Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report

(Period ending 12/31/2013)

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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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 an 8-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 first quarter of this project 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. The water temperature data spans the years 1968 to 2013, and entire profiles containing any physically unrealistic or clearly erroneous values (i.e. negative temperatures or temperature values greater than 16°C or less than 4°C at 200 m) were eliminated. The 2122 remaining open-ocean temperature profiles 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 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. We are currently using 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 Strucutre 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 almost complete, and a manuscript is in preparation describing the results of the 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 thermodynamic modeling, we are also beginning the analysis of all available archive acoustic backscatter data along the Washington margin. These acoustic backscatter images will allow us to locate regions of the seafloor that have substantial (>50 meter) areas of carbonate deposits and will be compared with potential fluid flow pathways (i.e. fault zones, sand layers) observed in the archive MCS data.

PROGRESS, RESULTS, AND DISCUSSION

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

Task 2.0 Compile relevant archive data
Completed – 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
In Progress – 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. Vp vs depth profiles from Line 4 of the Langseth MCS line offshore Gray's Harbor have already been used to estimate porosities and thermal conductivities, and we are currently providing estimates for the other nine lines of that survey.

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.

Task 5.0 Analyze recent temperature data and long-term bottom water record
Completed – 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
In Progress – In collaboration with Robert Harris at Oregon State University we are using 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) and spot verified using the CSMHYD software (Sloan and Koh, 2007). The model is stepped through time over the 45-year historic record of bottom water temperatures for the WA margin. We have characterized model sensitivity to model parameters such as the initial geotherms and sediment thermal diffusivity. Preliminary 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 profiles simulated along the margin. This modeling effort will also guide the field program in Phase II of the research project.

CONCLUSIONS

These 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. Three of these six tasks were completed during the first quarter of the project while the other three are still in progress. 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 $1,545 for the first quarter, however no direct costs were incurred by either Co-PI during this period. Salary for E. Solomon and P. Johnson will be paid in the second quarter in support of their effort. Current archive data recovery efforts by students involved in this project (Ms Marie Salmi, PhD student; Ms Una Miller, undergraduate student) were supported by NSF and UW fellowships.

PROBLEMS OR DELAYS

None.

PRODUCTS

Completion of the Project Management Plan and this quarterly report

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