SUPPORT OF GULF OF MEXICO HYDRATE RESEARCH CONSORTIUM: ACTIVITIES TO SUPPORT ESTABLISHMENT OF A SEA FLOOR MONITORING STATION PROJECT

SEMIANNUAL TECHNICAL REPORT
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* includes seismo-acoustic characterization of sea-floor properties and processes at the hydrate monitoring station until vertical seismic profile (VSP) data can be collected

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ABSTRACT

The Gulf of Mexico Hydrates Research Consortium (GOM-HRC) was established in 1999 to assemble leaders in gas hydrates research. The Consortium is administered by the Center for Marine Resources and Environmental Technology, CMRET, at the University of Mississippi. The primary objective of the group is to design and emplace a remote monitoring station or sea floor observatory (MS/SFO) on the sea floor in the northern Gulf of Mexico by the year 2007-8, in an area where gas hydrates are known to be present at, or just below, the sea floor. This mission, although unavoidably delayed by hurricanes and other disturbances, necessitates assembling a station that will monitor physical and chemical parameters of the marine environment, including sea water and sea-floor sediments, on a more-or-less continuous basis over an extended period of time. In 2005, biological monitoring, as a means of assessing environmental health, was added to the mission of the MS/SFO.

Establishment of the Consortium has succeeded in fulfilling the critical need to coordinate activities, avoid redundancies and communicate effectively among researchers in the arena of gas hydrates research. Complementary expertise, both scientific and technical, has been assembled to promote innovative research methods and construct necessary instrumentation. The observatory has now achieved a microbial dimension in addition to the geophysical, geological, and geochemical components it had already included.

Initial components of the observatory, a probe that collects pore-fluid samples and another that records sea floor temperatures, were deployed in Mississippi Canyon 118 (MC118) in May of 2005. Follow-up deployments, planned for fall 2005, had to be postponed due to the catastrophic effects of Hurricane Katrina (and later, Rita) on the Gulf Coast. Station/observatory completion, now anticipated for 2008-9, has, therefore, been delayed.

Although delays caused scheduling and deployment difficulties, many sensors and instruments were completed during this period. Software has been written that will accommodate the data that the station retrieves, when it begins to be delivered. In addition, new seismic data processing software has been written to treat the peculiar data to be received by the vertical line array (VLA) and additional software has been developed that will address the horizontal line array (HLA) data. These packages have been tested on data from the test deployments of the VLA and on data from other, similar, areas of the Gulf (in the case of the HLA software).

The CMRET has conducted two research cruises during this reporting period: a June cruise to test the ability to collect shear-wave data with a horizontal array and another, in July, to perform the second set of sea trials of the Station Service Device (SSD), the custom Remotely Operated Vehicle (ROV) built to perform several of the unique functions required for the observatory to become fully operational. July's efforts included test deployments of the SSD and Florida Southern University's mass spectrometer designed to measure hydrocarbon gases in the water column. It was hoped that instruments left on the sea-floor in September, 2006, could be retrieved on

this cruise but due to a combination of difficulties, both technical and natural, this was not possible. A follow-up cruise is planned for November. A second generation Specialty Devices' storm monitor array was deployed to record disturbances during the hurricane season. Other instrumentation was left on the sea-floor until modifications of the SSD are complete and a return cruise is accomplished.

The seafloor monitoring station/observatory is funded approximately equally by three federal Agencies: Minerals Management Services (MMS) of the Department of the Interior (DOI), National Energy Technology Laboratory (NETL) of the Department of Energy (DOE), and the National Institute for Undersea Science and Technology (NIUST), an agency of the National Oceanographic and Atmospheric Administration (NOAA).

Subcontractors with FY03 and FY04 funding have fulfilled their technical reporting requirements in previously submitted reports. Unresolved matching funds issues remain and are being addressed in the report of the University of Mississippi's Office of Research and Sponsored Programs. In addition, Barrodale Computing Services Ltd. (BCS) completed their work for FY05; their final report is the bulk of the semiannual report, 41628R14.

Noteworthy accomplishments of Consortium researchers during this six month cycle funded with DOE's contributions to this multiagency effort include:

- Data Management and Processing Software for the Sea-floor Monitoring Station (Barrodale Computing Services Ltd. (BCS)): Completed. See 41628R14.

