Electrical Resistivity Investigation of Gas Hydrate Distribution in Mississippi Canyon Block 118, Gulf of Mexico

Project Quarter 3 Report

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ABSTRACT

Electrical methods offer a potential geophysical approach to determining the sub-bottom distribution of gas hydrate in the deep marine environment. Gas hydrate is essentially non-conductive. Hence, sediments with pore spaces partially filled with hydrate or containing veins filled with hydrate are more resistive than surrounding sediments with pore spaces filled with seawater. To date, attempts to map the sub-bottom distribution of gas hydrates using electrical methods have been done on an experimental basis using the controlled source electromagnetic method (CSEM). The CSEM method involves the generation of low-frequency EM signals from a source instrument and the reception of the signals by separate receiver instruments.

This project will evaluate an alternative electrical method, the direct current resistivity (DCR) method, for gas hydrate exploration. The DCR method involves the injection of a direct current between two source electrodes and the simultaneous measurement of the electric potential (voltage) between two or more receiver electrodes. In applications in which electrical coupling to the environment is not a problem and large source-receiver offsets are not required, the DCR method provides subsurface information comparable to that produced by the CSEM method, but with much less sophisticated instrumentation. Because the receivers are simple electrodes, large numbers can be deployed at relatively low cost.

To evaluate the direct current resistivity DCR method for use in future commercial gas hydrate exploration, a prototype seafloor DCR system will be developed and used to conduct experiments at a site of known hydrate occurrence in Mississippi Canyon Block 118 (MC 118). The intent is not to develop a system that is optimized for collecting data in a production mode, but rather to develop a flexible system that can be used to conduct multiple experiments. The objectives of these experiments will be to test the DCR method to determine its applicability in gas hydrate exploration, to collect baseline seafloor electrical data useful in the design of future commercial seafloor DCR systems, and to contribute to the fundamental understanding of gas hydrate systems at the MC 118 site.

From April 2007 – June 2007:

- Assembly of the DCR electrical components in the seafloor pressure housing was begun;
- The order was placed for the 504 m long, 28-electrode array.

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List of Acronyms and Abbreviations

BSR	Bottom simulating reflection
CSEM	Controlled source electromagnetic
CRP	Continuous resistivity profiling
DC	Direct current
DCR	Direct current resistivity
DGPS	Differential global positioning system
GOM-HRC	Gulf of Mexico-Hydrate Research Consortium
GPS	Global positioning system
MC 118	Mississippi Canyon Block 118
RS232	Electronics Industries Association common computer interface standard
UNOLS	University-National Oceanographic Laboratory System
4D	four-dimensional (three spatial dimensions and time)

1.0 Introduction

1.1 Project Background

One of several ongoing projects investigating the gas hydrate deposits on the northern Gulf of Mexico slope is being conducted by the Gulf of Mexico-Hydrate Research Consortium (GOM-HRC). This is a group of 15 academic institutions and various State and Federal agencies formed to conduct multi-disciplinary studies of hydrate systems in the northern Gulf of Mexico. The group has had funding from DOE (Project numbers DE-FC26-00NT40920, DE-FC26-02NT41628 and DE-FC26-06NT42877), NOAA, and the MMS since 2001 to establish a multi-sensor seafloor monitoring site at a methane hydrate location. The current work of the group is focused on Mississippi Canyon Block 118 (MC 118). Gas hydrate deposits at this site are believed to be derived from thermal gas actively migrating up deep-seated normal faults that intersect the seafloor.

To date GOM-HRC has conducted site reconnaissance by direct sampling from a deep submersible, gravity coring, multi-beam profiling, and shallow source – deep receiver seismic profiling. This work has established that there are both active and dormant gas vents at the site and that gas hydrate is exposed at the seafloor in the active vents. An apparent bottom simulating reflection (BSR) beneath the vent area suggests that the base of the hydrate stability zone is approximately 200 m below the seafloor. The group's near-future plans include the deployment of a seabed seismic array and pore-fluid samplers, bottom-towed P- and S-wave seismic profiling, and vertical array seismic profiling.

