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Discussions

Interactive comment on "Organic carbon rich sediments: benthic foraminifera as bio-indicators of depositional environments" *by* Elena Lo Giudice Cappelli et al.

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Review of the ms "Organic carbon rich sediments: benthic foraminifera as bioindicators of depositional environments" by Elena Lo Giudice Cappelli et al.

The review is based on the version of the manuscript received in April 2019.

The aim of the present study is "To investigate the relationships between sedimentary OC in six west Shetland voes and the associated changes in benthic foraminiferal assemblages. . ." in order ". . .to: 1) Fingerprint the source (terrestrial vs. marine) and quality (refractory vs. labile) of organic matter and the form (organic vs. inorganic)

of sedimentary carbon. 2) Establish benthic foraminiferal biogeography in Shetland's voes from recent surficial sediments. 3) Investigate the use of benthic foraminifera as bioindicators of OC content in coastal sediments and their potential for palaeoâĂŘOC reconstruction purposes". This is a very topical theme, an interesting approach, and the manuscript should be of interest to the readers of Biogeosciences. The manuscript is generally well organized and well written, all figures and tables are necessary, and adequate literature is cited. However, my concern is the weakly described quantitative relationship between the foraminiferal assemblages and the associated geochemical parameters. This relationship is supposed to serve as the baseline for using foraminifera as indicators for OC enrichment (see aims) and, hence, ought to be more clearly addressed. Methodological weaknesses (see examples below) which potentially affect the relationships/correlations should be identified and discussed. Following the referee's suggestions, we strengthen the discussion regarding the use of benthic foraminifera as indicators of OC content in marine sediments with emphasis on the relationship between forams and geochemical parameters (par 3.2.1 and par. 4.3). We additionally revised the methods and discussed potential weaknesses that could affect the strength of the relationship between forams and OC.

Page 1, lines 13âĂŘ14: ". . .. evaluate the use of modern benthic foraminifera as bioâĂŘindicators of carbon content in six voes (fjords) on the west coast of Shetland." I guess the authors do not mean any kind of carbon? Please specify. The same applies other places in the manuscript. We added organic before carbon (Pg. 1 line 14 and following instances).

Page 1, lines 14âĂŘ16: "Benthic foraminifera are sensitive... . ." Please make it clear to the reader if these statements are based on previous studies or results of the present study. We rephrased this sentence to make clear that the statement is based on previous studies (Pg. 1 lines 14-16).

Page 3, line 20: ". . .subâĂŘsampling the top layer of each grab,. . ." What was the thickness of the "top layer"? How do the authors know if the sampled top layers in the

grabs were intact and had not lost some of the fines from the sedimentâĂŘwater interface, i.e. that the samples were comparable? Since no replicates were collected, how do the authors know how representative the OC and OM data were for each site? The thickness of the top layer is $\sim$ 1 cm (Pg. 4 line 21). We did not have a way of controlling for loss of fine material at the sediment-water interface when collecting grab samples; however, our results compare well with the grain size distribution found in other Scottish sea lochs (Pg. 10 lines 28-31) suggesting that if there were a loss of fines, it was most likely negligible. We did not have replicate samples for OC measurements, but we did have two pairs of replicate samples for OM which resulted in a mean relative error of $\pm$ 0.07 % for LOM, $\pm$ 0.06 % for ROM and $\pm$ 0.03 % for TOM (Pg. 5 lines 17-19), pointing to a very good reproducibility of data and representation of local conditions.

Page 3, lines 22âĂŘ23: "....foraminiferal counts are 'total' (live + dead) because the sampling technique may lead to underrepresentation of 'live' foraminifera." This needs some explanation. Following this suggestion and comments of Referee #3, we revised this part of the ms to improve clarity (Par. 2.6).

