may produce similar sedimentary structures under similar environmental conditions. Even if a fossil MISS has morphological features similar to a modern one, it does not necessarily mean that both were produced by cyanobacteria. Rather, both mats included microbes that expressed the same microbial behavior affecting the sediments in the same fashion (Noffke et al., 2013). Early workers such as Gisela Gerdes and Wolfgang Krumbein focused on easily accessible microbial mats composed of cyanobacteria in tidal flats. Later studies expanded on other benthic microbes, and there is still a wide field to cover. In light of this logical development of a research field over time, Davies et al.'s comment on an apparent contradiction on various MISS-forming microbes in the literature is misplaced.

3. MISS formation and preservation

Unclear from Davies et al.'s article is, what the authors believe to be the cause for MISS: on the one hand the paper describes MISS as microbial constructions, on the other hand as caused by biostabilization. Fig. 5 of their paper mixes trapping, dragging and wrinkling with biostabilization, combines growth with binding and baffling, and separates trapping by EPS from EPS adhesion. These interactions as well as 'palimpsetting', however, appear to be hypothetical assumptions, as they are neither documented in field work on modern microbial mats, nor in laboratory experiments on formation or preservation. Empirical field studies have demonstrated that biostabilization is not simply related to microbial mat thicknesses like Davies et al.'s paper assumes.

By monitoring the formation of MISS by microbial mats in a modern tidal setting, a modification-index (MOD-I) was developed (Noffke and Krumbein, 1999; Noffke, 2010). This MOD-I expresses the effect of microbial mats on sedimentary structure morphologies. Microbial influence includes (i), baffling and trapping, (ii), biostabilization, and (iii), binding. These are fundamentally different microbial activities, each triggered by a specific physical sediment dynamic situation. 'Physical sediment dynamics' is defined by three regimes: (i) erosion (net removal of sediment by moving water or wind), (ii), deposition (net vertical accretion of sediment), and (iii) latency (a time period during which neither erosion nor deposition of sediment takes place). Each of the three regimes initiates an immediate microbial response: erosion initiates biostabilization, deposition causes baffling and trapping, and latency allows microbial binding (the establishment of a mat fabrics by actively moving microbes, wherein growth does not play a role). A very detailed description of these processes, also related to different cyanobacterial communities, can be found in Noffke, 2010.