Paleontological and geochemical records of early life in Archean rocks from the Pilbara Craton, Australia

Roger Buick[1]

[1] Univ. of Washington

The Pilbara Craton in northwestern Australia contains a well-preserved suite of low-grade Archean metasedimentary rocks from 3.5-2.5 Ga that are perhaps the best anywhere for investigating biological and environmental evolution of the early Earth. Though there have been various reports of microfossils, including probable cyanobacteria, all have met with skepticism because of doubts about their age and/or biological origin. Stromatolites are diverse and abundant in 2.72 Ga lacustrine rocks and have been reported from sediments as old as 3.47 Ga, suggesting that oxygenic photosynthesis arose well before the atmosphere became oxygenated and that phototrophic metabolisms may have evolved within the first billion years of Earth's history. Highly depleted carbon isotopes from 2.8-2.6 Ga sediments from both terrestrial and marine environrmnts attest to the appearance of methanotrophic Bacteria and presumably methanogenic Archaea. A ~20 per mil fractionation between sedimentary del13C(carb) and del13C(org) in 3.52 Ga greenschist-facies rocks is perhaps the oldest robust evidence of life on the planet, now that older evidence from Greenland has been disputed. Sulfur isotopes of microcrystalline pyrite in evaporative sulfate (barite after gypsum) crystals 3.47 Ga old indicate that mesophilic sulfate-reducing Bacteria were early inhabitants. Hydrocarbon biomarker molecules have been extracted from 2.7-2.5 Ga (and recently 3.2 Ga) kerogenous shales from the least-metamorphosed parts of the craton, providing evidence of the early existence of cyanobacteria, methanotrophs, and eukaryotes. Taken together, these observations allow conservative dates to be placed on the rRNA Tree of Life, implying that most major microbial metabolisms and phyla evolved very early in the Archean. Coupled to observations of changes in the chemical environment but stasis in the physical environment, this suggests that microbial evolution has been responsible for global thermal homeostasis through time, but that geochemcial factors have dominated biochemical constraints in controlling the redox state of the atmosphere and hydrosphere.