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Biogeosciences Discussions

Interactive comment on "Contrasting trends in element incorporation in hyaline and miliolid foraminifera" *by* Inge van Dijk et al.

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A paper by van Dijk et al. reported different trends in elemental incorporation between rotaliid and miliolid foraminifers. In addition, this paper showed increasing trends of some (Zn, Ba) elemental incorporation with high pCO2 conditions, together with a chemical model that explain these trends. In particular, the latter results are attractive to many readers studying biocalcification and paleoceanography, with significant implications for proxy developments of paleo-pCO2. Although the manuscript includes novel data and ideas, is well written and structured, and seems suitable for publication in Biogeosciences, I suggest that authors consider the following points to improve the final version of the manuscript.

1) Authors should reconsider what is the main purpose (hypothesis), what is the main

results, and what are conclusions obtained from this study. In the Introduction, you may need more elegant story to explain why you conducted pCO2 controlled experiments as well as why you used symbiotic tropical large benthic foraminifera for this study, to understand trace element incorporation in foraminifera. I think the main important results in this study were increasing some trace element incorporation (Zn, Ba) with high pCO2 environments and a chemical model to explain this phenomenon.

2) Authors are mainly concerned about a correlation, but not dealt with the quantity (amount) of elemental incorporation in foraminiferal calcite. Even if both Zn and Ba ion availability increases with high pCO2 conditions, the amount incorporated in foraminiferal calcite differs between the two elements (Zn is four times more incorporated than Ba). We know that ionic radius is related to trace element incorporation in calcite from many inorganic studies. How does your chemical model explain the incorporation of elements quantitatively?

3) This paper is not discussed anywhere (only briefly mentioned in the Introduction) about effects of temperature on element incorporation in foraminifera, which are well established by many papers. In Figure 3, you compared results of your study with those of previous similar studies. However, I wonder these results are not simply comparable because of different species from different environments (water depths and latitudes, i.e. different temperature and salinity ranges) as shown in Supplementary Table S1. Temperature effects should be normalized to compare real DMg between different foraminiferal species. In addition, authors should discuss the relative sensitivity on E/Ca between temperature and carbonate chemistry when both parameters are variable.

4) This study assumes only Ca-channel model as a possible ion transport mechanism. However, other possible mechanisms of ion transport have been proposed in foraminifera. I suggest that authors compare advantages and disadvantages of several transport models and justify the Ca channel model as the most appropriate to explain results in this study.

5) I wonder if laser abrasion (LA) method is appropriate for biocalcification study. As you know, hyaline foraminiferal shells are composed of the primary layer and the secondary layers (coating) with the organic matrix. The LA method cannot discriminate differences in element incorporation between these different layers. In addition, the spatial heterogeneity of E/Ca among calcite crystals in a chamber wall has been reported by many studies. How do authors overcome these problems by using the LA method?

6) What kinds of other trace elements except for those examined in this study are sensitive to pCO2 based on the chemical model? That is useful information to find new proxies for paleo-pCO2. In addition, I wonder what cause differences between sensitive and insensitive elements on pCO2.

7) Authors are confused about the terminology of Foraminifera. Throughout the text, the authors used “hyaline” and “miliolid” as comparable terms. But the term “hyaline” indicates the quality of shell appearance and the term “miliolid” is a taxon name belonging to the Order Miliolida. I suggest authors use comparable terms of “hyaline vs. porcelaneous” as shell appearance, “perforate vs. imperforate” as shell perforation, and “rotaliid vs. miliolid” as the two main taxonomic group.

Specific comments are as follows:

L1: Title is vague and general, should be changed to include keywords and reflect the main results of this paper; for example, Calcification model of some trace element (Zn, Ba) incorporation in foraminifera under high pCO2 environments.

Abstract

L11-12: need an explanation why you conducted pCO2 controlled experiments for this study.

L13-19: How do you explain your results if other ion transport models are assumed?

L18: I think this is the main original results of this paper.

L22, due to differences in size: any other explanations possible (e.g., symbiont effects)?

Introduction

L38-40: This sentence is strictly speaking incorrect. Diverse miliolid foraminifers belonging to larger benthic foraminifera (LBF) are found particularly in the Atlantic and the Caribbean. In addition, LBF do not cover a large Mg/Ca range, but only intermediate and high Mg/Ca ranges. The authors have to explain advantages to use LBFs for their study in more detail.

L55: Is a paper in review OK to cite? If it is OK, it should be listed in the Reference.

L60: Not listed in the Reference.

L65: I do not understand why the authors conducted pCO2 control experiments for this study. Explain the rationale to conduct such experiments.