- Progress on the Applications of Vertical Seismic Profiling (VSP) Technology for Evaluation of Deep-Water Gas Hydrate Systems (University of Texas Bureau of Economic Geology's Exploration Geophysics Laboratory, EGL): completed. See 41628R18.

- Progress on the Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements:
    - Analysis of peeper data has been completed.
    - July cruise participants went prepared to recover sea-floor instruments. However, conditions dictated recovery of the SSD prior to recovery of any pore-fluid sampling devices.

- Progress on the Microbial Activity Related to Gas Hydrate Formation and Sea-floor Instabilities (Mississippi State University): Completed. See 41628R18.

- Progress on the Experiment to Generate Shear Waves in the Sea-Floor and Record them with a Horizontal Line Array
    - The application of the Input/Output 3-axis accelerometer sensor to the Sea Floor Observatory has required adapting the communications system

used in its normal seismic application to the communications requirements of the Sea Floor Observatory. Both I/O and SDI wrote software to resolve this communications problem. The new combination of cards and software was packaged and tested at sea with the MMRI Sled combination S- and P-wave source in June.
    - Accelerometer shear data generated from the MMRI-developed seismic gun shear sled were recovered during an in-water test conducted in Biloxi, Mississippi.
    - The shear data exhibited excellent signal to noise ratios with the shear data from the I/O sensors appearing to have better signal to noise ratio than that from the hydrophones.

- Administration of the Monitoring Station/Sea-floor Observatory project this reporting period has consisted of
    - Organizing and carrying out two cruises: a June cruise to test the borehole array in horizontal configuration and to use it to record shear data and a July cruise that provided the second opportunity to test the Consortium-designed and built robotic Station Service Device (SSD) at sea. Additional observatory projects were tested as time at sea permitted.
    - CMRET scientists J. R. Woolsey, Tom McGee and Carol Lutken attended the April meeting of the DOE Methane Hydrates Advisory Council in Golden, Colorado in April. At the invitation of the Council, Carol gave an update of the monitoring station project.
    - Consortium members participated in the DOE Merit Review held in Golden, Colorado in September. Tom McGee presented the science, plans and progress toward completion of the geophysical systems of the monitoring station; Jeff Chanton presented the scientific questions behind the development of systems and data-collection of the geochemical team; Carol Lutken presented an overview of the scientific challenges and the Consortium's responses to these over the history of the Monitoring Station Project.
    - Reporting to and interacting with sponsoring agencies and their officers as well as with Consortium members. The semiannual progress report, 41628R18, for DOE Award Number DE-FC26-02NT41628 was submitted in June and 42877R04, for DOE Award Number DE-FC26-06NT42877 was submitted in August. Monthly reports have been made to DOE each month of the reporting period.
    - The CMRET, with input from subcontractors as well as DOE, submitted a rewrite of the Horizontal Line Array (HLA) funding (DE-F26-06NT42877) that provides for the completion of four HLAs (rather than two), each 500m in length (rather than 400m) containing only hydrophones (rather than hydrophones and accelerometers).

TABLE OF CONTENTS **PAGE**

SUBCONTRACTORS……..ii
DISCLAIMER.....iv
ABSTRACT….....v
TABLE OF CONTENTS... viii
LIST OF GRAPHICAL MATERIALS.....viii
INTRODUCTION.....1
EXECUTIVE SUMMARY..... 1
EXPERIMENTAL.....8
RESULTS AND DISCUSSION.....8
CONCLUSIONS.....8
REFERENCES.....9

SUMMARIES/TECHNICAL REPORTS SUBMITTED BY THE SUBCONTRACTORS

FOR FY04 and FY05:
Task 3 (04-05): Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements …… 10
Task 2 (05): Experiment to generate Shear Waves in the Sea-floor and Record them with a Horizontal Line Array……14

LIST OF ACRONYMS AND ABBREVIATIONS.....17

LIST OF GRAPHICAL MATERIALS

Locations of Monitoring Station/Sea-floor Observatory instruments, MC118…….4

Materials used to illustrate subcontractors' reports can be found in the individual reports submitted by the subcontractors.

