Benthic Oxygenic Photosynthesis on the Archean Landmass

KURT O. KONHAUSER1 AND STEFAN V. LALONDE2

1Department of Earth and Atmospheric Sciences, University of Alberta, T6G 2E3
2European Institute for Marine Studies, Technopole Brest-Iroise, Plouzane, France

A remarkably coherent ensemble of evidence point to a significant accumulation of atmospheric oxygen for the first time in Earth’s history beginning ca. 2.45 Ga, the so-called Great Oxidation Event (GOE). This includes, amongst many, the loss of sedimentary sulfur isotope mass-independent (S-MIF) anomalies from the rock record. However, several trace element and isotopic proxies have recently suggested oxidative weathering hundreds of millions of years earlier. This apparent discrepancy has been addressed by two models: (1) that pre-GOE oxidative weathering is the result of transient oxygenation events driven by ‘oxygen oases’ in the marine realm, and (2) that oxidative weathering proceeded at atmospheric O2 concentrations below 10−5 present atmospheric level. We propose here a third model - intense O2 generation at sub-meter scales by benthic oxygenic photosynthesis in the terrestrial realm. Despite the absence of a UV-protective ozone layer in the Archean, a terrestrial phototrophic biosphere may have existed in various sheltered environments, including biological soil crusts and freshwater microbial mats covering riverbed, lacustrine, and estuarine sediments. We calculate that the rate of O2 production via oxygenic photosynthesis in these ecosystems provides sufficient oxidizing potential to mobilise sulphate and a number of redox-sensitive trace metals from land to the oceans while the atmosphere itself remained anoxic with its attendant S-MIF signature. These findings demonstrate the plausible antiquity of a terrestrial biosphere populated by cyanobacteria.