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Changing primary productivity influenced eukaryotic evolution at the start and end of the Neoproterozoic Era

LUCY C. WEBB[1], HUNTER OLSON[1], MAYA THOMPSON[1,2], CHRISTINA WOLTZ[3], CARL SIMPSON[4], DANIEL MILLS[5] AND ERIK A. SPERLING[1]

[1]Stanford University
[2]Utah State University
[3]Imperial College
[4]University of Colorado Boulder
[5]Heinrich Heine University Düsseldorf

In the geological literature, limiting oxygen and/or nutrient concentrations during the Neoproterozoic are often hypothesized to have controlled the timing of the evolution of complex multicellular eukaryotes, including early animals. However, biological hypotheses commonly focus on reasons why multicellularity would have been positively selected (e.g., protection from predation or more efficient nutrient usage). Here, we evaluate how nutrient concentrations and primary productivity changed from 2050-400 Ma by conducting statistical analyses on geochemical data from >23,000 fine-grained siliciclastic samples from the Sedimentary Geochemistry and Paleoenvironments Project (SGP) Phase 2 database. Specifically, total organic carbon, copper, nickel, phosphorous, and pyrite iron concentrations were used as proxies for export productivity or flux of organic carbon to the seafloor. Geochemical data binned by era indicate the Neoproterozoic Era was significantly different from the Mesoproterozoic and Paleozoic Eras and the median concentration of all proxies was lower in the Neoproterozoic than the Mesoproterozoic and Paleozoic. To account for geographical or temporal sampling biases, a weighted bootstrap resampling method was used to evaluate the dataset and similar trends were observed across all proxies. These more temporally detailed results suggest that productivity likely decreased at the start of Neoproterozoic and increased near the end. In contrast to permissive environment hypotheses where low nutrient concentrations delayed the evolution of larger, multicellular body forms, we propose that nutrient scarcity in the early and mid-Neoproterozoic (and nutrient scarcity plus cold seawater temperatures in the mid to late Neoproterozoic) selected for the evolution of new multicellular body forms. Finally, the increase in nutrients in the latest Neoproterozoic to early Paleozoic helped drive the ecological flourishing of these new algal, fungal, and animal forms.