Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report

(Period ending 03/31/2014)

Characterizing the Response of the Cascadia Margin Gas Hydrate Reservoir to Bottom Water Warming Along the Upper Continental Slope

Project Period: October 1, 2013 – September 30, 2016

Submitted by:
Evan Solomon
Digitally signed by Evan Solomon
DN: cn=Evan Solomon, o=University of Washington, ou, email=esolomn@uw.edu, c=US
Date: 2014.04.30 10:02:30 -08'00'
University of Washington
DUNS #: 605799469
4333 Brooklyn Ave NE
Box 359472
Seattle, WA 98195-0001
e-mail: esolomn@u.washington.edu
Phone number: (206) 221-6745

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United States Department of Energy
National Energy Technology Laboratory

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Office of Fossil Energy

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EXECUTIVE SUMMARY

In October 2013, the University of Washington initiated a three-year study funded through DOE-NETL entitled: Characterizing the response of the Cascadia margin gas hydrate reservoir to bottom water warming along the upper continental slope. The objective of this project is to understand the response of the WA margin gas hydrate system to contemporary warming of bottom water along the upper continental slope. Through pre-cruise analysis and modeling of archive and recent geophysical and oceanographic data, we will (1) inventory methane hydrates along the WA margin and define the upper limit of gas hydrate stability, (2) refine margin-wide estimates of heat flow and geothermal gradients, (3) characterize decadal scale temporal variations of bottom water temperatures at the upper continental slope, and (4) use numerical simulations to provide quantitative estimates of how the shallow boundary of gas hydrate stability responds to modern environmental change. These pre-cruise results will provide the context for a systematic geophysical and geochemical survey of methane seepage along the upper continental slope of the WA margin during a 10-day field program. This systematic inventory of methane emissions along this climate-sensitive margin corridor and comprehensive sediment and water column sampling program will focus on determining methane sources (microbial, thermogenic, gas hydrate dissociation), sinks, and fluxes within the sediment and water column, and how they relate to contemporary intermediate water warming.

During the second quarter of this project we continued to refine our estimates of the long-term bottom water temperature trend along the upper continental slope of the Washington margin. We identified 2122 high-quality, open-ocean temperature profiles between the years 1968 and 2013. The temperature data, which covers the entire WA margin, was linearly interpolated to 10 m depth intervals ranging from 50 to 1000 m. Averaged over the entire region, the temperature at the upper limit of gas hydrate stability shows a constant and significant warming trend off the WA margin over the last 40 years. The time series also clearly shows the influence of the Pacific Decadal Oscillation (PDO) at the upper limit of gas hydrate stability. We used a 2-D conductive heat flow model to simulate the change in temperature distribution in the shallow sediments at the upper limit of gas hydrate stability resulting from the observed warming of intermediate-depth water temperatures. The models include the thermodynamics of Structure I methane hydrate and simulate the shoaling of the gas hydrate stability zone and propagation downslope over the period of historical warming. The modeling effort is complete, and a manuscript is in preparation describing the results of the bottom water temperature trend in the NE Pacific and its potential impact on the WA margin gas hydrate reservoir. In addition to the water column data processing and thermal modeling, we are continuing our work on identifying BSRs along the WA margin and are focusing on the COAST MCS survey lines collected in 2012. In addition to providing a map of BSRs, these results will be used to provide regional heat flow estimates.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0 Project management and planning
Completed in previous reporting period - The project management plan was finalized and submitted on October 17, 2013.

Task 2.0 Compile relevant archive data
Completed in previous reporting period – We have compiled the relevant MCS profiles and swath bathymetry on the WA margin. All available high-resolution CTD, glider and ARGO float temperature profiles, extending to a depth of at least 200 m, were extracted and compiled from the World Ocean Database 2013 (National Oceanographic Data Center) for the region 124.5°W to 127.5°W and 46.5°N to 48.5°N off the Washington margin. We have also compiled all of the acoustic backscatter data from archive and recent (EM122 and EM302 data) Langseth, Thompson and Atlantis expeditions to the Washington margin.

Task 3.0 Estimate sediment porosity and in situ thermal conductivities
Completed this reporting period – We are currently converting existing MCS data to Vp-vs-depth profiles and then will use these data to estimate sediment porosities. From the estimated sediment porosities, we will estimate thermal conductivities along the WA continental slope. We have completed a compilation of sediment core archives from legacy coring programs on WA margin for sediment lithology in order to provide guidance regarding the distribution and partitioning of the sediments into turbidites and pelagic sediments within a specific geographic area, which is necessary to convert seismic velocities and structural components into a plausible model of thermal conductivity.

