

Carbonate-Associated Phosphate evidence for a small phosphorus reservoir in the terminal Ediacaran ocean

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The terminal Ediacaran (ca. 551-539 Ma) is characterized by profound biological innovations and environmental upheavals, in which phosphorus (P)—the ultimate limiting nutrient for marine productivity is postulated to have played a key role. However, the P availability in the terminal Ediacaran ocean remains largely debated mostly due to the lack of direct proxy records. To better reconstruct seawater P levels in the terminal Ediacaran ocean, we analyzed carbonate-associated phosphate [CAP; expressed as CAP/(Ca+Mg)], a direct proxy for P availability in ancient oceans, across three key late-Ediacaran successions: Nama Group in Namibia (GRIND-ECT drill cores), Shibantan Member of Dengying Formation in South China (Wuhe in Three Gorges area), and Algal dolomite/Gaojiashan/Beiwan Member of Dengying Formation in South China (Gaojiashan in Shaanxi). Our results reveal consistent low CAP/(Ca+Mg) values (maximum/minimum:0.69/0.02, mean:0.12, median:0.11. Unit:mmol/mol, the same below) in the three study sections, which are notably lower than those observed during the Ediacaran Shuram Excursion (~574-567 Ma) (maximum/minimum:2.18/0.01, mean:0.22, median:0.16). Lithological examination, oxygen isotopes, Mn/Sr and Mg/Ca ratios indicate that these low CAP/(Ca+Mg) values in the study samples cannot be attributed to diagenesis, recrystallization or dolomitization. Instead, the low CAP values from different continental margins reflect a generally small P reservoir and weak P recycling in the terminal Ediacaran ocean. We propose that this weak P recycling may lead to low productivity and organic burial, which resulted in low oxygen levels in the ocean and atmosphere during this period. The appearance of most modern metazoan body plans and ecologies may have been delayed until the early Cambrian. This study highlights the interplay between nutrient cycling, redox dynamics, and biological evolution during one of the most impactful transitional periods in Earth history.