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Constraining the redox landscape in Mesoproterozoic mat grounds: A possible oxygen oasis in the 'Boring Billion' seafloor

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The Boring Billion, referring to the time interval between 1.8 Ga (billion years ago) and 0.8 Ga, is characterized by the absence of significant carbonate carbon isotope excursions, low marine productivity, and sluggish evolution of eukaryotes. It is generally accepted that the atmospheric O_2 level was extremely low (< 1% PAL) and the widespread sulfidic continental margins might have scavenged some micronutrients, such as Mo and Cu, from the ocean inventory, hampering the evolution of eukaryotes. However, recent studies report complex multicellular eukaryotes and episodic/sporadic inception of ocean oxidation in Mesoproterozoic. These findings suggest the possible occurrences of oxygen oasis in predominant anoxic ocean, providing habitable niches for eukaryotes in the context of extremely low atmospheric O_2 level. Such oxygen oasis was favored at shallow water environment with the development of microbial mat that generated O_2 at seafloor. To elucidate the habitability of these potential oasis, reconstruction of seafloor redox condition is paramount. In this study, we analyzed pyrite sulfur isotope and pyrite content of the Mesoproterozoic Wumishan Formation (~1.4 Ga). The Wumishan Formation is composed of cyclic deposition of, from deep to shallow, the subtidal calcareous shale, massive thrombolitic dolostone, and microbial laminated dolostone. We apply One-Dimensioned Diffusion-Convection-Reaction (1D DAR) model to simulate syndepositional pyrite formation in sediments. Sedimentation rate can be well constrained by the sedimentary cycles. The modeling results indicate high fraction of H_2S that was generated in dissimilatory sulfate reduction (DSR) and limited supply of organic matter from the surface ocean. Thus, the seafloor O_2 fugacity was not low, and the primary productivity, both from the surface water and seafloor, was still low. This study indicates that the shallow water microbial mat-ground might be the oxygen oasis in Mesoproterozoic with extremely low atmospheric O_2 content.