Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12741

Co-evolution of atmosphere and marine biosphere driven by oxygenic photosynthesis before the Great Oxidation Event

YASUTO WATANABE[1], EIICHI TAJIKA[2] AND KAZUMI OZAKI[3]

[1]Meteorological Research Institute
[2]The University of Tokyo
[3]Toho University
Presenting Author: yyywww1227@gmail.com

Oxygenic photoautotrophs would have emerged in the early ocean during the Archean (4.0–2.5 Ga) and impacted the chemical condition in the ocean-atmosphere system in the early Earth, as evident from the first major rise of atmospheric oxygen level at the Great Oxidation Event (GOE) (~2.4–2.2 Ga) [1]. The emergence of oxygenic photosynthesis would have affected the chemical condition of the ocean-atmosphere system, hence the primitive marine biosphere that utilizes reduced chemical components as electron donors (e.g. H_2, CO, Fe(II), etc.) [2]. To elucidate the links between the atmospheric composition and marine biogeochemical cycles in the early Earth, we employed a novel marine microbial ecosystem model, which is coupled with an atmosphere photochemical model [3]. We show that the productivity of H_2-based photoautotrophs and CO-consuming chemoautotrophs diminishes when the supply rate of oxygen to the atmosphere exceeds that of methane, causing the decreases in the atmospheric levels of methane, hydrogen, and carbon monoxide and the supply rate of electron donors available for the primitive anaerobic marine biosphere. This behavior is explained by the increase in the production rate of OH-radicals in the atmosphere from biogenic oxygen, which becomes the primary sink of biogenic methane and electron donors (H_2 and CO). The decrease in atmospheric methane level causes surface cooling, which may have enhanced the supply rate of nutrients from continents by increasing the steady-state pCO_2 and the contribution of continental weathering relative to seafloor weathering in regulating the climate [4]. This mechanism may have enhanced the variability of the primary productivity of oxygenic photosynthesis and the atmospheric methane level in the early Earth. Our results enlighten the relationships between the atmospheric oxygenation, climate, and transformations in marine microbial ecosystems in the early Earth after the emergence of oxygenic photoautotrophs, which demonstrates the co-evolutions of ocean, atmosphere, and marine biosphere before the GOE.

[1] Lyons et al. (2014). Nature, 506(7488), 307-315.
[2] Kharecha et al. (2005). Geobiology, 3(2), 53-76.
[3] Arney et al. (2016). Astrobiology, 16(11), 873-899.
[4] Watanabe and Tajika (2021). Earth, Planets and Space, 73(1), 1-10.