Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report (Period ending 03/30/2017)

Characterizing Baselines and Change in Gas Hydrate Systems using EM Methods

Project Period (10/01/2016 – 09/30/2019)

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EXECUTIVE SUMMARY

The major accomplishments for this quarter was the resurrection and installation of the electrical conductivity cell at the USGS gas hydrate laboratory in Menlo Park, and the collection of a baseline data set. This involved purchasing and installing a new electrical impedance spectrometer, writing and commissioning some new MATLAB code to automate the data collection, and re-plumbing the pressure cell. This all went extremely well and we have successfully collected our first electrical conductivity data during depressurization melting of gas hydrate.

We have also been preparing the Vulcan and SUESI instrumentation systems for use in the Gulf of Mexico later this year. It has been two years since these instruments were used, and so a thorough test and checkout is required. We updated some hardware and software for the navigation data logging systems, and also needed to re-build the emergency trip systems on our topside power conditioning units.

Finally, we have been coordinating with the vessel operators to prepare for our data collection cruise in June/July.

ACCOMPLISHMENTS

Major goals of project

Methane hydrates require cool temperatures, high pressures, and methane in excess of solubility to form, conditions that are met in both marine and permafrost regions worldwide. Concentrated accumulations of structural hydrate may be the target for resource exploitation, and there have been several production tests of natural gas from hydrate, both on land, such as at the Mallik site in NW Canada or the Mt Elbert test well on the Alaska North Slope, and in the ocean, such as in the Nankai Trough and an ice platform off Prudhoe Bay.

Much naturally occurring hydrate exists at the edge of thermodynamic stability, and as such represents an environmental hazard that threatens release of a potent greenhouse gas as a consequence of warming. Also, one way to produce methane from hydrate is to destabilize the structure by depressurization.

Current geophysical surveying methods for identifying hydrates, such as seismic methods and well logging/coring, are limited. Quantifying the volume fraction of hydrate in sediments is possible with careful processing and inversion of seismic data, although the relationship between seismic velocity (or attenuation) and hydrate concentration is complicated and usually needs to be calibrated with well data. Electromagnetic (EM) methods, on the other hand, are sensitive to the concentration and geometric distribution of hydrate because regions containing hydrate are significantly more resistive when compared to water saturated zones. The current state of the art for imaging gas hydrate using EM methods is represented by the Vulcan system developed by Scripps Institution of Oceanography. This system uses multiple, 3-axis EM receivers towed at source-receiver ranges of up to 1,000 m behind an electric dipole transmitter. The whole array (transmitter and receivers) is "flown" 50–100 m above the seafloor in order to (a) reduce noise, (b) avoid seafloor infrastructure and other obstacles, and (c) allow all three components of electric field to be measured. The Vulcan system was used in 2014 and 2015 to successfully collect 1,000 km of high quality data over gas hydrate prospects in Japan, as well as two studies offshore San Diego, California.

For the next advance in this technology, under the current agreement we will collect extensive 3D Vulcan data sets over two or three sites in the Gulf of Mexico where drilling and coring of hydrate systems has been, or will be, carried out. We plan to study the Walker Ridge 313, Orca Basin, and Green Canyon 781 prospects, but as we did under previous NETL funding, we will consult with DoE and the drilling consortium before choosing final targets. With 2–3 days of data collection over each prospect, we will be able to collect at least 10 lines of data 10–20 km long. With a line spacing of 500–1,000 m, this will provide a dense data set of 100–200 line km covering 50–100 square km.

Under prior NETL funding we designed a specialty pressure cell plumbed for high-pressure gas access, in which we formed gas hydrate samples while simultaneously measuring impedance spectra. Such impedance measurements of methane hydrate are needed for modeling of gas hydrate systems, yet had never been established prior to our work. Under the current agreement, we plan to extend these laboratory experiments to further utilize the unique apparatus we have designed, and build on our previous results and baseline measurements. We will introduce additional parameters that mimic the effects of induced or environmental factors that may act to destabilize gas hydrate systems and contribute to the onset of partial dissociation to solid or liquid water.

Work accomplished during the project period

Electrical conductivity measurements.

