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Lamination as a tool for distinguishing microbial and metazoan biosystems from inert structures

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Vladimir Ivanovich Vernadsky (1863-1945), who is regarded as one of the founders of modern biogeochemistry, has stated in "Scientific Thought as a Planetary Phenomenon" (1991:120) that "the biosphere appears in biogeochemistry as a peculiar envelope of the Earth clearly distinct from the other envelopes of our planet". One of the distinctive features of living matter is the tendency to occur in sheets, laminae, and multilaminar structures that often include sediment particles. The objective of our study is to develop and to present a catalogue of microbial structural signatures in sediments, sediment surfaces, but also in the growth of macroorganisms such as Bryozoa (Moss animals). Moving from the actualistic viewpoint to rock records, structures of microbial, metazoan and abiotic origin may thus be recognized, and provide evidence on facies-dependent biological activities in bygone terrestrial and aquatic environments.

Microorganisms occur everywhere. Even the optically clean parts of the surfaces on earth are usually covered by biofilms and microbial mats consisting of bacteria, cyanobacteria, microalgae and/or fungi. They grow on almost any solid substrate interfaced with air or water or both, and they show distinct microzonation on inconspicuous microtopographic features such as sand grains. The surfaces of certain multicellular organisms provide additional nannohabitats for many species of the microscale world. Regardless of substrate, any surface colonized by microbiota shows an increased information content when compared to an uncolonized surface determined by physical and chemical gradients alone. Such biological organization should translate in sediment structure or – when the substrate is alive – in structural modifications of the "living sediment" of a metazoan.

There is numerous evidence that especially the microbially dominated biosystems are often (but not always) laminated. In microorganisms, lamination depends on the presence of external cycles of development (annual and diurnal climatic cycles, for example) controlling the formation of compact layers of slime, extracellular metabolic products, or pigments. For example, the deposition of layers (rock varnish on very compact rocks) and preservation of lamination is substrate dependent, because a porous substrate will act as a sponge letting organisms and their products to enter the pores and thus will absorb the superficial layering. In case of penetration into the substrate, however, the lamination will involve an upper part of the substrate, because then upper layers of substrate will be penetrated (form the top to the bottom) at first by organisms, and by diffusing metabolites thereafter.

Rock Varnish of different age. Left (light brown): 4 years; centre (green biofilm): date of photo; right (dark brown): 1967; down right corner (black): exposure time unknown. In the centre cyanobacterial growth is visible, black fungi were also identified (photo W. E. KRUMBEIN).	

In contrast, a metazoan dominated biosystems show a clear tendency to overcome lamination due to certain constraints of engineering and constructional morphology: hydroskeletons require the biological potential to displace fluids and thus produce annulations and (coelomic) cavities rather than laminated structure. Nevertheless, in a metazoan we can produce for example arteriosclerosis as laminated and microbially controlled structure; this is usually harmful for the metazoan host.

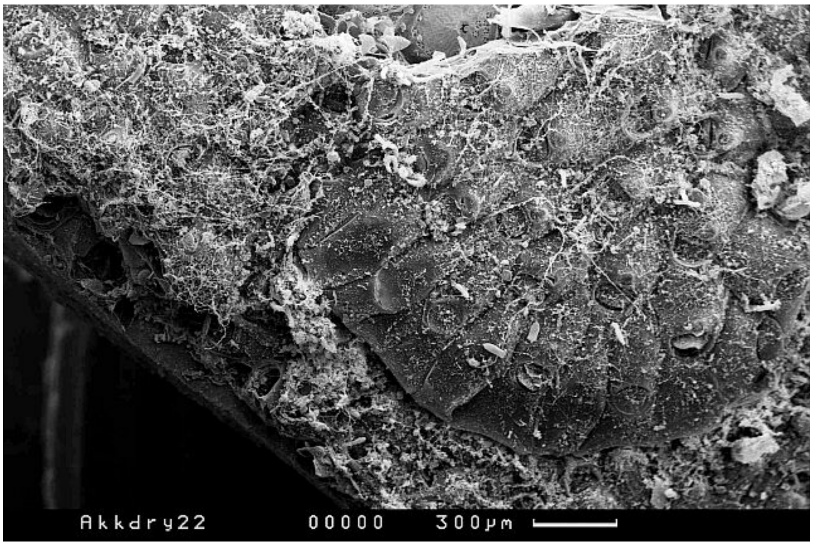
Yet, processes are actually more complicated than a simple world at war between macro- and microorganisms. Two aspects have to be taken into account:

(1) In being operationally closed, a metazoan biosystem usually requires small surface and large volume (which is just the opposite of what is favourable for a microorganism that depends on Brownian movement of particles for its metabolism). On the other hand, there is no exclusive metazoan biosystem possible since living matter, as a global morphoprocess, is not organized in organisms isolated from each other. "Every organism is in the nature of semi-parasitic, semi-mutualistic community; life of the wholeness is based on the conflict and destruction of parts." (BEKLEMISHEV 1994, written 1928). According top BEKLEMISHEV, any living system is a part of the *global morphoprocess* (evolution of the total sum of the living matter on earth), which is never interrupted even when the subsystems transform or disintegrate. Accordingly, there are no 'organisms' from this viewpoint, there are only more or less individualised biosystems representing the moments in the development of the global morphoprocess. That is why life can be defined only as a planetary phenomenon.

(2) Perhaps, such a view explains why certain colonial organisms can be transferred from unilaminar sheets into multilaminar structures when interacting with microbial mats. This has been studied in bryozoan-dominated communities from Japan, Philippines, New Zealand, Red Sea, and other regions.

Bryozoans commonly grow in a way that the modifications in bryozoan skeleton growth reflect most of the specific environmental factors they are subjected to. Like other factors, the occurence of benthic microorganisms on bryozoan frontal surfaces and surrounding substrate areas leaves a specific signature in reactive bryozoan growth. It has turned out that bryozoan interaction with potential stromatolites (= microbial mats) is probably the most important environmental control in a bryozoan´s life.

Competitive intergrowth of bryozoans and microbial mats often results in the formation of "bryostromatolites" = bryozoan stromatolites (see below). Actually, some bryozoans are rather a microbial mat or a microbial colony, with the metazoan performing the transport function of feeding currents. Therefore, laminated structures produced by bryozoans and microbial mats often become very similar to true stromatolites. Both bryozoans and microbial mats need surface contact for metabolic requirements. In the course of mutual overgrowth, bryozoan carbonate layers may will not only the micororganisms themselves, but also sediment particles that stabilize the microbial mats.



Bryostromatolite formation as a result of competitive intergrowth of microbial mats and bryozoans. Illustration shows an example from shallow water habitats off Akkeshi, Japan.

Taking into account also endozoic associations such as fungi occuring in the coelomic cavities of many bryozoans species, we may speculate that stromatolites did not decrease throughout the phanerozoic fossil record. They never died - they simply faded away into the realm of association with zoobenthos.

Conclusion:

Lamination often indicates the presence of microbial or microbially dominated biosystems. Furthermore, laminated structures are an important borderline to distinguish micro- and macroorganisms, although such a distinction is relative. Both the presence and absence of lamination are lawful phenomena based on the fundamental physical and biological/biogeochemical principles.