Light-dependent primary productivity in a proterozoic ocean analog

T. L. HAMILTON[1*], M. WEBER[23], C. LOTT[23], C. CLARK[4], L. B. BIRD[4], D. DE BEER[3], A. DRON[3], K. H. FREEMAN[4] AND J. L. MACALADY[4]

[1]Department of Biological Sciences, University of Cincinnati, Cincinnati, OH 45221, USA
(*correspondence: trinity.hamilton@uc.edu)
[2] HYDRA Institute for Marine Sciences / Elba Field Station, Via del Forno 80, I-57034 Campo nell'Elba, Italy
[3]Max-Planck Institute for Marine Microbiology, Celsiusstrasse 1, D-28359 Bremen, Germany
[4] Department of Geosciences and the Penn State Astrobiology Research Center (PSARC), The Pennsylvania State University, University Park, PA 16802, USA

The delay in the rise of oxygen to present day levels at the end of the proterozoic represents an important gap in our understanding of ancient biogeochemical cycling. One hypothesis suggests contributions to primary production by anoxygenic phototrophs, including metabolically versatile cyanobacteria, effectively limited oxygen production throughout Earth's middle age. Little Salt Spring, a karst sinkhole in Sarasota County, FL, USA, has low sulfate concentrations (<5 millimolar) and micromolar concentrations of both oxygen and sulfide in the photic zone, conditions that may have been widespread in surface oceans during long stretches of the Proterozoic. Phototrophic pinnacle mats comprised of cyanobacteria and green sulfur bacteria occupy the sediment-water interface in the sunlit upper basin of the sinkhole. The water chemistry of the sinkhole combined with these conspicuous microbial populations provide a model analog system for determining the role of anoxygenic photosynthesis in the delay of oxygenation of the surface oceans.

Bicarbonate uptake indicates higher levels of primary productivity in the light. Inhibition of photosystem II via DCMU reveals cyanobacterial members of the pinnacle may be capable of anoxygenic photosynthesis and thus contributing to primary production in the absence of oxygen evolution. Indeed, characterization of the dominant cyanobacterium from the pinnacle mat indicates the isolate is capable of both anoxygenic photosynthesis and synthesis 2-methyl hopanoids, important biomarkers. The isolate requires no induction time following the addition of sulfide to perform anoxygenic photosynthesis. Under the optimal light conditions for oxygenic photosynthesis, rates of anoxygenic photosynthesis are nearly twice as high. This characterization represents a significant step toward unraveling the role of biology in planetary redox evolution. In Little Salt Spring, anoxygenic phototrophs contribute to primary productivity in the water column where sulfide and oxygen co-exist. These data support the hypothesis that anoxygenic phototrophs, including metabolically versatile cyanobacteria, could have played a role in delaying the rise of oxygen on early Earth.