

## ***Interactive comment on “Early Paleogene variations in the calcite compensation depth: new constraints using old boreholes across Ninetyeast Ridge in the Indian Ocean” by B. S. Slotnick et al.***

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We thank Anonymous Referee #1 for thoughtful and detailed commentary, which improves the manuscript. We agree with the vast majority of comments, as well as several recommendations. We provide responses to the comments below, and have amended the manuscript accordingly.

TEXT Page1: Affiliations 2 and 4. To me they look very similar. Am I wrong? -Changed.

Page 2, line 7: delete “assemblage”. -Changed.

Page 2, line 8: “sediments” instead of “sediment”. Existing sites: I would delete existing

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because this gives the idea that Site 213 still exists on the sea floor, which is unlikely. -Changed.

Page 3, line 25: add “from the ocean-atmosphere” after carbon. -Changed.

Page 3, line 26: add “to the ocean- atmosphere” after carbon. -Changed.

Page 4, line 3: “deep-sea carbonates” instead of “deep-sea carbonate accumulation”. -Changed.

Page 4, lines 25-27: The amount of carbon is certainly crucial but: Does the magnitude of these changes be also controlled by the rate of the input? Comparing with the ongoing release of GHG into the ocean-atmosphere, this also is a crucial factor to take into account. -Yes, the amount of carbonate dissolution depends on both the amount and rate of carbon addition. We have clarified this point.

Page 5, line 8: see comment on Page 2, line 8. -The word ‘existing’ removed.

Page 6, line 24: “Sediment age was determined primarily through calcareous biostratigraphy”. Biostratigraphy does not give absolute ages, but relative. Ages are determined with biochronology. These are two substantially different concepts. The sentence should be re-phrased so that it is immediate what the authors mean. -Has been rephrased now to take this useful point into account.

Page 7, line 2: may be “sediments” instead of “sediment”. -Agree. Changed.

Page 7, line 9: delete “depth”. -Clarified. It is now “low spatial resolution between samples”.

Page 7, lines 10-12: This mostly due to the fact that the Paleogene Time Scale is not fixed. Even the recalibration (absolute ages) proposed by the authors is going to change shortly, I guess. -This is correct and these lines now have been reworded. At present, very few early Paleogene records are on a common and current time scale, one that appears to be close to reasonable absolute age. As should also be clear

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from our work and that of several other papers, many previously generated deep-sea records have not been spliced properly (i.e., they contain core overlaps and core gaps). Consequently, it is not a straightforward matter of sliding data to a revised age model. The age model used in this study is, at least now, the simplest to use for comparing early Paleogene records, because several high quality records that have been spliced correctly exist on this age model.

Page 7, line 18 to Page 8, line 7: I do not know if I get it correctly: the authors assumed a core gap of 1m between successive cores, they also assumed that the total length of core gaps are variable because the total length of the gap is equal to 1m (constant for each core) plus the difference between and ideal core length (9.5m) and the actual length of the recovered core. If this is what you mean, this is lost in the text and the sentences should be probably rephrased. -We have reworded this portion of the paper for better clarification. For reference, there are "core gaps" between each successive core, which we arbitrarily set at 1 m. ". However, there are also cores with incomplete sediment recovery. The two "phenomena" are distinct. In particular, as clearly shown at many sites drilled in the last 10-20 years, even successions of complete 9.5 m cores typically have core gaps, which average about 1 m.

Page 8, line 19: "Calcareous nannofossils were investigated in 62 samples to refine ages." The authors are not calibrating CN datums, they simply provide the better positioning for each calcareous nannofossil datum. The sentence should be: "Calcareous nannofossils were investigated in 62 samples to refine biostratigraphic datums". Again biochronology is not a synonymous of biostratigraphy. -Agreed. These lines have been revised accordingly.

Page 9, lines 7-8: make reference to previous works that provide this kind of biochronologic data -Added.

Page 9, lines 6-9: This is confusing to me. I would suggest to change this sentence because its meaning is ambiguous at this moment : I would say something such "some

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of these biohorizons have been used to construct CN zonal schemes such as those of Okada and Bukry (1980) and Martini (1971), the latter adopted as biostratigraphic scheme in this work. -Okay. We have changed.

