Oil & Natural Gas Technology

DOE Award No.: DE-NT42959

Quarterly Report

October 1 – December 31, 2009

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

Submitted by:
Baylor University
One Bear Place, Box 97354
Waco, TX 76798

Principal Author: John A. Dunbar

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

January 15, 2010

Office of Fossil Energy

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

Project Quarter 13 Report

Report Type: Quarterly

Starting October 1, 2009
Ending December 31, 2009

Author:
John A. Dunbar
Baylor University
Department of Geology

Janurary 15, 2010

DOE Award Number:
DE-FC26-06NT142959

Submitting Organization:
Baylor University
One bear Place 97354
Waco, Tx 76798

DISCLAIMER

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 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 October 2009 – December 2009:

This was an unfunded project quarter, meaning that the report on the results of Project Phase 1 was submitted at the end of Quarter 12 and no funds were available to continue the work until permission to continue on Project Phase 2 was granted. However, during this quarter a talk was given on the results from Project Phase 1 at the annual meeting of the Gulf-of-Mexico Hydrate Research Consortium (GOM-HRC), held in Columbia, SC in November, 2009. At that meeting, new, high-resolution bathymetry data for the MC118 site were made available to the consortium members. In December, 2009, the reconnaissance DCR survey data from MC118 collected in Phase 1 of this project were reprocessed, to account for seafloor topography using these new data. The following conclusions can be drawn from the re-processed results:

- After reprocessing the DCR data to account for variation in seafloor topography, it was found that, for the most part, resistivity beneath the vent area of MC 118 still ranges

from 0.5 to 1.0 Ωm to a depth of 120 m below the seafloor. This range is consistent with normal, non-hydrate-bearing marine sediment and implies that a pervasive layer of hydrate-rich sediment is not present beneath the vent area.

- The magnitude and shape of localized anomalies were changed by the reprocessing. There are still localized resistivity anomalies, ranging from 10 to 100 Ωm, with dimensions of 20 to 40 m in width and thickness. In most cases these anomalies correlate with the seafloor expression of previously mapped faults that dissect the vent area. The high resistivities suggest that the anomalies may be caused by massive hydrate blocks lodged within the fault zone.

- In the reprocessed images there are still several narrow (20 m wide), relatively low-amplitude anomalies of 2 to 4 Ωm that extends vertically from a depth of at least 120 m to the seafloor. Most of this anomalies have no bathymetric expression. The geometry and relative low resistivity of the anomaly suggest it may be caused by hydrate or free gas in low concentration.

- In addition to localized resistivity anomalies in excess of 10 Ωm, the reprocessed data show a number of larger areas of elevated resistivity (1 to 5 Ωm), that may be associated with disseminated hydrate or free gas.

Table of Contents

Section: Title **Page**

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
ROV	Remotely operated vehicle
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 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 deployment of a seafloor seismic array, 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. Attempts to map the distribution of hydrates seismically have not yet produced usable results. Electrical methods offer an alternate approach to mapping the concentration of hydrates within the stability zone. Gas hydrate is essentially non-conductive. Hence, massive hydrate blocks have 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 from resistivity logs (e.g. Hyndman et al., 1999; Collett and Ladd, 2000).

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 electrical 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 (many kilometers) 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, potentially resulting in higher resolution images of the hydrate distribution. 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 at 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 as originally planned was to be conducted in two phases. The first phase involved the development of an experimental bottom-towed DCR system, configured for continuous resistivity profiling (CRP) on the seafloor. Once complete, the experimental system was used to conduct a reconnaissance survey of the methane vent area at the MC 118 site. The resulting data will be complimentary to seismic data, previously collected at the site and will help characterize the overall hydrate distribution at the site. Depending on the results for the first phase, the second phase of the project would involve reconfiguring DCR system for high resolution 3D surveying of the methane vent area of MC118. The resulting data would be used to better constrain the 3D distribution of hydrate within the vent region of MC118.

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 and 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 that 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.

Markus Lagmanson and personnel of Advanced Geosciences, Inc. of Austin, Texas (AGI) will be the subcontractor in charge of fabricating 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 Markus 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 Quarter 13 of the project, from October 2009 through December 2009.