The electrical conductivity cell that we had designed, constructed, tested, and used under a previous DoE contract had not been used since 2011, and the impedance spectrometer (LCR meter) associated with it had been removed and re-purposed. The first step for the current project was to re-build the plumbing and conductivity cell, and purchase and install a new LCR meter. The new meter (Gwinstek LCR-6000) has the ability for remote control over a serial port, and so it was decided to automate data collection using MATLAB software (we had not previously automated data collection because the earlier LCR meter only had a GPIB interface, which requires a RS232/GPIB converter that at the time was hard to obtain and unreliable in operation).

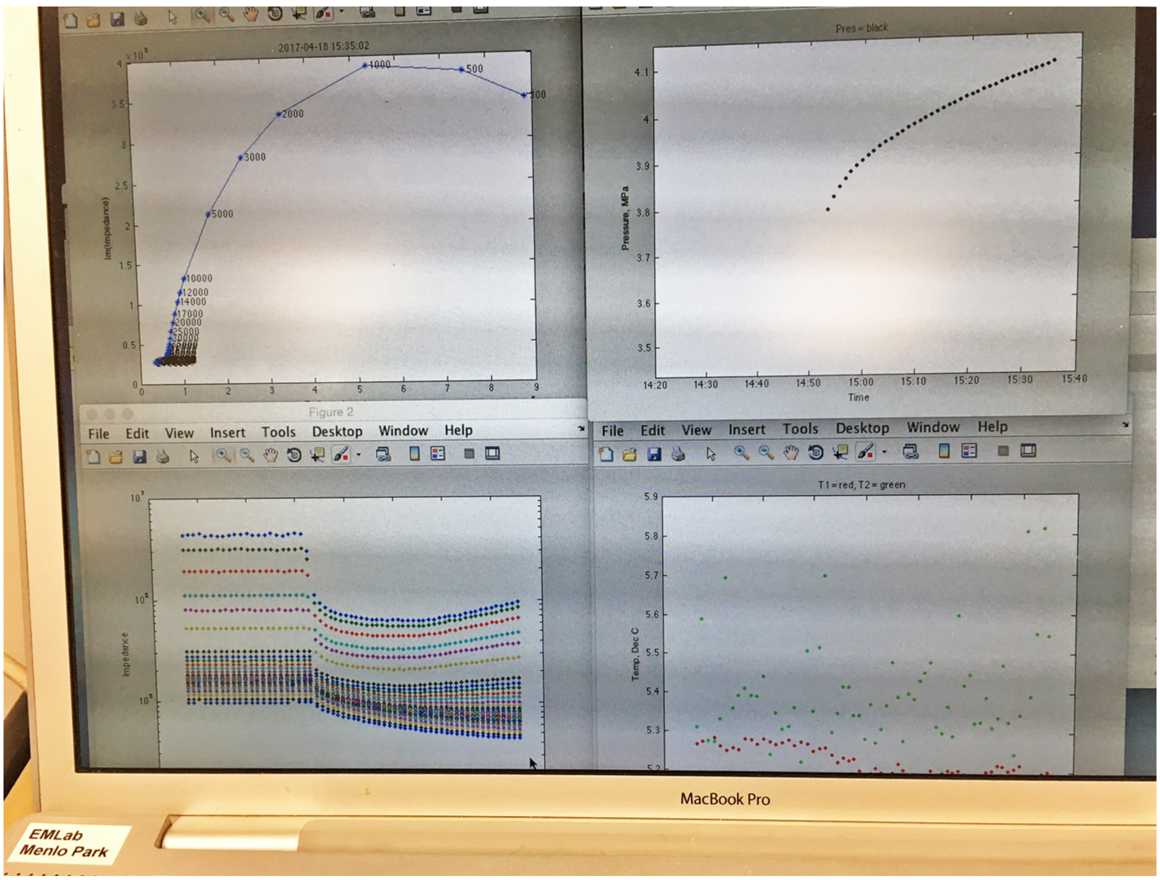

Figure 1. MATLAB-based automated data collection from the conductivity cell and auxiliary systems. Top-left: Impedance spectrogram of current measurement. Top-right: Methane pressure as a function of time. Bottom-left: Impedance data as a function of time (colors are different frequencies). The change in impedance with de-pressurization is evident. Bottom-right: temperature of the cell bath (green) and conductivity cell (red), as a function of time.

