

Y. Cohen: PROTOCYANOBACTERIA: OXYGENIC AND ANOXYGENIC  
PHOTOSYNTHESIS IN MAT-FORMING BACTERIA

The oldest record of life, preserved in prePhanerozoic stromatolites dated 3500 million years old, is most likely of filamentous mat-forming cyanobacteria. The sedimentary records of cyanobacterial mats in stromatolites are the most abundant record of life throughout the prePhanerozoic. Stromatolites persisted into the Phanerozoic Eon, yet they become much less pronounced relative to earlier ones. The abundance and persistence of cyanobacterial mats throughout most of geological time point to the evolutionary success of these kinds of microbial communities and their possible role in the evolution of the earth and atmosphere.

Recent cyanobacterial mats are restricted to hypersaline environments, sulfur springs, and alkaline lakes where the grazing organisms are excluded or their populations drastically reduced. Solar Lake cyanobacterial mats serve as good models for the study of the physiology of recent mat-forming cyanobacteria.

Facultative anoxygenic photosynthesis utilizing  $H_2S$  as an alternative electron donor for PS I (photosystem I)-dependent photosynthesis was described for *Oscillatoria limnetica* isolated from Solar Lake. Other PS I-dependent characteristics of this cyanobacterium include the use of  $H_2$  as an electron donor alternatively to  $H_2S$ ,  $H_2$  production from  $H_2S$  under  $CO_2$  limitation, sulfide-dependent  $N_2$  fixation, and anaerobic respiration with elemental sulfur as the electron acceptor. These PS I characteristics are found also in other mat-forming cyanobacteria.

While PS II of *Oscillatoria limnetica* is fully inhibited at sulfide concentrations as low as 10  $\mu M$ , other mat-forming cyanobacteria can operate oxygenically even under 5 mM  $H_2S$ . *Microcoleus chthonoplastes*, a cosmopolitan mat-forming cyanobacterium, as well as several isolates from sulfur springs, have a different PS II which is significantly more resistant to  $H_2S$  toxicity than planktonic cyanobacteria, algae, and plants. Several isolates carry out exclusively oxygenic photosynthesis under high sulfide concentrations, while others operate oxygenic photosynthesis in concert with anoxygenic photosynthesis. Recently  $Fe^{++}$  ions were found to serve as a sole electron donor to PS II in several benthic cyanobacteria under anaerobic reduced conditions.  $Fe^{++}$ -dependent  $CO_2$  photoassimilation is DCMU-sensitive. However, about 20 percent of the  $Fe^{++}$ -dependent carbon dioxide photoassimilation is carried out in the presence of 5  $\mu M$  DCMU. This indicates that there may be two different sites of  $Fe^{++}$ -dependent  $CO_2$  photoassimilation, one at PS II which is sensitive to DCMU and another at PS I.

$^{13}\text{C}$  values for organic matter in the Solar Lake mats were found to range between -6 and -8 per mil and thus represent the heaviest values for organic matter recorded. Preliminary observations point to the fact that the ribulose biphosphate carboxylase system in several mat-forming cyanobacteria is different from other cyanobacteria.

The differences in PS I, PS II, and possibly the ribulose biphosphate carboxylase in mat cyanobacteria may point to the antiquity of this group among cyanobacteria. Mat-forming "protocyanobacteria" may well represent the prePhanerozoic forms responsible for Archean stromatolites and possibly for the Banded Iron Formations (BIF's).  $\text{Fe}^{++}$ -dependent carbon dioxide photoassimilation by cyanobacteria may be related to the deposition of BIFs in the absence of free oxygen.

Note: The compound DCMU, 3-(3,4) dichlorophenyl -1,1 dimethyl urea, is a selective inhibitor of photosystem II, i.e., of the oxygen process in photosynthesis.

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