2.0 Results and Discussion

2.1. CRP data processing

The initial processing of the DCR data collected in the reconnaissance survey of MC118 was done assuming a flat seafloor, because bathymetric data of sufficient resolution were not available at the time. In November, 2009, workers at the University of Mississippi made available the results of their AOV multi-beam survey of the site, done in summer 2009. The multi-beam survey consists of approximately 1 million bathymetric points, over the methane vent area, at a spatial resolution of approximately 3 m. Reprocessing of the reconnaissance DCR survey data to account for bathymetric variation involved the following steps:

- Geographic coordinates of the track of the ROV used to tow the DCR system during the survey were merged with the resistivity readings through synchronized time stamps in both data sets. The ROV track line was used to estimate the geographic coordinates of the electrodes during each DCR measurement. A map of the resistivity profiles collected at MC118 is shown in Figure 2.1. Seafloor elevations relative at each electrode coordinate along the profile were then extracted from the multi-beam bathymetric data. For 2D processing, the x,y,z coordinates were projected onto straight lines that passes through the profile track lines and exported in terms of the 2D distance along the profile.

- Typical CRP profiles consist of many thousands of measurements, which is far too many to invert in a single run. Instead, the long lines were inverted using a special continuous resistivity profiling (CRP) technique. The CRP technique involves breaking long profile in to multiple shorter, overlapping segments, which were independently inverted, then merged to reconstitute the long profile. This process was applied, making use of the multi-beam seafloor topography information along the profile to build finite element meshes that represent the true geometry of the seafloor.

- In the DCR method, estimates of subsurface resistivity are computed from surface voltage and current measurements using inversion algorithms. AGI’s finite element inversion code compares forward modeled the apparent resistivities values based on a simple starting model with the measured values. The Jacobian matrix between modeled resistivity and subsurface measurements is then used to adjust subsurface resistivities to produce a better fit. Because the problem is significantly under constrained, a smoothness condition is applied, such that the algorithm seeks the smoothest possible distribution of subsurface resistivities that explains the data within a specified RMS error. Using the estimated upper bound on the measurement noise (8.2% in this case) insures that the resulting inversion is the simplest resistivity distribution that explains the good data, without trying to fit the noise. An example comparison between the original processing and the reprocessing with seafloor topography is shown for in Figure 2.2.

