Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.37717

Continental Growth as a Tectonic Gatekeeper of Early Earth Oxygenation

MOJTABA FAKHRAEE[1] AND PETER CROCKFORD[2]

[1]University of Connecticut
[2]Carleton University

Continental Growth as a Tectonic Gatekeeper of Early Earth Oxygenation

The rise of atmospheric oxygen and the onset of Paleoproterozoic glaciations are commonly attributed to biological innovation, particularly the emergence of oxygenic photosynthesis. Yet geochemical evidence indicates that oxygen production predated the permanent rise of atmospheric O_2, implying that biological capability alone was insufficient to drive sustained oxygenation. Here we present results from a coupled ocean–atmosphere box model demonstrating that continental growth and shelf emergence acted as tectonic gatekeepers of long-term atmospheric redox evolution.

We introduce the concept of a *continental oxygen inventory*, defined as the product of shallow continental shelf area and dissolved oxygen concentration, to quantify the spatial constraint on oxygen export from the ocean to the atmosphere. Model results reveal two critical thresholds. When the relative inventory exceeds ~0.01% of its modern value, atmospheric O_2 surpasses the mass-independent sulfur fractionation (S-MIF) threshold (~10^{-5} PAL). When it exceeds ~1%, enhanced methane oxidation drives atmospheric CH_4 collapse, triggering global glaciation. Below these thresholds, even oxygenated surface waters fail to oxygenate the atmosphere.

Because shelf area is ultimately controlled by continental crust volume, mantle thermal state, plate mobility, and hypsometry, these results imply that deep Earth processes fundamentally regulated the timing and magnitude of atmospheric oxygenation. The Great Oxidation Event, therefore reflects not solely biological innovation but the progressive expansion of oxygen-producing habitats enabled by tectonic evolution during late Archean–early Proterozoic continental growth.

More broadly, this work highlights tectonics as a first-order control on planetary oxidation state and climate stability. By linking mantle dynamics to atmospheric composition through evolving continental geometry, our framework reframes Earth's oxygenation as a coupled deep Earth–surface process. These findings have implications not only for interpreting the tempo of Earth's environmental and biological evolution, but also for assessing the likelihood of atmospheric oxygen accumulation—and thus detectable biosignatures—on rocky exoplanets with differing tectonic regimes.