Response to Thomas Algao

Page 5: seafloor is one word; superscript 15.

Response: thanks for spotting that we can make those changes.

Page 9: ”lamination” is a process; “laminae” are the features themselves

Response: we can change this in the text to “laminae”.

Page 15: awkward acronyms

Response: we will adapt this, and use TE etc.

Page 17: use subscripts for “HR” and “T”

Response: we will adapt this.

Page 24: “post-depositionally” or “in post-depositional environments”

Response:

Response: Thanks, we will use post-depositionally.

Page 26: there is no “Algeo and Lyons 2009” paper, this may be “Algeo and Tribovillard, 2009”

Response: we will make sure that we reference the right paper.

Page 27 I will call your attention to this paper:

Wang, X., Algeo, T.J., Li, C. and Zhu, M., 2023. Spatial pattern of marine oxygenation set by tectonic and ecological drivers over the Phanerozoic. Nature Geoscience, 16(11), pp.1020-1026.

Response: we can add this reference.

Page 29: “kyr” is plural no “s” needed.

Response: this can be changed in the text.

Page 48: “FB” should a subscript following “d15N”

Response: we disagree, as “FB-d15N” is the conventional way to abbreviate “foraminifera-bound nitrogen isotopes” in the community. We acknowledge that this is different to the format used for bulk sedimentary nitrogen isotopes (d15Nbulk), but to keep the proxy name similar to what is published in the fossil-bound nitrogen isotope papers we would like to keep the naming as it is.

Page 49: “CS” should a subscript following “d15N”

Response: same comment as before, this is the conventional format used in the fossil-bound d15N community.

Page 51: I am puzzled by the shown relationship of higher d15N to lower O2. In my experience, lower d15N signals lower O2, especially where ammonium plays a role.

Response: We will explain in the following three aspects. (1) As we have explained in section 6.4.1, denitrification is the predominant process determining d15N changes in an ODZ. Denitrification strongly discriminates against the heavier isotope 15N, progressively enriching the remaining nitrate pool in 15N as nitrate consumption proceeds. However, we also state that there is not a quantitative relationship between d15N and O2. It is rather that exceptionally high d15N (nitrate d15N is typically above 15 permil in the ODZ) is a result of denitrification which occurs when O2 concentration is below a threshold. (2) In the ocean since the oxygenation of the Earth’s surface, nitrate should be the predominant inorganic species available in the ocean, which also serves as the main form of nitrogen nutrient for organisms. The nitrate is assimilated by organisms, thus its isotopic signal is recorded in the biomass, and if the fossils are preserved, their d15N provides information mostly on the d15N changes of nitrate pool in the ocean. As a result, the exceptionally high fossil d15N (in foram, diatom, coral and others) would be best explained by high nitrate d15N resulting from denitrification in low oxygen environment. This may be different from an ammonium ocean prior to the oxygenation of the ocean. Since our paper focuses on the ODZ which is a phenomenon only relevant in the oxygenated ocean, we will not consider the events/periods when the whole ocean is anoxic. (3) Ammonium concentration is almost always lower than 1uM in the open ocean today, including the ODZ. In the ODZ, the ammonium is produced by degradation of organic N, and consumed by anammox and nitrification. Measuring ammonium d15N is challenging because of its low concentration, but the both anammox and nitrification discriminate against the heavier isotopes, so should also cause ammonium d15N to increase in the ODZ. However, as most of ammonium is completely removed within the ODZ, these processes have no influence to the surrounding ocean. In some special environment such as observed in the Bering Sea shelf, high organic flux is remineralized in the sediment to produce ammonium. The ammonium is not completely nitrified so some of the ammonium enriched with 15N is released to the water column and subsequently is taken up by phytoplankton. It is seen in such environment that ammonium produced in low oxygen environment can also generate high d15N signal (see Granger et al., 2011 JGR ocean. https://doi.org/10.1029/2010JC006751). So in summary, the processes involving ammonium do not have a strong effect on d15N changes in the ODZ as most of the ammonium produced in the ODZ is completely removed, and even if there is remaining ammonium, its d15N should also be high.

Page 101: I noted citations to 3 or 4 Algeo papers in the text that are not included in the reference list, so the citations and references have not been cross-checked for completeness.

Response: in our proposed revised manuscript we will check all this.