

Dear Editor,

Below you will find the our response to the reviewers comments to: Geochemical consequences of oxygen diffusion from the oceanic crust into overlying sediments and its significance for biogeochemical cycles based on sediments of the NE Pacific

Gerard J. M. Versteegh et al.

In general, we followed all suggestions for improvement made by both reviewers. Apart from many small adjustments to the text the larger changes are as follows:

- The main changes are that we considerably expanded upon how the manuscript relates to earlier research on this topic and notably the research on the oceanic central gyres.
- We revised a considerable part of section 4.1 on pore water oxygen, clarifying questions on the oxygen state in the deepest sediments.
- For section 4.2 on pore-water nitrate, we added a global perspective of nitrate profiles in marine sediments and under what circumstances these sediments are nitrate sinks or sources. We provide a general subdivision in eutrophic regions with sediments becoming anoxic at depth and be, more mesotrophic regions with sediments becoming at most suboxic, and oligotrophic regions with sediments entirely oxic. This expansion also addresses the comment made by both reviewers that a larger perspective should be added to the paper.

Below you will find a detailed account of all replies to the reviewers, with the line numbers referring to the manuscript as it has initially been submitted. You will find the reviewers comments in black, our responses in blue.

on behalf of the authors,

sincerely yours,

Gerard Versteegh

RC1: 'Comment on bg-2021-112', Charles Wheat, 19 May 2021

This is a nice contribution that should be published. The interpretation is sound, but some of the wording that describes the interpretation should be changed to match the exact meaning. While I know what the authors are trying to convey, some of the wording isn't exactly correct. There are some newer publications that should be examined especially those by D'Hondt and his collaborators. Even though there are a lot of suggested changes, most changes are related to word choice and if I didn't provide an accurate response, please change the sentence so that others will understand the point. I consider my suggestions to require minor modification and the manuscript should be published without the need to send it back to me. Geoff Wheat

21 This is especially the case where sediments are thin or in the proximity of faults. Also in the middle of gyres e.g. D'Hondt papers and IODP Exp. 329.

[We added 'such as in the middle of gyres'.](#)

28 basement becomes a nitrate source. The basement is not a source of nitrate. The sediment is a source of nitrate to the basement but I understand that later in the paper you note that the nitrate in the basaltic formation fluid is higher than the concentration in pore waters. Nevertheless, this sentence needs to be fixed.

[We fixed this by rephrasing into: ' and nitrate diffuses from the basement fluid into the sediment'](#)

Abstract in general - first describe completely the oxic situation, then describe the suboxic condition. Currently the text goes back and forth.

[Has been fixed.](#)

40 Most of the ocean floor has cooled over long periods and conversely, most ventilation of the basaltic crust occurs at low temperatures. What are long periods? Crust that is 0.5 Ma is often very cool.

['long periods' has been changed into "over time"](#)

47 replace poor with low

[done](#)

50 a more recent paper by Hulme and Wheat- Hulme, S. M., & Wheat, C. G. (2019). Subseafloor fluid and chemical fluxes along a buried basement ridge on the eastern flank of the Juan de Fuca Ridge. *Geochemistry, Geophysics, Geosystems*, 20, 4922–4938. <https://doi.org/10.1029/2019GC008408>

[has been added](#)

58 is available it becomes - replace it with dissolved oxygen

[done](#)

69 benthic consumption deeper into the sediment - needs a reference – Steve Emerson and or Jim Murray did a lot of this work decades ago.

[added Emerson and Hedges, 2003.](#)

77 add Orcutt et al. 2013. Why single out these two locations where as the central gyres are DO depleted (IODP Exp. 329)??

[has been added](#)

83 In this zone of upward diffusing oxygen, oxygen exposure time of OM decreases upward from the sediment-basement interface to the point of DO depletion; however, in the case of a completely oxic sediment column, oxic conditions have persisted since deposition.

The statement after 'however' is only true if the sediment column or the bottom waters have always been oxic. However, during the past, bottom water DO levels have been temporarily considerably lower than today and carbon flux to the sediment may have been higher. As a result, the suboxic zones in the sediment may have expanded and sediment columns which are completely oxic today may not have been so in the past. With water entering the basement having significantly reduced DO levels and oxygen consumption in the basement, it remains to be seen if on their way through the porewater in the basaltic basement has become (regionally) anoxic and conversely, oxygen diffusion from the basement into the sediment (regionally) ceased.