Task 4.0 Constrain hydrate distribution and geothermal gradients
In Progress – We are currently evaluating Bottom Simulating Reflectors (BSRs) from legacy MCS cruises to establish the distribution of gas hydrates and geothermal gradients along entire WA margin in combination with heat flow measured during our recent WA margin heat and fluid flow survey (Johnson et al., 2013; Johnson et al., 2014).

Task 5.0 Analyze recent temperature data and long-term bottom water record
Completed this reporting period – As stated in the Executive Summary, after filtering, there are 2122 high-quality, open-ocean temperature profiles that were linearly interpolated to 10 m depth intervals ranging from 50 to 1000 m. Averaged over the entire region, the temperature at the upper limit of gas hydrate stability shows persistent warming over the last 40 years. The time series also clearly shows the influence of the Pacific Decadal Oscillation (PDO) at the upper limit of gas hydrate stability. Taking into account other independent variables such as latitude, water depth, and the monthly PDO index, our calculations studying sensitivity to methodological choices yield a constant and significant warming trend off the WA margin from 1960 to present.

Task 6.0 Non-steady state thermal simulations and impact of bottom water warming on the upper limit of the gas hydrate stability field
Completed this reporting period – In collaboration with Robert Harris at Oregon State University we used a 2-D finite-element conductive heat flow model to simulate the change in temperature distribution in the shallow sediments at the upper limit of gas hydrate stability resulting from the

warming intermediate-depth water temperatures. The upper boundary of the thermal model is based on the historic temperature records on the WA margin, and the bottom boundary condition is set by the heat flow estimated from regional BSR data, historic heat flow surveys, and borehole data. In situ thermal conductivity is estimated from MCS data using seismic velocity to estimate porosity, then porosity to thermal conductivity (Task 3.0). Thermal diffusivities were also measured during a recent GeoPRISMS expedition off the coast of WA by Johnson and Solomon (Johnson et al., 2013, EOS: Homola et al, submitted to JGR, 2014). The base of the gas hydrate stability zone is calculated integrating the Pitzer equations in Tishchenko et al. (2005). The model is stepped through time over the 45-year historic record of bottom water temperatures for the WA margin. Results show that the upslope limit of the gas hydrate stability zone on the WA margin is sensitive to the contemporary warming of intermediate waters and retreats downslope over the 40-year period along all three profiles simulated along the margin. This modeling effort will also guide the field program in Phase II of the research project. The results of the characterization of the long-term bottom warming trend and these model simulations are in preparation for publication.

Task 7.0 Planning and Preparations for Research Expedition
In Progress – During this reporting period, we have begun preparing for the research expedition in the Fall of 2014 and developing a cruise plan in consultation with the operators of the *R/V Thompson*.

CONCLUSIONS
The first six tasks comprise Phase 1 of the research project aimed at providing the context for a systematic geophysical and geochemical survey of methane seepage along the upper continental slope of the WA margin during a field program in October 2014. To date, 5 of the six tasks have been completed. We have started preparing for the research expedition (Task 7), which is the first task for Phase II of the project. We are off to a great start and are on track to meet Milestone #1 in June 2014.

MILESTONE STATUS
No project milestones have been completed within this quarter

COST STATUS
We projected a DOE expenditure of $4,635 for the second quarter, and $5,945 was spent to support our modeling efforts, for preparation of a manuscript detailing the results, and cruise preparation.

PROBLEMS OR DELAYS
None.

PRODUCTS
Completion of this quarterly report

We also prepared an article for the quarterly GeoPRISMS newsletter that highlights our upcoming expedition on the R/V Thompson in the fall of 2014.

Johnson, H.P., Solomon, E.A., Harris, R., Salmi, M., Berg, R., 2014. A geophysical and hydrogeochemical survey of the Cascadia subduction zone. GeoPRISMS Newsletter, Issue No. 32, Spring 2014.

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

13131 Dairy Ashford, Suite 225
Sugarland, TX 77478

1450 Queen Avenue SW
Albany, OR 97321-2198

Arctic Energy Office
420 L Street, Suite 305
Anchorage, AK 99501

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