

Interactive comment on “A universal carbonate ion effect on stable oxygen isotope ratios in unicellular planktonic calcifying organisms” by P. Ziveri et al.

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T. Toyofuku (Referee)

We thank Dr. Toyofuku for reviewing our manuscript. Below we are providing detailed answers to all comments consecutively.

P3L6: I think some explanations are necessary about difference of calcification mechanism among coccolithophores, dinoflagellates and planktonic foraminifers. Can the difference of calcification be counted to explain the variable f and slope of $\delta^{18}\text{O}/[\text{CO}_3^{2-}]$ (around P8L26)?

C4005

ANSWER: In the “Experimental results and discussion” section, we are clarifying now the calcification mechanisms in coccolithophores, dinoflagellates (*T. heimii*) and planktonic foraminifera at page 7582 line 8 of the BGD manuscript.

“Interestingly, a similar vesicle-based calcification mechanism has been proposed for the common calcareous dinoflagellate *Thoracosphaera heimii* (INOUYE, I. & PIEN-AAR, R.N. (1983). Observations on the life cycle and microanatomy of *Thoracosphaera heimii* (Dinophyceae) with special reference to its systematic position. *S. Afr. J. Bot.*, 2: 63–75). Although planktonic foraminifera are thought to calcify in an extracellular space (Spero, H.J., 1988, Ultrastructural examination of chamber morphogenesis and biomineralization in the planktonic foraminifer *Orbulina universa*. *Mar. Biol.*, 99 (1988), pp. 9–20. The role of seawater endocytosis in the biomineralization process in calcareous foraminifera, S. Bentov, C Brownlee and J. Erez, *PNAS*, 2009, 106 no. 51 21500-21504) mechanism is indeed remarkably similar to the one of coccolithophores and *T. heimii*. The extracellular calcification space of foraminifera is isolated from the seawater by a so called pseudopodial network, so that, in effect, also foraminifera calcify in a space which is isolated by means of plasmamembrane not only from the seawater, but also from the cytoplasm. This common basic feature of the calcification of the three phylogenetically distinct groups of calcifiers, coccolithophores, foraminifera, and dinoflagellates, can partly account for the fact that it is possible to formulate one single model explaining the dependency of $\delta^{18}\text{O}$ on carbonate chemistry as will be discussed in the following.” As now stated in the manuscript, we believe that the similarities between the calcification mechanisms of coccolithophores, foraminifera, and dinoflagellates can account for the possibility of describing the carbonate chemistry dependency of their $\delta^{18}\text{O}$ using one single model. It is equally likely that the differences in the calcification mechanisms can account for the different slopes observed. Unfortunately it is at present not possible to name the responsible differences, because the state of the art knowledge does not suffice to link the components of the model, e.g. the f factor, to specific sub-processes of calcification. Doing so would be a major step towards a process-based understanding of isotope fractionation during calcification.

C4006

P4L6: Kurihara et al. (2008MEPS 373, 275-584) reports that biological reactions against pH variation are difference between CO₂ method and HCl method. Some biological consideration about two way of CO₃²⁻ variation of this study will be mentioned.

ANSWER: This issue has been already discussed in the manuscript (see page 7579, 5-21).

P9L10: How do *T. heimii* organism maintain low salinity in the vesicle? I think water shall soak into the low salinity vesicle by osmosis. Mg/Ca influence: The magnesium contents are variable among the species. Even magnesium is also working as calcification inhibitor, there are no consideration about magnesium effect on calcification process. Will the effect of Mg be appeared on relation between carbonate ion and $\delta^{18}\text{O}$? How much is Mg/Ca range of *T. heimii*?

ANSWER: The osmotic regulation of *T. heimii* is unknown. But it is not uncommon for cells to compensate for low salinity by using organic molecules. This might also be the case in *T. heimii*.

The suggested mechanism is not based on endocytosis of seawater. Probably, there is a strong fractionation against Mg²⁺ and PO₄ during the intracellular transport of Ca²⁺ and CO₃²⁻. Having said this, the question how much Mg the calcite of *T. heimii* contains is not per se relevant to our model.

Small points.

"3. EXPERIMENTAL RESULTS AND DISCUSSION" seems bit long as one section. Some division of section 3 can be entitled for easy reading.

ANSWER: We now have a section 4. "Conclusions" following the section 3. Experimental results and discussion. This will include the text from page 7585 line 4.

Fig. 1: Labels of x-axis, y-axis are necessary..

C4007

ANSWER: Fig. 1. Labels are indicated (y-axis: ($\delta^{18}\text{O}$, ‰ PDB) and x-axis: [CO₃²⁻], $\mu\text{mol Kg}^{-1}$). In the revised manuscript [CO₃²⁻] will be changed in [CO₃²⁻].

Fig. 2: I think "coccolith vesicle (V)" will be changed to "calcification vesicle (V)" in schematic figure if the figure can be applied on both *C. leptoporus* and *T. heimii*

ANSWER: Fig. 2. V is indicated as calcifying vesicle.

The accuracy of temperature will be indicated. Are the flasks situated in some incubators?

ANSWER: During the experiments the flasks are maintained at the same temperature in incubators.

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C4008