Page 9, lines 8-11: This sentence is floating delete it or, better, define all the biohorizons you are going to use. In this contest you can mentioned the particular case of the Base/Base common of *D. lodoensis*. -These lines have been modified.

Page 9, lines 23-25: Specify How many samples did not give reliable values. -Okay. We have now specified.

Page 10, lines 3-5: Looking at Figs 4-6 it seems more from NP7-8-NP13 (Site 213), NP475-NP12 (Site 214) and NP7/8-NP13 (Site 215). -This is correct, and these lines have been revised accordingly.

Page 10, line 9: "selected taxa" instead of "assemblage components". -Ok. Changed.

Page 10, line 10: "Age estimates are from Agnini et al.:" add "of CN biohorizons" after Age estimates. -Added.

Page 10, line 12: "constrains" instead of "criteria" -Changed.

Page 10, line 15: upper case for Top (T), add (base of Zone NP13) after *T. orthostylus*. -Changed.

Page 10, lines 17-18: upper case for Base (B), add (base of one NP12) after *D. lodoensis*. -Changed.

Page 11, lines 8-9: delete "several of these criteria" and add "information derived by the integration of CN stratigraphic ranges". "The simultaneous presence" instead of "the overlap in range". "Observed" instead of "occurs". -Changed.

Page 11, line 12: "its disappearance is calibrated" to instead of "disappears" (that refers to a taxon not to a biohorizon) -Changed.

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Page 11, line 13: Zones NP7 and NP8 are undifferentiated. Please use NP7/8 instead of NP7. -We have reworded, along with reference for why this is the case.

Page 11, line 14: upper case for Base. -Changed.

Page 11, line 15: upper case for Base. -Changed.

Page 11, line 16: put 60.90 Ma in brackets after Zone NP5. -We removed this sentence, as not needed.

Page 11, lines 17-18: upper case for Base. -Changed.

Page 11, line 22: upper case for Base. -Changed.

Page 11, line 23: add “Based on these data” at the beginning of the sentence. -Added.

Page 11, line 23: “Biostratigraphic data” instead of “criteria” -Changed.

Page 11, lines 26-28: These two biostratigraphic data (diverse and abundant fasciculiths and absence of *E. robusta*) should be integrated to be used properly. “.Diverse and abundant Fasciculithus spp. indicate an age older (minimum) than 55.47 Ma.” Diverse and abundant fasciculiths are present up to the onset of the PETM (55.53 Ma). 55.47 Ma is the calibration for the CO between Fasciculithus spp. and *Z. bijugatus* that occurred during the PETM (after the onset). Decrease in diversity, also known as Top of Fasciculithus richardii group (see Agnini et al. 2014 for details) should be added in Table 1. What about *D. multiradiatus*? I suppose *D. multiradiatus* is also present in this interval (where you have diverse fasciculiths and no *E. robusta*) and the presence of *D. multiradiatus* is the datum based on which you are sure to be in NP9 and not in an older interval. -Added to table 1. Tables 2 and 4 and Figures 8 and 10 now show NP9 correctly. Yes, *D. multiradiatus* is present during this interval.

Page 12, line 1: upper case for Base. -Changed.

Page 12, line 1: “These biostratigraphic data” suggest instead of “this composition suggests”. -Changed.

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Page 12, line 5: upper case for Base. -Changed.

Page 12, line 6: upper case for Base, add “within zone NP7/8” at the end of the sentence. -Changed.

Page 14, lines 12-14: Based on biostratigraphic data, I'd suggest that these lows in  $\delta^{13}\text{C}$  document B1/B2 events. Because of the short stratigraphic range reported in literature for *E. robusta* (Raffi et al., 2005; Agnini et al., 2007) you might hypothesize that the core gap between core 14 and 13 is very limited. - These are interesting comments. Yes, it is possible the minor CIEs may represent B1/B2, but they could also be C1/C2, or even something else. We have not modified the text. The duration of *E. robusta* is approximately 0.4 Myr. The long-term sedimentation rate at Site 215 is approximately 9 m/Myr, such that *E. robusta* should span about 4 m. According to our data, it spans about 9 mcd at Site 215, which includes missing section and a presumed 1 m core gap. We thus see the point of the comment, and have added a short paragraph. However, for consistency, we have kept the core gap at 1 m between cores 14 and 13.