When we installed the LCR meter and laptop controller in the USGS gas hydrate laboratory in Menlo Park, we were also able to connect the laptop to the data acquisition unit that measures pressure and temperature on the cell. This replaces a very old, LabView-based system which is no longer supportable, and also allows all the relevant data to be merged during data acquisition. Figure 1 shows the data collection system running on a hydrate sample in the laboratory.

Figure 2. Left: The conductivity cell installed in the Menlo Park gas hydrate laboratory. Right: Removing the sample after quenching in liquid nitrogen.

We decided that our first run should be a baseline measurement on pure methane hydrate, in order to establish that we had successfully resurrected the conductivity cell. At the end of the run we tested our ability to partially dissociate a sample through depressurization in order to produce a hydrate product with a coexisting liquid water phase. The sample was then quenched in liquid nitrogen for analysis using cryogenic scanning electron microscopy (Figure 2). This work in ongoing.

CSEM data collection.

Our proposal included controlled-source EM (CSEM) data collection in the Gulf of Mexico using the R.V. Pelican. While this vessel is relatively inexpensive yet capable, one concern was the installation of our transmitter power supplies, since the hatchways to the laboratories are a few inches too small. In negotiations with LUMCON, the vessel operator, it was decided to put our work on the R.V. Point Sur, a slightly larger vessel, at no extra cost to the project. Currently we are on the schedule for June 26th to July 5th this year.

As with the electrical conductivity cell, it has been several years since we used the Vulcan CSEM system in the field. During this quarter, we started testing the Vulcan systems and looking at extending the length of the towed array from 1,000 m to 1,500 m, in order to get deeper penetration over the Walker Ridge hydrate prospect. We have upgraded the hardware and software that logs pitch, roll, heading, and depth in the Vulcan receivers. We also discovered that the batteries and battery chargers that operate the shunt trips in the topside power supply units for SUESI, our CSEM transmitter, had failed. We have replaced this critical safety system with new components.

We have been coordinating with Peter Flemings and Kevin Meazell at UT-Austin, as well as Ann Cook and Derek Sawyer at Ohio State, with regards the survey locations, since as of January the drill site locations were still being finalized (although they have only changed by a few tens of meters). Although we do not yet have access to the seismics at Orca Basin and GC781, those who do have suggested tow line orientations that are perpendicular to geologic strike. Seth Haines at USGS has published seismics from WR313 that we will be using to orient the survey lines there.

Training and professional development.

Peter Kannberg, PhD student at SIO, is preparing for the field operations later this year, and is carrying out experimental design for the survey parameters and assisting with the instrument preparation. He plans to submit his thesis by the end of summer and will continue work on this project as a postdoc.

Ryan Lu, a postdoc at LLNL, has started work on the laboratory electrical conductivity studies and has been learning about hydrate synthesis and the operation of the conductivity cell.

Plans for next project period.

During the next project period we will analyze the data collected in the first conductivity run. We will continue to collect laboratory data at Menlo Park, and prepare the field equipment for shipment.

Table 1: Milestone status report.

Milestone Title	Planned Completion Date	Actual Completion Date	Verification Method	Comments on progress
First set of conductivity runs	08/1/2017		Internal review	ongoing
Field data collection	12/1/2017		200 line km collected	
Second conductivity runs	30/12/2017		Internal review	
Final set of conductivity runs	9/1/2018		Internal review	
Field data inverted	12/1/2018		2D inversions done	
Publications(s) submitted	9/1/2019		At least 1 pub. submitted	
Publications(s) accepted	12/30/2019		Publication accepted	

PRODUCTS

Project Management Plan. The revised Project Management Plan was accepted on 3 February 2017.

The following papers acknowledge this or past DoE funded research:

Sherman, D., P. Kannberg, and S. Constable, 2017. Surface towed electromagnetic system for mapping of subsea Arctic permafrost. *Earth and Planetary Science Letters*, **460**, 97–104.