Page 3, lines 26âĂŘ27: "An earlier field survey of Shetland voes carried out in August 2009 measured bottom water temperature (BWT), salinity (BWS) and oxygen (O2) at the same locations as this study (Fig. 2)". If this implies that the present foraminiferal data collected in 2015 were only compared with 2 hydrographic data from 2009, it should be addressed in the discussion; particularly the statements postulating "low" or "poor" oxygen concentrations in Olna Firth, should be modified throughout the ms. We agree with the referee in that BWT, BWS and O2 in 2009 may be different from those of 2015 and we have now discussed this possibility in our ms (Pg. 9 lines 25-27; Pg. 12 lines 27-29; Pg. 13 lines 22-24).

Page 5, lines 14âĂŘ17: "Both size fractions were analysed. Depending on sample volume, we subdivided each sample into a number of splits using a standard splitter and, when possible, picked at least 300 specimens ...". The samples were dryâĂŘsieved and dryâĂŘsplit? Please clarify. It is not clear why the samples were sieved into two

size fractions? How did the authors ensure that the proportion between the two size fractions was the same in the counted splits as in the original sample? This is essential and needs to be explained. Samples were dry-sieved and dry-split. We added in the methods that samples were split in the two size fractions prior to this study and that we analysed both size fractions to make sure that no environmental information was lost due to changes in biodiversity and/or in the composition of benthic foraminiferal assemblage between the two size fractions (Pg. 6 line 30 to Pg. 7 line 9).

Page 5, line 21: total assemblages (live + dead) were analysed. Please explain how you distinguished in situ tests from tests transported into the sites. This is particularly relevant in the more high-energetic environments and deserves some comments. We had no means to systematically distinguish in situ tests from advected ones when counting unstained specimens. What we did was to compare our assemblages with published data from other Scottish locations and fjords to detect possible inconsistences that may suggest advection of material from other locations, especially in the more energetic environments. Our data overall compare well with other studies, suggesting that advection of tests from other locations is negligible in our sample set. We included this information in Pg. 15 lines 19-21.

Page 5, lines 23âĂŘ26: "Ten taxa ...." This belongs to results. Moved. Pg. 9 Lines 12-15.

Page 6, lines 3âĂŘ5: = results. Moved. Pg. 9 Lines 15-16.

Page 6, lines 11âĂŘ12: "...despite having very different geomorphologies (unrestricted vs. restricted) and circulation patterns (high vs. low energy) (Fig. 3)." This belongs to discussion. Removed.

Page 7, line 3: "...at sites closed to land ..." ..... close to land Changed. Pg. 8 Line 13.

Page 7, section 3.1.4: Most of this belongs to discussion. How meaningful is the aver-

age stable isotope values of the different lochs? Would you not expect that the average values depend on how many samples are collected and analysed from different parts of the landâĂŘsea transect? Moved to discussion and included range of isotope values and/or number of measurements when possible (Pg. 14 lines 17-20).

Page 8, line 7: “In Vaila Sound, an unrestricted geomorphology (Fig. 1), . . .” It is not obvious, based on Fig. 1, that Vaila Sound has an unrestricted geomorphology; please explain, and perhaps modify Fig. 1. We modified Fig. 1 and this part of the discussion.

Page 8: Section 4.1 may be shortened, particularly since the data are not used in the further discussion. Following the comments of Referee #3 we now included % Clay in our discussion, revised Figs. 3 and 4 accordingly, and moved to the supplement Fig. 3b (now supplementary fig. 2).

Page 9, lines 24âĂŘ32: These are results. Moved into a new paragraph in the results (par 3.2.1).

Page 10, lines 2 and 26: I cannot find the Supplementary Fig. 1 and Fig. 2. We apologise for the missing of supplementary material. There must have been a problem when we uploaded those files as we were not aware they were missing. We have now included both supplementary figures.