To take this into consideration we didn't change the second part of our statement as suggested.

86 - Need to rethink the minimal aspects as there has been a lot of work related to 329 and a similar study led by D'Hondt in the Atlantic gyre (post 329)

We changed the statement by acknowledging the more recent developments and increase in understanding, adding also D'Hondt et al., 2015, 2019 and Morono et al., 2020.

94 - I don't think Ziebis hit basement and it was a piston/gravity coring expedition. Orcutt et al 2013 was drilling related in North Pond.

This statement is about ex. situ measurements and not about hitting the basement and Ziebis et al., 2021 did just that. We added Orcutt, 2013 as it is also a good example.

98 2018) thus ----- 2018), thus
changed

99 sedimentation and seawater circulation within the upper basaltic crust that delivered dissolved oxygen to the overlying sediment which penetrated the entire sediment column or at least to the deepest sediment recovered.

changed

101 long periods of oxidation
changed

102 phenomenon in abyssal ocean deposits - again Exp. 329 papers. Better to start here and go down the list. There are a lot of relevant papers related to the Pacific work and the more recent work in the Atlantic.

[https://scholar.google.com/citations?](https://scholar.google.com/citations?hl=en&user=n57iAiYAAAAJ&view_op=list_works&sortby=pubdate)

[hl=en&user=n57iAiYAAAAJ&view_op=list_works&sortby=pubdate](https://scholar.google.com/citations?hl=en&user=n57iAiYAAAAJ&view_op=list_works&sortby=pubdate)

This has been modified acknowledging the inferred widespread occurrence of completely oxic sediments in the oceanic gyres as based on oxygen measurements on sediments and modeled by D'Hondt et al., 2015 and updated by D'Hondt et al., 2019.

109 has been ---was
changed

114 the current carbonate compensation
changed

118 the basaltic crust – the oceanic crust is made up of basalt and the overlying sediment
changed

128 Sediments have been - Sediment was
changed

129 cores consist generally of stiff and compact brown clays with color depending on the MnO₂ contents. For example, less MnO₂ (< concentration) resulted in a lighter brown color and more MnO₂ (> concentration) resulted in a darker color

changed

142 pressure) and was calculate
changed

154 have been - were – replace all and the have not been to were not
changed

204 For most oceanic sediments oxygen is high at the sediment–water interface and steeply decreases to zero at depth (e.g., 205 Wenzhöfer and Gludd, 2002) due to mineralization of organic matter (OM - this reflects a portion of the ocean – the gyre are huge - you should re-think this statement.

We rethought this statement and took into consideration D’Hondt et al., 2015 who estimated that that 9-37% of the sea floor has sediments that are completely oxygenated. This leaves 63-91% of the sea floor where oxygen concentrations decrease downwards to such an extent that oxygen becomes depleted in the sediment at depth. This can be shallow in the shallower and more productive sites or at tens of meters below the sediment surface in the oligotrophic gyres at large water depths. We modified the statement by removing ‘steeply’ and adding the estimate of D’Hondt et al. that 63-91% of the sea floor doesn’t have oxygen throughout the sediment.

209 consumption rates are low
changed

221 with a suboxic zone with a second oxic zone
changed

233 In the case where oxygen consumption exceeds supply
changed

245-255 – too much emphasis is placed on the “measured” sediment thickness. The basaltic crust has hills and valleys at many different scales included at the scale that the sonar measurements were taken that interrogate a large footprint. Ship mounted sonars are insensitive to variations that one might consider for a basaltic mound or a depression.

The information on sediment thickness is based on both parasound and seismic profiles (using a 100 m long streamer chain for signal detection and a GI airgun), and thus not only on ship mounted sonars. As such the measured sediment thicknesses are of sufficient accuracy to support the discussion. We added this extra information on the quality of the seismic profiles to the material and methods section, and had another critical look at the sediment thicknesses.

259 Especially in combination with extension, pore volumes may increase, so that it is conceivable that faults increase sediment permeability – there are no data to make this assertion or references. Even if the permeability is slightly increased this does not affect the diffusion of oxygen. Diffusion of DO is affected by porosity and tortuosity but you have no measurements and no data to suggest this permeability statement as fact. Odds are that the seafloor is not flat and the core was taken neat a topographic high that was not identified in the sonar data that encounters a wide swath and does poorly in rough terrain and against seamounts.