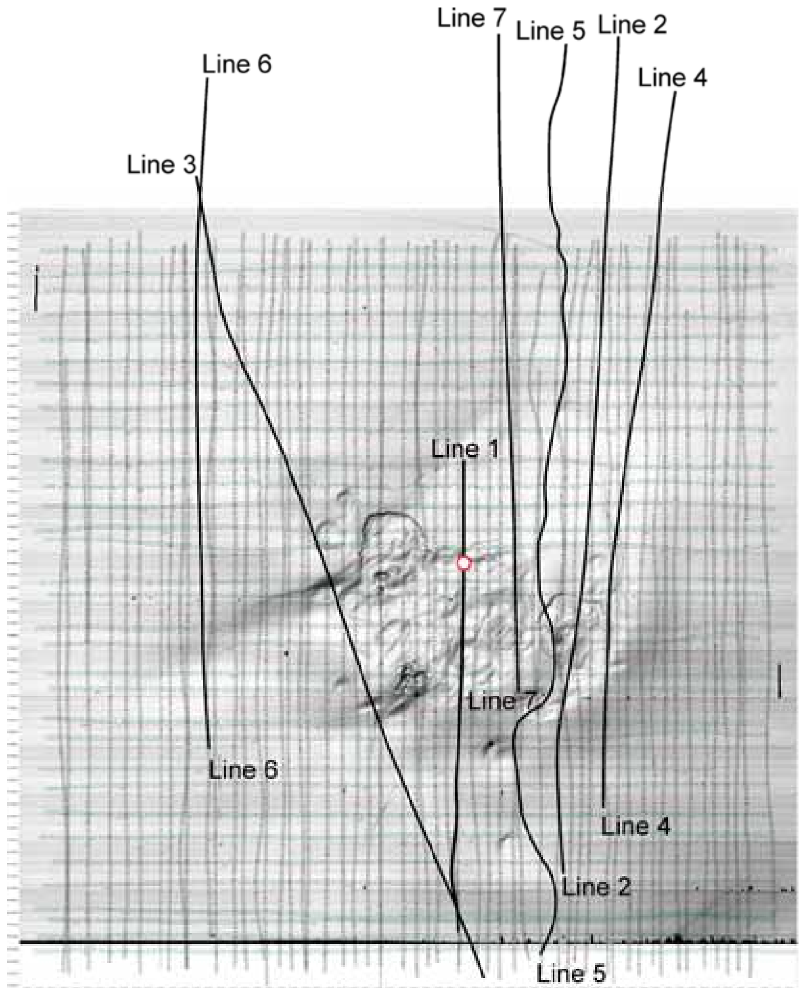

Figure 2.1. Resistivity profile track lines for reconnaissance survey of MC118. Resistivity lines 1 through 7 are shown in black. Grey lines indicate the locations of previously collected high-resolution seismic profiles.

