Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.19393

Environmental stabilisation and biological diversification in the aftermath of the Sturtian Snowball glaciation

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The Cryogenian Period (720–635 Million years ago, Ma) hosts sedimentary and geochronological evidence for two long-lived global-scale glaciations during the Sturtian (ca. 717–660 Ma) and Marinoan (ca. 650–635 Ma) cryochrons. Radiometric and chemostratigraphic data, in addition to climate modelling, support an approximately synchronous global deglaciation from the Sturtian cryochron (ca. 660 Ma), followed by a non-glacial interval with abundant globally-distributed marine sedimentary successions. The palaeontological record of Cryogenian non-glacial successions is dominated by microfossils and problematic macrofossils, some of which have been interpreted as possible sponge-grade organisms. Biomarker analyses also hint at the rise to dominance of green algae and the possible first appearance of demospongiae during this interval. Oxygen and nutrient availability can fuel biotic complexity, however Cryogenian non-glacial palaeoredox and palaeonutrient (e.g., phosphorus, P) dynamics are poorly understood. Furthermore, while regional lithostratigraphic and chemostratigraphic correlations of carbonate-dominated Cryogenian non-glacial sedimentary successions are well documented, the temporal calibration of globally distributed carbonate and siliciclastic successions has not been attempted. Without a global chronostratigraphic framework, the regional versus global nature of geochemical responses to Earth System perturbations and the sequence of biotic events throughout this interval remain obscured.

Here we present new high resolution palaeoredox and P phase association data from five globally distributed Cryogenian non-glacial drill core successions. The combination of Fe speciation and trace element palaeoredox reconstructions with P speciation data clearly show dynamic changes to bioavailable P recycling in response to local and global scale nutrient-driven palaeomarine redox conditions. We also present a new global Cryogenian non-glacial chronostratigraphic framework for the calibration, in relative time, of geochemical and palaeontological data from carbonate and siliciclastic-dominated successions. This enables our new data to be interpreted in the context of the highly dynamic global C and S cycles and biotic record throughout this interval. This approach, in combination with new insights from climate models that constrain changes to atmospheric CO_2 and temperature, sheds new light on the mechanisms for global changes to ocean redox and nutrients, and possible drivers that may have been partly responsible for an increase in biotic diversity during the Cryogenian non-glacial interval.