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Oxygenation of the atmosphere and oceans

David C. Catling (1), M.W. Claire (2), and K. J. Zahnle (3)

(1) Astrobiology Program/ Earth and Space Sciences, Box 351310, University of Washington, Seattle, WA 98195. U.S.A., (2) Astrobiology Program/ Dept. Astronomy, Box 351580, University of Washington, Seattle, WA 98195 U.S.A., (3) NASA Ames Research Center, MS 245-3, Moffett Field, CA 94043. U.S.A.

The intimate connection between atmospheric O2 and changes in Earth's biological evolution makes understanding the history of O2 one of the most important problems in Earth history. Numerous geochemical differences between the ancient and modern world show that there were two prominent, stepwise increases in O2 levels: a "first" rise of O2 at 2.4-2.2 Ga and a "second" rise in the late Neoproterozoic at ∼750-580 Ma. The second increase may be further subdivided into separate stages. A plausible explanation for why little atmospheric O2 accumulated prior to the 2.4 Ga rise, despite the apparent presence of O2-producing cyanobacteria, is that environmental reductants consumed oxygen, in effect producing a global redox titration. Our models demonstrate that a transition would have been reached when organic carbon burial (the long-term source of O2) exceeded geological sources of reductants. At this tipping point, O2 flooded the atmosphere until O2 levels reached a new plateau where O2 production was balanced by losses to continental weathering. Nonetheless, O2 levels remained limited and subsequent biological evolution progressed slowly. In some ways, the second rise of O2 is more difficult to understand than the first, which is indicated in the diversity of ideas put forward for its cause. Geological proposals include the enhanced production of clays that adsorbed and buried organic matter, continental reconfigurations conducive to organic burial, subduction of sulfides, or the exhaustion of seafloor weathering buffers on oxygen. Biological proposals include an infusion of weathered carbon from terrestrial biota or the evolution of marine organisms that somehow permanently enhanced the burial of sulfides or organic carbon. Alternatively, moderately high levels of atmospheric methane throughout the Proterozoic promoted hydrogen escape to space and irreversibly oxidized the Earth. In this talk, ideas for the first and second rise of O2 will be critically discussed.