Discoveries from the Archean Biosphere Drilling Project (ABDP)

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The Archean Biosphere Drilling Project (ABDP), an international scientific drilling project involving scientists from the USA, Australia and Japan, was initiated in Pilbara Craton, Western Australia. The scientific objectives of the ABDP are the identification of microfossils and biomarkers, the clarification of geochemical environment of the early Earth, and the understanding of geophysical contribution to the co-evolution of life and environment. Through 2003 and 2004 activities, we have drilled 150-300 m deep holes to recover fresh (modern weathering-free) geologic formations that range from 3.5 to 2.7 Ga in age. The drilling targets were: (1) 3.46 Ga Towers Formation, (2) 2.9 Ga Mosquito Formation, (3) 2.77 Ga Mt Roe Basalt, (4) 2.76 Ga Tumbiana Formation, (5) 2.74 Ga Hardey Formation. The initial investigations on the ABDP drill cores have already produced many interesting data and observations.

3.46 Ga Marble Bar Jasper could provide clues to the argument about the early photosynthetic cyanobacteria that have produced free oxygen and have evolved the oxygen level on the earth. There have been many ideas how the hematite in jasper was formed. Our most important discoveries are the confirmations that hematite, magnetite and siderite precipitated separately as primary minerals, and that there is a remaining texture which resembles microfossil using FE-SEM, ESCA, Laser-Raman and cathodoluminescence. Taking into account the carbon isotopic ratios of remains from -33.9 to -21.1 permil, these iron oxides might be biogenic. We need to identify the iron bacteria in detail to deduce the early surface environment. In addition, the black shale of Apex Basalt overlying Marble Bar Jasper contains organic carbon from 0.7 to 5.2 percent, and the carbon isotopic ratio of which is from -30.1 to -21.2 permil, suggesting that various microbes inhabited in the early Archean ocean.

2.77 Ga Mt Roe Basalt, which is composed of basaltic lavas interbedded with tuffs, clastic sediment and minor evaporites, well preserves the primary biogeochemical, geochemical and geophysical phenomena. The discovery of black shale with sulfide nodules is worthy of special attention. Our study suggests that the following succession of events occurred more than once, (1) eruption of amygdaloidal basaltic lava followed by eruption of tuff into shallower water, (2) deposition of sandstone and black shale, and (3) concurrent hydrothermal activity with reduced fluids altered the tuff and the lowermost clastic sediments. The extremely light carbon isotopic ratios suggest the activities of methanogene in hydrothermal veinlets and methanotroph in black shale. In addition, the wide range of sulfur isotopic ratio in black shale suggests activity of co-existing sulfate-reducing bacteria in the black shale. Occasional presence of sandstone, especially in late stage of clastic sedimentation, suggests the sedimentation near coastal environment. Stromatolite-like microtexture in the sandstone suggests the existence of photosynthetic microbes, which is supported by heavy carbon isotopic ratios (up to -25 permil) and by the signals of hopanoids biomarker. The three dimensional geochemical data suggest the existence of marine environment from oxic at shallow site to euxinic at the deeper site.

Paleomagnetic analyses suggest the episodic initiation of the earth dynamo at about 3.5 Ga and the increase of momentum since at least 2.77 Ga. Taking into account the biogeochemical evidences confirmed from other ABDP cores, the increase of geomagnetic intensity might have accelerated the diversification of early life.