

Dear Editor and Reviewers,

Thank you for handling our manuscript and for the reviewers' thoughtful comments. We appreciate the time and attention invested in evaluating our work. We have revised the manuscript accordingly and believe the changes will improve its clarity and quality. Below, we provide a detailed, point-by-point response to all reviewer comments. Each comment is reproduced in full, followed by our corresponding response. Because a revised manuscript has not yet been requested at this stage, page and line numbers for a revised version are not included here.

Sincerely,

Izabela De Mey-Śnieżyńska on behalf of all the co-authors

## RESPONSE TO REVIEWER #2

We thank Reviewer #2 for the careful and constructive evaluation of our manuscript. We agree that several aspects of the manuscript require clearer geochemical support and more precise terminology, particularly regarding pockmark activity, porewater freshening, and the interpretation of GDGT distributions. In response, we will revise the manuscript to strengthen site characterisation, incorporate porewater chloride, sulphate, and methane profiles, and distinguish more clearly between direct observations and interpretation.

*Reviewer comment 1: As noted by the authors in the introduction, pockmarks can be both active and non-active. Apart from Supplementary Table 1 where a qualitative description is given for the sites, quantitative constraints to what extent the pockmark sites display porewater freshening, SGD, methane ebullition or dissolved gas seepage are lacking. Furthermore, as it seems that some of these sites have been investigated previously, it would benefit the study if some data is presented to confirm the duration of methane seepage or SGD over the years. Such porewater chemistry data is rather essential to support statements in the manuscript such as "which may reflect the dynamic geochemical conditions characteristic of these gas systems" (line 698), "likely result from SGD-marine water mixing within a shallow redox-transition layer" (line 822), "Results suggest that submarine groundwater discharge and pockmark activity drive geochemical conditions and microbial distribution." (line 876) and "site-specific hydrographic conditions associated with SGD" (line 885).*

**Author response 1: We agree that clearer and more quantitative site characterisation is essential. Studies of the deep-water (>70 m) pockmarks in the MET1, MET3, and MET4 areas of the Gdańsk Basin are relatively recent; except for MET1-MP, these sites were first identified in 2019 and investigated during 22 cruises between 2019 and 2025. In the revised manuscript, we will therefore expand the site descriptions using available geophysical and geochemical evidence, including morphology, activity status, and porewater chloride, sulphate, and methane profiles. Published studies already document porewater freshening in MET1 sediments and persistent methane seepage at MET1-BH, while acoustic evidence also supports methane occurrence at MET1-MP. For MET3 and MET4, the currently published evidence is more limited, and we will state this explicitly. A separate manuscript on the geomorphology, activity, and origin of all studied pockmarks is currently in preparation. To support the present activity classification, we will add supplementary raw Simrad EK80 echograms illustrating the lack of ebullition at MET3 and localized bubbling at MET4. Where the evidence remains incomplete, we will make this clear and avoid overinterpretation.**

**Author changes in the manuscript:**

- We will expand the site descriptions using available geophysical and geochemical evidence.
- We will add porewater chloride, sulphate, and methane profiles for all studied stations.
- We will highlight references documenting MET1 freshening and methane activity, and supplementary echograms for MET3 and MET4 where published evidence remains limited.

*Reviewer comment 2: To what extent do the authors think that the considerable variability and lack of compositional differences (as described in Figure 3) can be explained by accounting for present-day porewater chemistry. For example, reference sites might experience methane production and seepage without pockmark formation, and pockmark sites might have been inactive for a long time. Do significant differences arise when active vs non-active seepage sites are compared?*

**Author response 2: We fully agree with the reviewer that present-day porewater chemistry partly, but not fully, explains the observed variability. In the revised manuscript, we will use methane, sulphate, and chloride profiles to distinguish more clearly between active, currently inactive, and reference settings. We also agree with the reviewer that methane production occurs throughout the sediments of the Gdańsk Basin. However, our 2019–2025 datasets reveal distinct geochemical and geophysical differences between pockmarks and reference sites. While the reference sediments contain methane, we have never observed gas ebullition in the area outside of pockmark structures during the mentioned research surveys. Additionally, pockmark sediments generally show higher methane concentrations and a shallower sulphate-methane interface compared with reference sites. We will therefore clarify that methane production occurs more broadly in the Gdańsk Basin. We will revise the text to avoid implying that methane-bearing sediments are restricted to pockmarks, indicating that pockmark sediments exhibit generally higher methane concentrations and distinguishing persistent activity (gas flares) at sites such as MET1-BH from currently inactive settings such as P/MET3.**

**Author changes in the manuscript:**

- We will revise the interpretation of site-to-site variability in light of methane, sulphate, and chloride profiles.
- We will distinguish more explicitly between active, currently inactive, and reference settings.
- We will revise phrases and wording implying that methane occurs only within pockmarks.