Constable, S., P. K. Kannberg, and K. Weitemeyer, 2016. Vulcan: A deeptowed CSEM receiver. *Geochemistry, Geophysics, Geosystems*, **17**, doi:10.1002/ 2015GC006174.

Du Frane, W., L.A. Stern, S. Constable, K.A. Weitemeyer, M.M. Smith, and J.J. Roberts, 2015. Electrical properties of methane hydrate + sediment mixtures. *Journal of Geophysical Research*, **120**, 4773–4787, doi:10.1002/2015JB011940.

Weitemeyer, K., and S. Constable, 2014. Navigating marine electromagnetic transmitters using dipole field geometry. *Geophysical Prospecting*, **62**, 573–593, doi: 10.1111/1365-2478.12092.

Du Frane, W.L., L.A. Stern, K.A. Weitemeyer, S. Constable, J.C. Pinkston, J.J. Roberts, 2011. Electrical properties of polycrystalline methane hydrate. *Geophysical Research Letters*, **38**, doi:10.1029/2011GL047243.

Weitemeyer, K.A., S. Constable, S. and A.M. Trehu, 2011. A marine electromagnetic survey to detect gas hydrate at Hydrate Ridge, Oregon. *Geophysical Journal International* , **187**, 45-62.

Weitemeyer, K., G. Gao, S. Constable, and D. Alumbaugh, 2010. The practical application of 2D inversion to marine controlled-source electromagnetic sounding. *Geophysics*, **75**, F199–F211.

Weitemeyer, K., and S. Constable, 2010. Mapping shallow geology and gas hydrate with marine CSEM surveys. *First Break*, **28**, 97–102.

PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS

Name:	Steven Constable
Project Role:	PI
Nearest person month worked:	1
Contribution to project:	Management, scientific direction
Funding support:	Institutional matching funds
Foreign collaboration:	Yes
Country:	Canada
Travelled:	No

Name:	Peter Kannberg
Project Role:	PhD student/SIO
Nearest person month worked:	3
Contribution to project:	Planning field program. Experimental design.
Funding support:	This project
Foreign collaboration:	Yes
Country:	Canada
Travelled:	No

Name:	Laura Stern
Project Role:	Scientist
Nearest person month worked:	1
Contribution to project:	Gas hydrate synthesis and conductivity measurements.
Funding support:	USGS
Foreign collaboration:	No

Name:	Wyatt DuFrane
Project Role:	Scientist
Nearest person month worked:	1
Contribution to project:	Postdoc supervision/conductivity measurements.
Funding support:	This project
Foreign collaboration:	No

Name:	Ryan Lu
Project Role:	Posdoc/LLNL
Nearest person month worked:	1
Contribution to project:	Conductivity measurements.
Funding support:	This project
Foreign collaboration:	No

CHANGES/PROBLEMS

No changes or problems to report at this time.

BUDGETARY INFORMATION

Table 2: Spend profile

	Budget Period 1							
baseline	10/1/16 – 3/31/17		4/1/17 – 6/30/17		7/1/17 – 9/30/17		10/1/17 – 12/31/17	
	Q1		Q2		Q3		Q4	
	Q4	Cum. Total	Q1	Cum. Total	Q2	Cum. Total	Q3	Cum. Total
Baseline cost:								
Federal	$29,103	$29,103	$158,910	$188,013	$149,463	$337,476	$29,103	$366,579
Non-federal	$45,121	$45,121	$45,121	$90,242	$45,121	$135,363	$45,121	$180,484
Total	$74,224	$74,224	$204,031	$278,255	$194,584	$472,839	$74,224	$547,063
Actual cost:								
Federal	$18,512	$18,512	$	$	$	$	$	$
Non-federal	$?	$?	$	$	$	$	$	$
Total	$?	$?	$	$	$	$	$	$
Variance:								
Federal	-$10,591	-$10,591	$	-$	$	$	$	$
Non-federal	$?	$?	$	$	$	$	$	$
Total	-$?	-$?	$	$	$	$	$	$