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Geophysical Influences on Ocean Circulation and Spatiotemporal Patterns of Marine Oxygenation in the Precambrian

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Planetary oxygenation is crucial to the evolution and persistence of complex multicellular life on Earth and possibly beyond. However, our understanding of the mechanism of Earth's oxygenation, particularly 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, remains unclear [1].

In parallel with biological innovation and associated impacts on biogeochemical cycles and ocean-atmosphere chemistry, changes in Earth's continental configuration and rotation rate significantly affected ocean circulation and mixing. Earth's diversity of continental distributions and its slowing rotation rate through time may have altered nutrient supply to the marine biosphere and the transport of oxygen to the deep ocean [2], potentially affecting O_2 production and ocean ventilation. At present, our oxygenation timeline lacks consideration of global biogeochemistry and the dynamics of marine O_2 in this evolving geophysical and oceanographic context.

We use a sophisticated 3D Earth system model (cGEnIE) to explore the impact of changing continental distribution and rotation rate on marine productivity and resolve the overall contribution to marine oxygenation. We find that continents shape the spatial patterns of upwelling and deep-water formation, and thus primary productivity and benthic oxygenation. However, our results also show that these features are strongly influenced by rotation rate. Slowing rotation strengthens overturning circulation, enhancing nutrient recycling and marine O_2 production and leading to greater ventilation of the seafloor. We will discuss how these effects may have factored into the timeline of Earth's oxygenation as well as possible constraints on habitability for complex life posed by rotation rate and continentality on exoplanets.

[1] Lyons, T. W. et al. (2014) *Nature*, 506(7488): 307–15.
[2] Olson, S. L. et al. (2020), *ApJ*, 895(1): 19.