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# The isotopic consequences of living large

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A peculiar marine carbon cycle characterized Earth's exit from the Marinoan snowball Earth event ≈640-635 million years ago. Paired carbon isotope records show that unusually small differences between $\delta^{13}C_{carbonate}$ and $\delta^{13}C_{organic\ carbon}$ values (<10‰) are common in sedimentary rocks immediately atop Marinoan glacial strata [1]. Only environmental causes have been considered previously for this carbon isotope signal, such as weathering of $^{13}C$-enriched organic carbon from metamorphic rocks [1], decoupling of carbonate precipitation from marine organic carbon cycling due to a large dissolved organic carbon pool in the ocean [2], and photosynthetic carbon isotope fractionation under a $CO_2$-poor post-Snowball atmosphere [3]. However none of these environmental solutions appear to provide a satisfactory explanation for the carbon isotope observations.

Here we examine how biological innovation might have affected the carbon isotope dynamics of the post-Marinoan carbon cycle by exploring the isotopic consequences of photoautotrophs living together in colonies or multicellular aggregates. We show that living together can change the $\delta^{13}C$ value of bulk photoautotrophic biomass by >10‰. The magnitude of this isotopic shift is largely controlled by a non-dimensional number - the Thiele modulus - that characterizes the relative timescales of $CO_2$ diffusion into the aggregate and $CO_2$ consumption within the aggregate. We calibrate the Thiele modulus based on C isotope studies on colonial photoautotrophs in modern environments, and use the calibrated model to explore the possible size evolution of post-Marinoan photoautotrophic aggregates and colonies implied by the post-Marinoan C isotope record. We will discuss potential causal relationships between any biological innovations associated with these size patterns and the unique environmental dynamics of the post-Marinoan ocean.

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[3] Sansjofre, Ader, Trindade, Elie, Lyons, Cartigny & Nogueira (2011) *Nature* 478, 93-96.