Page 15, line 8: “our nannofossil assemblage” should be substituted with “Our calcareous nannofossil biostratigraphic data” -Changed.

Page 15, line 9: add “and the presence of core gaps” -Changed.

Page 15, lines 11-15: This sentence is not clear to me. I would ask the author to re-write this sentence. -We have rewritten this sentence to make things more clear (hopefully).

Page 15, line 16: “have proved” to instead of “can” -Changed.

Page 19, line 24: “NP9” instead of “NP10” (see Table 2). This shift actually occurs within Zone NP9 as correctly reported in Table2. This should be corrected also in Figure 8, where NP9 is missing. -This is correct. Writing modified.

Page 19, lines 27-29: The interpretation proposed by the authors is difficult to be

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proved. The K-X event (ca. 135 mcd at Site213, if the authors are right) usually occurs at the base of Zone NP12 (ca. 139 mcd at Site 213). These events are thus separated by four meters that likely represent a copious amount of time. Do you have any reliable estimation of sediment accumulation rates (SAR) in this interval? I guess, It should be quite low since you are in a deep sea ocean setting with relatively low CaCO<sub>3</sub> content. This could suggest low SAR, may be on the order of 0.5-1 cm/kyr. If this estimate is reliable then the four meter (separating the two events) document 400-800 kyr in term of time. This point is crucial and the authors should offer a more complete a substantiate explanation of their interpretation because at this point it is not very strongly supported by data. - This is an awkward topic because the start of Discoaster lodoensis is pulsed at several locations. By strict definition, the K/X event occurs within NP12, because it broadly correlates to the time when Discoaster lodoensis becomes common. (Agnini et al., 2007; Dickens and Backman, 2013). This is at 137.52 Mcd at Site 213..We have rewritten to make this clearer.

Page 20, lines 3-4: Not at Site 213, where the CaCO<sub>3</sub> content remains very low throughout the interval (see Fig. 8). -High carbonate contents immediately after the most prominent events do suggest overshoots at Site 213, at least during the recovery phase of the PETM. CaCO<sub>3</sub> increases to ~100% in samples at 149.98 and 149.55 MCD or during the recovery phase of the PETM at Site 213. The potential recovery phase of the supposed K/X event cannot be discussed because it lies in core gap.

Page 20, lines 2-6: This sentence is quite weak because of previous comment on Site 213. Specifically it should be post-dated at Site 213, where your interpretation of the K-X event is questionable. In addition, you have no data available to support this interpretation at Site 215. -We have rewritten to clarify. Neither the PETM nor the K/X event were recovered at Site 215. At Site 213, only the recovery of the PETM and probably the onset of the K/X were recovered.

Page 20, lines 6-7: see comment above and that (on the same issue) at page 19, lines 27-29. -See above comments.

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Page 23, line 13: delete "assemblage", add "and" -Changed.

Page 24, line 13: delete "especially" -Changed.

TABLES Table 1: -Add Fasciculithus decrease diversity or Top F. richardii group (55.53 Ma), see comment on page 11, lines 25-27. -Added to Table 1.

- Fasciculithus tympaniformis should be in italic Table 2-4. Nannofossil indicators should be substituted with nannofossil taxa or something similar. -Italicized and modified.

FIGURES AND FIGURE CAPTIONS Figure 1 caption: -"such as for much of the early Eocene at Sites 1219 and 1221, as noted by Hancock et al., 2007)." I can not see any data from Site 1221 in Figure 1. -We thank this referee for catching this. Site 1221 has been removed from the figure caption.

-“Calcareous Nannofossil biozones are taken from Martini (1971), but adjusted to the current time scale”. This sentence is misleading and formally wrong and needs to be rephrased. For instance you should say something like: The biozonal scheme adopted is that of Martini (1971). Ages of calcareous nannofossil biohorizons are those proposed by Agnini et al. (2006, 2007) recalibrated using Option 1 of Westerhold et al. (2008). -Figure 1 caption modified.

-Add something on how you put PCIM, PETM,H,I; EECO on this figure. Which data do you use? And Why do you decide not to put K-X event on this figure? - Add something on CCD reconstruction curve (in brown). This is not even mentioned in the caption. Explain how you built up this curve. -All of this has now been added to this figure caption.

