Oil & Natural Gas Technology

DOE Award No.: DE- FE0010141

Quarterly Research Performance Progress Report

(Period ending 3/31/2014)

Submitted April 30, 2014

Temporal Characterization of Hydrates System Dynamics beneath Seafloor Mounds: Integrating Time-Lapse Electrical Resistivity Methods and In Situ Observations of Multiple Oceanographic Parameters

Project Period: October 1, 2012 – October 31, 2015

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Prepared for:

The Department of Energy - Methane Hydrates Program
United States Department of Energy
National Energy Technology Laboratory

Office of Fossil Energy

RESEARCH PERFORMANCE PROGRESS REPORT

Temporal Characterization of Hydrates System Dynamics beneath Seafloor Mounds: Integrating Time-Lapse Electrical Resistivity Methods and In Situ Observations of Multiple Oceanographic Parameters

ACCOMPLISHMENTS:

Major objectives of the project are to:
1) characterize, geophysically, the sub-bottom distribution of hydrate and its temporal variability and,
2) contemporaneously record relevant environmental parameters (temperature, pressure, salinity, turbidity, bottom currents and seafloor microseismicity) to investigate possible links of the variability to climate. In order to achieve these overall objectives, we have identified the following goals:

a) employ the Direct Current Resistivity (DCR) method as a geophysical indicator of hydrates,
b) identify hydrate formation mechanisms in seafloor mounds,
c) detect short-term changes within the hydrates system,
d) illuminate relationships/impacts of local oceanographic and microseismic parameters on the hydrates system and, indirectly, the benthic fauna,
e) monitor fluid/hydrate motion and seafloor instability that these changes might produce.

Accomplishments achieved in relation to these goals include the following (Quarter 1):

- Completion and acceptance of the Project Management Plan; successful "kick-off,"
- Successful completion and testing (at sea) of the I-SPIDER (patent pending), a new deployment and surveying system,
- Beginning of the assembly and evaluation of existing data from the research site at MC118,
- Renovation of the Direct Current Resistivity (DCR) cable in preparation for the September survey.

Accomplishments achieved in relation to these goals include the following (Quarter 2):

- We have used the I-SPIDER, the Integrated Scientific Platform for Instrument Deployment and Emergency Recovery, successfully on three successive cruises both surveying and deploying instruments;
- CMRET's shop and SDI's shop have coordinated effort to build the communications software that will enable us to have live communication with the DCR array while in survey mode;
- We have completed the consolidation of electronics into a single "topside system" that greatly increases our ability to control and monitor at-sea operations;
- We have installed Ultra-short Baseline (USBL) transponders in the hull of the R/V *Pelican* to maintain our exceptional navigation/locating capabilities while at sea;
- We have made significant progress in processing the 2013 multibeam data from MC118;
- We have established a processing protocol for the new polarity-preserving chirp data from MC118;
- We have begun to build the Integrated Portable Seafloor Observatory (IPSO) lander;
- We have made repairs to the damaged resistivity system resulting from the flooding event, summer 2012;
- We have determined what caused the instrument to flood;
- We have devised a solution to the flooding problem;

- We have begun work to devise a means whereby operation of the array can be accomplished autonomously while on the seafloor;
- We have scheduled two cruises for 2014 on the R/V Pelican: April 7-12 and October 3-6.

Accomplishments achieved in relation to project goals include the following (Quarter 3):

- We have completed the survey-mode communications electronics;
- We have upgraded the SSD and I-SPIDER individually and as a tandem system;
- We have selected primary and secondary target sites for the DCR survey and have plotted the survey;
- We have built the IPSO lander frame, researched and ordered instruments and installed them on the IPSO lander;
- We have begun processing the new polarity-preserved chirp data from MC118;
- We have completed repairs to the seafloor DCR system associated with the housing flooding that occurred in July 2012;
- SDI replaced the power and control though-housing connector to the DCR instrument with one that has higher current capacity;
- We have devised a system whereby the DCR system will be controlled remotely while on the seafloor;
- SDI built the Atom control computer and installed it in a pressure housing;
- We have developed/acquired new control software for autonomous operation of the DCR instrument;
- We have built a stand that will hold the DCR instrument electronics and housing end cap in an inverted position while assembling the DCR housing.

