

Early Archaean microbial biofilms and their influence on volcanoclastic and chemical sedimentation

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Recent field studies in the Early Archaean terrains of Barberton (South Africa) and the Pilbara (Australia), combined with detailed, microscope-based, sedimentological and palaeontological studies, document intimate interactions between microbes and their sedimentological environment.

The ≥ 3.4 Ga portions of these greenstone belts represent volcanic, volcanoclastic and chemical sediment deposition in a mostly shallow water setting. Littoral, evaporitic and subaerial environments are rarer. Hydrothermal activity is pervasive and is manifested by numerous syndepositional dykes, sills, and vents. These >3.4 Ga formations host the oldest morphological evidence of life to be found to date (Walsh, 1992; Westall et al., 2001).

In this strongly hydrothermal setting, microbial mats are common on the surfaces of volcanoclastic and hydrothermal sediments, and are even found on top of the cupole of hydrothermal vents. Delicate mats consisting of bacteria with a filamentous (<0.2 μm wide, up to 10s μm long) and coccoidal (0.5-1 μm) chain habit in a fine film of polymer are common in quiet, shallow water depositional environments. More robust mats comprising thick polymer films and authigenically precipitated minerals (halite, calcite, tourmaline, gypsum?) occur in exposed (partially) subaerial environments. Biofilms with rod-shaped bacteria (up to 3.8 μm in length) are also observed. One mechanically-torn, streamlined mat resembles mats formed around subaerial hot springs in New Zealand.

The organic templates acted as sites of nucleation for the chemical deposits of hydrothermal origin (silica, iron oxides, barite, carbonate). In the majority of cases, the mats have been silicified (even the carbonate horizons have been silicified). Although bulk Corg values are generally low for these sediments ((0.05% but occasionally up to 1%), varying amounts of carbon remain trapped in the mineralised biogenic structures, as revealed by light element EDX analysis.

The widespread distribution of microbial mats in these Early Archaean sediments suggests a close relationship between biogenic activity and mineral precipitation. It is difficult, however, to determine the extent to which microbial activity controlled physical/chemical sedimentation and the extent to which the microbes simply opportunistically profited from the suitable environments available.

References

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Contributions to our understanding of the global sulfur cycle: evidence from Paleozoic sediments

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We have determined abundances and isotopic compositions for pyrite- and organic bound sulfur (OBS) in 180 sediment samples of Paleozoic age derived from a wide variety of (paleo)localities. In addition, relevant data have been screened from the literature.

Quantification of sulfur abundance reveals significant amounts for pyrite and organic bound sulfur (mostly between 0.1 and 0.6 wt.-% each), yielding total sulfide concentrations of around 1 wt.-%. Thus, preservation of organic sulfur compounds even in Paleozoic sediments is evident and its importance during mass balance considerations obvious. Sulfur isotope values for sedimentary sulfur are showing the expected enrichment in ^{32}S that is typical for its biological origin. A substantial spread in $\delta^{34}\text{S}$, however, is obviously reflecting either bacterial sulfate reduction under closed system conditions and/or bacterial disproportionation.

The isotopic composition of OBS shows a strong correlation with pyrite, indicating its principal formation from hydrogen sulfide. The timing of sulfurization seems to be sequential, depending on the relative reactivity of both iron and organic compounds towards hydrogen sulfide. Although distinctly different for individual sample sets, no clear correlation with the depositional environment and/or lithology is apparent.

Isotope results reveal that in half of all measurements, OBS displays a $\delta^{34}\text{S}$ -value that is more positive than coexisting pyrite. This suggests a later diagenetic reaction of hydrogen sulfide with less reactive organic matter, probably after consumption of reactive Fe-phases utilized for pyrite formation. Furthermore, (a) in more than 1/3 of all measurements, a more or less contemporary formation of pyrite and organic bound sulfur is indicated, and (b) in nearly 1/6 of all cases, more negative $\delta^{34}\text{S}$ -values for OBS than for pyrite sulfur exists. The latter suggests an early diagenetic reaction of hydrogen sulfide with reactive organic matter, outcompeting reactive iron. This heterogeneity of isotope results is in contrast to previously published data.

Abundance data and sulfur isotopic compositions for pyrite and organic bound sulfur in Paleozoic sediments reveal the complex interplay between the process of bacterial sulfate reduction which leads to hydrogen sulfide, and its reaction either with reactive iron or sedimentary organic matter. Iron sulfides and organic bound sulfur form essentially across the entire field of diagenesis, based on sulfur isotope evidence. We strongly feel that the global sulfur cycle is insufficiently described when solely looking at sedimentary pyrite.