

## ***Interactive comment on “Algal constraints on the Cenozoic history of atmospheric CO<sub>2</sub>?” by J. Henderiks and R. E. M. Rickaby***

**U. Riebesell**

uriebesell@ifm-geomar.de

Received and published: 16 February 2007

The concept proposed by Henderiks and Rickaby - that the CO<sub>2</sub> sensitivity of modern coccolithophore calcification reflects the CO<sub>2</sub> concentration at the time of their origination - is a very intriguing idea. It provides a new angle of looking at CO<sub>2</sub>/pH effects on coccolithophores, gives an evolutionary perspective to species-specific differences in calcification responses, and serves to stimulate the discussion on the potential for coccolithophores adaption to projected ocean acidification.

The proposed concept rests upon three crucial assumptions: 1. Coccolithophore calcification is directly sensitive to CO<sub>2</sub> (independent of an indirect effect of CO<sub>2</sub> through its coupling with pH, carbonate ion concentration and carbonate saturation state). 2. Photosynthesis and calcification in coccolithophores are closely coupled. 3. "The cou-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

pled photosynthetic and calcification potential of the various taxa is optimized for ocean carbonate chemistry at their time of origin and has been locked into genetic make-up since declined."

As far as I can tell, there is no convincing evidence in the literature for either of these assumptions. Accordingly, no attempt was made in the manuscript to assess their legitimacy. Nevertheless, I think it is worthwhile to take a look at the available data to assess the odds of each of these assumptions.

The experimental data used to support the proposed concept was obtained under experimental conditions in which CO<sub>2</sub>, pH, carbonate ion concentration and carbonate saturation state were tightly coupled. As mentioned in the manuscript "In the geological past, carbonate saturation state and pCO<sub>2</sub> were likely decoupled (Tyrrell and Zeebe, 2004)." So unless there is a direct effect of CO<sub>2</sub> on calcification, independent of its coupling to seawater carbonate chemistry, it would be impossible to relate CO<sub>2</sub> sensitivity of calcification to atmospheric CO<sub>2</sub> on geological times scales.

If I understand correctly, the mechanism for a direct effect of CO<sub>2</sub> on calcification is postulated to be a coupling between photosynthesis and calcification (so assumption 1 actually goes hand in hand with assumption 2): "Rather than a calcification dependency on saturation state, pH or [CO<sub>3</sub><sup>2-</sup>] alone, the critical factor determining the calcification tolerance of different species may be the photosynthetic capacity to harvest energy from CO<sub>2</sub>." (page 4, line 24ff). Although I am not sure what is meant with "... the photosynthetic capacity to harvest energy from CO<sub>2</sub>", I suppose this is connected with the statement on page 4, lines 22ff: "... with coherence between lower energetic requirement for calcification at high saturation and pH, and lower photosynthetic energy available from low pCO<sub>2</sub>."

In the context of the proposed concept this probably means: A species which evolved at times of low CO<sub>2</sub> (e.g. such as the modern *Emiliana huxleyi*) prioritizes energy allocation into photosynthetic (organic carbon fixation) over that into calcification and

[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)

hence shows high sensitivity of calcification in response to CO<sub>2</sub> induced changes in carbonate chemistry (as indeed observed). In contrast, the ancient *Coccolithus pelagicus* is best adapted to the high CO<sub>2</sub> at the time it evolved and hence was selected to prioritize energy allocation towards calcification relative to photosynthetic carbon fixation. In analogy to the CO<sub>2</sub> sensitivity of *E. huxleyi*, one should then expect to see the reverse sensitivity in *C. pelagicus*, i.e. low CO<sub>2</sub> sensitivity for calcification and high CO<sub>2</sub> sensitivity of photosynthetic carbon fixation. Looking at the data of Langer et al. (2006) this does not appear to be the case.

If calcification and photosynthesis are closely coupled in the way proposed by Henderiks and Rickaby, high availability of photosynthetic energy should serve to partly compensate for the effect of high CO<sub>2</sub>/low pH on calcification. This, however, is not supported by data. The results of Zondervan et al. (2002) show a similar relationship between CO<sub>2</sub> and calcification in *E. huxleyi* over a wide range of photon flux densities. So again, the proposed tight coupling between calcification is not supported by the available data.

It should also be noted that the ability to calcify fully intact coccoliths at extremely high CO<sub>2</sub> is not unique to *C. pelagicus* (cited as S. Krug personal communication). Cells of *E. huxleyi* were found to formed fully intact coccoliths at pCO<sub>2</sub> levels as high as 3000  $\mu$ atm (Koch and Engel, personal communication).

Concerning assumption 3, I agree with the comment of referee #2 that the bell-shaped response of *Calcidiscus leptoporus* calcification with an optimum at modern pCO<sub>2</sub> values (Langer et al. 2006) indicates adaptation to modern present-day CO<sub>2</sub> levels in this strain. A similar response with calcification optimized at modern ocean CO<sub>2</sub> values was also observed in recent experiments with a newly-tested strain of *E. huxleyi* (Koch and Engel, personal communication). This indicates the potential for strain-specificity in calcification responses. As pointed out by referee #2, it argues against assumption 3 of the proposed concept.

[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)[Discussion Paper](#)

In the discussion of their thought-provoking concept the authors may want to give more attention to the available literature and may want to provide a more detailed discussion on the underlying key assumptions. This being said, I congratulate the authors on their stimulating new perspective on coccolithophore calcification responses and look forward to the further development of this idea.

Best regard, Ulf Riebesell

References:

Langer, G., M. Geisen, K. Baumann, J. Kläs, U. Riebesell, S. Thoms, and J. R. Young (2006) Species-specific responses of calcifying algae to changing sea-water carbonate chemistry, *Geochemistry Geophysics Geosystems*, 7, Q09006, doi:10.1029/2005GC001227.

Tyrrell, T., Zeebe, R.E. (2004) History of carbonate ion concentration over the last 100 million years. *Geochim. Cosmochim. Acta*, 68, 3521-3530

Zondervan, I., Rost, B., Riebesell, U. (2002) Effect of CO<sub>2</sub> concentration on the PIC/POC ratio in the coccolithophore *Emiliana huxleyi* grown under light-limiting conditions and different daylengths. *Journal of Experimental Marine Biology and Ecology* 272, 55-70

---

Interactive comment on *Biogeosciences Discuss.*, 4, 1, 2007.

**BGD**

4, S22–S25, 2007

---

Interactive  
Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper