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Balancing the redox budgets of Oceanic Anoxic Events

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Oceanic Anoxic Events (OAEs), as well as many similar Phanerozoic events, are a product of significant environmental upheaval that are generally well-recognized in the geologic record by the widespread burial of organic matter and a significant positive carbon isotope excursion. These events bury considerable amounts of reduced materials such as organic carbon and pyrite, which ultimately results in a net release of oxygen. Therefore, the processes surrounding OAEs are counterintuitive given that the excess oxygen production should limit the duration of OAEs to only a few thousand years; yet the durations of these events range from hundreds of thousands to millions of years. This decoupling implies that there are likely other mechanisms involved in the removal of oxygen beyond those typically invoked as probable causes of the OAE.

There are many OAEs and OAE-like events, though not all, that are associated with large igneous provinces (LIPs) or similar volcanic events. The dominant anoxia-inducing mechanism explored has been related to nutrient delivery driving primary production. It is suggested that the release of volatile gases from LIPs drive climatic perturbations eventually inducing these bioproductivity increases, which connect these phenomena. Excess reductants (e.g., gases, solid-phase aerosols, and/or particles) released during volcanism, however, can also provide a mechanism to remove oxygen from the ocean-atmosphere system.

A forward box model was assembled to quantify, at a first-order, the excess oxygen produced via organic carbon and pyrite sulfur burial as well as the effectiveness of LIP reductants to remove this oxygen. The two most well-studied OAEs, Cretaceous Oceanic Anoxic Event 2 and the Early Jurassic Toarcian Oceanic Anoxic Event, were both analyzed with this model under various parameters to determine the effectiveness of reductants released from the LIPs in the removal of oxygen. Overall, a large portion of the oxygen produced during these OAEs was removed through the introduction of various reductants that may have accompanied LIP emplacement under numerous scenarios. Therefore, this poorly studied aspect of LIP eruptions can provide additional means to induce the removal of oxygen, extending the duration of OAEs and more closely balancing the oxidant and reductant budgets.