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Biogeosciences Discussions



# *Interactive comment on* "Calibration of $\delta^{18}$O of laboratory-cultured deep-sea benthic foraminiferal shells in function of temperature" *by* C. Barras et al.

**C. Barras et al.**

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The authors are grateful for all the constructive comments made by the referees that contributed to greatly improve the manuscript. Each of their comments was address separately.

[Comment] The title reads much better as something like "Calibration of 18O of cultured benthic foraminiferal calcite as a function of temperature" [Answer] The title has been changed to simplify it.

[Comment] Page 336, line 2: It is not the chemical composition of the foraminifera, but

that of their calcite that is used for paleoreconstructions. [Answer] The text has been changed.

[Comment] Page 336, line 3: “in situ” reads better as “field” [Answer] We changed the word.

[Comment] Page 336, line 8: “in experimental conditions” should be “under experimental conditions” [Answer] The expression has been corrected through all the manuscript.

[Comment] Page 336, line 15: “benthic foraminifera” should be “this species” [Answer] The text has been changed.

[Comment] Page 337, line 8: “all these factors are interfering” reads better as “many of these factors co-vary” [Answer] The text has been changed.

[Comment] Page 337, line 14: “On the contrary” reads better as “However” [Answer] The text has been changed.

[Comment] Page 339, line 14: “very clean (. . .)” reads better as “transparent with no mineral adhesives visible” [Answer] The text has been changed.

[Comment] Best to state explicitely that Bulimina marginata has no photosynthetic symbionts. [Answer] This information has been added.

[Comment] Could the authors include (table?) the reproduction and growth rates for the different conditions? [Answer] The authors have published in JFR (vol. 39, p. 155-165, 2009) a paper discussing in detail reproduction and growth rates of Bulimina marginata in different conditions of food and temperature. This paper was reporting the observation made during the experiments presented in this paper, as well as other experiments. We stated in the text that these information are available in the JFR paper.

[Comment] The axes of figure 1 should be switched so that T is on the horizontal one and the 18O’s on the vertical one (like in figure 2). I also think the figure would improve



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if all four panels are combined into one. The data in figures 1 and 2 may be better plotted as averages and SD's, with the number of measurements (n) in the caption. [Answer] The axes in Figure 1 have been switched, and averages and SD's have been plotted instead of separate data points in Figure 1 and 2. However, we cannot combine the four panels into one for Figure 1 because the figure would not be clear and readable anymore.

[Comment] Section 3.3 relates the 18O results from cultured Bulimina's to inorganically precipitated calcite (Kim and O'Neil, 1997). Previously inorganic-biological/18O-T relationships have resulted in the same conclusion: namely that the effect of temperature on fractionation of oxygen isotopes during calciïňĄcation in foraminifera follows equilibrium values. Therefore, 18O of foraminiferal calcite is believed to be a relatively good proxy for sw temperature. I don't see why a complete section should be devoted to this comparison. [Answer] The comparison between inorganic calcite and benthic foraminifera entirely calcified under controlled laboratory conditions has never been done and we think that it is important to discuss it. The $\delta$18O-T relationships, which have been previously determine on the basis of field material, may be influenced by a wide range of uncontrolled parameters. Our presents results, obtained in controlled conditions, validate the paleotemperature equations based on field material, which is absolutely essential for their use in paleoclimatology studies. Our observations also allow us to say that B. marginata calcifies in equilibrium with seawater (as defined by Kim and O'Neil, 1997) and therefore presents no vital effect on its fractionation. Finally, with this comparison, we calculate that using the equations that we obtained in culture for size fractions 150-200 and 200-250 $\mu$m to reconstruct temperature from $\delta$18O data of B. marginata shells, leads to a maximum error of 0.7°C.

[Comment] More interesting is the evidence for a significant, size-specific offset in the oxygen isotope fractionation for Bulimina marginata. Why would this be? And how does this influence the use of this species in paleoceanography? Therefore, I think that the porté of section 3.3 could be summarized in a few sentences and that the



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implications of the results explored in section 3.2 could be widened somewhat (see also suggestions below). [Answer] We discuss the possible reasons to explain the size-specific offset in the oxygen isotope fractionation of Bulimina marginata in part 3.2. The influence of the use of this species in paleoceanography is discussed in the last paragraph of part 3.2.

[Comment] On the limited size of the dataset: However well-executed the culturing experiments are, the presented dataset is on the small side. The main conclusions of Barras et al. conïňĄrm a similar T-dependency and ontogenetic offset previously found in other species (see refs in sections 3.1 and 3.2). The authors therefore should take their discussion one step further: which, in fact, should be easy with their novel way of culturing (benthic) foraminifera. The obtained calcite should provide more than enough material for other analyses (e.g. Mg/Ca and Sr/Ca from single chambers, 11B, 26Mg from complete specimens, morphological characteristics). [Answer] We actually obtained a large number of shells with our experiments (cf Appendix added in the revised manuscript). However, most of the shells were used for $\delta$18O measurements because we wanted to obtain reliable measurements with replicate data. For the smaller size fractions, it was necessary to use around 150 juveniles to reach the required weight for one $\delta$18O measurement. Furthermore, we obtained less large shells than small ones. Now that the protocols to produce foraminiferal shells entirely calcified in controlled conditions are well established and prove to give reliable results, the next step will be to perform experiments to test the influence of other parameters on foraminiferal shells geochemical composition.