Accomplishments achieved in relation to project goals include the following (Quarter 4):

- We have inventoried data from MC118 that has and will continue to inform our survey and deployment strategies;
- We have established a processing protocol for the polarity-preserving chirp data from MC118;
- We have designed and begun acquiring components for the replacement battery system for the IPSO;
- We have completed a paper describing the new resistivity data processing method that will be used to process the targeting data as a 3D data set;
- We have developed a data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor;
- We have submitted a no-cost extension request to complete Year 1 work that has been approved.

Accomplishments achieved in relation to project goals include the following (Quarter 5):

- We have completed the electronics integration for command and control throughout survey and deployment/monitoring modes;
- We have tested the joint operation of the IDP, the control computer, and the resistivity instrument in the remote-control and autonomous monitoring mode of operation;
- We have built/modified a deployment system for the 1000m long DCR array.
- We have a plan for processing initial reconnaissance DCR data
- We have a plan in place for the cruise to collect survey data and to place the DCR array and lander for a 6-month data-collecting period;

We have completed the electronics integration for command and control throughout survey and deployment/monitoring modes.
The seafloor lander used in this project will have three electronics devices onboard, each contained in its own pressure housing. The first device is the Integrated Data Power Unit (IDP), which is low-power timer/controller, that can be programmed to turn the power to other instruments on and off on a set schedule and manages communications with the surface vessel via fiber optic link in the tow cable, if present, or an acoustic modem. The second device is a low-power Atom computer that will provide instructional control of the resistivity instrument. The third device is the seafloor resistivity instrument itself, which also contains a computer to manage the details of the resistivity data collection.

Due to the delay in deployment, this system was disassembled and recharged at SDI, the software reset for the new desired sampling dates and sampling plan including the time on for each sample and resetting the frequency for awakening the system. The data logger and AGI system were then married together and tested over several weeks to make sure the system and internal short duration batteries were still sufficient after the delay.

We have tested the joint operation of the IDP, the control computer, and the resistivity instrument in the remote-control and autonomous monitoring mode of operation
During the January through March, 2014 project quarter, John Dunbar and graduate student Tian Xu made three trips to SDI's office in Wylie, Texas to prepare for the April research cruise to MC118. The main objective of the trips was to test the joint operation of the IDP, the control computer, and the resistivity instrument in the remote-control and autonomous monitoring mode of operation to be used in the April, 2014 cruise. During these trips, Dunbar and Xu worked with Paul Higley and Scott Sharpe, of SDI. Bench-top tests of the joint operation were performed during the first two trips, first in the remote control mode, without the Atom control computer involved, and then in the autonomous operation mode, controlled by the software on the Atom computer. In the final trip a test was performed in an open field near the SDI office, in which a 260m segment of the seafloor cable was deployed and run in both modes. An attempt was made to run a test in a local water reservoir; however, high winds made that test impractical.

We have built/modified a deployment system for the 1000m long DCR array.
During previous experiences with long arrays, we have deployed the systems manually. For this deployment of the 1000m long DCR array, we devised a new system that makes use of a wide-angle shiv. The array has been configured so that the nodes are narrow and well-taped to preclude catching on the cable or within the shiv. This system is designed to make a quicker, less dangerous deployment.

We have a plan for processing initial reconnaissance DCR data
There will be two phases of work during the upcoming cruise to MC118 in April, 2014. The goal of the initial phase will be to locate a suitable resistivity anomaly for long term monitoring. This will be done by collecting multiple, closely spaced, resistivity profiles across a fault trace along which high resistivity anomalies were observed in the 2009 reconnaissance survey of the site. Ideally, the profiles would be 1 km long and spaced approximately 50 m apart along the trace of the fault trace. These profiles will be processed in real time, as the electrode array is being repositioned for the next profile. Profiles will be collected in this way until a suitable monitoring target is identified. Once this task is complete, the DCR system will be retrieved, reconfigured for the autonomous monitoring operation, and redeployed over the chosen target. Once the initial deployment cruise is complete, we plan to reprocess the initial targeting data as a 3D swath volume. This will provide a 3D resistivity image of the targeted anomaly to

serve as a context within which to interpret the repeat 2D profiles collected during monitoring. The 3D resistivity swath will also test the potential value of collecting such data sets over entire seafloor mounds in the future.

