Oil & Natural Gas Technology

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Quarterly Progress Report
(Period ending September 30th, 2013)

Gas Hydrate Dynamics on the Alaskan Beaufort Continental Slope: Modeling and Field Characterization
Project Period: October 1, 2012 – September 30, 2015

Submitted by:

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ABSTRACT

FY2013 fourth quarter research associated with the DE-FE0010180 grant included progress on two separate tasks for this quarter, as well as early starts on several tasks for the first quarter of the next fiscal year (Q1 FY2014). As a result, the government shutdown during the beginning of the current quarter has had no significant impact on our study. As we discuss in this quarterly report, we are on schedule, with completion of the hydrate stability analysis for the Beaufort Sea, completion of the ship scoping report, and preparations for the 2014 cruise on going. The tasks for Q4 2013 (as stated in the PMP) included (1) completing all numerical modeling of 1977 USGS legacy data with the required deliverable of having results submitted to a peer-reviewed journal (JGR) by the end of FY2013 and (2) completion of the ship scoping exercise that ensures an appropriate ship of opportunity exists to conduct summer 2014 research. We completed both of these tasks during this past quarter. Furthermore, we have already begun moving forward with detailed ship scheduling procedures for next summer on the *MV Norseman II*. Additionally, and although not yet required according the PMP, OSU microbiologists developed artificial methane seep experiments during Q3 2013. Results from these experiments, which demonstrate that methanotrophic bacteria may colonize a seep in as little as a week, will be applied directly to the upcoming 2014 cruise results. During this past quarter, we also presented our initial FY2013 results as a series of invited talks and submitted abstracts for multiple international meetings for Q1 FY2014. Initial year 1 results were also presented directly to DOE headquarters in August. Recent geophysical analysis associated with hydrate stability in the Beaufort include revised estimates for the amount of methane hydrate currently dissociating along the Beaufort margin based on 1977 seismic and ocean temperature data. Preliminary numbers for the amount of hydrate dissociating along the Beaufort margin are conservative and will likely be revised upward in the future given recent ocean warming trends and on-going analysis of USGS 2012 Beaufort Sea seismic data. As preparation for our upcoming cruise, we have held multiple calls between SMU and USGS personnel--some of which also occurred during (and despite) the recent government shutdown. Results from these discussions combined with analysis of historic ice conditions in the arctic lead us to request a preferred time window for the 2014 cruise of 2nd-4th week of September on the *Norseman II*. Although this is our request, there is no guarantee we will be provided with these exact cruise dates. We are therefore currently preparing contingency coring/HF plans in the case that less than ideal timing/ice conditions exist during the 2014 Beaufort cruise. An upcoming conference call scheduled with the ship operator in November will further clarify expected cruise dates, and allow us to plan accordingly.

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EXECUTIVE SUMMARY

In October 2012, Southern Methodist University in close partnership with The United State Geological Survey at Woods Hole and Oregon State University, began investigating methane hydrate stability in deep water (>100 mbsf) environments below Alaskan Beaufort Sea. This research is part of a three-year study funded by the Department of Energy's (DOE) National Energy Technology Laboratory (NETL). Key goals of this study include integrating and processing marine seismic data collected at the USGS with dynamic 2D/3D/4D heat flow models developed at SMU to determining the depth, location, and dynamics of methane hydrate stability along the Alaskan Beaufort Margin. A key component of this study is to constrain how the methane hydrate stability zone is changing with time. Additional goals of this study include determining areas where concentrated methane hydrate might exist in the subsurface and to understand the role methane hydrate plays in slope stability along the Alaskan Margin.

The fourth quarter of FY2013 was dedicated primarily to (1) analysis, writing, and submission of 1977 3D heat flow model results to JGR and (2) finalizing a ship of opportunity that best fit our needs for the 2014 heat-flow/coring study. Both of the goals (and associated deliverables, including manuscript and ship-scoping results) were achieved during this quarter. Results presented in the manuscript outline in detail Beaufort Sea regional heat flow, ocean temperature changes in the Beaufort Sea for the past 30 years, and the impact ocean temperature changes have on hydrate stability in this region. Based on these results, we show that methane hydrates along a large swath of the Beaufort Margin is destabilizing and provide a conservative estimate for the amount of hydrate dissociating. These results are in manuscript form and in review at the Journal of Geophysical Research-Solid Earth. We have begun presenting these results at invited talks; we will also present these results at two international meetings within the next two months. Results from the USGS-led ship-scoping exercise confirm that the *M/V Norseman II* provides the best platform for the 2014 cruise for our budget. We are currently in negotiations with the ship operator to determine the time window for the 2014 cruise, with the 2^{nd}-4^{th} week of September representing the optimum time frame. We are also, however, in the midst of making contingency heat-flow/coring data collection plans in the case that either this time frame is not available, or heavy ice conditions exist.