Page 10, lines 4âĂŘ5: “In general, foraminiferal assemblages do reflect the geomorphology of the six voes (restricted vs. unrestricted basins) and the seaward gradient in OM and OC distribution (Figs. 4 and 5).” The links between the foraminiferal assemblages and the distribution of OM and OC are neither easily seen from Figs 4 and 5, nor from the descriptions in the following sections. If the authors can show that the statement above actually holds, they should provide some clearer justifications. Under the light of the referee’s comment, we added canonical correspondence analysis of our dataset (foraminifera relative abundance + 10 env parameters: WD, BWT, BWS, O2, IC, OC, LOM, ROM, ïĄď13C, % Clay) to better constrain the relationship between environmental parameters and benthic foraminifera assemblage distribution and better

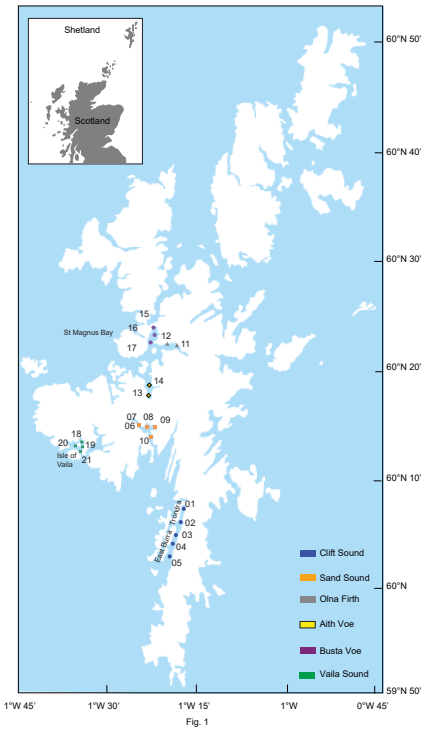
illustrate the links between forams and OC (par. 3.2.1 and par. 4.3 and Fig. 4)

Page 13, Conclusions, lines 28 and 32: The usefulness of benthic foraminifera as bioâĂŘindicators for OC is mentioned in the abstract, in the aims of the study, and in the conclusions but it is not addressed in the discussion. Hence, the importance of foraminifera as bioâĂŘindicators for OC in the present study should either be tuned down, or it should be thoroughly addressed in the discussion with concrete, quantitative, examples illustrating how they can be used. Following the referee’s comment, we expanded the discussion about the relationship between forams and OC to better illustrate how benthic foraminiferal assemblages can be used as indicators of past changes in OC deposition and accumulation in marine sediments.

Page 17, Fig. 2 caption. Please add that the CTDâĂŘdata are from August 2009, whereas the sediment samples for the present study were collected in August 2015. Done. Pg. 20 Line 11.

To summarize, this is a generally well written manuscript on a timely topic which should be of interest to the readers of Biogeosciences. The figures and tables are all needed and wellâĂŘpresented but some should be adjusted to show the postulated relationships between the benthic foraminiferal assemblages and the associated geochemical data. If possible, it would be helpful for the reader if Fig. 1 is modified so it indicates the difference between unrestricted and restricted geomorphologies of the voes. We thank the referee for constructive comments and this commendation. We have modified Fig. 1 to better illustrate the geomorphology of each voe and extended the discussion regarding the links between foram assemblages and environmental parameters. Additionally, Suppl. Fig. 1 illustrates type of soils in Shetland and % TOC in soils.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2019-125/bg-2019-125-AC2-supplement.pdf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Scotland
St Magnus Bay
Isle of Vaila
East Burra Firth
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Clift Sound
Sand Sound
Olna Firth
Aith Voe
Busta Voe
Vaila Sound
60°N 50'
60°N 40'
60°N 30'
60°N 20'
60°N 10'
60°N
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1°W 45'
1°W 30'
1°W 15'
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0°W 45'
Fig. 1

Fig. 1.

