Nature and habitat of pre-Cryogenian algae

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The ecological rise of archaeplastid algae carried large consequences for the Earth system by enhancing carbon burial and global oxygenation, and by shifting the respiration of organic matter to deeper waters, thereby creating shallow-marine oxygenated niches required by the first benthic animals [e.g. 1]. An increase of eukaryote-derived sterane (S) *vs.* bacteria-derived hopane (H) biomarkers in sediments deposited after Snowball Earth was linked to increased marine phosphorus (P) levels [2] and paralelled by the diversification of steranes [3]. Recently, 'early' elevated S/H were reported for Tonian deposits [4], which appears more congruent with the microfossil record and molecular clock observations [5]. Yet, Tonian marine P levels would have likely been too low to sustain significant algal communities on a global scale [6].

We find that Tonian rocks with molecular clues for algal relevance tend to contain signs for a significant contribution of non-marine organic matter—observations that harmonize with a principally continental source of Tonian P and low marine P levels [6]. Sparse individual Tonian accounts of elevated S/H are thus likely of restricted applicability to understanding global marine ecosystems. In addition, ratios of 26-alkyl- over 3-alkylsteranes—diagenetic products whose relative abundance we show to depend on functional properties of the original lipid molecule—are indicative of elevated desmosterol/cholesterol in Tonian source organisms. These novel insights into the paleo-functionalisation of fossil lipids suggest a significant ecological role of Rhodophytes in Tonian ecosystems. While red algae locally rose to ecological relevance prior to the Cryogenian glaciations, the persistent and global rise of algae was delayed to the radiation of Chlorophytes after the Cryogenian/Ediacaran transition [1,2].

[1] van Maldegem et al. (2019) *Nat. Comm. 110: 476.* [2] Brocks et al. (2017) *Nature* **548**, 578–81. [3] Hoshino et al. (2017) *Sci. Adv.* **3**, e1700887. [4] Zumberge et al. (2020) *Geobiology* DOI: 10.1111/gbi.12378. [5] Knoll (2014) *Cold Spring Harb Persp Biol* **6**, a016121. [6] Laakso & Schrag (2019) *Geobiology* **17**, 161–171.