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Quarterly Research Performance

Progress Report (Period ending 09/30/2016)

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

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

Submitted by:
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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 will collect samples in three expeditions, the first of which happened Oct 7-21, 2014. We were able to also join an expedition to the area onboard the RV Helmer Hanssen during May15-29, 2015 and two other expeditions one onboard the RV Heincke August-September 2015, and June 2016. We completed a modification of the SOPO to include participation in an upcoming MeBo drilling expedition in this region, scheduled for 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 consnetrations, 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) and a manuscript has been submitted for publication to "Scientific Reports", also published by the Nature consortium and has an impact factor of ~5. The paper is now under revision.

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 entitled "A possible on-off switch for shallow water Arctic gas hydrate reservoirs", submitted to Nature Communications in June, 2016 is now underway. We now completed analyses of major and minor ions as well as some selected Sr isotope data, which suggest a complex system with various fluid sources and advective flow regimes. More analyses are currently being conducted. Preliminary results will be presented at a Gas In Marine Sediments conference to be held in Tromsoe, September 2016. Abstract is attached.

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 in preparation. Abstract attached.

4. Microbiology sampling. Scott Klasek (funded by this grant) had the opportunity to join the CAGE team on an expedition during June 2016. The primary objective of this cruise (CAGE 16-5) was to use NTNU's remote-operated vehicle (ROV) for seafloor mapping and targeted sample collection at selected CAGE study locations, focusing on methane seepage areas west and south of Svalbard. A total of ten sediment samples from five locations (two seeps and three methane-rich sites overlying gas hydrates) were collected from ROV dives or by gravity coring and preserved in sterile anoxic bags at 4˚C for high-pressure incubations. Onboard alkalinity titration of porewaters identified appropriate depths for sampling sediment interfaces associated with the highest rates of anaerobic methane oxidation (sulfate-methane transitions). An additional 150 sediment samples from gravity cores and multicores were frozen for complimentary in situ microbial community analyses post cruise.

5. Microbiology incubations. To investigate how the microbial communities that anaerobically oxidize methane adapt temporally to increases in methane flux, and to relate community dynamics to changes in methane oxidation rates, sediments are being incubated at in situ temperatures and pressures in a timeseries under different methane concentrations. Methane consumption, sulfate reduction, and sulfide and dissolved inorganic carbon production will be measured. In addition to microbial community analysis, we plan to quantify cell abundances and functional genes and transcripts associated with anaerobic methane oxidation and sulfate reduction. This work is partially supported by a Deep Carbon Observatory Deep Life Cultivation Internship grant to enrich or cultivate carbon-cycling microbes from subsurface environments.

6. MeBo Expedition: Torres traveled to Germany and met with G. Bohrmann (chief scientists for upcoming MeBo expedition), to plan details of the collaborative program. Sampling supplies were shipped to Germany, and will be transported with all the equipment to the vessel (M.S. Merian). Geochemical sampling and analyses onboard will be coordinated by WeiLi Hong and Joel Johnson, and samples will be shipped to OSU immediately after the cruise for analyses. This expedition is currently underway

PROBLEMS OR DELAYS

Some problems were encountered with contamination of enriched samples for microbiology. We secured a place for Scott to sail on another expedition to Svalbard (June 2016), in which additional samples will be collected.

PRODUCTS

- Two papers published on numerical model aspects of the project (attached). 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

- Paper submitted to Scientific Reports June 2016 (abstract attached), now under revision Mau, S. Roemer, M, Torres, M. et al. 2016. Widespread methane seepage along the continental margin off Svalbard - from Bjørnøya to Kongsfjorden

- Paper submitted to Nature Communications June 2016 (abstract attached), now under revision. Hong W-L, Torres, M. et al., 2016. The on-off switch for shallow water Arctic gas hydrate reservoirs.

- Manuscript in preparation 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 attached

- Abstract submitted to Gas in Marine Sediments Conference (attached)
  Hong W-L, Torres M. et al., 2016. Fluid geochemistry from a shallow water gas hydrate pingo field south of Svalbard: The role of gas hydrate in fluid transport

Widespread methane seepage along the continental margin off Svalbard - from Bjørnøya to Kongsfjorden

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Numerous articles have recently reported on gas seepage offshore Svalbard, because the gas emission in this area was postulated to result from gas hydrate dissociation, possibly triggered by anthropogenic ocean warming. Here we report on findings for a much broader extent of seepage in water depths at, and shallower than, the gas hydrate stability zone. More than a thousand gas seepage sites were imaged as acoustic flares, the majority of which cluster along the trace of the Hornsund Fracture Zone (HFZ) and generate a methane plume that extends for hundreds of kilometers. We postulate that the HFZ provides a pathway for upward advection of methane-rich fluids, which discharge preferentially on bathymetric highs because fluid flow is hindered by the glaciomarine and Holocene sediments that fill the troughs. During our August 2015 survey we observe that a fraction of this dissolved methane emissions (~1.8%) was oxidized whereas a minor but measureable fraction (0.05%) was transferred into the atmosphere. The large-scale seepage reported here is not linked to anthropogenic warming.

