Geophysical Research Abstracts, Vol. 8, 09853, 2006
SRef-ID: 1607-7962/gra/EGU06-A-09853

A New Perspective on the Archean Biosphere: A Summary of Recent Investigations on ABDP Cores

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Current popular models for the evolution of the atmosphere, hydrosphere, and biosphere suggest that the Archean world was very different from today: the atmosphere was dominated by reducing gases (H2 and CH4); the oceans were entirely anoxic (except in local oxygen oases) and richer in Fe2+ but poorer in SO42-, H2S, U, Mo, and V, compared to modern oceans; anaerobic photoautotrophs mostly carried out primary production in the oceans by utilizing Fe2+ and/or H2S (with lower productivity), and methanogens mostly carried out the recycling of organic matter; land surface was mostly free of organisms; the sulfur cycle was strongly influenced by native S0 and SO42- that were generated by the UV photolysis of volcanic SO2; and the geochemical cycles of many redox-sensitive elements were quite different.

The Archean Biosphere Drilling Project (ABDP) was initiated in 2003 by M. Nedachi (Kagoshima Univ.), M. Barley (Univ. of Western Australia), A. Hickman (GSWA), and H. Ohmoto (Penn State Univ.), with major funding from the Japanese Government and the NASA Astrobiology Institute. The major objective of this project is to recover modern-weathering-free and low-metamorphic grade Archean sedimentary rocks (focusing on black shales, cherts, and carbonates) for research aimed at testing and improving the above models of early Earth. We have recovered a continuous drill core (˜150 - ˜350 m in length) containing sedimentary and volcanic rocks ˜3.5 to 2.7 Ga in age at eight locations in the Pilbara Craton, Western Australia. The lithology, textures, and mineralogy of each core were thoroughly examined. Detailed investigations have been completed on several hundred specimens to determine a variety of mineralogical and geochemical characteristics of bulk rocks, minerals, and organics, including: the abundances, textures, morphologies, and paragenesis of minerals; the elemental abundances (C, S, N, REEs, major and minor elements); and isotope ratios (MIF-S, C, O, N, Fe, Nd, Sm, Re, and Os).

The results of these investigations suggest that the chemical and biological natures of the Archean world were basically the same as today, including: the O2, H2, and CH4 contents of the atmosphere; the redox structure of the oceans (globally oxygenated but locally euxinic); the major and trace element chemistry of the oceans; the dominant microbes in the oceans and on land; and the elemental cycles of S and other redox-sensitive elements. However, there were notable differences: the atmospheric pCO2 was much higher, the oceanic pH lower, and the climate warmer; these combined effects contributed to higher weathering rates and higher nutrient fluxes to the oceans, which resulted in higher biological activity in the Archean biosphere.