We have a plan in place for the cruise to collect survey data and to place the DCR array and lander for a 6-month data-collecting period.
In order to achieve both survey and monitoring objectives during the April cruise, the Integrated Portable Seafloor Observatory (IPSO) will be required to operate in two modes. In the initial phase of the April cruise to MC118, the lander will be used in a reconnaissance profiling mode, controlled remotely by an operator on the surface vessel, to collect a series of resistivity profiles to inform the selection of a profile to be monitored over the initial 6-month monitoring period. In this remote-control mode, the I-SPIDER (Integrated Scientific Platform for Instrument Deployment and Emergency Recovery, patent pending) ROV (remotely Operated Vehicle) device will be attached to the lander, to provide live video feed from the bottom and real-time positioning data for navigating the instrument package. Two-way communication between the operator at a workstation on the surface vessel and the seafloor resistivity instrument will transmit through a fiber optic link within the tow cable to the I-SPIDER, through the IDP, which will transmit it to the resistivity instrument as RS232 instructions. In this way, the operator can instruct the instrument which acquisition parameters to use during data collection, when to start taking data, monitor the quality of the data as they are collected, and retrieve the data from the seafloor instrument after the data acquisition is complete. One potential problem in this mode of operations is the chance that the communication link between the resistivity instrument and the shipboard workstation will hang. In this situation, one of the devices operates as if communication is still on-going, while the other operates as if it has been terminated. If this happens, there is no mechanism to restore two-way communication using commands sent through the fiber optic link. For this possibility, an acoustic modem option was added, such that the IPD could be signaled from the surface vessel by the acoustic modem to cycle the power to the resistivity instrument, causing it to re-boot. This would allow communication through the fiber optic link to be re-established.

Once the reconnaissance resistivity data are collected, processed, and a suitable profile is selected for long-term monitoring, the plan is to bring the I-SPIDER and lander back onto the ship, reconfigure the lander to operate in the autonomous monitoring mode without the I-SPIDER but with the addition of the oceanographic parameters sensors/instruments. In this mode, the IDP will be programmed to turn power onto the control computer and the resistivity instrument at a set interval, such as once per week, and leave the power on for a set time, such as three hours. Both the control computer and resistivity instrument are set to boot automatically when they receive power. The resistivity instrument boots and waits for instructions. The control computer boots and automatically executes a control program written to perform the monitoring task. Each time the control program runs, it first establishes RS232 communication with the resistivity instrument. Then it downloads any data files left on the resistivity instrument to the larger solid state control computers. Once the data are retrieved, the control program erases the data from the resistivity instrument to make room for the new data set. The control program then transmits a set of measurement instructions to the resistivity instrument and tells it to start data collection. Once data collection on the resistivity instrument is initiated, the job of the control computer is complete, so the control program initiates the shutdown of Windows. The resistivity instrument continues to collect data until its command set has been completed and then it waits for further instructions. In this mode there is not a mechanism for the resistivity instrument to signal the IDP or control computer that it has completed data acquisition. Instead, the IDP is programmed to leave the power on to instrument for approximately twice the time required to collect the data and then to shut it down. This sequence will repeat until battery power is insufficient for it to continue, estimated to be 30 cycles.

We anticipate collecting 3-6 profiles in survey mode, though we are prepared to do more. Past experience tells us that the profile directions will be governed, at least in part, by prevailing winds and bottom currents. Ideally, we will need very little bottom current and that it be either with or 180 degrees from the direction of the wind for the captains to have the best chance at successfully navigating reasonably straight survey lines. The time required to have the DCR on the seafloor collecting data is estimated at 2-3 hours which will require the captain to maintain position within a watch circle of about 50m radius. We have plotted bottom hazards so will need to avoid known hazards, including instruments (probes with attached drive weights), coral colonies and other benthic communities. Many of the instruments were removed during 2013 cruises so their number is less than at times in the past, minimizing our chances of entanglement.