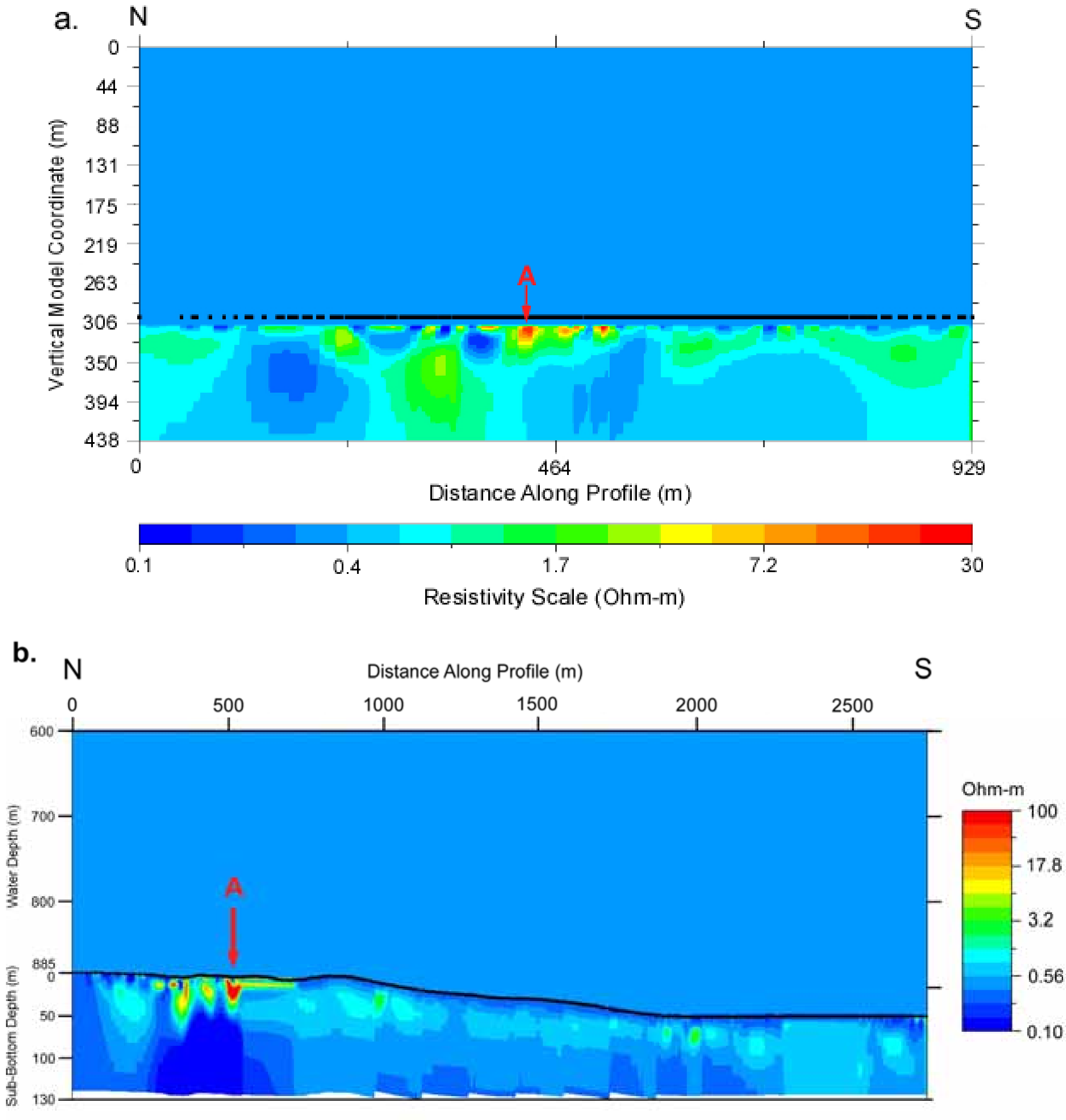

Figure 2.2. Example inverted resistivity sections. (a) Segment from Line 1 with original processing, which does not account for seafloor topography. (b) Larger segment of Line 1, after reprocessing to account for seafloor topography.

2.2.3 Interpretations of re-processed DCR profiles.

The re-processing of the DCR data to account for seafloor topography was necessary to rule out the possibility that the spatially small anomalies detected in the survey were due to topography rather than sub-bottom variations in resistivity. The repressing changed the shape and amplitude of previously detected anomalies, but topography alone cannot account for the anomalies. Hence, the conclusions based on the original processing still hold. Based on the resistivity data, the methane vent area of MC118 appears not to be underlain by an extensive layer of disseminated hydrate. Instead, there appear to be blocks of massive hydrate on the order of 20 m or less in thickness within the upper 50 m of previously mapped fault zones.

3.0 Milestone and budget tracking.

As of the end of Project Quarter 13, the main goals of the Project Phase 1 have been accomplished. Analysis of the reconnaissance survey data was completed (Task 6) and a topical report on the results of Phase 1 was submitted. The results of Phase 1 demonstrate that valid DCR data can be collected in nearly 1 km of water. There were reviewers at various stages of the project that expressed doubt that a long electrode array could be towed over the bottom and that even if it could, it would quickly be destroyed by abrasion. In the reconnaissance survey the 1.1 km long array was towed for 30 hours of the bottom, collected over 26 km of data, and the recovered array shows no sign of ware or damage. This proves that seafloor DCR data can be collected in deep water. The resulting data contains resistivity anomalies of up to 100 Ωm, which from their location and amplitude strongly suggest the causative bodies are hydrate. Although it has not been proven by direct sampling, it appears that the DCR method can be used to detect and map shallow hydrate deposits.

Some of the objectives of Phase 1 have not been met in full. At the time the proposal for this project was written, the best estimate of the depth to the base of the hydrate stability zone beneath the vent area in MC118 was 200 m. Hence, one of the objectives of the project was to image to a depth of 200 m. This depth was not achieved. However, the latest estimate of the depth to the base of the hydrate stability zone is 120 m, based on an apparent bottom simulating seismic reflection beneath the vent area. This depth was achieved with the Phase 1 DCR data. It is also clear that the goal of characterizing the overall distribution of hydrate at the site has not been completely met. This failing is due to the unexpected distribution of the hydrate. Rather than occurring as an extensive hydrate-rich layer, as previously speculated, it appears that hydrate may occur as small blocks or patches along the surfaces of the major faults. The distribution of hydrate in this mode cannot be characterized by a few sparse 2D profiles, using a long array with 20 m electrode spacing. Instead, it requires a high-resolution 3D resistivity survey using a shorter electrode array with much smaller electrode spacing.

The likely hydrate anomalies detected in Phase 1 leave several important questions unanswered. It is not clear whether hydrate is distributed continuously along fault traces or if it occurs discontinuously, like a string of pearls. It is also not known whether the hydrate occurs over a range of depths or only just beneath the seafloor.

3.2 Discussion of time and budget history of Phase I.

As of July 31, 2009, the Phase 1 timeline for this project was $21,826 over budget (12%) and two years behind the original schedule. The Federal share was spent, but not exceeded. The overrun in budget occurred in the nonfederal share. The overruns in time and effort are attributable to two events. First, from the time the budget for the project was proposed in the spring of 2006 until the project begin in the fall of 2006, the price of copper, the principle raw material for the electrode array, tripled. This led to a series of re-designs of the array and much time spent looking for a low cost builder. In the end, the spike in copper prices caused a one-year delay in completing the first electrode array. The second event occurred during the June 2008 initial sea trial of the DCR system, when the long awaited electrode array was destroyed by sharks in its first deployment. As a result, in July 2008 the array procurement process began again, two years into the project. All of this extra work led to the overrun in matching labor costs. AGI supplied parts and labor for the second array at a greatly discounted price in order to make the completion of Phase 1 possible.