PROGRESS

Primary project goals for the fourth quarter of this project, as outlined in figure 1 of the project management plan (PMP) include the following:

TASK 1—Complete all 3D hydrate stability analysis using Legacy USGS 1977 Data

-Completed. We submitted a ~45 page manuscript to JGR-Solid Earth outlining result from our 3D heat flow model. This manuscript is also concurrently being examined by USGS internal review. We anticipate receiving editor/reviewer feedback from JGR in Q1 2014.

TASK 2—Complete ship-scoping exercise for 2014 research cruise

-Completed. We submitted results from the ship-scoping exercise to DOE in August 2013.

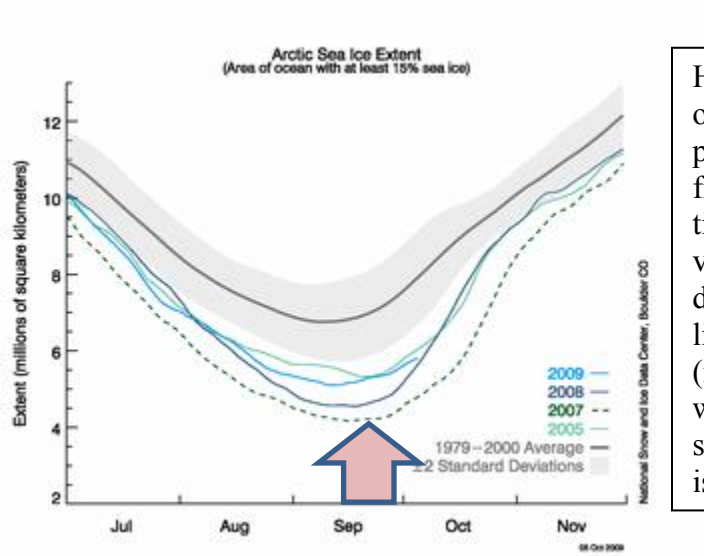
ADDITIONAL MICROBIOLOGY TASKS: development of an artificial methane seep.
-Begun. Although the PMP does not require a start in microbiology cruise preparations until Q1 FY2014, OSU researchers have already begun early cruise preparation and data analysis by developing an artificial methane seep that we will use to ground-truth upcoming 2014 cruise microbiology results.

RESULTS & DISCUSSION

Task 1, Manuscript Completion (SMU-Led): The manuscript we have submitted to JGR-Solid Earth outlines in detail all year 1 results. This analysis includes a revised heat flow model for the north slope of Alaska, the Alaskan Margin, and the Beaufort Sea. It also demonstrates that ocean temperatures at intermediate water depths (~300-600 mbsl) are steadily warming at ~0.02 degrees per year. Combining these results with regional estimates for thermal conductivity, we demonstrate that methane hydrates along a broad swath of the upper Beaufort Margin are destabilizing. We provide a conservative estimate for the amount of methane hydrate destabilizing in this region and recognize that up-coming cruise results combined with seismic data collected by the USGS in 2012 should provide even tighter constraints on methane hydrate dissociation with time. As we note below, on-going analysis will provide insight into how this dissociation should effect methane hydrate accumulations, methane migration, and slope stability with time.

Task 2, Ship-scoping completion (USGS-Led): A report outlining the results of the ship-scoping exercise was submitted to DOE in August. The report indicates the *MV Norseman II* provides the best platform for the coring/heat-flow study next summer. As a result of this report, we have moved quickly to lock-in our requests for ship time that minimizes the likelihood of encountering heavy sea ice conditions in the Beaufort Sea. The USGS and SMU had multiple discussions regarding cruise time-frame just before the government shutdown. Ultimately we requested that

the ship operator provide us a cruise date of the 2nd-4th week of September 2014 as this is when arctic sea ice conditions are typically at their minimum. In reality, a week on either side of this request will likely fall near typical historical sea ice minima, however, the rate of ice growth in early October is rapid (see figure below). As a result, if our preferred time window of mid-to-late September is not available, we will likely request dates earlier as opposed to later in the season.



Historic sea ice extent in the Arctic ocean during summer and fall. The pink arrow indicates the request time frame for the 2014 cruise, with alternative dates occurring earlier. The prevailing East-to-West shallow water drift in the Beaufort means we will likely encounter the most significant (multi-year) sea ice to the west. We will conduct our most westward analysis when the lowest ice conditions exist during our cruise window.