[Comment] An alternative option is to link the 18O measurements to the mode of chamber formation. Since measurements of large individuals present a mixed signal from small and large chambers, the values for large specimens are ‘diluted’ by relatively low 18O values for the smallest chambers. This means that the difference in oxygen fractionation between small and large chambers is even bigger than seems from the presented results. Could the authors estimate these differences? What does this mean



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for measurements based on dissected chambers (e.g. Filipsson et al., 2010)? Could there be a relation between the mode of chamber formation and size-specific patterns? [Answer] At present, no information exists on the influence of the mode of chamber formation on the $\delta$18O composition of the test. Our data do not shed new light on this question, and any discussion on this topic would necessarily be highly speculative. As to the difference in isotopic composition between smaller and larger chambers, the reviewer is right. This is the inherent conclusion of our data. Following the suggestion of the reviewer, we estimated the differences in $\delta$18O composition of the calcite added from one size fraction to the next one, according to the weight differences between the successive size fractions. It is more relevant to use test weight than shell volume since B. marginata is a radiate foraminifera which adds a new calcite layer over the entire test when a new chamber is formed. For specimens from CSI experiments (where we had sufficient data points), the $\delta$18O of the newly added calcite is on average 0.14‰ heavier (minimum of 0.0‰ and maximum of 0.29‰ than the $\delta$18O of the whole shell (see Fig. 1). Our data do not show a trend towards lower $\delta$18O differences between newly formed calcite and entire shells in later ontogenetic stages, as we would expect if the kinetic fractionation decreases with increasing size. However, our data set is probably not large enough to draw a firm conclusion. We think that this question can only be addressed in a serious way in a specific paper on this topic.

We agree with the reviewer's suggestion that dissected later chambers should have a particularly high $\delta$18O, which can not be compared with measurements performed on the whole tests. However, we also think that this is outside the scope of our paper, which does not want to present a critical analysis of other papers.

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Interactive comment on Biogeosciences Discuss., 7, 335, 2010.





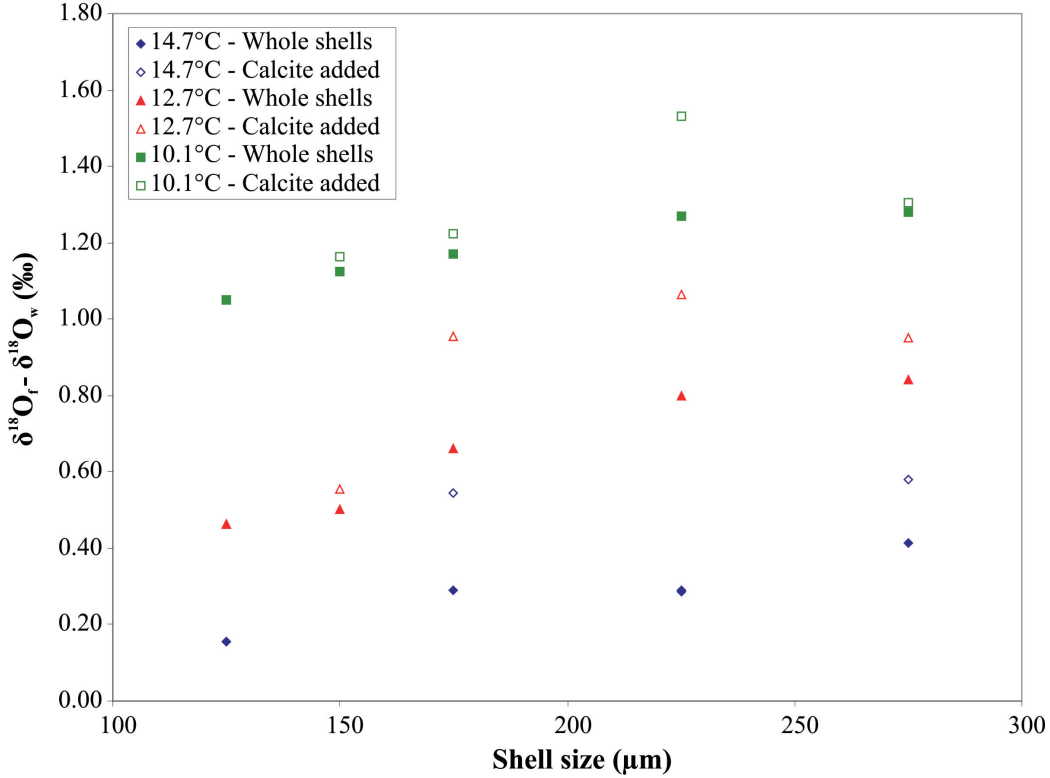


**Fig. 1.** Comparison between the $\delta$18O of the whole shells (full symbols) and the $\delta$18O of calcite added since the previous size class (empty symbols) for B. marginata (CSI experiments at 10.1, 12.7 and 14.7°C).



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