INTRODUCTION / PROJECT SUMMARY

The Gulf of Mexico-Hydrate Research Consortium (GOM-HRC) is in its seventh year of developing a sea-floor station to monitor a mound where hydrates outcrop on the sea floor. The plan for the Monitoring Station/Sea Floor Observatory (MS/SFO) is that it be a multi-sensor station that provides more-or-less continuous monitoring of the near-seabed hydrocarbon system, within the hydrate stability zone (HSZ) of the northern Gulf of Mexico (GOM). The goal of the GOM-HRC is to oversee the development and emplacement of such a facility to provide a better understanding of this complex hydrocarbon system, particularly hydrate formation and dissociation, fluid venting to the water column, and associated microbial and/or chemosynthetic communities. Models developed from these studies should provide a better understanding of gas hydrates and associated free gas as: 1) a geo-hazard to conventional deep oil and gas activities; 2) a future energy resource of considerable significance; and 3) a source of hydrocarbon gases, venting to the water column and eventually the atmosphere, with global climate implications.

Initial funding for the MS/SFO was received from the Department of Interior (DOI) Minerals Management Service (MMS) in FY1998. Funding from the Department of Energy (DOE) National Energy Technology Laboratory (NETL) began in FY2000 and from the Department of Commerce (DOC) National Oceanographic and Atmospheric Administration's National Undersea Research Program (NOAA-NURP) in 2002. Some ten industries and fifteen universities, the United States Geological Survey (USGS), the US Navy, Naval Meteorology and Oceanography Command, Naval Research Laboratory and NOAA's National Data Buoy Center are involved at various levels of participation. Funded investigations include a range of physical, chemical, and, more recently, microbiological studies.

EXECUTIVE SUMMARY

A consortium has been assembled for the purpose of consolidating both the laboratory and field efforts of leaders in gas hydrates research. The Consortium, established at and administered by the University of Mississippi's Center for Marine Resources and Environmental Technology (CMRET), has, as its primary objective, the design and emplacement of a remote monitoring station on the sea floor in the northern Gulf of Mexico by the year 2007. The primary purpose of the station is to monitor activity in an area where gas hydrates are known to be present at, or just below, the sea-floor. In order to meet this goal, the Consortium has begun assembling a station that will monitor physical and chemical parameters of the sea water, sea-floor sediments, and shallow subsea-floor sediments on a more-or-less continuous basis over an extended period of time. Central to the establishment of the Consortium is the need to coordinate activities, avoid redundancies and promote effective and efficient communication among researchers in this growing area of research. Complementary expertise, both scientific and technical, has been assembled; collaborative research and

coordinated research methods have grown out of the Consortium and design and most construction of instrumentation for the sea-floor station is essentially complete.

The MS/SFO was designed to accommodate the possibility of expanding its capabilities to include biological monitoring. A portion of FY04 funding from the MMS was directed toward this effort to support the study of chemosynthetic communities and their interactions with geologic processes. In addition, results will provide an assessment of environmental health in the area of the station. NOAA -NURP has, as a focal point, investigations of the effects of deep sea activities on world atmosphere and therefore, weather. In July of 2005, the Director of the National Institute for Undersea Science and Technology (NIUST) of NOAA-NURP made a portion of that agency's budget available *via* competitive grants to researchers with proven expertise in microbial research. A sea-floor microbial observatory is an objective of that agency and these sponsored projects sited at the MS/SFO are designed to fulfill that directive.

The centerpiece of the monitoring station, as originally conceived, is a series of vertical line arrays of sensors (VLAs), to be moored to the sea floor. Each VLA was to have extended approximately 200 meters from the sea-floor. Sensors in the VLAs include hydrophones to record water-borne acoustic energy (and measure sound speed in the lower water column), thermistors to measure water temperature, tilt meters to sense deviations from the vertical induced by water currents, and compasses to indicate the directions in which the deviations occur. During discussions among the members of the geophysical subgroup of the Consortium, it was discovered that the project may be better served if some vertical arrays are converted to horizontal line arrays (HLAs). The prospective horizontal water-bottom arrays, will consist of hydrophones and 3-component accelerometers (see amendment to this plan, p.7, first full paragraph), laid upon, and pressed into, the soft sediment of the sea-floor. They will be arranged into a cross so that they simulate two perpendicular arrays. Their deployment will be accomplished by means of a sea-floor sled designed to lay cable and deploy probes into shallow, unconsolidated sediments. This sled will also be used as a seismic source of compressional and shear waves for calibrating the subsurface seismo-acoustic array commissioned by the Joint Industries Program (JIP).

The prototype DOE-funded VLA has been completed and tested together with the associated data-logging and processing systems. Processing techniques have been developed for vertical array data by Consortium participants funded by the MMS.

