

# ***Interactive comment on “Geophysical and geochemical controls on the megafaunal community of a high Arctic cold seep” by Arunima Sen et al.***

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Reply to Interactive comment II on

Interactive comment on “Geophysical and geochemical controls on the megafaunal community of a high Arctic cold seep” by Arunima Sen et al.

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Relating the geochemistry to the species distribution of the macrofauna at seeps is always very difficult. Concentrations of possible energy sources, both in the surface layers, and within the sediment depth to which most macrofauna occur, can change by

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an order of magnitude or more over a distance of 10-50 cm from the seep outlet. In this study the positions of the cores with respect to the camera tracks are not that well constrained. Core 920 is shown here as NE of GHP5 while in Hong et al. (2017) it is shown as SE of GHP5.

Response: We agree completely, but we urge readers to remember that constraining the biology based on the geochemistry at a fine scale was not the aim of this study. We were instead looking at more general patterns over a larger scale. Namely, that pingo 5 does not have extensive mats of siboglinids like the other three pingos. We initially thought that lower sediment concentrations would explain this trend, but as it turns out, pingo 5 does not have lower sediment sulfide concentrations compared to the other pingos. However, there are multiple lines of evidence that suggest that overall geochemical conditions at pingo 5 are different, and we believe that these could explain the absence of siboglinids from pingo 5. These differences are: 1) lower methane concentrations at pingo 5 (even if it is not strictly only dissolved methane), 2) no hydrates were recovered from pingo 5 but were from the other pingos, 3) there are no prominent seismic chimneys below pingo 5, 4) sulfate flux rates are lower at pingo 5 compared to the others, 5) there are no rising gas flares into the water column from pingo 5, but there are from all the other pingos, and 6) ANMEs make up less of the total microbial community at pingo 5 compared to the others. Together, we believe that these differences suggest that overall at pingo 5, there is likely to be lower methane flux and a less active methanotrophic microbial community (i.e. lower AOM rates).

We checked our coordinates and it appears that there is a mistake in Hong et al., 2017.

We should mention that cores were not taken in sync with the imaging efforts. We are well aware that the cores do not line up with the mosaics or transects. And therefore, fine scale comparisons of geochemistry with biology is not possible. But we do believe that at the scale of one pingo as a whole compared to another, our sampling efforts were sufficient. In fact, the similar sulfide profiles from cores taken at pingo 5 and the other pingos indicate that our sampling efforts were adequate to obtain a general

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overview of geochemical conditions at the scale of individual pingos. Had we only got 'peripheral' data from pingo 5, then the sulfide concentrations from pingo 5 would be consistently lower, but this was not the case (instead, it was very similar to the other pingos).

My earlier comment regarding false dissolved methane readings by adding equal volumes of 1 M sodium hydroxide to samples for the analysis of free methane was influenced by my own early studies in which samples were not analysed at sea and had a longer storage time in contact with NaOH. I accept that a short exposure may not bias the results to the extent I believed, although it would be good to have results from an untreated pore water sample for comparison. Indeed Ertefai et al. also used 1 M NaOH treatment before measuring free methane and then continued the treatment for a longer period to measure adsorbed methane. Timing is everything!

Response: We agree with Dr. Dando that timing is crucial. In the future research we will conduct test measurements with and without NaOH solution in samples at different times after sampling. It is known that results of FID GC measurements of headspace samples require interpretation. We interpret measured concentrations from the samples collected in extremely active seepage site with massive gas hydrate layers within 1-3 m of sediment column, bacterial mats on the seabed and authigenic formations on the seabed as concentrations of the labile (dissolved) methane. GHP 5 clearly shows indications of some gas seepage (mats, fauna, etc.) making us confident that dissolved gas is present in the subsurface sediments. The GHPs are located within an area of 10 km<sup>2</sup> uniformly influenced by one sediment source and ocean currents implying no evidence of any appreciable heterogeneity in clayey mineral content and composition. Macroscopic observations of sediments from different pingos are in agreement with this. It means adsorption potential of bulk sediments is uniform within the area. Therefore, if some adsorbed gas contaminated our measurements, this contamination is likely uniform throughout the whole set of the samples. Thus, the trend of lower methane concentration in GHP5 compared to other GHPs should remain. Head space

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methane concentrations is one line of evidence for different methane seepage activity and geochemical conditions in pingos along with reflective seismic data, echosounder data, pore water chemistry results and video surveys. Complex interpretation of these data supports our conclusion of modest methane supply in superficial sediments of GHP5 as opposed to larger methane discharge in other GHPs.

There is at least one paper on free methane concentrations in sediments off Spitzbergen, that did not use sodium hydroxide pre-treatment for dissolved methane measurements, and should be cited Kneis et al. (2004). These authors analysed 26 sediment samples between 15 and 30 cm depth and found a thermogenic methane signature,  $\delta^{13}\text{C}$  of -50.8 (mean) in the adsorbed methane but a  $\delta^{13}\text{C}$  of -65.2 (mean) in the free methane. The free methane concentrations, 0.5 – 5.5 micromol/litre were lower than measurements from a similar sediment depths in the pingo areas, 6-330 micromol/litre (Serov et al. 2017). It was suggested, Kneis et al. (2004), that the adsorbed methane was not available to the microbes and that the free methane was probably a mixture from both thermogenic and biogenic sources. However, the methane isotope data reported from the pingo area (Serov et al. 2017) was taken from a greater sediment depth so that a direct comparison of the sources of the free methane cannot be made.

Response: We appreciate the suggestion to refer to a paper of our colleague from CAGE Dr. Knies. Despite, unravelling the source of gas is indeed an important topic, it is not a focus of our study. We submit that expanding the discussion chapter of our paper to cover isotopic compositions of adsorbed and dissolved gas in bottom sediments around Svalbard archipelago would dilute the focus of our work. However, one important conclusion may be drawn from comparing results of Knies et al., and Serov et al.,: concentrations of methane in pingos at the same subsurface depth are up to 660 times higher. As opposed to regional study of Knies et al., not targeting seeps, our study site demonstrates drastically different style of methane release with greater abundance of labile methane detected not only geochemically, but with direct and indirect geophysical observations.

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