Indeed we have no data to further support our statements. However, upon conceptualizing we should start with the most likely explanation (applying Ockhams Razor) providing an hypothesis which is falsifiable by further research. We observe that near faults, oxygen diffusion into the sediments from below seems enhanced and the obvious hypothesis is that this relates to fault activity. Possibly, some of these faults are extension faults, whereby the extension creates more space between the sediment particles resulting in faster diffusion.

271 Over time, the reactivity of the basement decreases as does temperature – not necessarily so. Reactivity could likely increase with age because of cracking and temperature increases with age

and because sediment thickness increases with age and acts like a blanket, warming the basaltic crust.

ah, yes, fully agree. The statement has been deleted.

275 As such it is conceivable that lateral oxygen diffusion, perpendicular to this venting, contributes to the upward oxygen profile for 69SL resulting in sediment columns in proximity of these venting systems that may be entirely oxic, possibly overruling the effect of sediment thickness. I don't see it. 69SL looks perfectly diffusional without any lateral interaction. While the data are not as monotonic as other profiles, the idea of invoking lateral flow means that you have lost. You have just introduced multiple degrees of freedom in a one-dimensional data set (barring figure 8). Also consider diffusion does not necessarily result in a linear concentration especially if there are changes in tortuosity or porosity. In addition, lateral diffusion would not be point source; however, the slight deviations would require a point source if diffusion or advection was the driving force. Also there is no force that would drive lateral advection. Thus I don't see the need to invoke lateral forces unless you can physically/mathematically prove it.

We see the point. We included this since we may expect the diffusion to be perpendicular to the highest concentration difference. This means that for the sites where the basement fluid has a vertical component (e.g. where fluid enters or leaves the basaltic basement, diffusion will have a horizontal component. For a relatively homogeneous sediment and minimum oxygen levels in the upper 5 m, we may expect that this horizontal component could reach as far as the sediment thickness minus a few meters, which in case of 69SL would be about 65 m. Indeed it remains to be seen if 69SL was taken in such close proximity to the site of venting. We still need an explanation for the high oxygen levels in 69SL. These can't be explained by a point source.

283 to see this – to observe this
changed

286 We find this back in the .. This result was observed in the multi core data
changed

289 OM mineralization slows down with
changed

297 have a relatively constant nitrate concentration – constant to what??
constant concentration is used in absolute sense (in $\mu\text{mol/L}$), otherwise it would be a 'constant relative nitrate concentration'

298 It also implies that the seismic-based estimates of sediment thicknesses must be relatively accurate.

It is not clear to us what has to be changed here.

300 This stability of nitrate concentrations at the sediment–basement interface contrasts with the variability of inferred oxygen concentrations at this interface suggesting very different dynamics such as a much stronger influence of processes in the basement on oxygen concentrations. - This could be true or it could be a result of the gradients and the higher diffusion coefficient for DO than nitrate. You will have to calculate the flux.

This is comment not clear to us. 1. gradients of what, 2. calculate fluxes of what? We neither know porosity nor tortuosity of the sediment.

317 edit
changed

335 the Wheat and Fisher paper is a little out of date given a better analysis in the Wheat et al EPSL paper in 2017. Cool seafloor hydrothermal springs reveal global geochemical fluxes that shows that the nitrate is the same as bottom seawater. However, this paper suggests that the nitrate concentration is the same as bottom seawater. Note that the Wheat et al 2020 paper in G-

cubed (North Pond) shows a higher nitrate concentration in basaltic formation fluids than bottom seawater. This one is more appropriate to your statement.

We added the Wheat et al 2020 paper

A good paper to check relative to the nitrate story is Wankel, S.D., Buchwald, C., Ziebis, W., Wenk, C.B., and Lehmann, M.F., 2015. Nitrogen cycling in the deep sedimentary biosphere: nitrate isotopes in porewaters underlying the oligotrophic North Atlantic. Biogeosciences, 12:7483–7502

Has been added

341 – this is the same as the pore waters drilled on IODP Exp 336, in which there is one profile with measurement Mn and none with Fe.