In May, 2005, the Sea-Floor Probe (SFP) was used to retrieve core samples from MC118 as part of the effort to select sites appropriate for deployment of the geophysical and geochemical probes. The northwestern portion of the mound area defined on images recovered during a C&C (Chance and Chance) autonomous underwater vehicle (AUV) survey April 30-May 2,

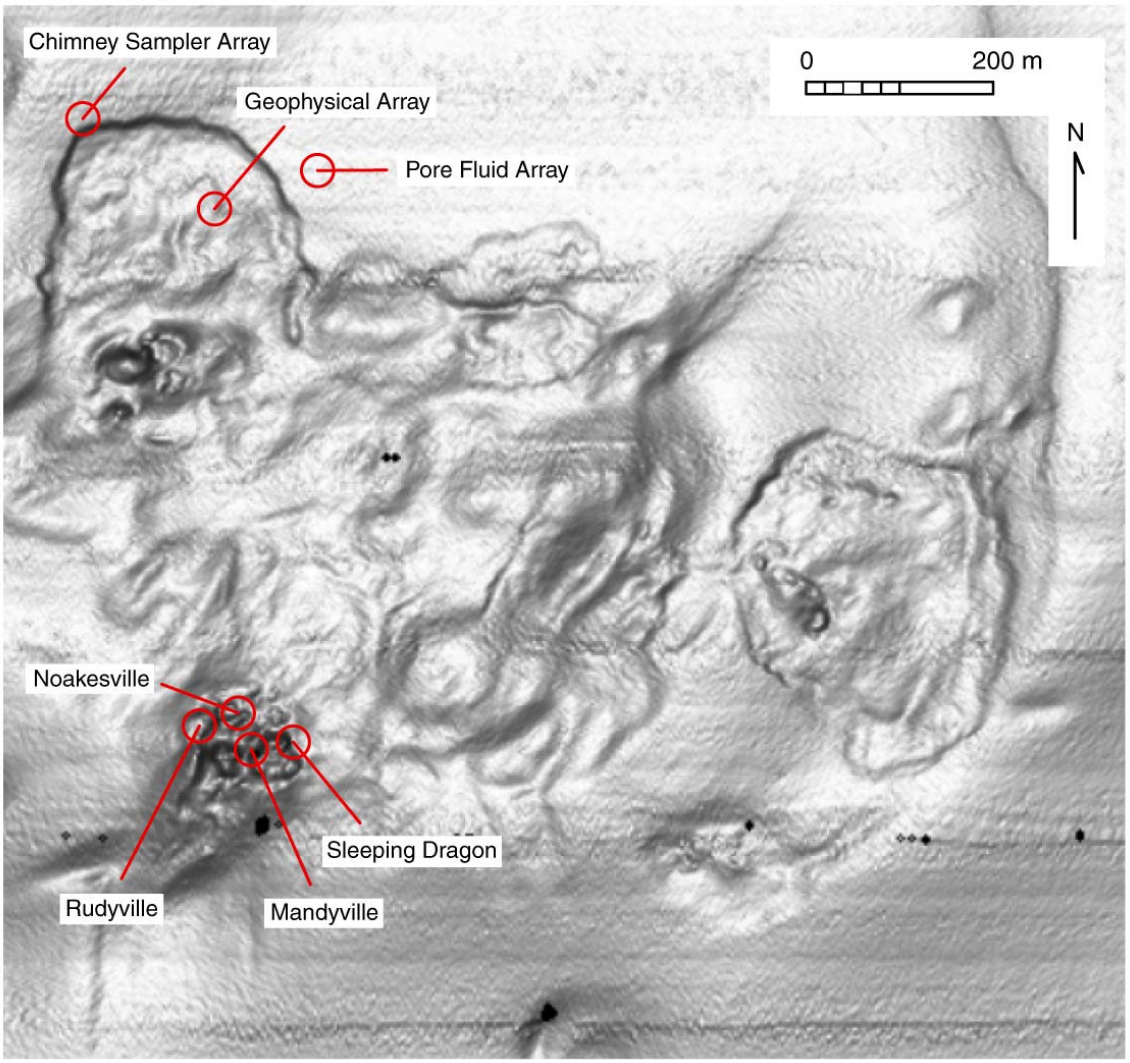
2005, was selected for probe deployments based on information from these cores. Both the pore-fluid array and the geophysical line array were deployed *via* SFP at MC118 in May, 2005.