*Reviewer comment 3: Line 60: remove “worldwide”.*

**Author response 3: We thank the reviewer for pointing this out. It will be removed.**

**Author changes in the manuscript:**

**-We will remove “worldwide”.**

*Reviewer comment 4: Line 60: Lithosphere could imply that pockmarks can also be formed in non-sediment parts of the lithosphere. Would be more specific here, e.g., use “sediments”.*

**Author response 4: We thank the reviewer for pointing out this imprecision. We agree with the presented reasoning. We will revise the wording to refer specifically to sediments.**

**Author changes in the manuscript:**

**-We will replace the broader term with 'sediments'.**

*Reviewer comment 5: Line 62: “fluid emanation”; perhaps clarify that pockmarks can be formed both due to fluid seepage as well gas seepage?*

**Author response 5: We thank the reviewer for pointing this out. Although ‘fluid’ in physics encompasses both liquids and gases, it can be misleading in the context of our manuscript. We will clarify this wording so that the sentence explicitly refers to liquid seepage and gas seepage, rather than using an imprecise umbrella term.**

**Author changes in the manuscript:**

**- We will revise the sentence to specify liquid seepage and gas seepage explicitly.**

*Reviewer comment 6: Line 68: Suggest to replace “Fluid types” with methane sources or something equivalent.*

**Author response 6: We will revise this wording to make the intended meaning more precise.**

**Author changes in the manuscript:**

**- We will replace 'fluid types' with more specific wording.**

*Reviewer comment 7: Line 90: “(from initiation through expansion to stabilisation)” it is unclear to me what the authors intend to say here.*

**Author response 7: We agree that this phrasing is vague. We will rewrite the sentence to clarify that it refers to the developmental evolution of pockmarks or remove it if it does not improve readability.**

**Author changes in the manuscript:**

**- We will rewrite or remove the sentence for clarity.**

*Reviewer comment 8: Line 94: “Under such conditions” the causal relation between these two sentences is unclear to me. Can the authors elaborate on the link between sediment trapping, porewater freshening and shallow methanogenesis?*

**Author response 8: We agree that the link was not sufficiently clear. We will replace this passage with a clearer and more cautious explanation of how sediment and organic-matter trapping, together with freshened porewater conditions and reduced sulphate**

availability in near-bottom waters, may modify redox zonation and create conditions favourable for shallow methanogenesis.

**Author changes in the manuscript:**

- We will revise this passage to clarify the links and remove the ambiguous wording.

*Reviewer comment 9: Line 188: I suggest to replace “methane bubbling” with methane ebullition.*

**Author response 9:** We thank the reviewer for this suggestion. We agree, and we will replace “methane bubbling” with “methane ebullition” where the intended meaning is upward gas emission from the sediment. Where a more specific hydroacoustic description is needed, we will use wording appropriate to the observed emission pattern.

**Author changes in the manuscript:**

-We will replace 'methane bubbling' with 'methane ebullition' where appropriate.

*Reviewer comment 10: Lines 364-366: report the STDV along with the median and means.*

**Author response 10:** We thank the reviewer for indicating this. We will report the standard deviation with the corresponding median and means where these values are presented.

**Author changes in the manuscript:**

- We will add standard deviation to the reported summary statistics.

*Reviewer comment 11: Figure 2: i) To facilitate easier comparison of the different cores please use the same ranges and ticks for the x-axes wherever possible without losing the downcore trends. ii) For the MET3 TOC figure, why is there no line for the pockmark datapoints? iii) Please elaborate on the error ranges or uncertainties for these plots. iv) In the figure caption “TOC concentrations are consistently elevated in pockmark sediments” > this does not seem to be true for MET3. v) Put the MET1-BH iGDGT plot y-axis to 95 cm to keep it consistent with other subplots.*

**Author response 11:** We thank the reviewer for these detailed suggestions regarding the figures. We will revise Fig. 2 to harmonize axis ranges and ticks, ensure a consistent plotting style, and clarify the error/uncertainty information in the caption. Additionally, we will align the panels for consistency with the other plots.