This is the profile for U1382B. As far as we know these data are only available from the Janus Database (<http://www-odp.tamu.edu/database/>). We added a remark to this observation.

362 water oxygen content – not correct in the sense that the crustal fluid is bottom seawater that is slightly aged (thousands of years) and deep-water DO changes on much longer time scales than a few thousand years.

However, there is a close link between marine production at the sea surface and oxygen consumption at the sea floor and conversely in it as well. This can change already from year to year but also may follow longer oscillations. These annual to decadal variations are likely to appear less pronounced in the crustal fluid due to the much larger time path involved in the transport of oxygen through the basalt, its diffusion through the sediment and ultimately its arrival at the site of consumption. We modified removed this statement to avoid further discussion.

372 movement -- diffusion
changed

374 – would help to incorporate thoughts from D'Hondts work in the comparison.

Yes, that would be interesting indeed. However, we consider a discussion on the degradation rates of the organic matter out of the scope of this paper. We have not investigated why oxygen profiles are quasilinear in the lower oxygen profiles, we only observe this in some cases - if this is due to the nature of the OM in these sediments, accessibility to degradation or to limitation by diffusion (as discussed by D'Hondt et al., 2019 doi: 10.1038/s41467-019-11450-z).

We changed the text to avoid the idea that we only consider the persistence to degradation of the OM as a variable.

376 reaction time is long and may equal sediment age - need to reword
changed to better illustrate the long duration of oxic conditions

376 Here, not oxygen exposure time is limiting the ... Here, oxygen exposure time is not limiting the
changed

384 Considering the large amount of time available, --while I agree the rest of the sentence, I don't follow the time statement. New DO is constantly be fluxed into basal sediment. The OC in basal sediment is refractory resulting in slow rates of reaction. I know what you are saying, but there must be a better way to say it.

changed

Line 395 equal flux - No flux????
changed into no flux

Section 4.6 - Introduce figure 8 in this section.
done

411 organic carbon mineralization is exhaustive – OM is not exhausted. There is some there. Only the more refractory compounds remain.
changed into very low

412 Nitrate production is larger than nitrate removal via denitrification – With ample DO why would there be denitrification?
changed

419 (see conclusion 4). -- add in the sampled region.
added

Conclusions – Much of the conclusions are a re-hash of the paper. The first 7 items should be shortened to get to the main point but with a broader brush as to how this work will be applicable to other areas and with how we think of global systems. The last two items #8 and #9 are good in that these statements go beyond the immediate data and area of study. Think big.
The conclusions 1-6 have been shortened.

The following considerations have been added.

The widespread interaction between basement fluid and the overlying sediment through diffusion of dissolved substances adds an important dynamic component to the geochemical interaction of sediment, basement and deep ocean (as compared to direct exchange between the surface sediment and the ocean bottom waters). This is most easily illustrated by imagining changes in the ocean bottom water oxic state:

The deep oligotrophic and fully oxidized ocean sediments possibly account for 30-50% of the ocean floor (D'Hondt et al., 2015). Most of the rest of the deep ocean is covered by sediments with oxic surface sediments and probably also oxic bottom sediments. All these sediments collect oxidized substances and store them for long periods of time.

Fig 2 and 3 - It would be nice to list the estimated sediment thickness for each core added and captions have been adapted accordingly.

RC2: 'Comment on bg-2021-112', Beth Orcutt, 21 May 2021 reply

General comments

This manuscript describes porewater and solid phase profiles of oxygen, nitrate, manganese, cobalt, and nickel in oligotrophic sediment within the German nodule exploration block of the Clarion Clipperton Zone in the northern Pacific Ocean. The authors document variable profiles of oxygen, with fully oxic sediment profiles in relatively thin sediment profiles near seamounts and thicker sediment packages overlying presumed subsurface faults. The profiles of oxygen indicate diffusion from the seawater-sediment and the sediment-basement interfaces, indicating oxic conditions in basement in this region, as had been documented before. By contrast, thicker sediment packages away from these features exhibit zones of suboxic conditions where dissolved manganese increases from solid phase Mn oxide dissolution, which also leads to mobilization of cobalt. It is presumed that oxygen also diffuses from basement into deeper layers of sediment, but the coring depths were too shallow to confirm this. The main points of the manuscript are that: 1) the depth of oxygen penetration from the seafloor is somewhat uniform, the depth of oxygen diffusion from basement is more variable and suggests highly variable basement oxygen concentrations, 3) nitrification in sediment can lead to a nitrate source to basement fluids in some instances, 4) cobalt and other redox sensitive elements are remobilized due to suboxic conditions and do not reflect initial burial conditions.

