# Significant interaction between biosphere and crustal materials on the early Earth: possible production of pre-biotic materials and evolution of the early biota in the early crusts

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The Archean is the oldest geological age of the Earth. Most Archean rocks contain remnants of the early life forms, and these rocks provide us an information of origin and early evolution of the life. Oceanic environments have been assumed for the place of chemical evolution of pre-biotic molecules and evolution of early biota by most previous investigators. However, there exist unsuitable situations for the evolution of early biota in the ocean environments: less availability of nutrients and energy. I have been examining the Archean rocks based on the alternative hypothesis that shallow crusts may have provided ideal conditions for the evolution of early biota.

Field surveys have been conducted in 3.8 Ga Isua Supracrustal belt of Greenland, 3.4 Ga Pilbara district of Australia in this study. Many new phenomena have been found in rock samples in the above regions: (1) organic carbon-rich veins developed in the oceanic crusts and (2) production of large amounts graphite in the Archean crusts followed by methanogenesis.

(1) Organic carbon-rich veins developed in the oceanic crusts

Remnants of Archean submarine hydrothermal activities are preserved in 3.2 billion-years rocks. Notably footwall rocks of sulfide ores (thus, inside of oceanic crust) contain veins enriched in organic carbon. Such organic carbon-rich veins were generated either by recycling of surface biota or sub-vent microbial community in oceanic crusts. Many geological circumstances suggest that the sub-vent region of the examined areas was suitable for early biota compared to the contemporary ocean water column because of the significant redox change (sulfate reduction, oxidation of rocks by water, etc) and the high availability of phosphate and bio-essential metals. This strongly suggests the existence of sub-vent microbial community in the 3.2 billion-years oceanic crusts.

(2) Production of large amounts of abiogenic graphite in crustal environments

A unique carbon cycle was most likely existed on the early Earth, because of the high concentration level of Archean atmospheric $CO_2$. Fixation of large amounts of $CO_2$ into oceanic crusts has been suggested by previous investigators. This $CO_2$-enriched oceanic crusts may have attached to continents by tectonic movements of the lithosphere and, then, recycling of $CO_2$ occurred in the early continents. During the recycling of $CO_2$ in the Archean continental crusts, it is found that large amounts of abiogenic graphite were generated. These graphite were also subjects for methanogenesis, suggested by carbon isotopes. Our experiments also suggest the possible production of amino acids in the crustal conditions using graphite. These data further leads to a new hypothesis that the pre-biotic organic molecules could be prepared in the Archean crustal environments.