Although hydrates are observed at the seafloor and a BSR marks the apparent base of the hydrate stability zone at the site, the distribution of gas hydrates within the stability zone has not been determined. Electrical methods offer a geophysical approach to mapping the concentrate of hydrates within the stability zone. Gas hydrate is essentially non-conductive. Hence, massive gas hydrate has high electrical resistivities (100 Ωm) and sediments with pore spaces partially filled with hydrate are more resistive (2 to 100 Ωm) than surrounding sediments with saline pore fluids (≤ 1 Ωm). This resistivity contrast has been widely exploited to quantify downhole hydrate concentration levels from resistivity logs (e.g. Hyndman et al., 1999; Collett and Ladd, 2000; Lee, 2001).

To date, the only attempts to map the sub-bottom distribution of gas hydrates by electrical methods have been done on an experimental basis using the controlled source electromagnetic method (CSEM) (e.g. Edwards, 1997; Hyndman at al., 2001). The CSEM method involves the generation of low-frequency EM signals from a source instrument and the reception of the signals by separate receiver instruments. The CSEM systems used in gas hydrate experiments were scaled-down versions of systems used in exploration for conventional petroleum deposits at depths of 3 to 6 km. Petroleum CSEM systems are, in turn, scaled-down versions of systems used in academic studies to image the electrical properties of the ocean crust and upper mantle to depths of 10 – 12 km (MacGregor et al., 2001).

The current project will evaluate an alternative electrical method, the direct current resistivity (DCR) method, for gas hydrate exploration. The DCR method involves the injection of a direct current between two source electrodes and the simultaneous measurement of the electric potential (voltage) between two or more receiver electrodes. In applications in which electrical coupling to the environment is not a problem and large source-receiver offsets are not required, the DCR method provides subsurface information comparable to that produced by the CSEM method, but with much less sophisticated instrumentation. Because the receivers are simple electrodes, large numbers can be deployed at relatively low cost. Also, because of the low power of the source and inherent stability of voltage measurements, adaptation of DCR instruments for use in long-term site monitoring will not be as difficult as would be the case with CSEM instrumentation.

In this project, the Recipient will evaluate the DCR method for gas hydrate applications at the MC 118 site. Because of the previous work done by GOM-HRC, the MC 118 site will make an ideal laboratory for this purpose. Massive gas hydrate blocks have been observed outcropping on the seafloor and a BSR underlying the site at a depth of approximately 200 m has been mapped. Hence, there is no doubt that the site contains gas hydrate. The ongoing work of GOM-HRC will provide a range of auxiliary data with which sub-bottom conditions can be independently constrained and the DCR results can be evaluated. In addition, infrastructure at the site, such as a site-wide power source and facilities for mass data storage and routine data recovery, will make long-term monitoring experiments using DCR instruments much easier than would be the case for a standalone experiment. For these reasons, work on the current project will be coordinated with that of GOM-HRC, results from the project will be presented at GOM-HRC meetings, and data generated will be freely shared with GOM-HRC members.

1.2 Project Objectives

The current project is a pilot study, the over arching objective of which is to evaluate the DCR method for future use in commercial gas hydrate exploration and exploitation. To this end, a prototype seafloor DCR system will be developed and used to conduct experiments at the MC 118 site. The intent is not to develop a system that is optimized for collecting data in a production mode, but rather to develop an inexpensive, yet flexible system that can be used to conduct multiple experiments. The objectives of these experiments will be to test the DCR method to determine its applicability in gas hydrate exploration, to collect baseline seafloor electrical data useful in the design of future commercial seafloor DCR systems, and to contribute to the fundamental understanding of gas hydrate systems at the MC 118 site.

1.3 Project Phases

The project will be conducted in two phases. The first phase will involve the development of an experimental bottom-towed DCR system, configured for continuous resistivity profiling (CRP) on the seafloor. Once complete, the experimental system will be used to conduct a reconnaissance survey of the methane vent area at the MC 118 site. The resulting data will be complimentary to previously collected seismic data and will help characterize the overall site. The second phase of the project will involve reconfiguring and deploying the bottom-towed DCR system for long term, static operation on the seafloor. In this mode, the system will be programmed to periodically re-profile a selected cross-section across the site for an initial period of one year. The data will be stored within the mass data storage unit at the site and retrieved on a semiannual basis, along with the other monitoring data at the site. The resulting data will be used to quantify changes in subsurface gas hydrate distribution over time.

