

Ocean detoxification and nutrient cycling in the early Neoproterozoic

ROMAIN GUILBAUD^{1*}, SIMON W. POULTON²,
NICHOLAS J. BUTTERFIELD¹, MAOYAN ZHU³ AND
GRAHAM A. SHIELDS-ZHOU⁴

¹Department of Earth Sciences, University of Cambridge,
Cambridge CB2 3EQ, UK

²School of Earth and Environment, University of Leeds, Leeds
LS2 9JT, UK

³State Key Laboratory of Palaeobiology and Stratigraphy,
Nanjing Institute of Geology and Palaeontology, Nanjing
210008, China

⁴Department of Earth Sciences, University College London,
London WC1E 6BT, UK

*correspondence: rjg71@cam.ac.uk

Several lines of evidence suggest that after ~1.8 billion years ago (Ga), the architecture of Proterozoic oceans was characterized by oxygenated surface waters, overlying sulphidic mid-depth waters along productive ocean margins, and anoxic ferruginous (Fe-containing) deeper waters. The spatial extent of sulphidic water masses likely varied, but this redox structure is thought to have persisted until the first Neoproterozoic glaciation ~0.717 Ga. In contrast, geochemical analyses of later Neoproterozoic basins suggest much scarcer sulphidic conditions whilst the global ocean remained largely ferruginous until the oxygenation of the deep ocean around 0.58 Ga. However, a major gap in the redox record exists in the early Neoproterozoic, hampering a detailed redox reconstruction of the terminal Proterozoic oceans.

Here, we utilise Fe-S systematics to assess ocean redox conditions across a suite of early Neoproterozoic successions (~1.0 to 0.717 Ga). Our data show a global transition from sulphidic to ferruginous mid-depth waters in the earliest Neoproterozoic, coincident with the amalgamation of the supercontinent Rodinia at low latitudes. We suggest that ferruginous conditions were initiated by an increase in the relative influx of highly reactive Fe, driven by a change in weathering regime and the precipitation of extensive continental evaporites on Rodinia. Such a radical change in redox conditions may also have major implications on the cycling and the availability of nutrients, and we complemented our geochemical dataset with detailed P speciation. Our results suggest that P was effectively removed in association with Fe minerals and sequestered in the sediment, driving the early Neoproterozoic ocean oligotrophic.