Abiotic syntheses of organic matter and Fe-oxides in Archean submarine hydrothermal plumes

HIROSHI OHMOTO[1], USCHI M. GRAHAM[2] AND YUMIKO WATANABE[3]

[1]Penn State Univ., University Park, PA 16802 USA
(*correspondence: hqo@psu.edu)
[2]Univ. of Kentucky, Lexington, KY 40511 USA
(graham@topasol.com)
[3]Tohoku Univ., Sendai 981-8576 Japan
(yumiko.wtanabe.a5@tohoku.ac.jp)

Our investigations of the 3.46 Ga Marble Bar Chert/Jasper (MBC) beds in the ABDP #1 drill core, utilizing advanced analytical HRSTEM and 2D and 3D elemental mappings, have revealed two modes of intimate associations of sub-nano- to nano-sized (<0.5 nm –100 nm) particles of Fe-oxides (FeNPs) and organic matter (OM). In the first mode, FeNPs occur abundantly both inside and outside of what appear to be "fossils of aerobic Fe-oxidizing microbes" (see Watanabe et al., this session). In the second mode, FeNPs and OM occur as a ~10-50 nm-sized spherical aggregate, comprised of an Fe-rich core (hematite ± magnetite + OM) and an outer zone that hosts intimate mixtures of sub-nano-sized particles of OM and FeNPs. Such aggregates are typically coagulated to form larger clusters of Fe-oxides and OM. Considering also the various geochemical data (e.g., Eu and Ce anomalies, Cu-Zn-Pb-Mo-U-Ba-S contents) of the MBC, we suggest that the Fe-oxides and OM were synthesized abiotically during the mixing in plumes of high-T hydrothermal fluids and deep (≥~2,000m) ocean bottom water. The abiotic reactions created colloidal Fe-organo compounds by utilizing CO_2 from the seawater and Fe^{2+} from the hydrothermal fluids; FeO and/or green-rust played an important catalytic role. The colloidal particles were subsequently transformed into sub-micron-sized particles of Fe-free OM and hematite (some to magnetite) through further reactions with seawater O_2 and hydrothermal Fe^{2+}. The abiotic production of OM in the Archean oceans would have been much more extensive than today because the atmospheric pCO_2 was ≥100 PAL, the pO_2 already ~1 PAL, and submarine hydrothermal activity more extensive. The abiotically produced OM would have been more easily digestible to organisms and more reactive than biogenic OM because of the absence of cell-wall lipids. Therefore, heterotrophic organisms probably flourished much more than today, and MIF-S signatures could have been more easily created via thermochemical sulfate reduction. The disappearance of MIF-S at ~2.5 Ga was possibly due to the drastic decrease in the abiotic OM production, rather than to a change from an anoxic to oxic atmosphere.