Additional MS/SFO deployments, scheduled for September and October, 2005, were delayed due to the devastation of the Mississippi Gulf Coast and environs by Hurricane Katrina and, to a lesser extent, the Louisiana Gulf Coast by Hurricane Rita. The immediate cause for delay was the removal of the *M/V Ocean Quest*, the vessel that, with its two submersibles, was to have provided the platform from which many of the bottom-founded sensors would have been deployed and cable connections made. It would also have provided the visual survey needed to make optimal choices of deployment sites for station components

In October, 2005, March, April and June, 2006, the CMRET conducted a series of cruises to MC118 aboard the *R/V Pelican*. These cruises accomplished many of the tasks that had been planned for the *Ocean Quest*, including the recovery of more samples from MC118 and the deployment of a microbial filter device. A complete SS/DR (surface-source/deep-receiver) survey was made and a drift camera designed, deployed and used successfully to survey the sea-floor, visually. However, a submersible or ROV was still required to accomplish many of the missions for which precise placement of instruments on the sea-floor was required.

Following several “false starts”, anticipating the use of other vessels which never did become available, the CMRET eventually secured seven days of ship time aboard the *R/V Seward Johnson* with use of its manned-submersible, the Johnson SeaLink. This vessel combination was used to retrieve the osmopump packages and data-loggers deployed in 2005, to conduct visual surveys of the observatory site at MC118 and to deploy, and in some cases recover, sensors and experiments. Experiments designed to assess microbial communities and activities, hydrate host materials, and composition of pore-fluids were left on the sea-floor for several months’ data collection. Cruises to recover these instruments and data-loggers were scheduled for 2007.

Delays attributable to hurricane activity in the Gulf of Mexico caused scheduling and deployment difficulties but many sensors and instruments were completed during this period. A second PFA osmosampler was placed on the sea-floor near the southwestern crater at the site designated “Rudyville”. Pore water equilibrators or “peepers” were installed at three sites at MC118. In addition to samples and data collected from these instruments, methane concentration and isotope samples were collected from 8 cores that were collected using the SeaLink at a variety of sites along transects across microbial mats (see location map).



Locations of Monitoring Station/Sea-floor Observatory instruments, MC118.

After 1.5 years, the Pore-Fluid Array's (PFA's) instrument package was recovered and replaced successfully during the September Johnson SeaLink dives. The four ports collecting pore-fluids *via* OsmoSamplers were located in the overlying water and 1.2 m, 3.2 m, and 8.5 meters below the seafloor (mbsf). During the months following the retrieval of the sample box, pore-fluids were extracted from the sampler coils and measured for chloride, sulfate, and methane concentrations and methane isotope ratios. Normal seawater conditions were found in the overlying waters, while at 8.5 mbsf, chloride concentrations provide compelling evidence for the intrusion of brine fluids. Brine was further indicated by the absence of sulfate. As expected with brine fluids, they were also characterized by high methane concentrations.

Defining mechanisms of sea-floor hydrate formation to aid in locating hydrates on the sea-floor is a long-term component of Consortium efforts. Laboratory findings relating to hydrate induction time and formation rates have shown that hydrate formation is catalyzed by biosurfactants, products of microbial activity. The microbes' bioproducts' hydrophobic moieties collect methane while the hydrophilic moieties collect and structure water, thus emplacing the components necessary for hydrate formation. This in turn, explains the close affiliation of particular bacteria with hydrate outcrops on the sea-floor and leads to further questions regarding their interactions. Some generalizations can be made regarding hydrate formation: formation rates increase with depth until a maximum is reached and induction time decreases with depth until a minimum is reached. These generalizations are influenced, and in some cases overcome, by other factors influencing hydrate formation such as salinity, the depth of the sulfate zone, availability of gases, bioactivity, clay mineral composition, bioproducts coating sediment grains, and sediment size.

Software has been written that will accommodate the data that the station retrieves, when it begins to be delivered. In addition, new seismic data processing software has been written to treat the peculiar data to be received by the vertical line array (VLA) and additional software has been developed that will address the horizontal line array (HLA) data. These packages have been tested on data from the test deployments of the VLA and on data from other, similar, areas of the Gulf (in the case of the HLA software).

