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# The response of calcareous nannoplankton to changes in temperature, fertility and $CO_2$ during the Aptian (Early Cretaceous)

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The Cretaceous was characterized by intervals of super-greenhouse climate and profound environmental perturbations, including the early Aptian Oceanic Anoxic Event (OAE) 1a. We investigated the effects of changes in temperature, surface water fertility and $pCO_2$ on carbonate production of calcareous nannoplankton during the Aptian. The new record extends the dataset of Erba and Tremolada (2004) and shows similar and coeval fluctuations in the Tethys and Pacific Oceans implying global factors influencing nannoplankton carbonate production. The highest values were displayed in the late Barremian, interpreted as the "optimum" for nannoplankton calcification, whilst during the latest Barremian – early Aptian paleofluxes underwent a stepped decrease reaching a 90% reduction during Oceanic Anoxic Event OAE 1a. In the recovery phase, after OAE 1a, paleofluxes never gained the "optimum" levels of the Barremian, not even during the N. truittii acme interval.
The collected dataset suggests that variations in nannofossil calcite paleofluxes derived from complex dynamics reflecting changes in climatic conditions, nutrients availability as well as volcanogenic $CO_2$ emissions. We assumed that past calcareous nannoplankton responded similarly to extant coccolithophores under fluctuating $CO_2$, and applied two methods for estimating paleo$CO_2$ from paleofluxes using a calibration based on experiments conducted on living coccolithophores (Riebesell et al., 2000). In addition, corrections were made for temperature and fertility effects on paleofluxes. The dataset shows, in fact, that there was a correspondence between increased fertility and reduced paleofluxes (and vice versa): higher trophic levels were probably unfavorable for the oligotrophic nannoconids causing/contributing to the decrease in abundance of these forms and, consequently, in total paleofluxes. Temperature variations were instead less relevant for nannofossil paleofluxes compared to fertility, although changes in temperature directly affected $CO_2$ solubility in oceanic waters with indirect implications for nannoplankton.
We concluded that $pCO_2$ was influencing nannoplankton calcification via altering the climate and surface water chemical and physical conditions. Volcanogenic $CO_2$ impacted the climate promoting greenhouse conditions and consequent continental weathering favouring nutrient recycling. Contrarily, maximum temperatures (>34°C) coincided with the highest $CO_2$ values during OAE 1a as well as with peaks in fertility and ocean acidification suggestive for extreme environmental conditions during OAE 1a. Cooler conditions after OAE 1a, and during the N. truittii acme interval, were probably promoted by temporary drops in paleo $CO_2$ under less intense or quiescent Large Igneous Province volcanism, whilst the coolest conditions of the latest Aptian occurred under higher paleo$CO_2$, possibly promoting enhanced oceanic absorption of $CO_2$ and, consequently, ocean acidification reflected by minimum values of nannofossil paleofluxes.

Erba, E. and Tremolada, F. (2004), Nannofossil carbonate fluxes during the Early Cretaceous: phytoplankton response to nutrification episodes, atmospheric $CO_2$ and anoxia. Paleoceanography, 19, $1^{-1}8$.
Riebesell, U., Zondervan, I., Rost, B., Tortell, P. D., Zeebe, R. E., Morel, F. M. (2000), Reduced calcification of marine plankton in response to increased atmospheric $CO_2$. Nature, 407(6802), 364-367.
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