Figure 2 caption: There are no green numbers in the figure 2. -Changed wording from 'green' to 'yellow-greenish' so that this comment could be taken into account.

FIGURES 4-6 General comment: In Fig. 1 x-axis represents time with older ages positioned on the left. Figures 4-6 show an inversed x-axis and this makes confusion.

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I would suggest the authors to maintain consistency between figures. I personally prefer the general set up of Figure 1. Vertical dashed lines defining biozones: -X-axis reversed so that X-axis in Figures 4-6 now consistent with X-axis in Figures 1 and 11

-I would prefer to have the numbers of biozones on the right of the figure on the y-axis.  
-We attempted this but this adds more confusion to Figures 4-6 than clarity. Keeping biozones along x-axis enables them to stay in age domain, which to us is more straight-forward.

-Dashed lines are misleading because, based on your biostratigraphic data, you generally know that you are within a specific Zone but you are not able to determine the base and top of that Zone. I would suggest the authors to use solid lines when they have identified the precise position of the biohorizon defining the boundary of a Zone (see for instance Zones NP11 and NP12 at Site 213). I would also suggest to add horizontal grey bands to emphasize floating biostratigraphic data. For instance, in Fig. 4 the interval Ft-Zb lies within Zone NP9 and should be highlighted with a grey band but it does not define the base or the Top of Zone NP9 (no solid lines are thus necessary). Basically, what I suggest is to rotate all biostratigraphic data (numbers of Zones as well as solid lines and grey bands) by 90° (clock-wise). This would guarantee a better readability of these figures (4-6). -This has been modified so that solid lines reflect precise position of biohorizons defining a boundary of a Zone or dash when not precisely determined. But, again, when I tried to move zones to y-axis along right side of figures, it confused things. So we moved zones back to original placement. Plus, had we kept this change, would loose age range for each biozone.

FIGURES 8-10 -Solid lines at biozone boundaries should be used only when a precise position of the biohorizons used to define the Zone (base or Top) has been really identified. In all the other cases you should use dashed lines or, even better, "grey uncertainty bands" because you are approximating boundaries with alternative biohorizons (e.g., the base of Zone NP10 is approximate with B D. diastypus) or, even worst, data just above core gaps. -Modified so that lines are dashed when not determined

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precisely or solid when determined precisely.

-Early/Middle Eocene. Early and Middle are not formally described in more recent timescales (GTS04; GTS12). Do you refer to Berggren et al. (1995)? If this is the case you should mention it, at least in the figure captions of Figures 8-10. Alternatively, you can use Ypresian (stands for Early Eocene in Berggren et al., 1995) and Lutetian (for the lower part of Middle Eocene as defined by Berggren et al., 1995). -Early and middle now lower case in Figures 8-10 since not formally defined. -Berggren et al. (1995) referred to in each figure caption now.

Figure 10 caption: -"The H events are in the core gap between cores 11-10. The NP10, NP11, and NP12 biozones and depleted  $\delta^{13}C$  enabled the EECO identification in core 10. The K/X event is in the core gap between cores 10-9.". This is wrong. Based on biostratigraphic data available H1/H2 events are always recorded in the lower part of Zone NP11. At Site 215, the entire Zone NP11 is found within core 10 and this implies that H1/H2 should be in core 10, likely in correspondence of the decrease in  $\delta^{13}C$  observed between 88.77 and 88.29 mcd. If this is right, the base of the EECO should be moved upward at least within Zone NP12. High carbonate contents recorded in core 10 also support this hypothesis (see also Site 213 for comparison). -Although this is consistent for H1, the magnitude of this 'potential' even too low to be that of H1. As such, we modified Fig 10 to show it as possibly H1 but with a '?' since it cannot be better constrained than this. The figure caption has also been amended to reflect this change.

Figure 11 caption: "Calcareous Nannofossil biozones are taken from Martini (1971), but adjusted to the current time scale". Again, this sentence is not correct, I would prefer the same sentence suggested for Figure 1 caption, that is "The biozonal scheme adopted is that of Martini (1971). Ages of calcareous nannofossil biohorizons are those proposed by Agnini et al. (2006, 2007) recalibrated using Option 1 of Westerhold et al. (2008)." -Figure caption rewritten to reflect this change.

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