Researchers at the Exploration Geophysics Laboratory (EGL) have developed a new approach to processing 4-component (4C) seismic data acquired with multicomponent sensors deployed on the seafloor. Utilizing the large elevation difference between source and receiver allows deep-water 4C data to be processed with algorithms similar to those used to make images from vertical seismic profile (VSP) data (also acquired with a large elevation difference between source and receiver). This processing approach produces images that have much higher resolution of geology located near the receiver station than do standard 4C data-processing techniques.

New 4C ocean bottom cable (OBC) seismic data-processing software structured to optimize image resolution in the immediate vicinity of seafloor seismic sensors has been written by EGL researchers. While this novel data-processing strategy offers no advantage for imaging deep geology, it produces optimal images of geology immediately below seafloor sensor stations where hydrate systems are embedded. Preliminary tests of this software have produced impressive high-resolution images of near-seafloor strata.

The problem of integrating the Input/Output (I/O) sensor – with superior resolution, accuracy and low frequency response to that of marine 3 axis geophone sensors - to the Horizontal Line Array appears to be resolved. Advances in the miniaturization of interface circuitry and support from I/O have

resolved the remaining engineering tasks and trial collection of 4C data will be completed in the near-future.

The possibility of using a new I/O marine DigiSeis capability has been investigated. The advantage of this system is that the marine version of this sensor has a hydrophone integrated with the three axis accelerometer. The drawback is that the present hydrophone sample rate is limited to 1 ms (1,000sps) and the effort involved in redesigning the system to achieve the desired 10,000 sps rate would require more investment than the entire borehole vertical array program's present budget. The decision was made to stay with integration of the 3 component DigiSies sensor into the SDI DATS array. SDI built additional circuitry and wrote software to resolve further communications and power challenges. New circuitry has apparently cured the last of the problems for packaging this technology in a format that will lend itself to installation on the sea floor.

The CMRET conducted two important research cruises during this reporting period: a June cruise to test the capability of the sea-floor sled to generate shear waves and the possibility of recording them with a horizontal array and a July cruise to perform additional sea trials of the Station Service Device (SSD), the custom Remotely Operated Vehicle (ROV) built to perform several of the unique functions required for the observatory to become fully operational. Initial requirements for the SSD included deployment and recovery of tools and sensors and the connection of underwater-mateable electric and fiber optic connectors at depth. The standard complement of equipment included: high resolution video with lighting, scanning sonar, robotic arm, precision positioning and thrusters for limited transit and maneuvering. The winch, tether and umbilical cable carry an optical fiber that provides video, scanning sonar, and vehicle attitude information to the operator and carry commands to the SSD tether winch, thruster control and robotic arm operations.

Members of the Consortium's geophysical team, including Specialty Devices Inc. and CMRET, in cooperation with Exploration Geophysics Laboratory (EGL) at the University of Texas and Scripp's Institution of Oceanography, University of California, San Diego, conducted a test of the 4-C prototype horizontal line array in June, 2007, offshore Biloxi, MS. The test was unique in that it featured an advanced accelerometer design, demonstrating its effectiveness for incorporation in a 4-component, hydrophone and accelerometer (for p- and s-wave reception, respectively) passive seismic array net work. The in-water test was conducted in Biloxi, Mississippi using the University of Mississippi's R/V *Kit Jones* as the shooting boat and the University of Southern Mississippi's R/V *Hermes* as the recording boat. Performed with new circuitry and software, the test resulted in successful recovery of accelerometer shear data generated from the MMRI-developed seismic gun shear-sled. Multiple accelerometer sensors were coupled with hydrophone sensors to simulate the sensor packages to be used on a down-hole array or the planned horizontal line

arrays. The shear phones were installed on the sea floor with three methods of handling the coupling of the sensor to the soft mud sea- floor. One sensor array was lowered to the bottom and pressed slightly into the mud bottom, one array was encased in a compartmentalized sand and one sensor array was installed and pressed approximately 2 ½ feet into the seafloor. Multiple data lines were shot using various shot point offsets and shot spacing. Data with excellent signal–to-noise ratios were recovered. This new concept in seismic array design will enable the use of natural surface noise (via hydrophone) and microseism noise from salt movement (via accelerometer) as energy sources. The goal is to use these passive seismic sources for long-term monitoring of structural and hydrocarbon fluid dynamics in a way analogous to conventional reservoir monitoring. The system will be incorporated into the SFO at the hydrate mound/salt dome complex at MC118. Benefits include the capability of long-term, continuous seismic monitoring that is marine mammal friendly through the elimination of the traditional seismic energy source. Data acquired during this test are being further evaluated at EGL.