**Author changes in the manuscript:**

- We will revise axis ranges, ticks, and panel consistency in Fig. 2.

- We will clarify uncertainty/error information in the caption.

- We will revise the caption wording so it does not overstate the visible patterns.

*Reviewer comment 12: Table 1: If I understand correctly, these GDGT-based indices are downcore means per core. If that is the case, please also report the STDEV or something similar to demonstrate the variability.*

**Author response 12: We agree with the reviewer. We will revise Table 1 to ensure that the degree of downcore variation is clearly visible to the reader, for instance, by adding the standard deviations or ranges.**

**Author changes in the manuscript:**

**- We will add a variability metric to Table 1 or show the downcore variability of indices.**

*Reviewer comment 13: Line 473, 528 and throughout manuscript: “sediment types” the phrasing of sediment types may be misleading, I suggest to be specific and say “between pockmark and non-pockmark cores/sites” or anything equivalent.*

**Author response 13: We agree, and we will revise the terminology throughout the manuscript to use the more specific terms 'pockmark' and 'non-pockmark/reference' for cores and sites to ensure clarity for the reader.**

**Author changes in the manuscript:**

**- We will replace the imprecise phrase 'sediment types' with site-specific wording throughout the text, i.e., 'pockmark' and 'non-pockmark/reference' cores or sites.**

*Reviewer comment 14: Line 571: “methane-bearing sediments (pockmarks)” > is it confirmed that all pockmark sites have active methane seepage? Similar comment for line 613 “methane-rich sediments”.*

**Author response 14: Thank you for this important clarification. We will revise the wording so that it does not imply that all pockmarks are actively seeping methane or that methane-bearing sediments are restricted to pockmarks. Methane occurs more broadly in the study area, including in reference sediments, but pockmark sites generally show higher methane concentrations and a shallower sulfate-methane interface, and observed ebullition was restricted to pockmark structures in our surveys. We will therefore distinguish active and currently inactive pockmarks more carefully and reserve “methane-rich” wording for contexts directly supported by the geochemical data.**

**Author changes in the manuscript:**

**-We will revise wording so that methane-bearing sediments are not equated with pockmarks only.**

**-We will distinguish more carefully between active, weakly active, and inactive pockmarks.**

*Reviewer comment 15: Line 637: “in the absence of fluid seepage”, do the authors refer here to methane seepage or SGD?*

**Author response 15: We will specify the relevant process explicitly in each instance, rather than using the ambiguous term 'fluid seepage'.**

**Author changes in the manuscript:**

**- We will clarify whether the text refers to methane seepage, SGD, or both.**

*Reviewer comment 16: Lines 653, 666, 679, 765: „add reference” for statements: “which are characterised by strong SGD”, “pockmark MET4 is characterized by low-intensity SGD”, “the MET3 and MET4 study sites were characterised by stable, non-ebullitive methane emissions”, “the inactive pockmark P/MET3”, and “low-SGD pockmark MET4”*

**Author response 16: We agree that these statements require more precise support. Accordingly, we will revise the wording and provide references where published evidence is available. Specifically, the phrase 'strong SGD' will be replaced by 'significant porewater freshening' and will be supported by citations of previous MET1 studies. The description of MET4 will be revised to refer directly to the freshening observed in chloride profiles, rather than to 'low-intensity SGD' without further qualification. Furthermore, the statements regarding MET3 and MET4 will be updated to more accurately reflect the lack of gaseous activity at MET3 and the presence of localized gas bubbles above MET4, based on split-beam echosounder observations. Likewise, the characterization of pockmarks P/MET3 as inactive and MET4 as influenced by freshening will now be directly supported by the included echograms and chloride profiles. Where published evidence is limited, we will make those constraints explicit to avoid overstatements.**

**Author changes in the manuscript:**

**-We will replace “strong SGD” with “significant porewater freshening” where this is supported by data.**

**-We will revise MET4 characterization to refer directly to chloride-profile evidence. The phrase “pockmark MET4 is characterized by low-intensity SGD” will be replaced by “porewater freshening, as observed based on chloride concentration profiles.”**