A possible on-off switch for shallow water Arctic gas hydrate reservoirs

Wei-Li Hong, Marta E. Torres, JoLynn Carroll, Antoine Crémière, Giuliana Panieri, Haoyi Yao, and Pavel Serov

Abstract

Arctic gas hydrate reservoirs located in shallow water and proximal to the sediment-water interface are potentially sensitive to bottom water warming that can lead to gas hydrate dissociation and the release of methane. As a strong greenhouse gas, methane plays an important role in both Earth's climate system and the global carbon budget. We evaluate bottom water temperature as a potential driver of gas hydrate dissociation and methane release from a recently discovered, gas-hydrate-bearing system in the western Barents Sea (~380 meters water depth)- the first shallow water site from which gas hydrate has been recovered in the Arctic. Non-steady-state porewater profiles and distinct layers of methane-derived authigenic carbonate nodules retrieved from sediments suggest repeated methane emissions beginning well before the onset of anthropogenic warming in the Arctic. We attribute the ongoing and past methane emission episodes to the reservoir's natural ventilation rhythm rather than warming-induced gas hydrate dissociation.

Fluid geochemistry from a shallow water gas hydrate pingo field south of Svalbard: the role of gas hydrate in fluid transport

(abstract submitted to Gas in Marine Sediments Conference, Tromosoe, Norway, September 2016)

Wei-Li Hong, Marta E. Torres, Brian Haley, and Evan A. Solomon

We present porewater geochemistry data from 7 gravity cores in a newly discovered gas hydrate field of the Storfjordrenna area (water depth ~380m), 50km south of Svalbard. The concentration of major (Ca, Mg, K, Sr) and minor (Li, B, Ba) elements; $\delta^{18}O$, δD of pore fluid and the and $^{87}Sr/^{86}Sr$ in dissolved phase are indicative of fluid sources and water-rock interactions. Concentrations of dissolved inorganic carbon (DIC), total alkalinity, hydrogen sulfide as well as $\delta^{13}C$ of the DIC were measured to investigate biogeochemical reactions.

Our observations confirm the significance of various biogeochemical reactions on fluid geochemistry. High concentrations of hydrogen sulfide, DIC, and alkalinity indicate rapid turnover of methane and sulfate through anaerobic oxidation of methane (AOM). This reaction fuels precipitation of authigenic carbonates, which largely determines the concentrations of Mg and Ca at sites with strong methane supply. Methane at these sites is transported in the gas phase and leads to the formation of gas hydrate in the upper 80 cmbsf. Gas hydrate formation may block fluid transport from depth. Oxygen (1 ‰) and hydrogen (2.5 ‰) isotopes of pore water are enriched relative to SMOW, but the data suggest influence of glacial melt water, rather than a gas hydrate signal.

The fluid systems beneath different pingos are contrastingly different. We detected enrichments of Li (up to 64 μM) and Sr (up to 96 μM) in one of the pingo sites, while these elements are depleted (13 μM in Li and 70 μM in Sr) at another pingo that is only ~1km away. Boron concentrations are generally lower than the bottom seawater concentration in all the cores investigated (250 to 300 μM). The enriched strontium isotopic ratios (up to 0.70987) measured at various sites suggest influence of weathering of continental material, a reaction that also explains the enrichment of Li and Sr in a few sites.

In general, the fluid at sites where the methane supply is weak, and show no evidence of gas hydrate formation, are enriched in ^{87}Sr, indicating influence of silicate weathering and deep fluid migration. On the other hand, in sites with strong methane flux and abundant gas hydrate, the strontium isotopic ratios are close to seawater indicating very little deep fluid contribution. We hypothesize that the transport of methane is decoupled from the transport of fluid. Gas hydrate seems to prevent upward migration of fluid and may lead to accumulation of methane gas beneath the hydrate.

Fluid flow in Vestnesa Ridge pockmarks: evidence for temporal and spatial variability of methane discharge into the Arctic

Giuliana Panieri[1]*, Stefan Bünz[1], Daniel J. Fornari[2], Javier Escartin[3], Pavel Serov[1], Joel J. Johnson[4], Pär Jansson[1], WeiLi Hong[1], Simone Sauer[5,1], Marta E. Torres[6], Rafael Garcia[7], Nuno Gracias[7]

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Abstract

The Vestnesa Ridge is a NW-SE trending, ~100 km-long, 1-2 km-thick contourite and turbidite sediment pile in the Arctic Ocean west of Svalbard. Pockmarks aligned along the ridge summit at a water depth of ~1200 m, are ~700 m in diameter and ~10 m deep relative to surrounding seafloor. Visual inspection and sampling using a high-resolution deep-sea camera and multicorer system indicate two of these pockmarks, named Lomvi and Lunde, contain authigenic carbonate in association with biota and gas hydrates exposed at the seafloor. Subbottom and seismic surveys, water column imaging, geochemical data from near-bottom sampling, and seafloor observations, all indicate on-going distributed and focused fluid flow through the seafloor within these two pockmarks. Diffuse methane venting at both Lomvi and Lunde supports extensive

chemosynthetic organisms, bacterial mats, and Siboglinidae tubeworms, all of which utilize the chemical energy provided by the seeping fluids. Focused venting forms gas hydrate in the subseafloor, and gas flares in the water column emanating from pits within the pockmarks, that are up to 50 m in diameter. Cycles of carbonate precipitation or exhumation of carbonate deposits within the sediment are indicated by scattered blocks of various size, slabs, and massive carbonate blocks up to 5 m.

Here we report on the first detailed seafloor imaging and the results of camera-guided multicore sampling of two of the most active pockmark along Vestnesa Ridge. We correlate seafloor images with seismically defined subseafloor structures, providing a geological and ecological context to better understands the formation mechanism of pockmarks and the impact of methane seeps on the seafloor environment in the Arctic. The extensive authigenic carbonates discovered here represent an important methane sink, preventing much of the methane from reaching the atmosphere and contributing to greenhouse gas accumulation.

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