Implications of bloom dynamics for phytoplankton-based pCO_2 estimates

HLO McClelland*[12], I Halevy[1], J Bruggeman[3] & A Bradley[2]

* email: harrym@weizmann.ac.il
1. Weizmann Institute of Science, Rehovot, Israel.
2. Plymouth Marine Laboratory, UK.
3. Washington University in St Louis, UK.

Accurate estimates of pCO_2 in Earth's geologic past are essential for understanding the climate system on timescales longer than the instrumental record. An important family of pCO_2 proxies is based on the carbon isotopic composition of biomass produced by phytoplankton in the surface ocean. Targets for analysis have included carbon compounds and biominerals in ocean sediment produced by a number of algal groups including coccolithophores, diatoms and dinoflagellates. In laboratory experiments and cellular flux models, the carbon isotopic composition of organic matter and of calcite have been found to depend on cellular carbon utilization – a compound variable that includes growth rate and cell size in addition to CO_2 concentration. However, in translating these observations from the laboratory to the geologic record, the nature of phytoplankton growth in the ocean has thus far been ignored.

With a simple mathematical representation of idealized algal blooms, I will show that the widely observed and accepted relationships on which phytoplankton-based proxies (such as the alkenone CO_2 proxy) rely, are likely to systematically misrepresent material that is exported from the surface ocean and ultimately preserved in sediment. Carbon utilization is a linear function of cell radius in both nutrient-replete batch cultures and nutrient-limited chemostats, but this relationship is highly non-linear within the ranges of algal cell size and nutrient concentrations that typify the euphotic zone. A consideration of bloom dynamics and the probable prevailing nutrient regime is essential for translating results from the laboratory to the geologic record. The implications of this systematic misprepresentation of the ocean in the laboratory range from phytoplankton-based pCO_2 paleobarometry to projections of carbon fixation and calcification in an anthropogenically altered future ocean.