1.4 Research Participants

Three institutions will contribute directly to the project. John Dunbar and his graduate students at Baylor University, Department of Geology, Waco, Texas will develop the geophysical specifications for the experimental DCR system, participate in the initial testing and offshore experiments with the system, process and interpret the resulting DCR data, and report the results of the project in national meetings and peer-reviewed journals. Dunbar will also have overall management responsibility for the project. For the purposes of identification in this document, work done or primarily led by John Dunbar along with his graduate students will be referred to collectively as work done by the Recipient.

Paul Higley and personnel at Specialty Devices, Inc. of Wylie, Texas (SDI) will be the subcontractor in charge of assembling the experimental DCR system and will take the lead in conducting the offshore operations. SDI is an industrial member of GOM-HRC and has been the prime subcontractor for the development and deployment of much of their seafloor instrumentation. Work done for the project by Paul Higley and his employees will be referred to collectively as work done by SDI.

Mats Lagmanson and personnel of Advanced Geosciences, Inc. of Austin, Texas (AGI) will be the subcontractor in charge of producing the electronics for the experimental DCR system. AGI is a leading manufacturer of commercial DCR systems used in near-surface geophysics on land and shallow marine applications. Work done by Mats Lagmanson and his employees will be referred to collectivity as work done by AGI.

1.5 Purpose of this report

The purpose of this report is to document the research results during the second quarter of the project, from April 2007 to June 2007.

2.0 Results and Discussion

2.1 Evaluation of strategies for deploying the seafloor DCR system

The deployment strategy adopted for this project is to place the DCR instrument in a pressure housing and tow it within the water column, near the seafloor and tow the active array directly behind the housing. In this mode of deployment, the housing will be placed on a deep-tow sled with connections compatible with widely available oceanographic instrument cables (UNOLS). UNOLS cables contain sufficient data transmission capabilities to control the instrument remotely and retrieve data during survey operations. This will make the system deployable from virtually any oceanographic research vessel.

2.2 Electrode array design for the seafloor DCR system (Subtask 1.3.2)

During this project quarter orders were placed for 530 m of gel-filled, 28-conductor marine cable with a braided Kevlar strength member for $7,200. Once this cable is received, Advanced Geosciences, Inc. of Austin TX (AGI) will mold 28 graphite electrodes onto the cable for $18,240, and Impulse Enterprises, Inc. of San Diego, CA will mold on the connector. The finished cable will have a 504 m long active segment, a 25 m lead-in and a 1 m tail. The remaining costs associated with the array will be for the connector molding, shipping, and high pressure testing. Even with these added costs, the total cost of the array will be within the budget of $33,500. We expect to complete the cable during the forth project quarter.

2.2 Pressure housing the seafloor DCR system (Subtask 1.3.3)

In this quarter Baylor received the completed instrument pressure housing from Ocean Innovations, LLC. of La Jolla, California. AGI is now in the process of mounting the DCR system components in the pressure housing. After discussions with AGI, the decision was made to make connections to the DCR system through three hull penetrations. The DCR system will contain two switch cards, which can accommodate a total 56 electrodes. Two penetrations will be made in the hull to connect with two 28-electrode arrays. Only one of these connections will be used in Phase 1 of this project. The second will be available so that a second 28-electrode array could be added for the long-term deployment in Phase 2 of the project. A third connector will be required to bring power and control instructions into the instrument from the sled and data out. We have settled on aluminum connectors with 30, #12 pins for the cable connections and a similar connector with 13, #16 pins for power and data. Both connector types will be purchased from Impulse Enterprises. The cost of the housing plus shipping was $8,700. The remaining costs to house the instrument will be for the mounting the system components in the housing, having the three hull penetrations, and the three connectors. The total budget for housing the instrument and mounting it on the deep-tow sled is $25,000. We expect to complete the housing in the forth project quarter within this budget.

