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Origin of organic matter in the 2.5 Ga Mt McRae Shale, Hamersley Basin, Western Australia

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Microorganisms play a role both in primary production of organic matter and its decomposition that may vary through time and across different basinal environments. Compound-specific carbon isotope analysis has shown that bacterial and archaeal remains dominate organic carbon (OC) accumulations in many modern anoxic seafloor environments [1]; however, only cyanobacteria and eukaryote biomarkers have been identified to date in Archaean strata [2]. Nevertheless the very negative $\delta^{13}C$ values in Late Archaean (2.8-2.5 Ga) organic matter world-wide provide good evidence for marine ecosystems dominated by biological oxidation and assimilation of methane [3]. Here we report the identification of well preserved encapsulated bacteria-like forms in a filamentous carbonaceous matrix in thermally immature organic-rich strata of the 2.5 Ga Mt McRae Shale, Hamersley Basin, Western Australia. The probable microfossils range from 1.5 to 5 microns in length, with an electron dense shell often encased in membraneous organic matter reminiscent of the structure of consortia of archaea and sulphate-reducing bacteria responsible for anaerobic oxidation of methane in modern cold seeps [4]. Bulk $\delta^{13}C$ values vary between -29.1 and -43.3 per mil and are consistent with OC sourced from several different groups of microorganisms. The major contributors to OC in the Mt McRae Shale are interpreted to be indigenous archaea and sulphate-reducing bacteria. This supports the hypothesis that Late Archaean atmospheric oxygen levels were sufficiently low to allow a global methanogen-methylotroph cycle [3]

References

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Behavior of light REE in Precambrian paleosols: Implication for atmospheric oxygen evolution

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Redox sensitive elements such Fe have been used to evaluate the oxidation state of paleosols in the Precambrian, and thus, atmospheric oxygen evolution. The fractionation of light REE occurs during modern weathering because Ce(III) is oxidized to form cerianite, CeO_2, and La and Nd are accommodated in light REE phosphates such as rhabdophane, $(REE)PO_4 \cdot nH_2O$. In contrast, La, Ce and Nd behave similarly and form rhabdophane during weathering with low oxygen concentration in the atmosphere [1]. To confirm rhabdophane is formed by weathering, the criteria have been proposed [1]; the abundance of rhabdophane increases toward the top of a weathering profile, and REE patterns are similar in the weathering profile and different from those of the overlying sediments.

Paleosols of Mt. Roe (2.80 Ga), Pronto (2.48-2.44 Ga), Cooper Lake (2.48-2.44 Ga), Ville Marie (2.38-2.22Ga), Flin Flon (1.9-1.8 Ga), and sub-Thelon (1.85-1.7 Ga) were examined by SEM-EDX; La, Ce and Nd concentrations in rhabdophane grains were analyzed by EDX. REE concentrations in bulk rock samples were analyzed by ICP-MS. The ratios of Ce to La (wt %) were in the range of 2.0 to 2.3 for rhabdophane grains of Mt. Roe, Pronto, Cooper Lake, and Ville Marie, suggesting anoxic weathering. On the other hand, the ratios were in the range of 0 to 1.0 for Flin Flon and sub-Thelon, suggesting oxic to slightly oxic weathering. Our results are consistent with the oxygen rise in 2.2 - 2.0 Ga. Because more dissolved oxygen is required to oxidize Mn than Ce, and Ce than Fe, and the amounts of dissolved oxygen required for the oxidation of Mn, Ce and Fe are determined thermodynamically, the complete oxidation events of Mn, Ce and Fe in paleosols constrain the atmospheric oxygen evolution.

Reference

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