MILESTONE CHART:

Milestones A, B, C and D are complete; Milestone E cannot be completed until the first Year 2 cruise sails.

Milestone	Planned Completion	Actual Completion	Verification Method	Progress/Deviation from Plan
Milestone A: Target sites selection for IPSO deployment at MC118	9/15/2013	9/17/2013	4 targets identified	2 days
Milestone B: Successful testing of the DCR cable in a pressure-testing facility – SW Research Institute or comparable.	9/15/2013	9/11/2013	Successful test of the DCR system at 1000m water depth equivalent	
Milestone C: Successful testing of a new Integrated Portable Seafloor Observatory (IPSO).	9/15/2013	9/25/2013	Successful onshore test of IPSO	10 days
Milestone D: Successful deployment of Integrated Portable Seafloor Observatory (IPSO).	4/30/2014	4/12/2014	Proper orientation and functioning of IPSO	
Milestone E: Recover data from MC118 with the IPSO	10/31/2014		IPSO recovered with data	
Milestone F: Recover data from MC118 with the IPSO	4/30/2015		IPSO recovered with data	
Milestone G: Complete analysis of temporal characterization of hydrates system dynamics at MC118	10/31/2015		Resistivity and temporal data produce reasonable temporal analysis	
Milestone H: Complete final report and submit to DOE	1/31/2016		Report accepted by COR	

PRODUCTS:

A new lander, the IPSO;
oceanographic instruments for the IPSO;
Command and control hardware and software;
A new cable-deployment system for the DCR.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

During this quarter, personnel from the University of Mississippi and from both subcontracting organizations participated in the project. Their contributions are as follows:

Name: Carol Lutken
Project Role: PI, University of Mississippi
Nearest person month worked: 1 (4 weeks)
Contribution to Project: Lutken executed all communications between participants and with DOE and LUMCON and made arrangements for the April, 2014 cruise. She worked with the MMRI shop to assure everyone's readiness for the April cruise. She continues to work with D'Emidio to analyze subsurface data available from MC118. She compiled information for and wrote the quarterly progress report. She is working with the DOE COR to prepare for the continuation presentation to DOE and committee evaluation scheduled for April 16.

Name: Marco D'Emidio
Project Role: Scientist, University of Mississippi
Nearest person month worked: 1 (4 weeks)
Contribution to Project: D'Emidio worked to assure all electronics and computing components are functional, up-to-date and ready to go in April. This included making backup copies of all data relevant to the cruise and data-collecting efforts. He maintains software licensing and updates. He continues to work with the ppchirp processing, focusing on the MC118 data.

Name: Matt Lowe
Project Role: Marine Systems Specialist, University of Mississippi
Nearest person month worked: 1 (6 weeks)
Contribution to Project: Lowe is the Chief of shop operations at MMRI/CMRET. During this quarter, he designed and fabricated replacement components for systems we will use on the cruise, collaborated with SDI on electronics integration and compatibility, and completed building the replacement battery systems for the IPSO lander. With Steven and Larry, Matt assures that the MMRI portable shop is fully equipped and that MMRI vehicles that are needed to transport people and equipment to the cruise are in working order and equipped for the trip.

Name: Steven Tidwell
Project Role: Research Associate, University of Mississippi
Nearest person month worked: 1 (6 weeks)
Contribution to Project: Tidwell is the MMRI/CMRET shop technician with a degree in geological engineering and expertise in machining and electronics as well as computer software. During this quarter, he worked to make duplicate housings, updated the TrakLink software, and moved the tracking navigation to a new computer.

Name: John Dunbar
Project Role: Co-I, Baylor University
Nearest person month worked: 0 (2 weeks)
Contribution to Project: Dunbar and Xu made 3 trips to SDI (Wiley, TX) to test the electronics systems in various configurations and to test the system as a unit.