3.0 Milestone and budget tracking.

During the third project quarter (April through June, 2007), no Critical Path Milestones were reached (Table 1). However, approximately 75% of Subtask 1.3, adapting an engineering DCR system for deployment on the deep sea floor, was completed within budget (Table 2). The charges to the Federal Share of the budget in this quarter were associated with the cost of the high pressure cable for the electrode array ($7,200), the cost of molding on the graphite electrodes ($18,240), one month of Dunbar’s salary ($7,1421), and one travel day to AGI’s office in Austin, plus benefits and overhead. The project is currently within budget, but the schedule as shifted approximately one quarter, due to delays associated with the electrode array redesign in second quarter. Even with this delay, we are on schedule for the first available cruse in winter to early spring, 2008.

Table 1: Critical Path Project Milestones. Grey shaded quarters indicate period of activity, by the end of which the milestones occur.

Task/ Subtask	Critical Path Project Milestone Description	Project Duration - Start: 10/2006 End: 9/2009												Planned Start Date	Planned End Date	Actual Start Date	Actual End Date	Comments
		Project Year 1				Project Year 2				Project year 3								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12					
1.4	Test of Bottom-towed system													4/07	9/07			
1.5	Bottom-towed survey													7/07	12/07			
2.1	Semi-autonomous operation													4/08	6/08			
2.4	Monitoring system deployment													7/08	12/08			
2.6	Analysis of monitoring data													10/08	9/09			

Table 2: Other Project Milestones. Grey shaded quarters indicate period of activity, by the end of which the milestones occur. Check marks indicate Milestones that have been completed.

Task/ Subtask	Critical Path Project Milestone Description	Project Duration - Start: 10/2006 End: 9/2009												Planned Start Date	Planned End Date	Actual Start Date	Actual End Date	Comments
		Project Year 1				Project Year 2				Project year 3								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12					
1.1	Research Management Plan	√												10/06	12/06	10/06	12/06	
1.2	Technology Status	√												10/06	12/06	10/06	12/06	
1.3	Adaptation of DCR system		√											1/07	6/07	1/07		
1.6	Analysis of bottom-towed data													10/07	3/08			
1.7	Phase 1 Topical Report													1/08	3/08			
2.2	Reconfiguration for monitoring													4/08	6/08			
2.3	Test of DCR monitoring system													7/08	9/08			
2.5.1	Data retrieval cruse 1													10/08	3/09			
2.5.2	Data retrieval cruse 2													1/09	6/09			
2.7	Final Report													7/09	9/09			

Table 3: Expenditures by project quarter.

Baseline Reporting Quarter	YEAR 1: Starting 10/06 Ending 9/07				YEAR 2: Staring 10/07 Ending 9/08				YEAR 3: Starting 10/08 Endi		
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**
Baseline Cost Plan											
Federal Share	2,402	54,333	60,063	12,638	4,204	33,215	26,620	21,492	14,495	14,495	14,495
Non-Federal Share	8,358	8,358	8,358		8,358	6,904	6,904		7,215	7,215	7,215
Total Planned	10,760	62,691	68,421	12,638	12,562	40,119	33,524	21,492	21,710	21,710	21,710
Cumulative Baseline Cost	10,760	73,451	141,872	154,510	167,072	207,191	240,715	262,207	283,917	305,627	327,337
Actual Incurred Cost											
Federal Share	1,874.11	52,658.74	41,497.20								
Non-Federal Share	16,716.00	8,358.00	8,358.00								
Cumulative Baseline Cost	18,590.11	79,606.85	121,105.05								
Variance											
Federal Share	527.89	1,674.26	18,565.80								
Non-Federal Share	(8,358.00)	0	0								
Total Variance-Quarterly	(7,830.11)	1,674.26	18,565.80								
Cumulative Variance	(7,830.11)	(6,155.85)	12,409.95								

4.0 Plans for the next quarter

In the forth project quarter we plan to complete the adaptation of the DCR system for use on the deep sea floor and begin testing the system. Initial tests will be conducted in a brackish water reservoir.

References

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