# The Moon and Cyanobacteria: Role of day length and microbial mats in Earth's oxygenation

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The current models of Earth's oxygenation struggle to identify the biotic and abiotic controls on oxygen that could explain both the persistence of static low-$O_2$ periods that characterized the vast majority of life's history on Earth as well as drastic shifts in atmospheric $O_2$, particularly the Neoproterozoic oxidation event. Recognizing the intriguing similarity of Earth's oxygenation and rotation rate patterns, we modeled and demonstrated that increasing daylength causes increased net oxygen export from photosynthetic mats, which were likely a dominant biotic feature of the ancient microbial Earth. This relationship emerges from the interaction of mass transfer physics and daylength-driven light dynamics.

Through measurements in a modern analogue of Proterozoic cyanobacterial mats, we observed unexpected dynamics of oxygen production and export ocurring due to microbial interactions. We found that net oxygen production by cyanobacteria only occurred after several hours of delay despite exposure to high light intensities. This effect was caused by large sulfur-oxidizing bacteria covering the cyanobacteria, reducing local light availability and hence oxygen production. A subsequent migration which exposed the cyanobacteria rendered high oxygen production. As oxygen production rates did not directly correlate to the momentary photon flux at the mat surface, diel oxygen export was highly sensitive to variations in photoperiod. Changing the daylength over values relevant to Earth's history turned photosynthetic mats from net oxygen sinks to sources. We suggest that shifts in day length, particularly in the Neoproterozoic, might have thus fundamentally impacted global benthic $O_2$ production rates.

Our observations demonstrate how microbial interactions can dramatically decouple the actual production of sedimentary systems from those predicted only from consideration of environmental conditions. Therefore, a biologically-nuanced perspective is needed to develop a predictive understanding of the production and export properties of microbial systems of geobiological significance.