**-We will support MET3/MET4 activity statements with added echogram evidence. The phrase “by stable, non-ebullitive methane emissions”, concerning MET3 and MET4, will be replaced by “by lack of gaseous activity in the case of MET3 pockmark and single gas bubbles above MET4 pockmark, as registered by a split-beam echosounder Simrad EK80 before sample collection (echograms presented in the supplementary materials).”**

**-We will make the level of certainty explicit where published support is still limited.**

**-We will add references for the site-specific activity/SGD statements and revised wording where evidence remains limited.**

*Reviewer comment 17: Line 834: “advective flushing sediment layer” it is unclear to me what the authors mean here.*

**Author response 17: We agree that the phrasing is imprecise. By "advective flushing," we intended to describe the advection-dominated transport regime where upward-moving fluids (such as freshened groundwater or methane-bearing fluids) actively displace interstitial water.**

**Author changes in the manuscript:**

**- We will rewrite the sentence for clarity.**

*Reviewer comment 18: In Supplementary Table 1 it seems that a decrease in chloride is used as an indicator for SGD. Are these profiles diffusive or advective? And for the sites with no porewater freshening, does saline SGD occur? Even in the absence of freshwater, advection of saline porewater could still have an important control on the depth of different redox zones, and thus archaeal composition.*

**Author response 18: We appreciate this important point and will now address it more explicitly. In the revised manuscript, chloride depletion will be treated only as an indicator of freshened porewater influence, not as a universal diagnostic of SGD. Where the available profiles allow it, we will describe the transport pattern more specifically. We agree with the reviewer that the absence of chloride freshening does not imply a lack of SGD activity. Upward advection of saline porewater—even when invisible in chloride gradients—remains a critical driver of redox boundary depth, directly shaping the vertical niche space and composition of the archaeal communities across these sites.**

**Author changes in the manuscript:**

**- We will clarify the interpretation of chloride depletion versus broader SGD.**

**- We will describe, where possible, whether individual chloride profiles are more consistent with diffusive or advective transport.**

*Reviewer comment 19: "Lines 648, 651, 674 > reference sources not found" and "Line 705: Table number is missing."*

**Author response 19: We thank the reviewer for pointing out the technical corrections. We will correct these technical issues in the revised manuscript.**

**Author changes in the manuscript:**

**- We will correct the inactive/missing references and add the missing table number.**

*Reviewer comment 20: There seems to be an inconsistency on a few occasions where SGD is used interchangeably to describe fSGD, while in lines 82 to 84 it is acknowledged that SGD can be both fresh or saline (which I fully agree with, although it is naturally a matter of definition). An example is: "SGD alters porewater chemistry through decreased salinity and chloride depletion" (line 98), which would imply that SGD is always fSGD.*

**Author response 20: We agree that the original terminology was inconsistent. In the revised manuscript, SGD will now be defined as the broader process of groundwater discharge to the sea, encompassing both freshened groundwater and recirculated saline porewater or seawater. We will no longer use SGD as a synonym for freshened seepage. Instead, when discussing chloride depletion, we will use more specific expressions, such as "freshened porewater discharge" or "freshened groundwater influence". Additionally, we will clarify the distinction between shallow coastal SGD systems (often nutrient-focused) and the deep offshore freshened discharge settings of our study area. We will revise the site descriptions to reflect that fact in our study area, providing clear descriptions and references, and, where available, clear evidence of freshened groundwater seepage.**

**Author changes in the manuscript:**

- We will revise the SGD definition and terminology throughout the manuscript.
- We will use specific wording for freshened discharge where chloride depletion is discussed.
- We will rewrite lines 90, 94, and 98 to present chloride depletion as a site-specific indicator of freshened influence rather than a universal requirement for SGD.

*Reviewer comment 21: “Freshwater infiltration” (line 32); I suggest to replace this with freshened porewater discharge, freshwater presence or an equivalent, as freshwater infiltration could be interpreted as freshwater infiltrating from the water column down into the core.*

**Author response 21: We agree, and we will revise this phrase to avoid the implication of downward infiltration from the water column.**

**Author changes in the manuscript:**

- We will replace 'freshwater infiltration' with more precise wording, e.g., 'freshened porewater discharge', 'freshened groundwater discharge', or 'freshened porewater seepage' where appropriate, i.e., where chloride depletion is observed in the studied part of the Gdańsk Basin.

