

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

### **Anonymous Referee #2**

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

The idea presented here by Henderiks and Rickaby -modern coccolithophores would have kept the ability to calcify under atmospheric/chemical conditions close to the one prevailing at the time of their origination- brings momentum to the debate on global acidification of the oceans, and deserves publication as a short comment.

Why a comment? Because the idea is largely based on a simple correlation: *C. pelagicus*, a 63 Myr old morphotype, secretes regular coccoliths under 915 ppm CO<sub>2</sub> (Langer et al. 2006), and it originated in the Paleogene when pCO<sub>2</sub> was supposed to be significantly higher than today according to various proxies. Building upon this

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observation, the authors suggest that physiological tests of upper tolerance to pCO<sub>2</sub> measured on living species with different origination times may allow reconstructing upper constraints of past pCO<sub>2</sub> for the Cenozoic. They do not bring new data or analyses to comfort their hypothesis, but catch different pieces of information from the literature to strengthen the theory.

However, the statement that a complex, most probably multi-functional, physiological process such as calcification is “frozen” within a given morphotype, is rather strong and needs to be balanced on several aspects.

General comments: (1) Adaptation. The hypothesis presented by Henderiks and Rickaby basically challenges the suggestion that populations of planktonic micro-organisms can adapt very fast to their changing environment. However, the belt-shape response of *C. leptoporus* calcification picking toward modern pCO<sub>2</sub> values (Langer et al. 2006) typically indicates adaptation of optimal calcification to modern atmosphere in this morphotype. In addition, Langer et al. show how fossil *leptoporus* were calcifying perfectly fine under pCO<sub>2</sub> values they do not tolerate today. The authors should discuss these observations in the frame of their hypothesis.

(2) Evolution: The authors claim that their new proxy (upper tolerance to pCO<sub>2</sub> of modern coccolithophores) reflects pCO<sub>2</sub> values from the time of “origin” or “emergence” of the morphotype. However, why wouldn't it be any time in-between the morphotype's origination and today? In other words, why would the “physiological memory” reflect upper values from the origin, and not from another period of time later, when pCO<sub>2</sub> was particularly high? And if this is the case, how can one use the “physiological memory” as a proxy?

More specific comments:

Methodology and Hypothesis: - The authors claim: “At face value, the levels of pCO<sub>2</sub> tolerated in cultures of the different coccolithophorid morphospecies coincide with the levels of pCO<sub>2</sub> from proxy reconstructions at the time of their emergence”. This is not

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true, the maximum value of pCO<sub>2</sub> tested for pelagicus (915 ppmv) is much lower than available proxies' estimation (>3000 ppmv) for its time of origination (see Figure 1). By the way, how could the authors draw an upper limit (dashed arrow) for pelagicus; if this is not based on experimental data, please remove.

Discussion: - page 4: “Is evolutionary capability preserved without degradation?” What is “evolutionary capability”, and “degradation”?? Please be more precise. It is a biological fact that genomes evolve, genes accumulate mutations, and genetic networks underlying cellular functions are under selective pressure. Selection doesn't necessarily lead to optimal phenotype, and there maybe stabilizing forces in certain aspects of coccolithogenesis; could the author explain their idea here in more precise terms.

- A bit further in the text: “Cruciplacolithus neohelis produces coccoliths that are highly similar to its Palaeogene counterpart, and persistently secretes low Mg-calcite in the high Mg/Ca modern ocean and in culture manipulations (Stanley 2005)”. How about the 2 other species reported by Stanley et al. (2005) in their paper, *P. carterae* and *O. neopolitana*, which appear to modulate the Mg content within their calcite depending on the ambient sea-water? Please comment.

- “the preservation of calcification tolerance may occur through genetic redundancy, variance in genetic expression, or ecological generalism versus specialism” What is “calcification tolerance” ? and does this sentence imply that certain species will preserve a “physiological memory” while others wont? Please explain.

In the last paragraph of the discussion, the authors recognize that groups of related coccolithophores have greatly varied in size. In addition, genetic data (Saez et al. 2003) tend to show that different sizes within a morphotype correspond to different species with specific eco-physiological ranges; could the authors discuss this aspect and tell us more about which, among the modern species, could be used for reconstruction of paleo-upper limit of CO<sub>2</sub>? In addition, which modern morphotypes would have long enough stratigraphic extension to be used as paleo-CO<sub>2</sub> proxy?

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Concluding remarks: “If anything, large coccolithophores will be more successful calcifiers, Ě” As far as I know, coccoliths were tiny during most of the Paleocene, when pCO<sub>2</sub> was the highest for the Cenozoic?

Details:

The text is generally well written; however: - the expression “calcification ability”, appearing 4-5 times in the text, is too vague. - page 1: “living geological record”: by definition the geological record is not alive - end of introduction: “ Ě and even though calcification ability declines, coccoliths are still produced up to much higher levels (Krug pers. Comm.) “ pCO<sub>2</sub> levels .. I guess. - Discussion, 1st paragraph: “genetically “older” extant species”. Please replace species by morphotype, or morphospecies. - Fig. 1b: remove “unpublished data”, now it is! - Concluding remarks: “If anything, large coccolithophores MAY be more ..”

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**BGD**

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