

Microbial records in sedimentary systems: What is biotic and how can we now?

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Geomicrobiology is an emerging transdisciplinary field that is, arguably, focused around biogeochemistry and element cycling. Here, we will review statements by two of several unsung heroes, whose straightforward statements summarized milestones in geo(micro)biology. Lourens G.M. Baas Becking [1] is known for the expression “Everything is everywhere but the environment selects” in which he modified Martinus Beijerinck’s notion of the omnipresence of microbes. Likewise, Judy A. McKenzie has made an impact by her numerous contributions on “bridging geochemistry and microbiology” at interface between the “biosphere and geosphere” [2]. Especially Judy’s summary statement “There is no such environment as an abiotic one” at an EGU session dedicated to Ocean Drilling in 2003 truly is a revelation for geomicrobiologist on either side of the aisle. By this statement, Judy has shed geological light on Louis Pasteur’s “Messieurs (*sic*), c’est les microbes qui auront le dernier mot”, and debunked Claude Zobell’s early ideas that the world’s ocean sediments were sterile below a few centimeters.

Understanding the mechanisms that preserve microbial signatures following early diagenesis has been an elusive quest for a long time. Here, we summarize recent investigations of this critical combined *geochemical* and *geomicrobiological* mechanism in a modern microbialites quintessential model systems where carbonate minerals precipitate. Though these investigations, significant progress has recently been made in understanding the general principles of organomineralization. Three critical microbial-mediated processes are involved in sediments: 1) metabolic reactions changing the saturation index of the carbonate mineral; 2) alteration of the organic nucleation template, or extracellular polymeric substances (EPS); and 3) coordination of community metabolism through chemical communication (quorum sensing). EPS affects organomineralization (i.e., carbonate precipitation) by initially binding Ca²⁺ (and Mg²⁺). Microbial and physicochemical alteration releases these cations, concurrently creating nucleation sites. In addition, low molecular weight organic compounds (LMW-OC) have unique chemical and microbial properties. Changes in these LMW-OC and EPS properties may also play a pivotal role in early diagenesis, which could result in the alteration of initial carbonate precipitate with depth. Despite recent progress, *critical gaps in our knowledge exist*:

1. From a *microbiological perspective*, few studies document details about the specific metabolic activities beneath the oxic zone and associated changes in microbial diversity (and gene expression), especially in deeper mat layers;

2. From a *geological perspective*, it is unknown what remains preserved in the rock record from the initial precipitation and subsequent alteration through the filter of diagenesis.

Enhanced understanding of initial precipitation and early diagenetic processes has the potential to link microbial activities, initial nucleation and formation of microbialites with the fossil record. Comprehensive studies combining microbial pure- and (more importantly) mixed cultures, EPS and LMW-OC properties, mineralogy, isotopic signatures, the hydrochemistry of the water column and porewater are necessary to interpret potential biosignatures in the fossil record.

[1] L.G.M. Baas Becking (1934) *Geobiologie*, van Stockum, The Hague, 1934. 263 pp..

[2] J.A. McKenzie (2003) *Geochimica et Cosmochimica Acta* **S67**: 285

[3] C.E. Zobell (1938) *J. Sedimentary Petrology* **8**, 10-18.