

## **Towards mechanistic interpretation of multiple spatio-temporal proxy records of Earth's oxygenation**

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Evidence for the oxygenation of Earth's oceans and atmosphere has evolved dramatically over the past two decades. Geologic observations, qualitatively interpreted to provide the basis for our current understanding, are increasingly augmented by rich geochemical and isotopic records, each with associated complexities and model-dependent interpretations. Typically, records are interpreted in isolation from one another, and with heavy reliance on insight from modern biogeochemical cycles.

The notion that there is valuable additional information in the relative timing of changes recorded in different redox-sensitive proxy records, as well as in spatial patterns in each of these records, is appreciated, but often overlooked. Furthermore, though modern biogeochemical cycles importantly constrain the interpretation of proxy records, processes that may have been of key importance in the early, anoxic cycles may be minor, or altogether absent, in today's oxidizing surface environment. These same processes may additionally be very poorly characterized in laboratory experiments and natural environments due to their minor present-day importance, making it difficult to account for them in the interpretations. Finally, though the goal is often to understand atmospheric composition and climate, information most commonly comes from a record of lithified marine sediments, with variably complex histories of interaction with seawater, diagenesis and metamorphism.

Thus, the information in multiple proxy records may yield quantitative insight into the sequence of events leading to and following from the rise of atmospheric oxygen only if processes governing the preservation of these records are adequately understood and are incorporated into models of sufficient biogeochemical and spatial sophistication. As the relevant chemical and isotopic parameters are often unknown, greater insight is gained by integrating experimental results into the numerical models. In addition to shedding light on the operation of early biogeochemical cycles, such models advance the state of knowledge by generating testable hypotheses and providing guidance to future observations and models. To demonstrate the utility of this approach, I will present an environmentally-resolved, experimentally-constrained model of Precambrian ocean chemistry, with an emphasis on the biogeochemical cycles of sulfur and iron.