'Snowball Earth' ocean chemistry driven by weathering of a shallow ridge system during Rodinia breakup

THOMAS GERNON[1*], THEA HINCKS[2], TOBY TYRRELL[1], EELCO ROHLING[3] & MARTIN PALMER[1]

[1]Ocean and Earth Science, University of Southampton, Southampton SO14 3ZH, UK *correspondance: Thomas.Gernon@noc.soton.ac.uk

[2]School of Earth Sciences, University of Bristol, Bristol BS8 1RJ, UK.

[3] Research School of Earth Sciences, The Australian National University, Canberra, Australian Capital Territory 2601, Australia.

'Snowball Earth' periods—extreme climate perturbations leading to the most extensive glaciations in Earth's history—are well documented in the Neoproterozoic, but are not well explained. The mechanistic causes of several features of these events, including the enigmatic cap carbonates, continue to be debated. Terrestrial silicate weathering during breakup of the Rodinia supercontinent has been invoked to explain 'snowball' onset, and, separately, cap carbonate production in post-snowball runaway greenhouses. Although qualitatively reasonable, this explanation is yet to be quantitatively demonstrated. Here we propose an alternative "shallow ridge hypothesis" (Gernon et al., 2016), in which extensive submarine volcanism during ridge spreading led to rapid weathering of volcanic deposits (hyaloclastites) and major changes in ocean chemistry. Our hypothesis achieves a first-order quantitative reconciliation of Snowball Earth glaciations and associated features, including the high calcium and magnesium fluxes required to produce extensive cap carbonates, and the high oceanic silicic acid concentrations inferred for the Neoproterozoic. Moreover, the hypothesis provides a critical quantitative explanation for sustained high dissolved phosphate inputs to late Proterozoic oceans. This enhanced supply likely drove the increase in primary productivity required to generate the large rise in atmospheric oxygen levels that occurred in the wake of Snowball Earth events. Shallow ridge volcanism associated with development of the Proto-Pacific and Iapetan rifts might also have prompted oxidation of the Ediacaran ocean, which is thought to have facilitated the emergence of multicellular life.

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