Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.11081

Multi-dimensional constraints on the history of deep ocean oxygenation from metal isotope systems

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The progressive oxygenation of the surface is a fundamental, planetary-scale, feature of Earth, one that is intimately linked with the evolution of the biosphere. The history of surface Earth oxygenation continues to be the topic of intense research effort, and questions involving the links to biological evolution, and the complex feedbacks between surface Earth oxygenation and the development of the biosphere, continue to represent some of the biggest in Earth Science. These feedbacks and connections also encompass other crucial shapers of the surface environment of the Earth, including the long-term carbon cycle and the nature and size of Earth's natural greenhouse effect. A number of recent studies [1,2] have underlined the fact that the deep ocean became oxygenated later than the atmosphere-surface ocean system, in the later Phanerozoic, controlled by the nature and strength of both the biological pump and the physical ocean circulation.

Developments in transition metal isotope geochemistry shed significant light on these issues, especially with the increasing application of multiple metal isotope systems. The modern oceanic isotope compositions of many of these metals are strongly fractionated by the outputs from the ocean to sediments, whose nature in turn strongly depends on the redox state of the deep ocean. Multi-dimensional constraints are available from the fact that different metals exhibit very different sensitivities to these redox-controlled sinks. This talk will present our current understanding of the modern budget of one of the newest of these systems - nickel (Ni) isotopes - whose oceanic composition is very sensitive to the output flux to sediments deposited under oxidising conditions. It will also show how the coupling of our new understanding of the biochemical cycling of Ni in the oceans to that of other metal isotope systems, that are more sensitive to sedimentary output fluxes under anoxic and sulphidic conditions, can yield new constraints on the late oxygenation of the deep ocean in the Phanerozoic [see also 3].

1. Lu, W. et al. (2018) Science 361, 174-177.
2. Stolper, D.A. and Keller, C.B. (2018) Nature, 553, 323-327.
3. Sun, M. et al. (2022) Goldschmidt conference, Honolulu, July.