The contract for the construction of the HLAs has been rewritten to reflect some of the findings of the June cruise as well as the input of the geophysicists working with noise data and shear data. The configuration of the arrays is designed to maximize the likelihood that they may later be useful for monitoring seismic events and hurricanes. Four hydrophone arrays, 500m in length, will be deployed on the surficial deposits of the sea-floor at the MS/SFO at MC118. They will be capable of collecting compression-wave data, via hydrophones, and sending them to the integrated Data Power Unit (IDP). Accelerometers will be added to the MS/SFO at a future date.

July's cruise accomplishments included test deployments of the SSD, and Florida Southern University's mass spectrometer designed to measure hydrocarbon gases in the water column. Cruise participants also went prepared to recover any and all instruments left on the sea-floor during the September Johnson SeaLink submersible cruise. Although a microbial fuel-cell was collected successfully, it was later lost when a brief power outage caused the mechanical arm to "let go" its burden. A replacement storm monitor was deployed at MC118 in preparation for the 2007 hurricane season. Other instrumentation was left on the sea-floor until modifications of the SSD and support vessel are complete and a return cruise is accomplished. A cruise report for these activities is nearing completion.

Reporting to and interacting with sponsoring agencies and their officers as well as with Consortium members is a primary administrative function of CMRET. The semiannual progress report for DOE Award Number DE-FC26-02NT41628 was submitted in June and the one for DOE Award Number DE-FC26-06NT42877 was submitted in August. They are 41628R18 and 42877R04, respectively. Regular monthly reports documenting progress of subcontractors as well as the Consortium in general were also submitted.

Wall-to-Wall, an independent television programming production company under contract to Discovery Television to produce the miniseries, *Building the Future* (previously *Surviving the Future*) aired the installment, *Energy*, for which they filmed portions of the September Johnson SeaLink cruise, four times in June, 2007.

EXPERIMENTAL

Experiments are described in the individual reports submitted by the subcontractors.

RESULTS AND DISCUSSION

Results and discussion of those results are described in the individual reports submitted by the subcontractors. Reports from the subcontractors follow.

CONCLUSIONS

This report covers the accomplishments of the six-months from April 1, through September 30, 2007 for Cooperative agreement Project #DE-FC26-02NT41628, between the Department of Energy and the Center for Marine Resources and Environmental Technology, University of Mississippi. The efforts of the Hydrates Research Consortium are reviewed; at-sea activities reported; laboratory projects reviewed. Progress reports from the subcontractors who have not yet completed the work proposed for this cooperative agreement are included as appendices to this report. Critical sea trials for the SSD have been performed and additional capabilities and needs defined. These have already begun to be addressed. Additional recoveries and deployments of additional station components are anticipated for the remainder of 2007.

Ship time remains tight in the Gulf. Cessation of DOE and MMS funding for this project continues to make progress in the Sea-floor Observatory completion schedule a challenge. CMRET has 10 more days of ship time scheduled aboard the *R/V Pelican* in 2007; rebudgeting of existing funds will be necessary in order to use these cruise days. Every effort has been – and will continue to be – made to maximize Consortium members' access to and benefit from the 10-day November cruise.

All FY03 subcontractors have completed their technical reporting although financial reports are not yet complete. The CMRET continues to work with the sponsored programs officials at several institutions to resolve these delays, most of which involve incorrect reporting of cost-sharing. The VLA and the SFP are complete and have been proven. Software development and innovative processing techniques are complete until additional sensor details become available. The "bubble counter" is complete and was successfully deployed and

recovered on the September 2006 cruise. Laboratory studies of gas hydrates have shown a direct link between microbial bioproducts and formation of gas hydrates. Additional influences on gas hydrate formation and stability have been identified and their impacts demonstrated.

The pore-fluid sampling probe and thermistor geophysical probe, emplaced on the sea floor in May of 2005, have been recovered in good condition with samples and data-loggers intact. The data-logger and sample-collecting box of these components contained the first data produced at the MS/SFO. Analyses of pore fluid samples from this deployment revealed that the salinity of the subsurface pore-fluids is ~8 times that of normal sea-water and may explain the lack of gas hydrates – whose formation is known to be inhibited by the presence of brine – at the northern vent site.

