Geophysical Research Abstracts, Vol. 8, 00770, 2006
SRef-ID: 1607-7962/gra/EGU06-A-00770

The Great Oxidation at ∼2.4 Ga as a bistability in atmospheric oxygen due to UV shielding by ozone

C. Goldblatt, T. M. Lenton, A. J. Watson
School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, U.K.
(c.goldblatt@uea.ac.uk)

Earth history has been characterised by a series of major transitions separated by long periods of relative stability. Chemically the largest transition was the "Great Oxidation Event" at ~ 2.4 Ga, when atmospheric oxygen rose from $< 10^{-5}$ PAL to between 0.1 and 0.2 PAL. This was substantially after the origin of oxygenic photosynthesis, at or before 2.7 Ga. The cause of the transition and the delay from the origin of oxygenic photosynthesis is hotly debated and its dynamics have not been explained. We show that there were two simultaneously stable steady states for atmospheric oxygen once oxygenic photosynthesis had arisen. The Great Oxidation can be understood as a switch between lower and upper stable steady states. This bistability was caused by UV shielding decreasing the rate of methane oxidation once oxygen levels were sufficient to form an ozone layer. The switch from lower to upper stable state typically takes 2×10^5 years. It was probably triggered by a decrease in reductant input to the atmosphere and ocean, but increased productivity or perturbation of the carbon cycle could also have been responsible. The higher stable state is more resistent to perturbation; transition to the lower state typically takes 3×10^6 years. This may explain why, once oxygen exceeded 10^{-2} PAL, it never returned to Archean values. Our results explain the Great Oxidation as a large, non-linear, response to a small change in forcing, credibly delayed from the evolution of oxygenic photosynthesis, and demonstrate that high oxygen levels following this transition were self-stabilising. The evolution of atmospheric oxygen and life are intrinsically linked and the Great Oxidation paved the way for subsequent diversification of multicellular, aerobic, life. Understanding the dynamics of this transition is a major step in understanding how early life influenced the global environment, creating the conditions necessary for the evolution of higher life forms.