*Reviewer comment 22: Line 83: Replace “freshwater groundwater” with freshened groundwater.*

**Author response 22: It will be corrected.**

**Author changes in the manuscript:**

- We will replace 'freshwater groundwater' with 'freshened groundwater'.

*Reviewer comment 23: In the introduction both SGD and methane seepage are discussed and the processes are described. When moving into the GDGT section of the introduction (lines 107-163), only methane and nitrate related GDGTs are described and SGD is disregarded. Is there anything known from literature regarding SGD-derived or influenced GDGTs? Or is there any hypothesis how SGD may impact GDGT presence? If little is known, it would be good to specify that, which only strengthens the motivation for the study.*

**Author response 23: We thank the reviewer for this helpful comment. We agree that the original Introduction did not sufficiently address the possible relationship between SGD and GDGT distribution. Direct evidence for an SGD-specific GDGT signature is still limited, and we will clarify this in the revised manuscript. We will revise the Introduction and Discussion to present SGD as a process that may indirectly influence GDGT distributions through its effects on porewater chemistry, transport regime, redox zonation, and archaeal niche structure, rather than implying a distinct SGD-specific biomarker signal. The newly added chloride, sulphate, and methane profiles will provide a stronger geochemical framework for discussing these controls in our study.**

**Author changes in the manuscript:**

**- We will expand the Introduction and Discussion to address the possible SGD-GDGT connection and to clarify the current lack of evidence for an SGD-specific GDGT signature.**

**-We will revise the Introduction and Discussion to present SGD as a potential indirect control on GDGT distributions.**

*Reviewer comment 24: Line 373: “When normalised to TOC”; which TOC? The LOI-derived TOC?*

**Author response 24: We thank the reviewer for pointing this out. We will identify these values explicitly as LOI-derived where applicable. We understand that direct TOC measurements are preferable. However, due to limited sample volume, these were not available for the full core set. To support the use of LOI-derived values, we compared measured TOC and LOI profiles for representative pockmark and reference samples and found that they show the same vertical trends. We will clarify this more explicitly in the Methods and relevant figure text.**

**Author changes in the manuscript:**

**- We will identify these values explicitly as LOI-derived where applicable.**

**- We will add the comparison between measured TOC and LOI profiles for representative pockmark and reference samples.**

**- We will revise the Methods and figure text accordingly.**

*Reviewer comment 25: Line 373: To what extent (quantitatively) is elevated summed iGDGT explained by elevated TOC contents in general?*

**Author response 25: We thank the reviewer for this important question. In the revised manuscript, we will address this point directly by comparing the downcore distribution of summed iGDGTs with organic matter content. Because direct elemental TOC measurements were not available for the full core set, we use LOI-derived values where applicable and identify them explicitly as such. Comparison of measured TOC and LOI profiles for representative pockmark and reference samples shows the same vertical trends, supporting the use of LOI as a proxy in this context. Based on these comparisons, summed iGDGT concentrations do not appear to be tightly coupled to bulk organic matter content, particularly at the more active sites, and thus cannot be explained solely by elevated TOC. We will revise the Results and Discussion accordingly.**

**Author changes in the manuscript:**

**- We will add the comparison between measured TOC and LOI profiles for representative pockmark and reference samples.**

**- We will revise the Results and Discussion to state that summed iGDGT distributions are not tightly coupled to bulk organic matter content and therefore are not explained solely by elevated TOC.**

*Reviewer comment 26: Line 680: “which could have contributed to the better preservation of iGDGTs” can the authors elaborate on through which mechanism?*

**Author response 26: We thank the reviewer for this important point. We agree that the original wording was too speculative. In the revised manuscript, we will avoid attributing elevated iGDGT concentrations to “better preservation” unless a specific mechanism is supported more clearly. Instead, we will revise the text to state more cautiously that the elevated concentrations at MET3 and MET4 may reflect local depositional setting, sediment focusing, and site-specific geochemical conditions associated with weak or non-ebullitive seepage, rather than direct evidence of enhanced preservation.**

**Author changes in the manuscript:**

- We will revise this passage to avoid an unsupported preservation claim.**
- We will rephrase the interpretation in terms of depositional setting, sediment focusing, and site-specific geochemical conditions.**