While this manuscript is well written and based on a very impressive dataset, I was disappointed that the authors did not put the results into a larger context of what is known about sediment-basement interactions at other locations. The results are described in exquisite detail, but the discussion section lacks comparison of these profiles and their patterns to recent comparable studies from the equatorial Pacific (Wheat et al. 2019, DOI: 10.1029/2018GC007933) or the south Pacific Gyre (D'Hondt et al. papers) or from the western North Atlantic (D'Hondt and colleagues) or from the flank of the Mid-Atlantic Ridge (Orcutt et al., 2013; Wankel et al. 2015, Ziebis et al. 2012, Kiel Reese et al. 2018). For example, how do the authors claims about sediment nitrate being a source or sink to basement compare to inferences from these other studies, besides just the earlier work from Fisher and Wheat 2008? (Disclaimer that this reviewer is a co-author on some of the work suggested for consideration and, thus, this suggestion may be viewed as a conflict of interest).

[We expanded our discussion and better integrated our comparison with published literature:](#)

[Putting together the nitrate concentrations through marine sediments there seem to be three kinds of profiles. The first situation occurs in the more eutrophic ocean and coastal margins, where sediments get anoxic at depth and \$\text{NO}_3^-\$ completely disappears from these anoxic sediments \(e.g. Froelich et al., 1979\). As \$\text{NO}_3^-\$ is absent from the deeper sediment, a flux of \$\text{NO}_3^-\$ will occur from the basaltic basement upwards, into the sediment where it gets consumed. Towards increasingly oligotrophic conditions, usually also with slower sedimentation, \$\text{O}_2\$ can diffuse deeper into the sediment. Denitrification rates \$\text{NO}_3^-\$ decrease conversely, the depth at which \$\text{NO}_3^-\$ is completely consumed increases as well e.g. just outside the South Pacific Gyre \(SPG\) core SPG-12 \(D'Hondt et al., 2009\), IODP 329 Site U1371 \(D'hondt et al., 2015\) and Western N. Atlantic KN223 Site 10 \(Buchwald et al., 2018\).](#)

Wheat, C. G., Hartwell, A. M., McManus, J., Fisher, A. T., Orcutt, B. N., Schlicht, L. E. M., Niedenzu, S., and Bach, W.: Geology and fluid discharge at Dorado Outcrop, a low temperature ridge-flank hydrothermal system, *Geochem. Geophys. Geosyst.*, 20, 487–504, doi: 10.1029/2018GC007933, 2019.

[A second situation occurs where \$\text{NO}_3^-\$ remains present throughout the sediment. It seems that this situation occurs with decreasing productivity/sedimentation rate and denitrification in the anoxic](#)

zone reduces such that it is insufficient to create a zone without NO_3^- . This occurs at e.g. at Dorado Outcrop on the East Pacific Rise (Wheat et al., 2019). Here, Mn reduction starts when NO_3^- gets below 10-20 $\mu\text{mol/kg}$. In such cases, the redox succession probably remains suboxic with Mn reduction, and doesn't enter the zone of Fe reduction. In the CCFZ cores we observe a linear negative relation and 1:1 relation between NO_3^- and Mn^{2+} concentrations (Fig 6). In the East Pacific Rise (Wheat et al., 2019) dissolved Mn appears if NO_3^- gets below 25 $\mu\text{mol/kg}$ and NO_3^- becomes depleted if Mn^{2+} concentrations are near 70 $\mu\text{mol/kg}$ so that a 1 μmol increase in NO_3^- results in a 2.8 μmol decrease in Mn^{2+} . As long as sedimentary NO_3^- remains lower than the NO_3^- in the basaltic basement, NO_3^- diffuses from the basalt upwards into the sediment. However, as maximum Mn^{2+} concentrations decrease, minimum NO_3^- concentrations increase and eventually, NO_3^- concentrations remain higher in the sediment than in the basaltic basement establishing a net NO_3^- flux from the sediment into the underlying basaltic basement. This is most probably the case at IODP 329 Site U1370 at the edge of the SPG (D'hondt et al., 2015).

