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Effects of Mesoproterozoic ocean environments on nitrogen cycling across the 1400 million years old Xiamaling Formation

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The Mesoproterozoic Era was a time of eukaryote evolution with fossil evidence of multicellular eukaryotes at least 1560 million years ago. Nitrogen is an essential limiting nutrient of modern biological production. The role of nitrogen balance played on Mesoproterozic bio-evolution and the linkage between nitrogen reservoir and paleo-ocean oxygenation are ambiguous. Here we studied Mesoproterozic ocean nitrogen dynamics in the ca. 1400 million-year-old Xiamaling Formation of North China by using bulk and kerogen $\delta^{15}N$ analyses. We also compiled $\delta^{15}N$ results from other Mesoproterozoic deposits, and compare Mesopreterzoic $\delta^{15}N$ with typical nitrogen isotope signals found in well-studied modern environments aiming to reveal the Mesopreterzoic nitrogen cycling. Overall positive $\delta^{15}N$ in Units 1-2 suggests that the nitrate source was sufficient to supply the nitrogen needs of the phototrophs despite likely nitrogen loss through denitrification/anammox. The low $\delta^{15}N_{bulk}$ values in high TOC intervals of Unit 3 indicate strong upwelling supplied more phosphorus but less nitrogen to the photic zone, encouraging more severe nitrogen limitation and hence inducing N-fixation. The $\delta^{15}N_{bulk}$ values of Unit 4 indicate limited production shown by low TOC contents and were contributed by nitrogen fixation. Units 1-4 of the Xiamaling Formation display a dynamic nitrogen cycle ranging from nitrate-replete to nitrate-deplete conditions which are very similar to modern environments, and maintained extensive regions of nitrate-replete conditions. These nitrate-deplete conditions could have corresponded with extensive areas of oxygenated seawater or vast nitrate-replete marine environments similar to modern oxygen minimum zone environments. Our work indicates nitrate was repletion or depletion in the depositional environment, but does not indicate whether nitrogen was limited in primary production.

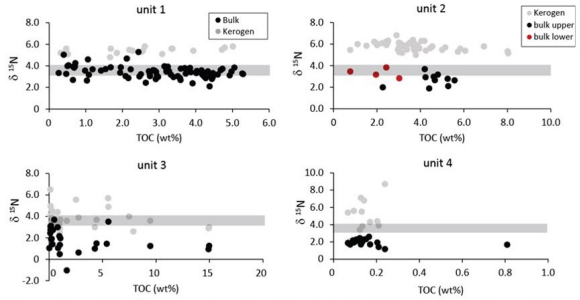

Figure 1 Trends in $\delta^{15}N$ versus TOC for different units of the Xiamaling Formation