Oil & Natural Gas Technology

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Quarterly Progress Report
(Period ending December 31st, 2012)

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

The first quarter of research associated with the DE-FE0010180 grant required progress on three separate tasks: (1) PMP development, (2) initial 2D heat-flow/hydrate model development coupled with processing of seismic data for the Beaufort, and (3) initiation of research vessel scoping for the up-coming 2014 cruise. All three tasks were completed. In addition, the research team generated new results showing evidence for long-term (decadal scale) deep water ocean warming in the arctic that has significant implications for hydrate stability changes with time in this region. Results associated both with model development and seismic imaging were presented by SMU and the USGS at the Annual AGU meeting this December. There were no significant delays or problems during the first quarter of work, and we anticipate obtaining additional publishable results and a clearer picture of research vessel options for the 2014 cruise during the next quarter.

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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 first quarter of this project was dedicated to development of a preliminary 2D submarine heat flow model for assessing hydrate stability in the subsurface and seismic data processing at the USGS. A key uncertainty with the heat flow model is the ocean temperature boundary condition and how this it varies in both space and time. Project personnel at SMU therefore spent much of this quarter focused on (1) compiling ~40 years of summer-fall ocean temperature measurements in the Beaufort to place end member values on ocean temperature boundary conditions, (2) developing statistical analysis numerical routines combined with Monte Carlo simulations to determine both annual and decadal trends in ocean temperature in the Beaufort, and (3) integrating ocean temperature data with 2D/3D numerical heat flow models to determine the effects of changing ocean temperatures on hydrate stability. The analysis, although preliminary, shows evidence for widespread ocean warming in the Beaufort Sea during the past 25 years to depths as great as ~1000 mbsl. Although further analysis is needed, the analysis implies ocean temperature warming in the Beaufort is not isolated to the surface or the upper few hundred meters of the ocean. The results have significant implications for the location of hydrate stability in both space and time. We presented some of these initial results at the Fall AGU meeting in San Francisco last month. In addition, the USGS spent much of the quarter analyzing and processing recently collected 2012 seismic data on the Beaufort Slope. In less than a year, the USGS has been able to generate invaluable high resolution seismic images that place tight constraints on the depth of the hydrate stability zone along the Beaufort Margin. Some of the USGS results were presented this fall at the annual AGU meeting. We are looking forward to integrating heat flow models with USGS results in the coming months.

Also this quarter, colleagues at the USGS have begun their due diligence for research vessel scoping/contracting with the goal of finding a ship that best fits our coring and heat flow needs. This includes contacting the M/*V Norseman II* and setting up a time in spring 2013 for USGS coring personnel to visit the ship. Additionally Oregon State colleagues have begun advertising this study to graduate students and appear to have attracted as least one quality candidate.

In summary, we have completed all tasks as outlined in the project management plan for this quarter. In addition, our groups have generated some unanticipated, but exciting new results associated with hydrates in The Beaufort. These additional results, as noted in our "Products" section, were presented at the fall AGU meeting in 2012, and some components are also now in manuscript form and ready for submission.

PROGRESS

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

TASK 1--development of a project management plan (PMP)

TASK 2--begin numerical modeling development for 1997 USGS data

TASK 3--Scoping of the R/V Noreseman II for 2014 Coring/Heat-flow research.

We have completed Task 1 and made critical progress on Tasks 2 and 3 during this quarter and also completed some additional, unexpected tasks as well associated with research. Our PMP was submitted by early November, our numerical modeling analysis began in earnest in October, and the USGS has already begun scoping out the R/V Norseman II as a potential research platform. In addition, we have some surprising, and unexpected results this quarter related to ocean temperature changes in the Beaufort that we discovered while developing our initial Beaufort heat-flow model. The discovery suggests widespread ocean warming in the Beaufort during the last ~25 years. We now have these results in manuscript form and ready for submittal in apeer reviewed journal. Some of these results were also briefly discussed in a talk presented by Hornbach at the Fall 2012 AGU meeting in December. Below, we discuss each of task accomplishments as well as the additional research results.

RESULTS & DISCUSSION

TASK 1--development of a project management plan (PMP)

Researchers at SMU, the USGS, and OSU, submitted a PMP to Robert Vagnetti at the DOE on 10/26/12. After suggested edits by the DOE, We returned a revised version of the PMP to DOE on 11/16/12. This version of the PMP is now the guiding document for each of our quarterly progress reports.

TASK 2--begin numerical modeling development for USGS data (SMU and USGS)

SMU Component—developing an accurate 2D/3D Heat Flow Model for Beaufort

In early September, just after Hornbach had been informed that DOE would likely fund project DE-FE0010180, Hornbach and Phrampus began working to develop a 2D/3D numerical heat flow model for the Beaufort Sea. Throughout the quarter, Hornbach and Phrampus met daily, to develop these models. It became clear early on in this study that a critical uncertainty for modeling hydrate stability along the Beaufort Margin is ocean temperature variability with depth in the Beaufort Sea. Shallow (<1000 mbsl) water hydrates are especially sensitive to small changes in temperature. Due to both the low (~3 degree) slope angle of the continental margin and the sensitivity of shallow hydrates to temperature, only slight shifts in ocean temperature significant impact the location of the hydrate stability zone. For example, a 3-5 degrees change in bottom water temperature along the shallow continental margin can result in a tens-of-kilometer shift in the

feather edge of the hydrate stability zone. Hydrate stability model accuracy hinges on accurate determination of Beaufort Sea water column temperatures.

