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Earth's geophysical evolution and the role of the marine biosphere in surface oxygenation

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Oxygen is crucial for complex life on Earth, but our understanding of the mechanism of Earth's oxygenation remains incomplete. In particular, the reasons for the 500 Myr lag between the evolution of oxygenic photosynthesis and the first major rise of atmospheric O_2 during the Great Oxygenation Event—and the nature of marine biogeochemical feedbacks during this time—remain uncertain [1].

Parallel to changes in biogeochemical cycling and chemistry of the ocean-atmosphere system during the Precambrian, Earth also experienced a coeval evolution of its orbit and continental configuration, possibly influencing biotic mechanisms of O_2 accumulation. A slowing of Earth's rotation rate through time may have drastically influenced ocean circulation patterns and nutrient availability to the marine biosphere [2]. Accompanying changes in diurnal illumination patterns may have also affected rates of O_2 production in benthic microbial mats, which were likely an important source of photosynthetic O_2 on early Earth [3, 4]. However, the interplay between these geophysical factors, global biogeochemistry, and marine productivity is unresolved on both global and mat scales.

We use a sophisticated Earth system model (cGEnIE) to explore the connection between marine productivity and rotation rate, and the overall contribution to O_2 production and atmospheric oxygenation. Additionally, we consider a range of hypothetical continent distributions and areal extents of microbial mat coverage. We find that increasing daylength increases global oxygenation due to benthic productivity, but this effect is additionally controlled by patterns of upwelling and mat coverage at global scales. We will discuss how these changes in productivity may have factored into the timeline of Earth's oxygenation, as well as possible implications for habitability constraints posed by rotation rate on exoplanets.

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[3] Klatt, J. M. et al. (2021), *Nat. Geosci*. 14(8), 564–70.

[4] Dick, G. J. et al. (2018), *Annu Rev Earth Planet Sci* 46(1), 123–47.