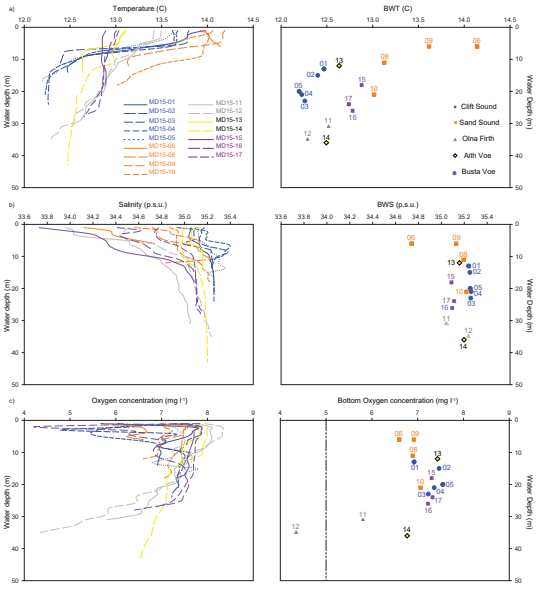

Fig. 2

Fig. 2.

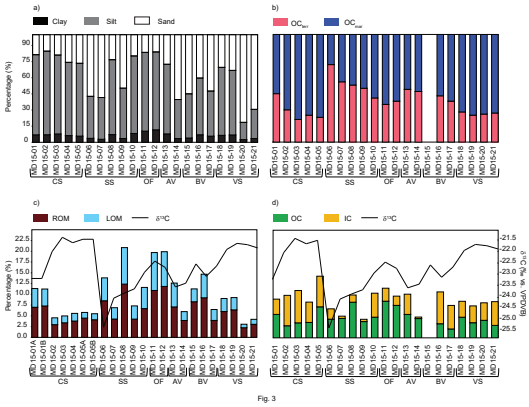

Fig. 3

Fig. 3.

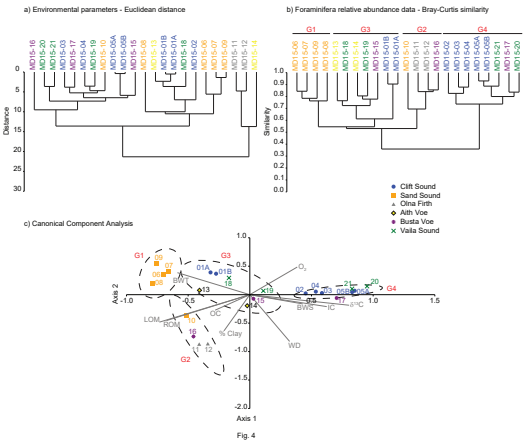

Fig. 4

Fig. 4.

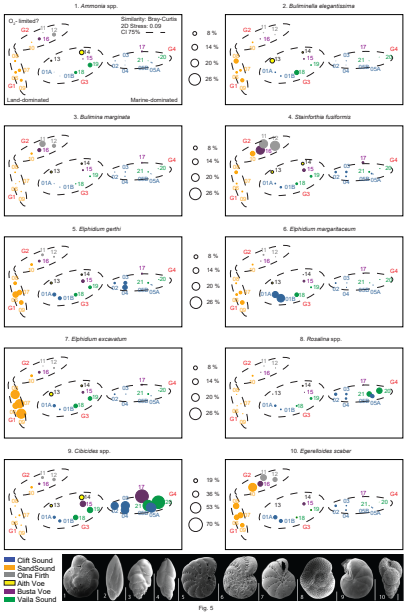

Fig. 5

Fig. 5.

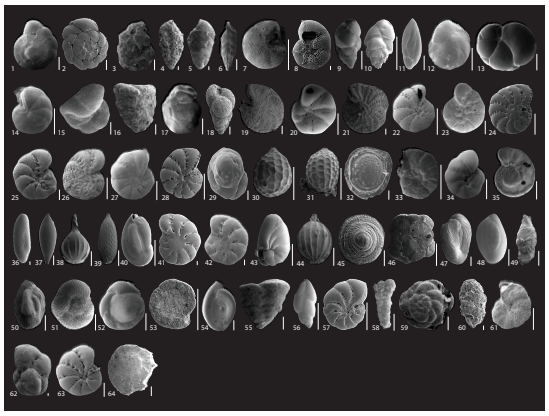

Fig. 6.