Table 1: Revised Project Milestones. Grey shaded quarters indicate period of activity, by the end of which the milestones occur. The √ symbols indicate the quarter in which project tasks/subtasks were completed. The X symbols indicate tasks not completed because of technical problems and associated milestones not met. The ◊ symbols indicate the time of go/no-go decisions at Critical Path Milestones. Grey-shaded quarters indicate originally planned period of activity and milestones. Red-shaded quarters indicate originally planned period of activity and milestones.

Task/ Milestone	**Task/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					
Task 1	Research Management Plan	√												10/06	12/06	10/06	11/06	
Task 2	Technology Status	√												10/06	12/06	11/06	12/06	
Task 3	Adaptation of DCR system																	
Subtask 3.1	DCR system components		√											1/07	6/07	1/07	3/07	
Subtask 3.2	Deep-Sea electrode array						√							1/07	5/07	4/07	3/08	
Subtask 3.3	Assembly of DCR system						√							5/07	6/07	4/08	5/08	
Task 4	Test of Bottom-towed system						X	System Repair						2/07	3/09	5/09	5/09	
CPM 1	**DCR system test successful**				◊		X				√◊			2/09	3/09	5/09	5/09	
Task 5	Bottom-towed survey													3/09	6/09	6/09	6/09	
CPM 2	**Completion of DCR survey**					◊						√◊		6/09	6/09	6/09	6/09	
Task 6	Analysis of DRC data												√	8/09	9/09	8/09	8/09	
Task 7	Project Final Report													9/09	9/09			In progress

Table 2: Expenditures by project month.

Baseline Reporting Quarter	**YEAR 1: Starting 10/06 Ending 9/07**											
	Q1			**Q2**			**Q3**			**Q4**		
	10-6	11-06	12-06	1-07	2-07	3-07	4-07	5-07	6-07	7-07	8-07	9-07
Baseline Cost Plan												
Federal Share	0	0	0	3,305	30,000	15,000	54,288	0	17,695	0	0	2,971
Non-Federal Share	2,263	2,263	2,263	14,995	2,263	2,263	2,263	2,263	0	0	0	14,995
Total Planned	2,263	2,263	2,263	18,300	32,263	17,263	56,551	2,263	17,695	0	0	17,966
Cumulative Baseline Cost	2,263	4,526	6,789	25,089	57,352	74,615	131,166	133,429	151,124	0	0	169,090
Actual Incurred Cost												
Federal Share	0	0	0	2,310	5,210	1,145	(914)	4,404	5,104	38,324	1,791	892
Non-Federal Share	2,263	2,263	2,263	14,995	2,263	2,263	2,263	2,263	0	0	0	14,995
Cumulative Baseline Cost	2,263	4,526	6,789	24,094	31,567	34,975	36,324	42,991	48,095	86,419	88,210	104,097
Variance												
Federal Share	0	0	0	995	24,790	13,855	55,202	(4,404)	12,591	(38,324)	(1,791)	2,079
Non-Federal Share	0	0	0	0	0	0	0	0	0	0	0	0
Total Variance-Monthly	0	0	0	995	24,790	13,885	55,202	(4,404)	12,591	(38,324)	(1,791)	2,079
Cumulative Variance	0	0	0	995	25,785	39,640	94,842	90,438	103,029	64,705	62,914	64,993

Table 2 continued.

