New perspectives on the evolution of CO2 in the late Cenozoic

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CO2 has long been suspected as a primary driver for climate changes over the Cenozoic, but the linkages between CO2, temperature change, and ice sheet buildup have been difficult to establish because of the many challenges in producing quantitative CO2 estimates for this timescale. In this contribution, we review the new perspectives that may be gleaned on CO2 evolution from quantification of adaptation of marine phytoplankton, organisms highly sensitive to CO2 because of its importance to thei photosynthesis. Coccolithophorids have dual requirements for carbon for both photosynthesis and calcification. The ACTI-CO model of carbon isotopic composition and fluxes into the cell shows that in modern cultures, at low CO2 the cells reallocate intracellular bicarbonate transport from calcification to photosynthesis. This adaptation is evident in the carbon isotopic fractionation of coccolith calcite, epsilon coccolith. This reallocation of cellular carbon from the calcification process to photosynthesis at low CO2 can also be manifest in reduced cellular calcification, which can be reconstructed from measurements of coccolith thickness. Finally, as suggested by previous authors, coccolithophorid mean cell size may be reduced with decreasing CO2 to relieve diffusive CO2 limitation. We show evidence for all three adaptations becoming important in response to CO2 decline since the mid-Miocene. We show how incorporation of these adaptations in cell models implies significantly higher absolute CO2 estimates in the Mid-Miocene from measured alkenone carbon isotopic fractionation during photosynthesis. Finally, we show initial data on changes in epsilon coccolith during other key transitions of the Cenozoic which suggest and important role for CO2 decline and resulting adaptation by coccolithophorids.

Diatoms provide a complementary perspective on CO2 evolution because it is possible to obtain records of their carbon isotopic fractionation during photosynthesis – a CO2 proxy – from cells of constant size and geometry. This contrasts with alkenone-derived records which require correction for changing cell geometry. Separation of pennate diatoms and measurement of the carbon isotopic fractionation in frustule-bound organic matter confirms a strong pCO2 decline over the last 11 Ma.