Deep Ocean Oxygenation

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The O_2 content of the deep ocean is largely set by a chemical titration between O_2 introduced from the atmosphere and organic carbon moving through the biological pump. A simple quantitative analysis of this relationship reveals two critical points. First, high concentrations of O_2 in the deep ocean, particularly those characteristic of the modern Earth system, require relatively high atmospheric O_2 unless the biological pump is extremely weak. Second, it is likely that the ocean would have remained pervasively reducing after the first dramatic rise in atmospheric O_2 but prior to the later rise of atmospheric oxygen to near modern levels [1].

Pinpointing when pervasive deep ocean oxygenation first occurred has been a long sought after but elusive goal. This has been a tough question to tackle since we have essentially no Paleozoic or Proterozoic deep-sea record. We will provide a new range of estimates for the timing of this event from models of the evolution of the Mo isotope reservoir in Earth's weatherable shell after the onset of deep-sea Mn oxidation and subduction—an event that more than any other marks true deep ocean oxygenation. Based on this approach we propose late—i.e., Phanerozoic—permanent deep ocean oxygenation.

[1] Canfield, D. E. A new model for Proterozoic ocean chemistry. *Nature* **396**, 450–453 (1998).