Formation of organic matter and iron oxides by aerobic Fe-oxidizing bacteria in a deep ocean 3.46 Ga ago

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Many researchers have suggested that life evoled in hydrothermal environments. Some have postulated that anaerobic photoautotrophic Fe-oxidizing bacteria (FeOB) played a major role in the Fe geochemical cycle (especially in the formations of banded iron formations) in the Archean. Recently Dodd et al. (2017) reported the finding of putative fossilized microbes in >3.77 Ga ferruginous sedimentary rocks in Canada. They interpreted that the microbes were anaerobic FeOB habitated near submarine hydrothermal vents. We have conducted nano-scale investigations of the morphology, and chemistry of organic matters (OM) and associated nanoscale minerals using HRTEM, HRSTEM, EELS, and 2D-elemental mapping (EDS) and of carbon isotopic compositions of OM in the 3.46 Ga Marble Bar Chert/Jasper (MBC) in East Pilbara, Western Australia. Our results suggest that some OM and nano-sized hematite crystals in the MBC are remnants of aerobic chemolithotrophic FeOB habitated on the seafloors of a deep ocean based on the following observations and intepretations: (a) The intricate nano-scale chemical features of the interface between the OM-rich layers and structurally supporting minerals suggest that the microbial mats were biochemically bonded to the minerals, rather than developed from the accumulation of remnants of photoautotrophs; (b) Sub-nano- to nano-scale (~0.5 nm–100 nm) morphology and chemistry of OM and associated Fe-oxides (mostly hematite) in the MBC closely resemble those of modern aerobic chemolithotrophs; (c) Large stratigraphic variations in the $\partial^{13}C$ values (-35 to -21‰) of kerogens suggest that they were composed of two populations of primary producers: one that utilized CO_2 via the Calvin-Benson cycle for C-fixation, including FeOB, and the other was involved in the CH_4 related cycle (e.g., methanogens, methanotrophs). All data suggest that the microbial mats in the MBC developed at the interface between CO_2- and O_2-rich bottom ocean water and the underlying unconsolidated cherts which were invaded by low-temperature, Fe^{2+}- and H_2S-bearing hydrothermal fluids.