Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report (Period ending 9/30/2013)

Mapping Permafrost and Gas Hydrate using Marine CSEM Methods

Project Period (10/1/2012 – 09/30/16)

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EXECUTIVE SUMMARY

In this quarter we finished construction of a extremely small but moderately powerful EM transmitter for use on this project, and carried out bench tests and software development. The student working on the project continued to develop skills in the 2D inversion of marine CSEM data over hydrate targets.

ACCOMPLISHMENTS

Major goals of project

Permafrost underlies an estimated 20% of the land area in the northern hemisphere and often has associated methane hydrate. Numerous studies have indicated that permafrost and hydrate are actively thawing in many high-latitude and high-elevation areas in response to warming climate and rising sea level. Such thawing has clear consequences for the integrity of energy infrastructure in the Arctic, can lead to profound changes in arctic hydrology and ecology, and can increase emissions of methane as microbial processes access organic carbon that has been trapped in permafrost or methane hydrate dissociates. There has, however, been significant debate over the offshore extent of subsea permafrost.

Our knowledge of sub-seafloor geology relies largely on seismic data and cores/well-logs obtained from vertical boreholes. Borehole data are immensely valuable (both in terms of dollar cost and scientific worth), but provide information only about discrete locations in close to one (vertical) dimension. Seismic data are inherently biased towards impedance contrasts, rather than bulk sediment properties. In the context of mapping offshore permafrost and shallow hydrate, seismic methods can identify the top of frozen sediment through the identification of high amplitude reflections and high-velocity refractors but simple 2D seismic surveys do little to elucidate the bulk properties of the frozen layers, particularly the thickness. However, permafrost and gas hydrate are both electrically resistive, making electromagnetic (EM) methods a complementary geophysical approach to seismic methods for studying these geological features. Deep ocean EM methods for mapping gas hydrate have been developed by both academia and industry, but the deep-ocean techniques and equipment are not directly applicable to the shallow-water, near-shore permafrost environment. This project addresses this problem by designing, building, and testing an EM system designed for very shallow water use, and using it to not only contribute to the understanding of the extent of offshore permafrost, but also to collect baseline data that will be invaluable for future studies of permafrost degradation.

We will use the new equipment to carry out a pilot project to map the contemporary state of subsea permafrost on part of the U.S. Beaufort inner shelf, reoccupying seismic lines acquired in 2010 to 2012. We will combine the interpretation of EM data with seismic data through a no-cost collaboration with Carolyn Ruppel of the USGS. Modeling suggests that a 500 m long EM array will be adequate to sense the top of permafrost in many of the areas where the USGS has completed mapping. The 500 m towed array will be supplemented by the deployment of 2 to 4 seafloor recorders that will be retrieved after the cruise so that nothing remains in the area. The use of a small number of seafloor recorders will allow us to collect data at larger offsets, providing insight into deeper structure.

We are exploiting the close association of hydrate and permafrost at high latitudes, and in particular their common response to changing climate. By using a second geophysical method to supplement seismic data, we will be able to better map the current extent of permafrost and so better understand the impact of past sea level rise on the hydrate stability field, and provide a critical baseline for studies which target the effects of current climate change.

Our work will not only expand our geophysical tool-kit but also expand our understanding of the geological and hydrological systems associated with gas hydrate. Instrumentation and analytical methods developed for this project can be easily applied for future mapping elsewhere.

Work accomplished during the project period

Construction and bench tests of EM transmitter. Our engineering and scientific group built the EM transmitter module that will be used for this project, developed the embedded software, and carried out extensive bench testing. A photograph of this unit is shown in Figure 1. Measuring only slightly more than 16 cm across, we have tested this unit at output currents of 50 amps. It operates from a 12 V supply, making it possible to run the unit off car batteries, the vessel's DC power, or 110 VAC using a commercial power supply. The timing for the waveform can come from an onboard clock accurate to a few milliseconds per day (the same clock as used in the receiver instruments), or an external GPS timebase. The flexibility in the power source and timing is important, since we will be operating this system off much smaller vessels than we are normally used to.

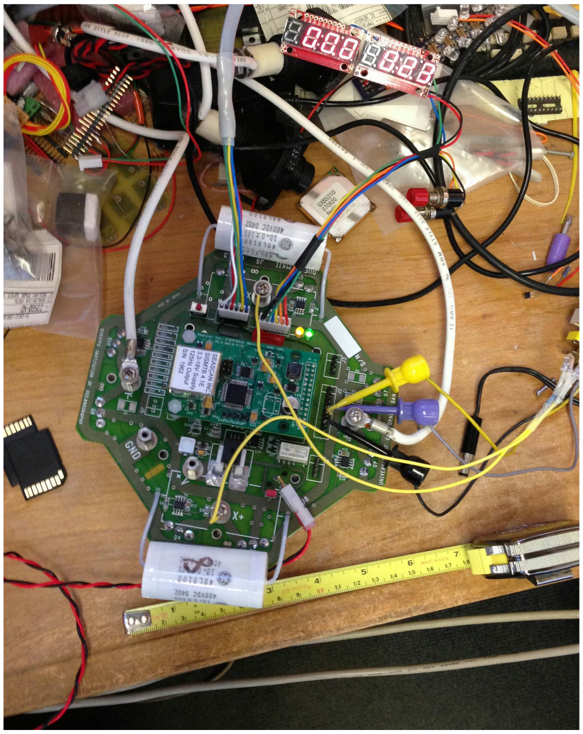

Figure 1. Our incredibly compact, 50+A, EM transmitter module being bench tested.

