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BOOK REVIEW

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# Robert E. Riding, Stanley M. Awramik (eds): Microbial sediments

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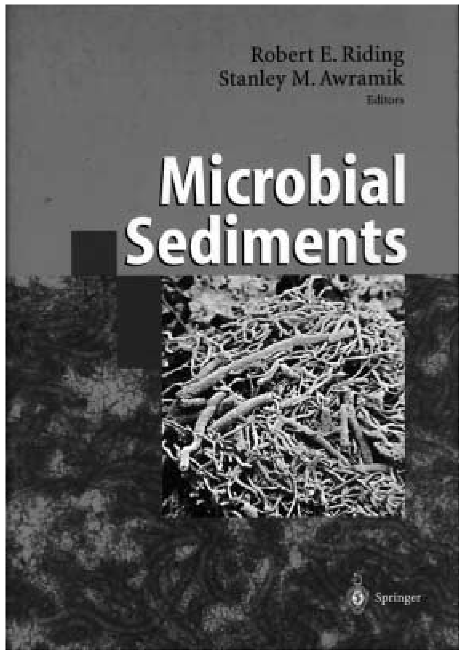
Minerals have been known and honored since humans realized their essential contributions to the *terra firma* and stone tools thrusted our species onto the path of cultural evolution. Bacteria are the oldest living creatures, probably inhabiting at least a few salubrious environments on the earth as early as 3,800 million years ago. Microorganisms have been leaving significant evidence of their presence and activities in sediments. At this moment in history we are only beginning to appreciate the intimate juxtaposition and interdependence of minerals and microbes. The widespread occurrence of microorganisms in sediments contributes to the immobilization of metals through a continuum of sorption and precipitation reactions. Depending on the prevailing environmental conditions and activity of indigenous microbial populations, individual cells can facilitate the nucleation and growth of distinct minerals. This is presumed to have been the instrumental of formation of some ore deposits such as gold. The central theme of *Microbial sediments* is the presence and activities of microorganisms in the sediments from the Archean outwards.




Uptake and release of chemicals by living organisms are necessary conditions of life, and cause perceptible geochemical changes in the surrounding environment. Continual evolutionary pressures have modified the coupling of biological processes with geochemical processes over the long history of life on earth. For this reason, uptake and release strategies employed by living organisms represent optimal solutions to particular physiological and biochemical design constraints. Organisms can perturb the geochemical speciation of metallic elements by releasing inorganic and organic chemicals into the surrounding extracellular environment. Bacteria exist predominantly as dormant tiny cells, also called "ultramicrobacteria" (0.3 μm diameter), in a wide variety of harsh oligotrophic systems, but they actually grow predominantly in exopolysaccharide-enclosed biofilms (complex association of microorganisms and microbial products attached to a surface). In these ecosystems, microorganisms grow and replicate. The planktonic mode of development is favored for dissemination and for persistence in a dormant form, while the biofilm is favored for growth. It is useful to consider the survival value of this strategy in the milieu of the primitive Earth. Bacteria cells would be attracted to the organic nutrients that concentrate at surfaces in aquatic systems, and the exopolysaccharides that mediate their adhesion to surfaces would further concentrate dissolved organic molecules and cations out of the bulk fluid. The positive selection for the biofilm phenotype in the modern Earth is evidenced by the predominance of this sessile mode of growth in virtually all permissive ecosystems. At a higher level of organization, bacteria

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within biofilms benefit from physiological cell cooperativity; such bacteria therefore constitute a coordinated functional community. Microbial mats may be considered complex biofilms, which resemble the tissue formed by eukaryotic cells, in their physiological cooperativity and in the extent to which they are protected from variations in bulk-phase conditions by a primitive homeostasis provided by the biofilm matrix. The environment of a biofilm or microbial mat is determined by physical and chemical characteristics. The interplay between these factors creates gradients and microenvironments that promote the growth and proliferation of certain species. The biogeochemistry of microbial deposits is complex and involves the entire microbial community in an interactive fashion. Microbes in sediments are responsible for retention of grains. In addition to trapping, binding and packing sedimentary particles, microorganisms are associated with (and presumably influence) mineral precipitation, thus contributing to sediment grain production, and grain binding by cementation. Mineral precipitation may be promoted by: (1) changes in the microenvironmental chemistry and hence saturation state caused by microbial metabolic process, (2) nucleation on surfaces of microorganisms (the cell envelope is very important for calcification) or microbial products. So, benthic microbes significantly modify, contribute to, and create sediments. Presently, from the nutrient-poor, open ocean environment to near-shore and lagoonal environments, organic matter sedimentation varies between 20 and 10 000 $g/m^2$ per year. Under such conditions, and assuming a calcium carbonate yield of 0.5, induced carbonate precipitation by bacteria may produce a layer from 4 μm to 2 mm thick. Bacterial carbonatogenesis thus could form a limestone layer 4–2000 m thick in one million years.

Microbial mats are an extremely ancient biological phenomenon. They best document their presence in the fossil record by producing laminated sedimentary rock structures termed stromatolites. Precambrian stromatolites are unique in Earth history. The predominance of microbes in ecosystems that they document, their specific global environments, and the scale of their evolution have no counterparts in the Phanerozoic. The persistence and abundance of stromatolites throughout most of geological time attest to the evolutionary success of the microbial mat ecosystems. Stromatolites, presumed to be the products of mat-forming prokaryotic microbes, are found in rocks as old as 3500 Ma from the Warrawoona Group of Western Australia. In the nineteenth century, several geologists cited in their works laminated similar structures, but did not recognize their biologic origin and their importance in the history of the Earth. For many years, it was difficult to understand exactly how these ancient remnants of bacteria were so well preserved. Clearly, they are mineralized and their shape is preserved in the rock matrix; but very little organic matter is left. The mystery revolves around the unequivocal fact that bacteria are entirely composed of "soft" matter. They do not possess a hard bony endo- or exoskeleton, which would help preserve their cellular structure over vast periods of time. At present, their high interaction with inorganic ions from the environment is recognized. Over their lifetime, bacteria collect an increasing burden of minerals on their surfaces. When they die, this burden continues to grow until they become completely mineralized. Although the organic matter may eventually disappear, the shape of the bacterium survives as a mineralized form possessing all of the contours and dimensions of the initial cell. These microfossils remain as such mineralized forms unless the geological horizon in which they are contained is subjected to harsh mineral-altering forces.

As V.I. Vernadsky (1863–1945) stated in his seminal book *Biosfera*, "If life were to cease the great chemical processes connected with it would disappear, both from the biosphere and probably also from the crust. All minerals in the upper crust – the free alumino-silicious acids (clays), the carbonates (limestones and dolomites), the hydrated oxides of iron and aluminium (limonites and bauxites) – as well as hundred of others, are continuously created by the influence of life. The biosphere is not only the face of Earth but is the global dynamic system transforming our planet since the beginning of biogeological time".

*Microbial sediments* consists of 34 contributions from different and renowned authors that explain in detail the above-described topics: (1) Formation of biofilm and microbial mats as survival strategy preserved of life, (2) microorganisms as architects of sedimentary structures: bacterial role in the precipitation of minerals, (3) different examples of microbial interactions with the sediments, such as tropical karst terrains, continental hot springs and geysers, and evaporite microbial sediment, and (4) relics of microbial activity as fossils through geological times. Besides the contents, the bibliography of each article has been accurately selected and the quality of the images is very good. *Microbial sediments* is an excellent reference book for both (micro)biologists and geologists.