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Evolution of photosynthetic carbon isotope fractionation in Dziani Dzaha lake during a high-CO_2 event: connecting modern and Precambrian conditions

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The $^{13}C/^{12}C$ carbon isotope fractionation associated with photosynthesis (ε_p) is widely used as a proxy for reconstructing ancient pCO_2 and investigating ancient primary producers' physiology [1]. So far, ε_p has been calibrated essentially using culture experiments and modern ecosystems with Phanerozoic levels of pCO_2. Only a few experimental studies focused on cyanobacteria at the extremely high pCO_2 expected for the Precambrian [2]. To fill this gap, we focus here on the Dziani Dzaha crater lake (Mayotte, Indian Ocean, France), a cyanobacteria-dominated lake analogous to Precambrian environments [3]. It presents magmatic CO_2 bubbling, which increased after the birth of the nearby underwater Fani Maore volcano in 2018 [4].We obtained pCO_2, ε_p and cell-count data for the 2020-2024 period in order to compare them to available data for the pre-eruption 2012 to 2017 period.

The results show that since 2021, pCO_2 has increased from approximately 3.000 to 80.000 ppm while ε_p has risen from +18.4 to +21.2 ‰. These changes were simultaneous to changes in the abundance of the main primary producers' species. Large cells (> 5µm) that initially dominated the ecosystem showed a smaller increase in ε_p with increasing pCO_2 than smaller cells (< 5µm) that now dominate primary production. This shows that both pCO_2 increase and changes in the ecosystem are accountable for the ε_p rise.

The range of ε_p values obtained here are within those obtained in culture experiments with similarly high pCO_2 [1], which validates the use of this proxy in natural, complex ecosystems and reenforces its extrapolation to Precambrian time. But it also demonstrates that even at extremely high pCO_2, large cells express a significantly lower ε_p (ca ≈ –2 ‰) than expected maximum values, so that changes in the $\delta^{13}C$-POC in Precambrian sedimentary rocks may also reflect changes in species rather than pCO_2.

References:

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