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Progress Report (Period Ending 06/30/2017)

Assessing the response of methane hydrates to environmental change at the Svalbard continental margin

Project Period (11/1/2013 to 10/31/2017)

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EXECUTIVE SUMMARY

In November 2013, Oregon State University initiated the project entitled: **Assessing the response of methane hydrates to environmental change at the Svalbard continental margin**. In this project, we will take advantage of a unique opportunity to collect samples from the Svalbard continental margin. The overall objective of this research is to constrain the biogeochemical response of the gas hydrate system on the Svalbard margin to environmental change. Because of a delay in the planned expedition, we reconfigured the program based on discussions with NETL program managers and submitted a revised SOPO. In the new plan, we collected samples in six expeditions: RV Helmer Hanssen, Oct., 2014; RV Helmer Hanssen, May, 2015; RV Heincke, July-August 2015 and August-Sept, 2015; RV Helmer Hanssen, June 2016, and MeBo drilling expedition in August-September, 2016.

PROGRESS, RESULTS, AND DISCUSSION

1. Water column results. We finalized analyses of our extensive sampling campaign of the water column along the entire Barents Sea-Svalbard margin in August-September 2015. These data, which include concentrations, isotope measurements and methane oxidation rates document the significance of methane release at the upper limit of gas hydrate stability relative to additional sources on the shelf. Preliminary results were presented at the 2016 Gordon Research Conference on Natural Gas Hydrate (Galveston, TX, March 2016). A manuscript detailing these results is now published in "Scientific Reports" (www.nature.com/scientificreports) doi:10.1038/srep42997. In addition we submitted a document summarizing these results, and additional atmospheric methane data for consideration it the FITI magazine, which is now under review by the editor. These results will also be presented at the upcoming ICGH in Denver, June 2017.

2. Geochemistry: Data from a series of cores recovered at on the fan of Storfjordrenna, west Barents Sea documents recovery of gas hydrate at ~ 0.82 mbsf indicate that the increase in methane flux inferred sulfate profile, may be linked to an enhanced gas hydrate dissociation in this area. Ongoing studies are aimed at testing this postulate, with the aim to bridge the gap between hydroacoustic flare detection in the water column and the mapping of hydrate reservoir at depth, and provide additional clues to unravel the complex interactions among ice, ocean, microbiology and climate and their sensitivity to both natural and anthropogenic change in Arctic regions. We presented these results at the Gordon Conference on Natural Gas Hydrates March, 2016. A revision of a manuscript on these observations was submitted to Nature Communications, and during the second review processes a reviewer recommended more analyses and modeling to further constrain the conclusions presented. We have spent significant effort in completing the requested analyses and modeling and a revised and more comprehensive version of the manuscript was submitted 2/21/17, and was published in Nature Communications on 7th June 2017(http://www.nature.com/ncomms) doi: 10.1038/NCOMMS15745. We have also completed analyses of major and minor ions as well as some selected Sr isotope data, which suggest a complex system with various fluid sources. Preliminary results were pre-

sented at a Gas In Marine Sediments conference to be held in Tromsoe, September 2016, and we are working towards a manuscript with these results.

3. Data integration/synthesis for the Vestnesa seeps. I have been actively collaborating with Norwegian colleagues to synthesize data collected during various cruises to the Vestnesa Ridge, with emphasis on the results from the CAGE15-5 expedition in which I participated. A manuscript with analyses of those data is now in press in Marine Geology.

4. MSM57 expedition (29 July-07 September, 2016). Analyses of samples from drilling expedition using the MeBo seafloor drill are underway. Preliminary data from drilling offshore Prinz Karl Forland were presented at the ICGH, with a manuscript planned for this fall. Hydrocarbon data from Vestensa Ridge, including isotope analyses of methane and dissolved inorganic carbon, will be presented at the upcoming GeoBremen2017, in September of this year. A manuscript with those data is in preparation. Analyses of pore fluids is ongoing, and preliminary data is indicative of various fluid sources/pathways feeding the hydrate system off Vestensa. We just finalized a series of XRF scans of three gravity cores collected on the Svyatogor Ridge during the MSM57 expedition, with the idea of presenting these data at the upcoming AGU meeting in New Orleans.

