Oil & Natural Gas Technology

DOE Award No.: DE-FE0013998

Quarterly Research Performance Progress Report

(Period ending 06/30/2014)

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

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July 31, 2014

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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 third quarter of this project we finalized our analysis of the bottom water temperature trend along the upper continental slope of the Washington margin between the years 1968 and 2013. Sediment thermal simulations of how long-term bottom water warming has impacted the upper limit of the gas hydrate reservoir are now complete. During this quarter, we prepared a manuscript for submission to Geophysical Research Letters describing these results. Our time was also spent preparing for the research expedition associated with this award to characterize methane seepage along the upper continental slope of the Washington margin. The cruise dates are finalized, and the research expedition will take place October 10-19, 2014 on the *R/V Thompson*. The PIs have been meeting weekly to discuss our sampling strategy, work flow, and cruise track. The staffing for the expedition is complete, and materials/supplies are currently being ordered and prepared for the cruise. In preparation for the upcoming expedition, we have been processing existing swath bathymetry and acoustic backscatter data on the Washington margin beneath our proposed cruise track-lines. In addition, we have acquired archive hydrocarbon emission sites on the Cascadia margin, both from the published literature and reported by local fishermen. These data are currently undergoing QA/QC and will be analyzed quantitatively for possible correlations with depth and slope over the entire Cascadia margin. We have continued our work on identifying BSRs along the Washington margin focusing on the COAST MCS survey lines collected in 2012. Heat flow and geothermal gradients have been estimated based on these BSRs and the results are being presented at the upcoming AOGS meeting in Sapporo, Japan (Salmi et al., 2014) and a manuscript is in preparation for submission in the summer of 2014.

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 in a previous 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
Completed/In progress – We have evaluated Bottom Simulating Reflectors (BSRs) from the COAST MCS cruise to establish the distribution of gas hydrates and geothermal gradients along the 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). This work has been completed for the region surveyed during the COAST MCS expedition in 2012, which overlaps with our proposed track-line for our research expedition in October 2014. We are currently evaluating BSRs from other legacy datasets along the WA margin

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 October 2014. The PIs have been meeting weekly to discuss our sampling strategy, work flow, and cruise track. The staffing for the expedition is complete, and materials/supplies are currently being ordered and prepared for the cruise.

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, the six tasks have been completed, however we are conducting additional work on Task 4.0 to expand our heat flow estimates to the northern segment of the WA margin. We are currently preparing for the research expedition (Task 7), which is the first task for Phase II of the project.

MILESTONE STATUS
Milestone #1 – Determination of the gas hydrate distribution and geothermal gradients along the WA continental slope based on COAST MCS data
Completed June 2014, however additional work continues on legacy datasets north of the COAST survey area.

COST STATUS
During the third quarter, $25,193 was spent to support our bottom water temperature and sediment thermal modeling efforts, for preparation of a manuscript detailing these results, and on cruise preparation.

PROBLEMS OR DELAYS
None.

PRODUCTS

Completion of this quarterly report

Ms. Marie Salmi, a graduate student supported through this project, presented the results of the COAST BSR and heat flow work at the AOGS meeting in Sapporo, Japan.

Salmi, M., Johnson, H.P., Solomon, E.A., Harris, R.N., 2014. Heat flow survey on the Washington margin of the Cascadia subduction zone. AOGS 11th Annual Meeting, Sapporo, Japan.