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# *Interactive comment on* "Ba incorporation in benthic foraminifera" *by* Lennart J. de Nooijer et al.

**Anonymous Referee #2**

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The manuscript 'Ba incorporation in benthic foraminifera' presents laboratory culture barium data for two species, *Heterostegina depressa* and *Amphistegina lessonii*. Ba/Ca ratios in foraminifera may be used to trace past changes in seawater [Ba], which in turn may be related to (e.g.) salinity or alkalinity, and the proxy is therefore of broader community interest. Whilst Ba/Ca has been successfully applied as a proxy using low-Mg foraminifera for some time, this study provides seawater-shell Ba/Ca calibrations for two high-Mg species. I was missing an explanation in the text of why the authors chose to use a range of seawater Ba/Ca ratios that are much higher than natural seawater. Nonetheless, the data are of good quality, and are suitable for publication in *Biogeosciences*.



## 1 Comments

1. In the abstract and introduction there is no mention of upwelling, which may complicate the use of Ba/Ca as a salinity proxy, especially in benthic organisms.

2. Lines 64-67, line 327, and lines 455-456. This is not the first time that Ba/Ca has been investigated in a high-Mg benthic species and therefore these sentences should be rephrased. Evans *et al.* [2015] *GCA* report Ba/Ca data for the high-Mg species *Operculina ammonoides* under variable seawater [Ba], and found a barium distribution coefficient (0.66) similar to that reported here for *H. depressa*. van Dijk *et al.* [2017] also report Ba/Ca data for *H. antillarum* which has a distribution coefficient of 1.2-2.2 according to that study.

3. Section 2.2. Please state the approximate volume of seawater in which the cultures took place. As these cultures were performed in petri dishes, presumably the volume was relatively small? If so: (1) How was evaporation monitored and avoided? (2) It is likely that the foraminifera modified the carbonate chemistry of the seawater in between water exchanges (once per week). Was this monitored?

4. The phrasing of lines 148-149 implies that the cleaning procedure has an impact on measured Ba/Ca. Either rephrase or state what this impact is.

5. There is far more detail given for the laser-ablation performed at the royal NIOZ. Whilst a reference is provided for the system at Utrecht University, it may be useful to state which LA and ICPMS systems were used and the wavelength of the laser for easy comparison. What is the accuracy and precision of the system used at Utrecht University?

6. Lines 164-169. Here the authors state that the final chamber of *A. lessonii* and the final two chambers of *H. depressa* did not yield reliable data because the

walls are thin. However, Fig. 3 shows data for F and F-1 for both species. Is this a mistake? If not, these data should not be shown if they are not reliable.

7. Lines 175-176. What is the possible source of Al and Mn contamination in cultured foraminifera?

8. Section 2.4. Consider changing the phrase 'field specimens'.

9. Lines 230-231. I agree that it is reasonable to assume no barium incorporation when there is no barium in seawater. However, forcing a linear regression through the origin also assumes that seawater and shell Ba/Ca must be linearly related across the full range of seawater Ba/Ca ratios, which may not be the case. Consider that the *H. depressa* zoo aquarium sample may be in agreement with the cultures if the regression is not forced through the origin.

10. Lines 232-233. Technically, if the regressions are not forced through the origin then there is not a single partition coefficient value, I suggest this is rephrased in terms of the seawater-shell Ba/Ca slopes.

11. Lines 241-242. Why is the aquarium seawater Ba/Ca higher than most natural seawater? If this is known it would be useful to state the reason. What is the meaning of the sentence starting on line 243? Is it an analytical problem or is there reason to suspect the aquarium seawater Ba/Ca ratio was not constant?

12. Section 3.3. It would aid the interpretation of these interesting data if the reader had an idea of how much of the foraminifera the final five chambers represent. Approximately how many chambers were precipitated in culture? Consider adding a representative image.

13. Lines 259-260. The phrasing is confusing here. Ba/Ca increases in the first sentence but decreases in the second sentence. Rephrase for consistency.



14. Lines 273-276. If the two slopes are significantly different, why combine the data from both species?

15. Section 4.2 and Figure 4. I am surprised that the range in Mg/Ca is so large, both within and between experiments, and this requires further explanation. For example, compare these *H. depressa* data to those reported in Raitzsch *et al*. [2010]. In that paper the Mg/Ca 2SD was 17 to 24 mmol mol$^{-1}$ ($\sim$10-20%), which is comparable to other studies reporting laser-ablation data. Here, some experiments are in line with this while others have a far larger range, for example *H. depressa* treatment D ($\sim$110-190 mmol mol$^{-1}$). The *A. lessonii* data are even more surprising, treatment D has a range from 30-140 mmol mol$^{-1}$, and treatment C has a range of 30-120 mmol mol$^{-1}$. Why is there so much variation compared to other studies? Could something in the experimental design have resulted in this? Is it a result of using juvenile foraminifera?

16. Line 363-366. Alternatively, van Dijk *et al*. [2017] showed that $pCO_2$ does impact Ba incorporation in *Amphistegina*, so perhaps the microenvironment carbonate chemistry can help to explain these data.

17. Line 428-431. This argument is not valid, we would not expect a doubling in *O. universa* Mg/Ca to exert a resolvable impact on Ba or Sr incorporation. For example, the $D_{Sr}$-Mg/Ca slope for inorganic calcite is $9.1\times10^{-4}$ [Mucci & Morse, 1983], so that a change in shell Mg/Ca of 10 mmol mol$^{-1}$ would result in a Sr/Ca increase of just $\sim$0.1 mmol mol$^{-1}$. If the relationship between $D_{Ba}$ and Mg/Ca is similar, we would not observe this effect in *Orbulina*. It is visible in high-Mg species only because the shell Mg/Ca ratios are 1-2 order of magnitude higher than low-Mg foraminifera.

18. Line 446. I think repeating the assertion that miliolids calcify intracellularly should be avoided. As stated a few lines later, it is intracellular only in the sense that

calcification takes place from endocytosed seawater, which may well be the case for rotaliid foraminifera as well.

19. Line 449-450. van Dijk *et al*. [2017] report Na, Zn and Ba data for miliolid foraminifera.

20. Line 458. You could also reference Hoffmann *et al*. [2014] *Geology* **42**:579 and Evans *et al*. [2015] *G-cubed* **16**:2598.

21. Figure 3. It would be more intuitive to plot the final chamber on the right hand side of the graphs, so that time goes forward from left to right.

22. Figure 4. Please use symbols for the two species that are easier to distinguish. Consider plotting the slopes discussed in the text.

## 2 Typos

1. Line 183. ‘naturel’.
2. Line 201. ‘costume-built’.
3. Line 221. Write out ‘2’.
4. Line 274. Delete ‘in a’.
5. Line 359. ‘maybe’.

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