Methods

L86: 90-600 μm fraction is too small for larger benthic foraminifers (almost juveniles).

L86: As far as I know, Marginopora vertebralis (Quoy & Gaimard) is not distributed in the Caribbean and Atlantic (see Langer and Hottinger, 2000 Micropaleontology). Recheck if identification is correct.

L94: Where is “Chapter 7 ”? I also found other chapters in the text somewhere.

L97-98: Add pCO2 unit. Explain what (A) means.

L108-109: Add the precision of temperature control.

L110-111: Note the light intensity level. In addition, I wonder if LEDs and yellow culture bottles (Fig. 1) affect wave length and hence the growth of symbiotic foraminifers?

L113: Does food affect water quality and chemical composition?

L126: Delete "." before "K2"

L131: What is "duplo", meaning "duplicate"?

Section 2.3.2 to 2.3.5: These sections have many abbreviations that were not mentioned in the first appeared in the text. Probably this is because I am not familiar with geochemistry though, I suggest that authors explain some specific terms to readers who are not experts in geochemistry.

L131: LDPE?

L134: JASPO?

L138: SeaFAST S2?

L142: NOBIAS?

L150, (Nardeli et al., 2016): not listed in the Reference.

L154, Barker et al. (2003): not listed in the Reference.

L154: PE?

L155: Could the organic matrix in a shell be removed by this method? Does data not include any elemental incorporation in the organic matrix?

L167: What is the main difference between this paper and Van Dijk et al. (in review)?

L179-180: SRM NIST glass standards?

L182: NIST612, NIST610?

L187: MATLAB SILLS?

L189: LOG?

L192: MACS-3?

L202: T-test > t-test

Results

L211-218: Recheck numerical numbers of maximum/minimum values, that were not consistent with Table 3.

L217-218: Explain the rationale (hypothesis) why the authors compare Mg/Ca with other TE/Ca?

L218-219: not only significant values, but also R2 values should be noted.

L223: Replace "then" to "than".

L227; DSr/DBa versus DMg are weakly correlated (Table 4), even though they are significant.

Discussion

L249-251: Compare advantages and disadvantages of several ion transport models and justify a Ca-channel model as the most appropriate to explain results in this study.

L260: I think miliolid foraminifera still need the major removal of Mg ions even if carbonate is directly precipitated from seawater.

L289: PHREEQC needs explanation

L290: llnl database?

Section 4.3: this section is mostly a review of previous studies. I suggest that authors explain an incorporation model shown in Fig. 6 in detail.

Section 4.4: Does size matter? authors mentioned that they measured only small size (L86). Calcarinids (Neorotalia in #15 in Fig. 3) are similar in size to Amphistegina, but have high Mg contents similar to a bigger Heterostegina. You may need another interpretation to explain the difference between two taxa. In addition, I think larger benthic foraminifers (in particular some taxa dwelling at a lower euphotic depth) have a strategy to attain a high surface area to volume ratio by flatting to get light for algal

symbionts. Please show the surface area to volume ratio between comparing taxa to justify your interpretations. Less Ca channels in the membrane of LBFs are also unlikely, because LBFs are bigger thus have much more membranes and channels than smaller foraminifers if channel density are the same. I think the second process is more feasible than the first process.

L347-350: I think this explanation is more plausible. Hyaline foraminifers are highly diverse and may have similar but slightly different calcification strategy acquired during evolution. I guess the relative contributions of primary and secondary layers and organic matrix may depend on hyaline foraminiferal taxa, which may cause interspecific variability of E/Ca compositions.

Section 4.5

L359: I think the major removal of Mg is necessary because your results show that DMg is much lower than 1.

L359-361: This sentence is a repetition of previous sentences.

L366-369: Is this correct? lower? I think higher or similar based on slope inclinations in Fig. 4. I do not understand how to estimate the relative contribution of seawater endocytosis and transmembrane transport. I guess some trans-membrane ion exchanges (Mg removal) occur between seawater vesicles and intrashell cytoplasm. High pCO2 seawater contains relatively large amounts of Zn and Ba ions, which are incorporated into foraminiferal cytoplasm via seawater vacuolization. Calcite needles are then precipitated from seawater vesicles with modifications by trans-membrane ion exchanges between seawater vesicles and intrashell cytoplasm.

Conclusions

These conclusions are not exactly what was found in this study and mostly speculative (hypothesis). I expect to see what this study revealed and what these results indicate.

Figure 6: Explain what bold types indicate.

Table 2: Better to write genus names in full in the table. A space between 450 and ppm.

Table 3: Better to indicate which species are either hyaline or porcelaneous.

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