Seasonal temperature variations in the ocean are poorly constrained in the Beaufort Sea due to several ice-covered months each year where data acquisition is difficult. Therefore, limited seasonal measurements for ocean Conductivity-Temperature-Depth (CTD) exist in the Beaufort. Nonetheless, in the summer and fall months relatively ice-free conditions prevail in the Beaufort and significant CTD data exist during these seasons, extending back more than 40 years.

SMU researchers therefore spent much of the first quarter analyzing these data and working to develop accurate ocean temperature boundary conditions for the model. This work entailed finding, downloading, and systematically analyzing all CTD data in the Beaufort Sea. In total, we integrated nearly ~3000 CTD records in the Beaufort extending back more than 40 years. Hornbach and Phrampus conducted a detailed statistical analysis of these data combined with Monte Carlo simulations to determine average (to 2-sigma) ocean temperature values with depth across the region. They also used their results to determine if any long term (decadal) trends exist in ocean temperature across the region. Preliminary results indicate slight, but real ocean temperature warming to depths up to ~1000 mbsl in the Beaufort Sea during the past few decades. These results, though preliminary, provide critical insight into the past, present, and (assuming warming trends continue) future location of the BSR and methane hydrate stability in the Beaufort Sea, and some of these initial results were present by Hornbach at the annual AGU Fall meeting in San Francisco this past December.

USGS numerical modeling support: Processing new USGS MCS seismic data.

At the end of November 2012, the USGS completed initial stacking, migration, and other processing of the 24-channel multichannel seismic data collected during summer 2012 on the US Beaufort slope and shelf, with sponsorship from the DOE-USGS Interagency Agreement. This data set includes 8 distinct crossings of the upper slope between approximately Cape Halkett and the proposed IODP drilling transect offshore Flaxman Island and will be critical for the modeling and fieldwork phases of the new SMU-USGS-OSU project. The processed seismic data were presented for the first time at the Fall AGU meeting in December 2012 in San Francisco, and the interpretations focused on how the seismic features imaged on the uppermost continental slope could be integrated with other data on short- and long-term fluctuations of the upper feather edge of the deepwater gas hydrate system. Patterns of slope failures, regular and disrupted sedimentation, and inferred gas and fluid expulsion have been linked to along-slope formation and dissociation of gas hydrate since the mid-Holocene. These interpretations were also combined with new data on contemporary water column methane concentrations and oxidation rates and with water quality parameters to understand shorter-term forcing of gas hydrate dynamics. In January 2012, the USGS presented part of this dataset at a workshop sponsored by the European Union's PERGAMON group for Arctic methane, in which the USGS is an official non-EU member. In early February 2012, USGS researchers will meet to review the entire data set and to set a timetable for finalizing data to be shared with SMU to advance the next generation of models.

TASK 3--Scoping of the R/V Norseman II for 2014 Coring/Heat-flow research (USGS)
The USGS is taking the lead on investigating the suitability of Alaskan vessels for summer 2014 coring on the upper continental slope. USGS researchers plans to tour available vessel(s) in spring 2013 with USGS operations personnel to ensure that coring and related analyses can be accomplished on the vessel. In early February 2013, Ruppel will meet in Woods Hole with some of the USGS operational personnel responsible for USGS piston coring operations to review vessel requirements.

COST STATUS

The only cost incurred so far at SMU is RA support for Hornbach's graduate student, Ben Phrampus. Not including fringe, this cost comes to ~$6,120 for the quarter.

PROBLEMS OR DELAYS

None significant. There has been a slight delay in transferring sub-contract funds from SMU to OSU primarily due to final approval of the DOE grant at SMU occurring so close to the winter holidays. Hornbach and Colwell have been in close contact on this issue and the process is moving forward.

ADDITIONAL UPDATES

Colwell at OSU has received the application of a student who wants to work on this project and would make an ideal fit. The potential student has also applied for an NSF Graduate Student Fellowship Stipend in November using the project plans as a template for his research. If he is selected then the project would be given even more latitude in how we approach the microbiology component.

PRODUCTS

(1) The research team completed a PMP for the project.

(2) The USGS presented preliminary seismic analysis of Beaufort Sea seismic data at annual AGU meeting in December, 2012.

(3) SMU presented preliminary ocean temperature results and heat flow models were presented at annual AGU meeting in December, 2012.

CONCLUSIONS AND FUTURE DIRECTIONS

In Summary, all tasks were completed for Quarter #1. During the next quarter, we anticipate completion of the following action items: (1) integration of ocean temperature results with 2D seismic data collected by the USGS in 1977, and from this, obtain preliminary but publishable results for hydrate stability across the Beaufort, (2) make corrections to our submitted Beaufort ocean temperature analysis manuscript, and (3) visit (or have a time-frame firmly established for a visit) with the MV *Norseman II* to determine it fits our needs, time-frame, and budget for the planned 2014 coring/heat-flow cruise.

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