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Revisiting the Interaction of O_2 and CH_4 in the Atmosphere-Ocean System During the Mid-Proterozoic

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The mid-Proterozoic (1.8–0.8 Ga), also known as the 'Boring Billion', is generally regarded as a transitional time between the anoxic Archean and the well-oxygenated late Neoproterozoic. The subsequent emergence of multicellular animals around 0.55 Ga suggests an atmospheric O_2 level (pO_2) above 0.5–4% times the Present Atmospheric Level (PAL), based on an analogy to demosponges (Knoll and Sperling, 2014), and above 10% PAL for other centimeter-scale animals that appeared shortly thereafter (Catling and Kasting, 2017). Capturing how mid-Proterozoic pO_2 evolved and what mechanism could stabilize is key to the coevolution of Earth's life and its environment. However, it remains one of the most challenging puzzles because different proxies and methodologies predict pO_2 values ranging from < 0.1% to 40% PAL. A related issue is the atmospheric methane concentration and whether methane could have helped maintain a warm mid-Proterozoic climate.

We have constructed a simplified biogeochemical box model to investigate the likely mid-Proterozoic pO_2, its regulation mechanism(s), and the associated atmospheric methane concentration. This model considers cycling of oxygen, methane, sulfur, and iron in a self-consistent manner in the atmosphere-ocean-sediment system, constrained by global redox balance at each imposed atmospheric O_2 level. We find that ~ 0.1 PAL O_2 in the mid-Proterozoic atmosphere is the most plausible solution, consistent with some earlier predictions (Daines et al., 2017). pO_2 remained stable during this time because it was regulated by strong negative feedbacks affecting both O_2 production and O_2 loss. Our results also suggest that marine productivity was high during this time and that much of the organic matter that was generated would have decayed to produce methane. Plausible CH_4 fluxes range from 4 to 7 times today's value. The atmospheric lifetime of CH_4 maximizes at 0.1 PAL O_2 (See Figure 1), making it possible to sustain climatically important concentrations of methane.

References:

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