We have scheduled a phone call with the ship operator for November 11th (currently the ship is still in the Arctic, or heading back to Seward, which is the reason for their delay). We believe there are a few reasons why we may not obtain the most ideal time window. Unlike a UNOLS (academic fleet) vessel, where the operator schedules far in advance at a specific rate, we likely pay less in day rate than the oil service companies that also hire this ship. At the very least, however, we hope to lock-in a date between the first week of August and the end of September. We were firm that October would be too late, as potentially deteriorating ice conditions (like those in 2009) could make coring very difficult during this time of year. The one advantage we have regarding timing is that we are collecting no seismic data, and therefore, are not constrained by the timing of whale hunts. Ice conditions will likely be worse the further north or west we survey due to east-to-west shallow water drift that pushes multi-year ice from Canada and Greenland towards the western Beaufort Sea, we will therefore attempt to acquire our most eastward cores when we expect minimal sea ice during our cruise window.

Additional results: Microbiology (OSU-Led): Most methane that escapes from subsurface marine reservoirs is likely consumed by methanotrophic bacterial and archaeal communities within the sediment. However, this understanding is derived from already formed (mature) methane seep environments. In areas of nascent seep formation the mitigation of methane by microbial communities has not been rigorously characterized function nor has the recruitment and/or proliferation of methanotrophic microbial communities in these sensitive areas. In order to begin microbiology research related to core recovery on the Beaufort slope in areas of nascent methane seep formation, we conducted studies to quantify the rate of microbial recruitment in estuarine sediments where methane is artificially added to the sediments. We created artificial seeps in intertidal microcosms in the laboratory and at a shallow subtidal *in situ* location in Yaquina Bay, OR. Methane saturated water was injected into the subsurface for either one or three weeks and

methanotrophic recruitment was tracked using the diagnostic aerobic methanotroph biomarker, 16:1(n-6) fatty acid. Pore waters were also extracted to determine methane concentrations. In contrast to control samples, aerobic methanotrophs proliferated in both *ex situ* and *in situ* experiments and became abundant members of the community within as little as one week although they continued to increase into the third week. These results suggest that methanotrophic bacteria may be able to rapidly respond to methane release in sediments and colonize the sediments in response to the presence of methane, as a source of carbon and energy. These empirical seep creation studies allowed successional tracking of the microbial communities responsible for the mitigation of methane emission and provided samples with which we can prepare to conduct the analyses on the Beaufort slope next summer.

COST STATUS

Costs incurred so far at SMU are
--RA support for Hornbach's graduate student, Ben Phrampus who is the lead-author on the JGR manuscript. Not including fringe, this cost comes to ~$6,120 for the quarter.
--Research Support for Hornbach (research support for summer). ~ $26,000.

Total approximate expenditures for SMU in Quarter #4: ~$32,120(not including overhead).

PROBLEMS OR DELAYS

Small delays related to personnel availability (Pat Hart) for USGS 2012 seismic component. SMU is awaiting final processing of these data to start initial 2012 hydrate stability analysis on the Beaufort Sea. Otherwise none.

PRODUCTS

1. Manuscript Submitted to JGR.

2. Ship Scoping Report.

3. Invited Presentation, SMU, "Integrating rock physics models with pore-pressures analysis to assess slope stability and methane hydrate stability," presented by Hornbach.

4. Invited Presentation, The University of Houston, "Methane hydrate stability on the U.S. Beaufort Margin, Alaska," presented by Hornbach.

CONCLUSIONS AND FUTURE DIRECTIONS

We remain on schedule and anticipate a significantly clearer picture of cruise timing and logistics following Q1 FY2014. Results for Year 1 will be presented as an invited talk (at no cost to DOE) in Kiel Germany at the PERGAMON meeting this November (Permafrost and gas hydrate related methane release in the Arctic and impact on climate change: European cooperation for long-term monitoring). We will also give an oral presentation at the AGU Fall Meeting, in San Francisco this December. As we await final analysis of the USGS 2012 data, we have begun additional methane hydrate modeling that will help constrain hydrate accumulation (and pore fluid pressure) evolution in both space and time in the western Beaufort Sea. More importantly, however, we continue to focus most of our efforts on cruise planning, with the goal of ensuring a well-organized and well-prepared cruise for next summer. This preparation includes multiple meetings/conference-calls phone with proposal proponents, ship operators, and coring operators in the current quarter (Q1, FY2014).

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