5. Microbiology incubations: A timeseries of incubations spanning several months was carried out on sediments collected from two regions overlying methane hydrates and one methane-free reference from CAGE cruise 16-5 (June-July 2016). Incubations were kept at approximate in situ conditions (temperature 4-6˚C, pressure 4 MPa) and lasted 1, 4, or 8 months. Incubation tubes contained seawater media and were periodically depressurized and sampled for CH_4, HS^-, SO_4^{2-}, and DIC to obtain methane oxidation and sulfate reduction rates. The final round of incubations ended this week and concluded with cell fixation for fluorescent in situ hybridization (FISH) microscopy and bulk sediment freezing for nucleic acid analysis. Final measurements of methane and sulfide have also concluded this week and are being used to calculate rates of anaerobic methane oxidation and sulfide production (data not currently available). Media from 4- and 8-month incubations was sampled five days before terminating the incubation, and again upon completion to generate final rate measurements of these processes. These will be compared to rates calculated from other intervals (e.g. 1-60 days and 60-120 days for the 4-month incubation). Methane samples collected upon depressurization of incubations, were used to estimate and consumption rates as differences between data from various time intervals. Preliminary results are shown in Fig 1 below; units of all graphs are nmol CH_4 consumed per gram bulk sediment per day. Note that the 1-month incubation consists of only one sampling interval (0-30 days). These results indicate that AOM was stimulated in all incubations where methane was added after as little as 30 days. Methane consumption rates appear highest in the sample from a gas hydrate-rich seafloor feature underlying a gas seep, lower at the slope of the feature, and lowest in the reference sediment taken from an area without methane migration. Along with geochemical rate calculations, sediment DNA extraction and 16s rRNA amplification and sequencing are planned for the coming months.