The third situation starts if Mn^{2+} approaches zero and the sediments become entirely oxic and denitrification ceases. This situation is reached in the CCFZ, NO_3^- concentrations reach 52 $\mu\text{mol/l}$. Mewes et al (2014) find a slightly higher threshold of 60 $\mu\text{mol/l}$ (Fig. 6 green dots). In all these cases, sediments are a NO_3^- source to the basaltic basement. This is also observed at North Pond, Western Flank of the Mid Atlantic Ridge, at IODP 336 sites U1382B, U1383D, U1384A (Wankel et al., 2015) and in the latter study maximum NO_3^- concentrations increase with decreasing reaction rates.

We observe that from this situation of minimum O_2 concentrations just above zero, sediments exist with much higher minimum O_2 values. We infer that towards increasingly poor settings such as towards the centers of the oceanic gyres, minimum O_2 values increase and despite lacking denitrification, maximum sedimentary NO_3^- concentrations decrease. This situation is encountered in the SPG, cores SPG 1-11 (D'Hondt et al., 2009) and at IODP 329 sites U1365 to U1369 (D'hondt et al., 2015) where maximum NO_3^- concentrations decrease towards the SPG centre. We observe that maximum NO_3^- concentrations remain close to those in the bottom waters and in the basaltic basement so that fluxes from the sediment to the basaltic are virtually absent and reduce towards the core centres.

Thus, on a global scale, the eutrophic regions and continental margins bear sediments with complete denitrification in the sediment and the basaltic basement is source of nitrate to the sediment. More mesotrophic conditions and at larger distance from land where sedimentation rates are lower, a zone occurs where denitrification is reduced such that NO_3^- remains available throughout the sediment. At the eutrophic side of this zone denitrification is sufficient to reduce sedimentary NO_3^- below basaltic basement values and a nitrate flux exists from the basaltic basement into the sediment. In the more oligotrophic side of this zone, denitrification is reduced such that NO_3^- values in the sediment remain higher than in the basaltic basement and the basaltic basement is a NO_3^- sink. Towards the oligotrophic oceanic gyres, the sediments become entirely oxic, and denitrification ceases. If the sediments are just oxic throughout, maximum NO_3^- concentrations approach those of sediments with a minimal suboxic zone. However, further to the oceanic gyres, increasing oligotrophy also increasingly limits the maximum NO_3^- concentration that can be reached will reduce again and approach (but still exceed) those in the bottom waters and basaltic basement and fluxes of NO_3^- from sediment to the basaltic basement (as well as to the bottom waters) reduce.

I am also a bit perplexed by the inference of the oxygen concentrations at the sediment-basement interface based on this study. In Table 2, the inferred basement oxygen concentration at one site is likely higher than bottom water oxygen concentration in this region (note: this isn't reported in the paper, but looking at the CTD profiles in the cruise report, along with WOCE datasets, indicates a regional bottom water concentration closer to 200 μM). Likewise, extrapolating the nearly linear profiles to the inferred basement depth in other profiles leads to similarly perplexingly high concentrations. The discussion section on porewater oxygen does not address this issue.

The data we report are based on gravity and piston cores. For both coring devices the uppermost sediment mostly gets lost upon recovery. Examining the World Ocean Atlas 2018 we arrive at 162 $\mu\text{mol/l}$ for the region which is close to values reported by Mewes et al., 2015 and Mogollón et al.,

2016 but these are higher than the value reported by Volz et al., 2018). Analyses of accompanying box cores shows that the values drop to those reported in the gravity- and piston-cores presented here within the top 5 cm. We added this information to the text.

Indeed, the inferred O₂ concentration at the sediment/basalt interface for core 69 is close to that of the bottom water concentrations. This is easy to explain if we accept that the site of inlet is close to the core site so that there has been virtually no drop in porewater oxygen concentrations on its way from the site of inlet to the core site. We took a closer look at the inferred sediment depths and the obtained regression lines, for all cores and took into account better estimates of sediment thicknesses. We added estimates of O₂ concentrations at the sediment/basalt interface for the other cores in Table 2, where possible and discuss this in the text. Site 69 provided the highest O₂ concentration (156 μM) inferred for the sediment/basalt interface. This equal to just below the concentration in the bottom waters. Core 69SL is taken close to a seamount which is a potential site for basement fluid intake. As such the waters circulating through the basement below 69SL must have entered the basement relatively recently and the site of inlet may be relatively active so that it may be expected that at the sediment/basement interface the O₂ concentration is close to that of the bottom waters.

