Atmospheric oxygen rise in the Paleoproterozoic

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Atmospheric oxygen increased irreversibly, first time in Earth's history, during the Paleoproterozoic, 2.5 - 2.0 Ga. The initial model (Holland, 1984; Rye & Holland, 1998) has proposed that atmospheric oxygen rose drastically at around 2.2 Ga based on compositions of paleosols, ancient soils formed by weathering. Subsequently, the timing of oxygen rise has been revised to be 2.45 Ga (Kump, 2008). This revision was in conjunction with the oldest evidence for the presence of cyanobacteria at around 2.7 Ga (Brocks et al., 1999). However, this evidence revealed by lipid biomarkers has been found to be incorrect and the earliest occurrence of cyanobacteria has been shifted to around 2.2 Ga (Rasmussen et al., 2008). Consequently, we have to revaluate the timing and pattern of atmospheric oxygen increase. Applying Fe(II) oxidation kinetics to paleosols, we have proposed that atmospheric oxygen increased gradually from less than 10^{-6} to more than 10^{-3} atm between 2.5 and 2.0 Ga (Murakami et al., 2007). Here, we examine the gradual-increase model considering the effects of factors that affect the Fe(II) oxidation kinetics, and glaciations.

The Fe oxidation rate is expressed as -d[Fe(II)]/dt = k[Fe(II)] $[OH]^2$ $(PO2)^x$ where x is the variable, from 0 to 1. If we define f as the ratio of [flowing-out Fe(II)]/[dissolved Fe(II)] in a whole weathering profile, the values of f can be obtained from paleosol data. Then, f/f(A) = (k(A)[OH](A)^2 (PO2)(A)$^{x'}$) / (k $[OH]^2$ $(PO2)^x$) where the parameters with A denote the values for reference paleosol A and x' the x value for paleosol A. In this equation, k is temperature dependent and [OH] is both temperature and atmospheric carbon dioxide dependent. From this equation we can calculate a value of PO2 at a given age if an f variation is obtained from paleosol data. We found that x, temperature and atmospheric carbon dioxide do not affect the PO2 variations significantly if temperature and atmospheric carbon dioxide do not change significantly in terms of long term or if their changes are limited for the long-term trend as suggested by some literature. That is, atmospheric oxygen increased gradually between 2.5 and 2.0 Ga. However, if snowball-type glaciations have occurred, there would have been a large short-term fluctuation of PO2.