

Impacts of Seasonal O₂ Availability on the Emergence and Diversification of Ediacaran Fauna

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Earth's surface ocean remained poorly oxygenated until the Neoproterozoic Oxidation Event (~539 Ma), when atmospheric pO₂ rose from ~1% of present atmospheric levels (PAL) to near-modern levels. The Ediacaran fauna, including some of the first animals on Earth, emerged in O₂-poor environments prior to the NOE. Previous work has explored possible links between environmental O₂ availability and increased biological complexity during the Ediacaran [1, 2, 3], extrapolating data from individual sites to understand planetary-scale events.

However, dissolved O₂ in the Ediacaran surface ocean would have varied significantly in both space and time. In particular, seasonal variations in surface O₂ availability may have placed important constraints on the regions where Ediacaran fauna could persist and thrive. Moreover, the magnitude of these seasonal variations may have had distinct regional patterns, acting as a spatial environmental driver of biological stress and/or innovation.

To address these questions, we used cGenIE, a 3D marine biogeochemical model, to simulate the spatial and temporal distributions of dissolved O₂ in the Ediacaran surface ocean. We modeled a range of Ediacaran atmospheric pO₂ estimates and continental configurations. We then quantitatively compared the distribution of fossils at sites in the Avalon (~575 - 560 Ma), White Sea (~560 - 550 Ma), and Nama (~550 - 539 Ma) assemblages [3] to dissolved O₂ in our simulations to investigate the impacts of latitudinal and seasonal O₂ variability on taxonomic abundance and morphological diversity at various sites. We find that sites in low latitudes experience less O₂ seasonality year-round and have higher taxonomic abundances than high-latitude sites. In addition, fossils with high surface area-to-volume ratios in their body plans are strongly correlated with high-latitude sites that experience highly seasonal O₂, suggesting that specific morphological characteristics may have allowed some Ediacaran fauna to thrive under O₂ stress. We therefore argue that environmental O₂ availability in space and time played a key role in early animal evolution.

References:

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- [3] Evans, S. D., et al. (2022). PNAS, 119(46), e2207475119.