Construction of receiver array. For the receiver array we will be simply re-packaging our existing electrode-amplifier-logger systems, and we have designed and machined the waterproof housings for this.

Student worked on data processing and interpretation skills. See "training and professional development" below.

Training and professional development.

The PhD student funded by this project, Peter Kannberg, has currently been working on a data set we collected over the carbonate pinnacle at Hydrate Ridge, Oregon. These data were a test of an innovative battery-powered deployed CSEM transmitter. One aspect of this system is that the orientation of the transmitter on the sea-floor is random, occasionally resulting in the receivers being positioned on nodal surfaces of the dipole fields. This makes inversion of amplitude and phase unstable (because of phase wrapping), so we have been working with methods to deal with this, such as inverting for polarization ellipse maxima. As always, experience with inverting real data will prove useful when we start collecting data for this project.

Peter has submitted an abstract for the International Conference on Gas Hydrates 2014 meeting.

Plans for next project period.

During the next project period we will package the new transmitter and test it at sea.

Table 1: Milestone status report.

Milestone Title	Planned Completion Date	Actual Completion Date	Verification Method	Comments on progress
Equipment design approved	5/1/2013	5/1/2013	Internal review	
Equipment passes tests	10/30/2013			
Harrison Bay data collection	9/1/2014			
Harrison Bay data processing	9/30/2014			
Camden Bay data collection	9/1/2015			
Camden Bay data processing	9/30/2015			
Publications(s) submitted	4/12016			
Publications(s) accepted	9/302016			

PRODUCTS

Project Management Plan. The revised Project Management Plan was accepted on 19 November 2012.

American Geophysical Union abstracts. The following 2012 abstracts were relevant to this and past DoE funded research:

Mapping methane hydrate with a towed marine transmitter-receiver array, Peter K. Kannberg; Steven Constable, presented in *GP33A. Advances in Electromagnetic Induction: From the Near Surface to the Deep Mantle III Posters.*

Mapping marine gas hydrate systems using electromagnetic sounding, Steven Constable; Karen A. Weitemeyer; Peter K. Kannberg; Kerry W. Key, presented in *OS34A. Marine and Permafrost Gas Hydrate Systems III.*

Electrical conductivity of lab-formed methane hydrate + sand mixtures; technical developments and new results, Laura Stern; Wyatt L. Du Frane; Karen A. Weitemeyer; Steven Constable; Jeffery J. Roberts, presented in *OS43B. Marine and Permafrost Gas Hydrate Systems IV Posters.*

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: United Kingdom
Travelled: No

Name: Peter Kannberg
Project Role: PhD student
Nearest person month worked: 3
Contribution to project: Development of analysis tools
Funding support: Institutional matching funds
Foreign collaboration: No

CHANGES/PROBLEMS

Due to delay associated with commitments to two other large ocean-going projects, we revised the date of the second

Milestone to December 6, 2013. This is still in good time to be ready for the 2014 field season. We have also extended the Project/Budget period 1 to December 31 2013 for similar reasons.

BUDGETARY INFORMATION

Table 2: Spend profile

	Budget Period 1							
baseline	10/1/12 – 12/31/12							
	Q4		Q1		Q2		Q3	
	Q4	Cum. Total	Q1	Cum. Total	Q2	Cum. Total	Q3	Cum. Total
Baseline cost:								
Federal	$49,969	$49,969	$33,192	$83,161	$19,810	$102,971	$18,771	$121,742
Non-federal	$9,897	$9,897	$9,897	$19,794	$9,897	$29,692	$29,897	$59,589
Total	$59,866	$59,866	$43,089	$102,955	$29,707	$132,663	$48,668	$181,331
Actual cost:								
Federal	$19,027	$19,027	$8,160	$27,187	$17,444	$44,631	$43,370	$88,001
Non-federal	$10,874	$10,874	$9,514	$20,388	$3,500	$23,888	$24,215	$48,103
Total	$29,901	$29,901	$17,674	$47,575	$20,944	$68,519	$67,585	$112,887
Variance:								
Federal	-$30,942	-$30,942	-$25,032	-$55,974	-$2,366	-$58,340	$24,599	-$33,741
Non-federal	$977	$977	-$383	$594	-$6,379	-$5,804	-$5,682	-$11,486
Total	-$29,964	-$29,964	-$25,415	-$55,380	-$8,763	-$64,144	$18,917	-$45,227

The remaining balance of institutional matching funds ($11,486) reflects instrument fabrication charges from our machine shops that are not yet reflected in our accounting system. The remaining Federal funds ($33,741) will be applied to November/December engineer salaries during the final testing of the equipment system.