Continuing the oxygen theme, the variable depths of the suboxic fronts are really intriguing to me. The authors state that the variability in the shallower front being related to variability in bottom water oxygen conditions. I am curious why the authors do not consider variable bioturbation impacts, a non-steady state phenomenon, also as a possible cause. The highly variable depth of the deeper suboxic front is also fascinating, and I'd like to see more discussion about that. Bioturbation appears to be highly variable in the German license area of the CCFZ but reaches mostly to only 7 cm and occasionally to 13 cm (Volz et al., 2018) and as such are not an explanatory variable to understand why in our cores the suboxic front varies between 10 cm and 350 cm below the sea floor. Even if we underestimate bioturbation depth by a factor 2 this would make no difference. For this reason, bioturbation was not taken into consideration in the paper. We included a statement on this now.

The highly variable depth of the deeper suboxic front is a direct consequence of the highly variable oxygen fluxes from the basaltic basement into the sediment. These in turn depend on the degree to which the basement fluid penetrates through the basement (flow rate), the length of way from the inlet to the site of diffusion into the sediment and the reactivity of basement and sediment on the route from the inlet to the lower suboxic front. There are too many uncertainties in these parameters to predict what will be observed in reality. We only can observe the positions of the lower oxidation fronts, infer from this oxygen concentrations at the basement/sediment interface and deduce from this that the oxygen flux must be very variable.

So, overall, I find this to be an interesting study, but I would like to encourage the authors to spend a bit more time putting the results in a larger context of what is known. Below I also highlight a few specific areas that need attention to improve clarity:

Specific comments

Line 95: I am not sure that the Fischer et al. 2009 and Ziebis et al. 2012 citations are appropriate references here for a comment about measuring oxygen in ocean drilling program cores, as these studies were on gravity core samples. More appropriate references would be D'Hondt et al. 2015 for the South Pacific Gyre and/or Orcutt et al. 2013 for North Pond, which are the only two drilling expeditions with porewater oxygen data.

Has been corrected

Line 171: I think "nearly linear" might be the more appropriate phrase here, since some of the deeper oxygen profiles show some curvature in their profile below the minimum oxygen depths.

Changed

In the methods and/or acknowledgement section of the paper, the authors should state that the working areas are within the area contracted by the International Seabed Authority to the German Federal Institute for Geosciences and Natural Resources for exploration of polymetallic nodules.

Done

Table and Figure comments:

- overall, there are several inconsistencies in the labeling of sites between tables and figures. please carefully check.

Done

Table

- consider adding an additional column, or to modify the core name column, to indicate the "SM" and "F" categories of the cores used in the figure.

We added these designations to the core names

Figure 1.

- there seems to be a mismatch in the shapes used to indicate the various working areas in panel B compared to the zoomed-in panels. For example, panel B indicates WA-1 is a vertical rectangle shape, whereas the zoomed in panel indicates a horizontal rectangle shape. Also the seamounts shown in the zoomed in panels do not match the features indicated for WA-1 and 2 in panel B. Please clarify.

The lower four panels are cut-outs of the working areas, taken such to best illustrate the bathymetry in approximate distance, and of relevance to the core locations (so far available). A reference to the original publication has been added).

- consider using different colors and/or shapes to indicate the core locations being either "SM" or "F", to aid in understanding.

The symbols have been modified

- Please indicate in the figure caption what software and datasets were used to create the bathymetric maps, or if the maps are already published. Also indicate what the contour spacing is, as it is hard to discern the small text in the figures.

Done

Figures 2-4: consider using different symbol shapes, in addition to color, to distinguish between variables in plots. This can aid with interpretation for those with color sensitivities or when viewing printed in black and white.

Done, we now use open and closed circles and triangles.

Figure 4:

- panel a: should the label be "9KL" instead of "9SL"?

corrected

- panel c: should the label be "42SL" instead of "42KL"?

corrected