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A rise of atmospheric oxygen triggered by the Paleoproterozoic deglaciations: Insights from osmium isotopes

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The Paleoproterozoic era is one of the most interesting periods in Earth's history to understand interaction between the atmosphere-ocean system and early life. A number of geological and geochemical evidences suggest that the atmospheric oxygen dramatically increased during the Paleoproterozoic, known as the Great Oxidation Event (GOE). Since repeated, severe glaciations also occurred at the time of the GOE, it is suggested that climate change would have played a key role in the rise of atmospheric oxygen. However, due to lack of detailed geochemical records constraining the redox conditions in the atmosphere and oceans during and immediately after the glaciations, the relationship between the GOE and the Paleoproterozoic glaciations remains poorly understood.

Here we investigate the evolution of the redox conditions in the atmosphere and oceans immediately after the first and second Paleoproterozoic glaciations based on the abundance and isotopic compositions of redox sensitive element osmium (Os) and rhenium (Re) in the sedimentary rocks in the Huronian Supergroup, Ontario, Canada. We found enrichments of Re and Os with high initial 187Os/188Os ratio immediately after the both glaciations. These results suggest an input of radiogenic 187Os to the sediments at the time of deposition. Considering that mobilization of continental radiogenic 187Os in the hydrological cycle requires moderately oxygenated atmospheres, our findings suggest that the atmosphere and shallow oceans have been oxygenated sufficient to deliver continental Os to the oceans (pO2 ˜ 10-5-10-4 times the present atmospheric level) immediately after the both of the glaciations. Based on the Os records together with other geochemical data of the present study, we conclude that the climatic recovery from the Paleoproterozoic glaciations would have promoted photosynthetic activities, leading to the rise of atmospheric oxygen. Coupled with previous geochemical data, oxygen spikes would have occurred in the aftermath of the first and second Paleoproterozoic glaciations possibly in the similar mechanism. Our results support the hypothesis of stepwise rise of atmospheric oxygen in response to the repeated glaciations during the Paleoproterozoic.

Keywords: Paleoproterozoic, glaciation, Great Oxidation event, Os isotope, geochemistry