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Dynamic redox and nutrient cycling response to climate forcing in the Mesoproterozoic ocean

DR. YAFANG SONG[1], FRED BOWYER[2], BENJAMIN J. W. MILLS[2], ANDREW MERDITH[3], PAUL B. WIGNALL[4], JEFFREY PEAKALL[4], SHUICHANG ZHANG[5], XIAOMEI WANG[5], HUAJIAN WANG[5], DONALD E. CANFIELD[6], GRAHAM A. SHIELDS[7] AND SIMON W. POULTON[4]

[1]University of Science and Technology of China

[2]University of Leeds

[3]University of Adelaide

[4]School of Earth and Environment, University of Leeds

[5]Research Institute of Petroleum Exploration and Development, China National Petroleum Corporation

[6]Department of Biology and Nordcee, University of Southern Denmark

[7]University College London

Presenting Author: yf.song@ustc.edu.cn

Emerging geochemical evidence suggest that ocean redox state in the Mesoproterozoic (1.6 – 1.0 billion years ago, Ga) was more dynamic than previously recognized. However, controlling factors governing this ocean redox heterogeneity during the Mesoproterozoic remain poorly constrained. This also limits our understanding of the bioavailability of essential nutrients, especially phosphorus, and their potential feedback on oxygenation in the Mesoproterozoic, which was preferentially regulated by ocean redox state. Here, we report ocean redox and phosphorus cycling across two high-resolution sections from the ~1.4 Ga Xiamaling Formation, North China Craton. We use Fe speciation, redox-sensitive trace element concentration and pyrite sulfur isotope data together to comprehensively provide regional redox information, and the phase partitioning approach is utilized to reconstruct P cycling. In addition, elemental ratios, such as K/Al and Ti/Al, are used as weathering indicators. The combination of multiple geochemical proxies indicates that: In the lower section, fluctuations in trade wind intensity regulated the spatial extent of a ferruginous oxygen minimum zone, promoting phosphorus drawdown and persistent oligotrophic conditions; In the upper section, high but variable continental chemical weathering rates led to periodic fluctuations between highly and weakly euxinic conditions, promoting phosphorus recycling and persistent eutrophication. A biogeochemical model is further employed to demonstrate how changes in geographical location relative to global atmospheric circulation cells could have driven these temporal changes in regional ocean biogeochemistry. Our combined approach suggests that much of the ocean redox heterogeneity apparent in the Mesoproterozoic could be controlled by climate forcing at individual locations, rather than specific events or step-changes in global oceanic redox conditions.