

Iron-Tolerant Cyanobacteria as an Effective Tool to Study Early Evolution of Life and the Development of Biosignatures. Igor Brown¹, Daniel Mummey², Svetlana Sarkisova¹, Carlton Allen¹, David S. McKay¹; ¹NASA Johnson Space Center, Houston, TX, 77058, USA, igor.i.brown1@jsc.nasa.gov; ²University of Montana, 59812; USA, Dan.Mummey@mso.umt.edu

What is the diversity of cyanobacteria in iron-depositing hot springs? We are currently conducting preliminary studies on the diversity of iron-tolerant CB isolated from iron-depositing hot springs in and around Yellowstone National Park (WY, USA).

Molecular analysis has confirmed the prediction [1] that the diversity of iron-tolerant CB is ill-defined. Analysis of 16S rRNA sequences from 15 unialgal isolates of iron-tolerant CB indicate that 7 species have only 93 to 95% similarity to published sequences. Several iron-tolerant isolates, including *Chroogloeocystis siderophila*, likely represents a new CB genera [1]. On the other hand, preliminary fingerprinting of unialgal isolates from Chocolate Pots Hot Spring shows the presence of such widespread genus as *Fischerella*. Relatively high abundance of unidentified CB species in iron-depositing hot springs could suggest that iron tolerance in CB is determined by their relation to specific lineages of CB. The presence of such species as *Fischerella* in iron-depositing hot springs may, however, suggest that there is no strong restriction on the occupation of this unique niche by originally non iron-tolerant CB. Thus, broad-scaled studies of the diversity of CB in iron-depositing hot springs, and the evaluation of the ratio between the quantity of unidentified CB and the quantity of species common to hot springs in general, could give clues as to whether contemporary CB derive from lineages of ancestral cyanobacteria or whether they have enhanced abilities to occupy a niche containing elevated iron.

What are evolutionary patterns of iron-tolerant CB?

Great strides have been made toward understanding bacterial evolutionary relationships in recent years. However, many important areas have yet to be resolved due to the lack of phylogenetic information pertaining to key intermediates [2], long branch attraction artifacts, lateral gene transfer, etc. This is especially true for groups likely to leave important traces in the geologic record. Evolutionary relationships among the cyanobacteria, in particular, are ill-defined with many "loner" sequences or groups for which no taxonomic inferences can be made except for isolated positions [3]. Although the Precambrian is thought to have typically supported thermo-tolerant organisms resistant to levels of soluble iron significantly greater than most extant terrestrial environments, the great majority of sequences used to construct phylogenies have been obtained from mesophilic strains [4] potentially biasing the results of these analyses. Well-developed contemporary iron-depositing environments provide not only a model for the study of microfossils and their generation, but also information necessary for the reconstruction of accurate cyanobacterial phylogenies.

What are the effects of iron concentration on the metabolism of iron-tolerant CB ?

It was found (Brown et al., 2005) that growth rate of *Chroogloeocystis siderophila* is positively correlated with FeCl₃ concentration within the range 0 to 0.4 mM. We have recently elaborated the model to study the growth of iron-tolerant CB upon hypoxic conditions and found that 0.5 mM of Fe²⁺ increased doubling time of unialgal isolate 14.3 fil.2 up to 2 times while freshwater cyanobacterium *Synechocystis* sp. PCC 6803 requires only 1 to 2 μM Fe²⁺ for maximal growth (Kato et al., 2000). Our preliminary data favor the idea that the Precambrian ocean was flourishing with iron-tolerant CB.

Were iron-tolerant cyanobacteria responsible for early oxygenation of Earth atmosphere?

It was shown that the Hamersley Basin (2.7 to 2.2 Ga), which rests upon the Pilbara Protocontinent of Western Australia [5], contains a record of the evolution of the earth's atmosphere and biosphere across the critical time period in the late Precambrian when oxygen first began to appear in the atmosphere. Preliminary data from concretions preserved in the banded iron formations contained in the basin fill suggest that oxygen began to be released into the ocean as much as 300 my before it appeared in the atmosphere. This implies that iron-tolerant oxygen producing organisms were important in the early biosphere.

Conclusion:

There is no consensus on the divergence of cyanobacteria from a common ancestor for either anoxygenic or oxygenic phototrophs. Anoxygenic photosynthesis may have provided energy for the common ancestor, but it is unclear what environmental pressure induced the evolving of oxygenic phototrophs. It is supposed, however, that predecessors of contemporary CB were capable of oxidizing various substrates other than water [6], and it is likely that Fe²⁺ could be one of those substrates [7]. If that were the case, the work of entire photosystems in Precambrian cyanobacteria and/or in their predecessors could follow three scenarios (at least): 1) ferrous iron may have been oxidized in PS II but *without* significant effects on oxygen evolution, and environmental iron could have been oxidized either enzymatically or chemically; 2) ferrous iron may have been oxidized *only* enzymatically by PS II, accompanied by the repression of O₂ evolution; or 3) ferrous iron may have been oxidized by PS I upon the *prevalence* of anoxygenic photosynthesis or *without* any effect on PS II. All of these scenarios will be the subject of our future studies with the aim to understand which lineages of CB could be typical for Precambrian time.

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