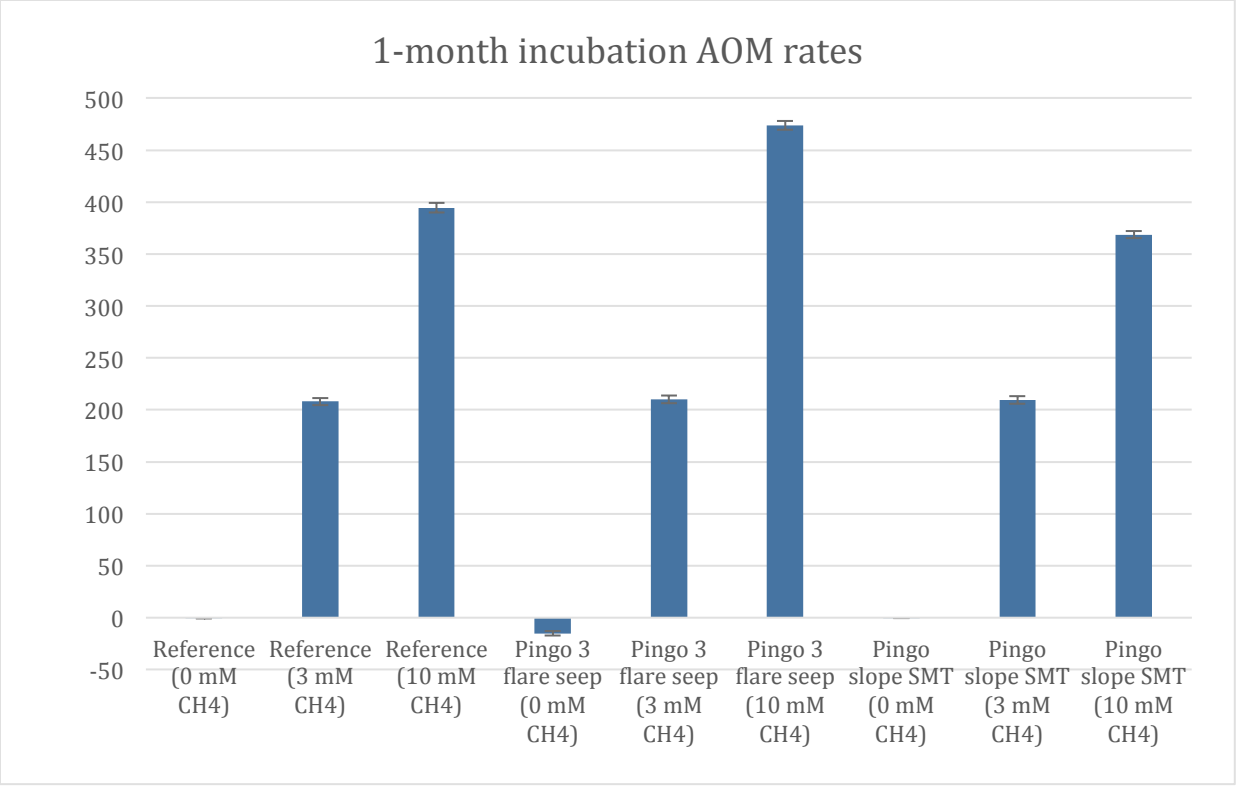

FIGURE 1. AOM estimates from incubation experiments given as nmol CH_4 consumed per gram bulk sediment per day, using samples from sediment collected in Storfjordrenna (west Barents Sea) at a gas-hydrate pingo location, and at a reference station.

PROBLEMS OR DELAYS

We requested and got approval for a one year no cost extension, which will allow us to complete some to the analyses/papers that are still underway. We originally had some delays because of problems with the research vessel R/V Merian. Even though this was unfortunate, this delay provided many alternate opportunities to collaborate with both German and Norwegian researchers to collect samples using a variety of tools/approaches. I believe this collaboration and multidisciplinary approach has been extremely beneficial, as evidenced by papers already published in high visibility journals. We are however, still generating (microbiology and geochemical) data from the most recent expeditions. As an example, to address the microbiological objectives, we had to change from a field sampling approach to cultivating microbes under in situ conditions to test the role that different levels of methane has on the microbial communities. These experiments are using samples collected using an ROV expedition last summer 2016, are underway and the samples still need to be analyzed for their microbial community structure. Sediment and pore water samples collected by the MeBo drilling expedition are still being analyzed and the data interpretation will be challenging due to the complexity of the system. Additional analyses such as high resolution XRF scans of the cores (now in Bremen) and some isotopic systematics in the fluids have been included in the overall data base to best constrain fluid migration and diagenetic processes.

PRODUCTS

- Two papers published on numerical model aspects of the project. Full citations: Peszynska, M., Medina, F.P., Hong, W.L. and Torres, M.E., 2015. Reduced Numerical Model for Methane Hydrate Formation under Conditions of Variable Salinity. Time-Stepping Variants and Sensitivity. Computation, 4(1), p.1.

  Peszynska, M., Hong, W.L. Torres, M.E., and Kim, J-H., 2015. Methane Hydrate Formation in Ulleung Basin Under Conditions of Variable Salinity: Reduced Model and Experiments. Transport Porous Media DOI 10.1007/s11242-016-0706-y

- A paper published in Nature-Scientific Reports.
  Mau, S., Römer, M., Torres, M.E., Bussmann, I., Pape, T., Damm, E., Geprägs, P., Wintersteller, P., Hsu, C.W., Loher, M. and Bohrmann, G., 2017. Widespread methane seepage along the continental margin off Svalbard-from Bjørnøya to Kongsfjorden. Scientific Reports, 7.

- A paper published in Nature Communications.
  Hong, W. L., Torres, M. E., Carroll, J., Crémière, A., Panieri, G., Yao, H., & Serov, P. (2017). Seepage from an arctic shallow marine gas hydrate reservoir is insensitive to momentary ocean warming. Nature communications, 8, 15745.10.1038/NCOMMS15745.

- Paper in press in Marine Geology: Fluid flow in Vestnesa Ridge pockmarks: evidence for temporal and spatial variability of methane discharge into the Arctic by Giuliana Panieri, Stefan Bünz, Daniel J. Fornari, Javier Escartin, Pavel Serov, Joel J. Johnson, Pär Jansson, WeiLi Hong, Simone Sauer, Marta E. Torres, Rafael Garcia, Nuno Gracias

- Abstract submitted to International Conference on Gas Hydrates, Denver June 2017; three abstracts submitted to the GeoBremen17 meeting; two presentations at the Bubbles17 school, Tromso, Norway.

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