Baseline Reporting Quarter	YEAR 2: Starting 10/07 Ending 9/08											
	Q5			Q6			Q7			Q8		
	10-7	11-07	12-07	1-08	2-08	3-08	4-08	5-08	6-08	7-08	8-08	9-08
Baseline Cost Plan												
Federal Share	2,971	2,971	5,930	3,068	0	0	0	0	0	0	0	0
Non-Federal Share	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	0	0	0	2,263
Total Planned	5,234	5,234	8,193	5,331	2,263	2,263	2,263	2,263	0	0	0	2,263
Cumulative Baseline Cost	174,324	179,558	187,751	193,082	195,345	197,608	199,871	202,134	0	0	0	204,397
Actual Incurred Cost												
Federal Share	1,179	7,876	1,492	2,979	1,321	1,321	16,423	1,279	4,400	2,220	29,686	0
Non-Federal Share	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	0	0	0	2,263
Cumulative Baseline Cost	106,539	116,678	120,433	125,675	129,259	132,843	151,529	155,071	159,471	161,691	191,377	193,640
Variance												
Federal Share	1,791	(4,905)	4,438	89	(1,321)	(1,321)	(16,423)	(1,279)	(4,400)	(2,220)	(29,686)	0
Non-Federal Share	0	0	0	0	0	0	0	0	0	0	0	0
Total Variance-Monthly	1,791	(4,905)	4,438	89	(1,321)	(1,321)	(16,423)	(1,279)	(4,400)	(2,220)	(29,686)	0
Cumulative Variance	66,784	61,879	66,317	66,406	65,085	63,764	47,341	46,062	41,662	39,442	9,756	9,756

Table 2 continued.

Baseline Reporting Quarter	**YEAR 3: Starting 10/08 Ending 9/09**											
	Q9			**Q10**			**Q11**			**Q12**		
	10-8	11-08	12-08	1-09	2-09	3-09	4-09	5-09	6-09	7-09	8-09	9-09
Baseline Cost Plan												
Federal Share												
Non-Federal Share	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263				2,263
Total Planned												
Cumulative Baseline Cost												
Actual Incurred Cost												
Federal Share	4693	2325	0									
Non-Federal Share	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263				2,263
Cumulative Baseline Cost												
Variance												
Federal Share	(4,693)	(2,325)	0	0	0	0	(300)	0	(693)	0	0	0
Non-Federal Share	(2,263)	(2,263)	(2,263)	(2,263)	(2,263)	(5,137)	0	(330)	0	(2,263)	(2,263)	(2,263)
Total Variance-Quarterly	(6,956)	(4,588)	(2,263)	(2,263)	(2,263)	(5,137)	(300)	(330)	(693)	(2,263)	(2,263)	(2,263)
Cumulative Variance	2,800	(1,788)	(4,051)	(6,324)	(8,577)	(13,714)	(14,014)	(14,344)	(15,037)	(17,300)	(19,563)	(21,826)

4.0 Plans for the next quarter

In November, 2009, the Recipient was given permission to proceed with work on Phase 2 of the project. The revised goal of Phase 2 is to collect high-resolution, 3D resistivity data within MC118 to better characterize the hydrate distribution in the block. The first task in Phase 2 will be to construct a suitable electrode array. Collecting high-resolution, 3D data with image depths of 100 m will require an electrode array with an active length of 500 m. To allow accurate 3D processing, a facility to track the array location during the survey will be needed. Also, experience in Phase 1 showed that the data quality and depth of penetration were limited by electrode polarization. This problem can be addressed through the use of non-polarizing electrodes. During Quarter 14 the Recipient will work with the industrial partners SDI and AGI to design an array with acoustic tracking and non-polarizing electrodes. In addition, the Recipient will participate in the annual review of the hydrate research projected funded by DOE, to be held in Atlanta, Georgia, in January, 2010.

References

Collet T. S. and J. Ladd, Detection of gas hydrates with downhole logs and assessment of gas hydrate concentrations (saturations) and gas volumes on the Blake Ridge with electrical resistivity log data, Proceedings of the Ocean Drilling Program, Scientific Results, v. 164, p. 179-191, 2001.

Edwards, R. N., On the resource evaluation of marine gas hydrate deposits using sea-floor transient electric dipole-dipole method, Geophysics, v. 62, p. 63-74, 1997.

Hyndman R. D., T. Yuan, and K. Moran, The concentration of deep sea gas hydrates from downhole electrical resistivity measurements, Earth and Planetary Science Letters, v. 172, p. 167-177, 1999.

MacGregor, L., M. Sinha, and S. Constable, Electrical resistivity structure of the Valu Fa Ridge, Lau Basin, from marine controlled-source electromagnetic sounding, Geophysical Journal International, v. 146, p. 217-236, 2001.

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

13131 Dairy Ashford, Suite 225
Sugarland, TX 77478

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681