Tracking oxygenic photosynthesis on the Archaean Earth

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Oxygenic photosynthesis fuels Earth’s modern biosphere and plays a significant role in modulating atmospheric composition and climate. Pinpointing the timing of this evolutionary event remains one of the most important and challenging problems in evolutionary biology and Earth system science. However, existing proxy evidence for the presence of oxygenic photosynthesis on the earliest Earth relies on tracking putative signals of manganese (Mn) oxidation in the sedimentary record, the interpretation of which is not always straightforward. Here, we use chemical sedimentology and the stable isotope record together with a model of 3-D ocean biogeochemistry to argue that large quantities of oxidized Mn were delivered to some Archaean marine sediments by at least ~3 billion years ago. We then use a simple kinetic model to show that dissolved O2 is required to prevent rapid reductive dissolution of Mn oxides prior to burial, regardless of the initial mechanism catalyzing Mn oxidation. Taken together, our results and previous observations from the rock record provide strong evidence for the emergence of oxygenic photosynthesis on Earth at least ~3 billion years ago, and by extension suggest that Earth’s ocean-atmosphere system can remain pervasively reducing on timescales of ~10^8 years despite the presence of an active oxygenic microbial biosphere.