Name: Tian Xu
Project Role: Graduate student, Baylor University
Nearest person month worked: 0 (0 weeks)
Contribution to Project: Xu works with Dunbar to define the processing of resistivity data collected during survey mode. Their work will determine the final site selection for deployment of the DCR instrument for a 6-month period. Although he remains heavily and vitally involved in the project, Xu has been supported by a teaching assistant position this semester so his time has not been charged to the project. Xu is the primary author on a paper resulting from this work.

Name: Paul Higley
Project Role: Co-I, Specialty Devices, Inc.
Nearest person month worked: 0 (1 week)
Contribution to Project: Higley instructed the electronics and programming staff who developed the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor. Designed and executed the systems tests.

Name: Scott Sharpe
Project Role: Electronics specialist, Specialty Devices, Inc.
Nearest person month worked: 0 (2 weeks)
Contribution to Project: Sharpe instructed the electronics and programming staff who developed the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor. Systems were tested and test-recordings made. He is responsible for all electronics systems oversight.

Name: SDI Technical staff
Project Role: Electronics and technical support, Specialty Devices, Inc.
Nearest person month worked: 0 (0 weeks)
Contribution to Project: Worked with Higley and Sharpe to develop the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor.

Name: SDI Programmer staff
Project Role: Electronics and programming support, Specialty Devices, Inc.
Nearest person month worked: 0 (0 weeks)
Contribution to Project: Worked with Higley and Sharpe to develop the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor.

IMPACT:

The Station Service Device (SSD) was not repaired and reprogrammed in time to prepare it for the April cruise. This difficulty is related to the failure of multiple thrusters on the vehicle during the September-December quarter (Q4). Although the manufacturer has agreed that the thrusters were flawed – or that the supporting electronics software was flawed – that has not gotten us any closer to resolving the issue. We have repaired/reconfigured some of the electronics difficulties and we are now engaged in more productive (we think) discussions with alternate thruster manufacturers. However, the fact that the SSD will not be available for an April cruise has been accepted and we have prepared the more robust I-SPIDER to perform all functions that the SSD was scheduled to perform. In fact, the major functions of the SSD for this project are those relating to emergencies or additional difficulties in a deployment or recovery for which the I-SPIDER lacks the maneuverability of the SSD. In addition to its functions of reconnoitering seafloor deployment sites, providing visuals on bubble streams and benthic communities, carrying instruments and landers to the optimal/selected site and releasing the payload on command, the I-SPIDER will tow the DCR array during both survey mode and deployment mode. The more robust I-SPIDER should handle the towing demands of the 1000m-long DCR cable more readily than the SSD and was always the vehicle of choice for the deployment of the lander with array. This system is designed to reduce risk to equipment in a hazardous environment, to improve chances of recovering data, and to recover data from the precise location or environment targeted. It will be used in this project to emplace the array and, subsequently, the instrumented lander with array in selected locations and to conduct surveys that include visual data matched precisely to a particular location.

The survey and deployment efforts of the resistivity instrument via the I- SPIDER will be guided by the use of seafloor imagery in-hand, including multibeam bathymetry and backscatter data and subbottom chip, surface source-deep receiver and industry deep data that inform our surface interpretations. We have extended the amount of processed high resolution multibeam data relevant to this project and are moving into backscatter extraction for the 2012 dataset. We anticipate that the shallow profiles will be able to be collated with hydrate sampled and detected via resistivity surveys and hope that will lead to its use as a prospecting tool for shallow hydrates.

Government, survey companies, seismic data-acquisition companies, research facilities, hydrocarbon companies and their support industries rely upon seafloor imagery to site, survey, build, operate and decommission seafloor structures. With more detailed information from the seafloor and shallow subseafloor, including the hydrate stability zone (HSZ), these operators can achieve their goals in a safer, more efficient manner. They can use the improved definition to focus on preferred sites and eliminate sites without characteristics that recommend others, saving needless expense and reducing risk.

Students and interns have long been a vital part of our projects. The methods that we have developed and that we are developing and are using, have been tested and some of them developed by students. We encourage these students to participate at all levels and expect at least one student to go to sea with us on every cruise in this project, as part of the scientific crew. We plan to have at least one student as a participant in the geological effort of this project and to add a student/intern as part of our shop team. Tian Xu will participate in the April cruise.

