We appreciate the time Colin V. Murray-Wallace took to review the manuscript and thank the reviewer for his constructive comments. We have tried to address them all and feel that they have improved the manuscript.

The reviewer's comments are in black italics, followed by our responses in blue. A revised manuscript with tracked changes is also included.

Colin V. Murray-Wallace

This is a very interesting and in many respects, throught-provoking manuscript because it tries to come to terms with a complex marine geological problem, while at the same time, resolve some of the typically challenging issues in Quaternary aminiostratigraphy. The latter involves the potentially different diagenetic temperatures and a genus-effect on racemization with their ultimate influence on the measured extent of amino acid racemization in fossils, and ultimatelty an assessment of age of the marine successions.

The manuscript discusses the potential difficulties of inferring the age of the successions in question and clearly outlines many geological and environmental attributes that confound a conclusive age interpretation. While concluding that the higher amino acid D/L values for the foraminifer C. wuellerstorfi is not due to a genus effect, a whole set of new questions arise to reconcile the basis for the extent of racemization observed in these individuals compared with other Arctic Ocean deep sea cores. In this sense, the existing manuscript is to some extent open-ended in its conclusions. Perhaps the conclusions can be more decisive?

We extended the Conclusions with two additional bulleted points.

Some additional more specific comments include:

Line 21 *and other instances - oxygen isotope stratigraphy and magnetostratigraphy are, strictly speaking, not 'dating methods' in themselves, although with appropriate calibration using geochronological methods have an obvious role in unravelling Earth history.*

We clarified in the text that we refer to dating and correlation techniques when using these terms.

Please be consistent in the spelling of racemization (either s or z but please be consistent throughout the text).

Corrected.

Line 24 *and other instances 'n' italic font*

Corrected.

Line 40 *epimerization*

Changed.

Line 51 and elsewhere *- do you mean calcium carbonate?*

Changed to calcium carbonate.

Line 62 *'upper Quaternary' is not a stratigraphically recognised term - please be more specific*

Removed '*upper Quaternary*'.

Line 82 *sample mass*

Changed.

Table 1 *please indicate unit of measurement for temperature*

Corrected.

Line 119 *correlated with*

Changed.

Line 149 *mL and for microlitre later in the same paragraph*

Changed.

Line 186 *high serine content - please quantify and explain in what sense.*

Clarified that this refers to subsamples with L-Ser /L-Asp ≥ 0.8.

Line 214 *fossil age (sample is something that you have collected)*

Changed.

Figure 4 caption - *uncertainties rather than 'error bars' - they are not really an error, meaning something that is incorrect*

We agree, and we use the term "uncertainty" throughout in the text. For the figure captions, however, "error bar" is commonly used to refer to the depiction of uncertainties.

Line 249 *compared with*

Changed.

Line 323 *as above*

Changed.

Line 334 *validity of this assumption?*

It is not known when *E. huxleyi* entered the Arctic Ocean – here we simply stated that the ages derived from the trend observed at the Greenland and Iceland seas could agree with the occurrence of *E. huxleyi* at these intervals, had this species entered the Arctic shortly after its evolutionary occurrence. We have altered the text to make this clearer.

Lines 341 to 345 *Is this a manifestation of the kinetics of racemization and overall form of the extent of AAR with time?*

We are unsure of what the reviewer is asking. The ages of Arctic Ocean foraminifera are based on AAR global and GIS equations, which are empirical fits to D/L vs independent ages.

Line 364 *but is this valid?*

How Arctic bottom water temperatures changed over time is poorly known, partly due to the chronological issues. We reiterated the findings from West et al. (2019) showing that temperature differences would need to be sustained at >4°C between sites to account for the D/L differences, which is unlikely.

Figure 9 *benthic oxygen isotope curve - perhaps have times arrow reading to the righthand side of the page?*

The main feature of this figure is the age versus depth plot in the centre. For this plot, it is conventional for time zero to be positioned at the upper left surface.

Line 391 *calcium carbonate.*

Changed to 'calcium carbonate'.