The collaboration of our shop with the NIUST shop has continued to be productive. Their expertise in electronics has enabled us to duplicate the electronics box and to make spare cards for the I-SPIDER so that when we do go to sea next, we will not be shut down if one of these functions goes down. We are doing our best to predict and prepare for any and all problems that may arise when we are at sea.

CHANGES/PROBLEMS:

Changes to this project this quarter center about the inavailability of the SSD. We had prepared for this possibility and do not anticipate major problems in the cruise activities. As stated earlier, we will miss the fine motor skills of the SSD but believe we have found ways to work around that requirement. Our lander and DCR instrument are ready and the DCR housing has passed the pressure testing Go/No-Go requirement. There have not been changes in approach since the addition of the I-SPIDER to our "fleet" of ROVs available to the project. Delays in our ability to execute the fall cruise were the major cause for our no-cost extension request that has been granted. Some changes that are currently being addressed are:

- The I-SPIDER has now been operated successfully on six cruises as a survey and deployment tool as well as a rescue vehicle, performing excellently in every case. For survey mode, we hope to accomplish this project's goals using the I- SPIDER, primarily because we will be able to monitor the survey, visually, as it is happening, thus avoiding hazards while acquiring the ability to match seafloor environment with resistivity anomalies.
- Although Tian Xu, Dunbar's student, has teaching responsibilities this semester, he has maintained key involvement in this project and will participate in the April cruise, assisting Dunbar in monitoring data-collection and preliminary processing that will determine final placement of the lander and array for the 6-month monitoring phase.
- Our cruise schedule has shifted. With no additional cost to the project, we have spread our time out to be sure to be prepared to go to sea while staying within the confines of the original budget. We have a follow-up cruise scheduled for October but have yet to schedule a "clean-up cruise for spring, 2015.

SPECIAL REPORTING REQUIREMENTS:

None noted.

BUDGETARY INFORMATION:

The expenses incurred during this quarter have been charged to both direct charges and cost-sharing. Subcontractors Higley and Dunbar have also charged time to the project as noted in the expenditure of time report. Please see the budget report spread sheet, below.

DOE Hydrates FY12 DE-FE0010141 Baseline Reporting by Quarter	Budget Period 1										Budget Period 2								Budget Period 3			
	Quarter 1 - Corrected		Quarter 2		Quarter 3		Quarter 4		Quarter 5		Quarter 1		Quarter 2		Quarter 3		Quarter 4		Quarter 1		Quarter 2	
	1/1/13 - 3/31/13		4/1/13 - 6/30/13		7/1/13 - 9/30/13		10/1/13 - 12/31/13		1/1/14 - 3/31/14		1/1/14 - 3/31/14		4/1/14 - 6/30/14		7/1/14 - 9/30/14		10/1/14 - 12/31/14		1/1/15 - 3/31/15		4/1/15 - 6/30/15	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q5	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total
Baseline Cost Plan																						
Federal Share	127,121	127,121	127,120	254,241	209,200	463,441	127,120	590,561	-	590,561												
Non-federal Share	36,912	36,912	36,912	73,824	36,912	110,736	36,912	147,648	-	147,648												
Total Planned	164,033	164,033	164,032	328,065	246,112	574,177	164,032	738,209	-	738,209												
Actual Incurred Cost																						
Federal Share	-	-	8,592	8,592	86,331	94,923	201,745	296,668	42,214	338,882												
Non-federal Share	22,599	22,599	5,770	28,369	12,584	40,953	-	40,953	55,488	96,441												
Total Planned	22,599	22,599	14,362	36,961	98,915	135,876	201,745	337,621	97,702	435,323												
Variance																						
Federal Share	127,121	127,121	118,528	245,649	122,869	368,518	(74,625)	293,893	(42,214)	251,679												
Non-federal Share	14,313	14,313	31,142	45,455	24,328	69,783	36,912	106,695	(55,488)	51,207												
Total Planned	141,434	141,434	149,670	291,104	147,197	438,301	(37,713)	400,588	(97,702)	302,886												