The Consortium continues to establish and foster cooperations through semiannual meetings and cruises. The June cruise proved the HLA-shear wave recording potential. The July cruise provided valuable sea time and tests for the Station Service Device, the custom ROV designed to perform various observatory functions including making and breaking connections, emplacing and retrieving instruments from the sea-floor and performing local surveys. The CMRET continues to monitor the many projects included in the Sea-floor Observatory Project and to press on towards it completion.

REFERENCES

Relevant references appear following contributions by the individual subcontractors.

Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements

Progress report for the period
April 1, 2007 – September 30, 2007

November 27, 2007

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Background to Peepers: Pore-water equilibration instruments (peepers) are used to collect fluids, passively, in shallow water systems and measure dissolved constituents (Hesslein, 1976; Mayer, 1976). Peepers contain several sample reservoirs in close succession to result in a high resolution depth profile. The collection is attained by each reservoir being covered by semi-permeable membrane that, when placed in the sediments, equilibrates with dissolved constituents, including gases. However, since typical peepers are used in shallow water systems, they are not affected by changes in pressure when collected and do not contain the samples at *in situ* pressures. Since methane comes out of solution readily, the use of peepers in deep water systems is subjected to pressure issues and may result in the loss of dissolved gases. Therefore, we are testing two modifications to the original peeper design (Figure 1). The first connects plastic bags to each sample reservoir, allowing evolved gases to expand into the bags (Figure 1a); the second design uses cut-off glass syringes whose barrel is allowed to move during gas expansion (Figure 1b).

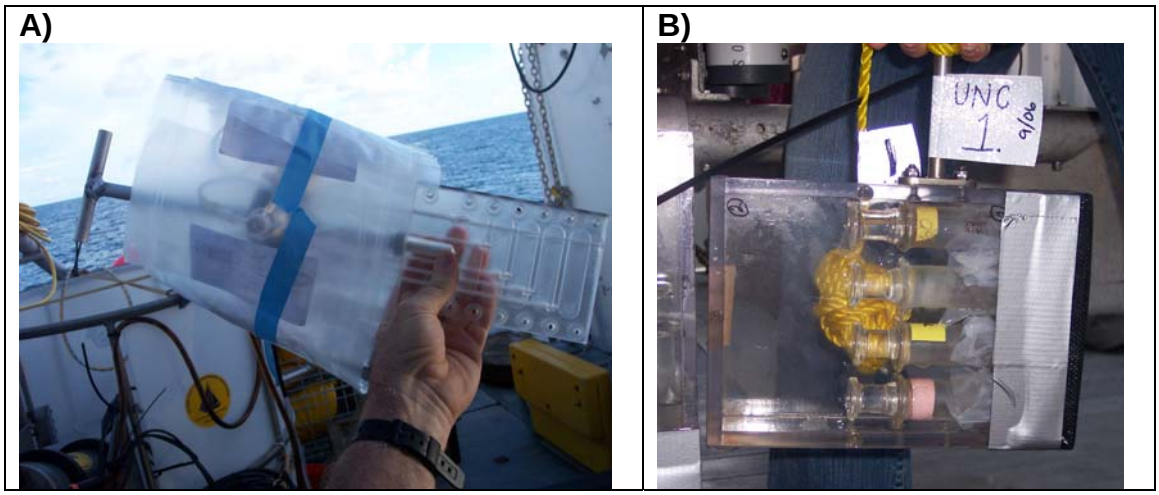

Figure 1: Photographs of modified peepers. A) Bagged peeper with sample reservoirs. B) Syringe peeper prior to deployment.

Results from March cruise:

Peeper retrieval: The Service Station Device (SSD) was deployed to MC 118 Mandyville site and one bagged peeper was retrieved (Figure 2). There was no visible degassing of the samples upon ascent in the water column. The peeper seemed in good shape except the T-handle arm corroded at the junction to the sample reservoirs. This did not disrupt the samples. Upon retrieval from the SSD manipulator arm, the peeper was sub-sampled and ~5 mL of pore-fluid was collected from each of 5 reservoirs. Fluids were placed into evacuated glass serum vials and frozen upside down to seal. The T-handle was replaced with a stainless steel handle, manufactured by Matt, and the peeper was prepared for re-deployment.

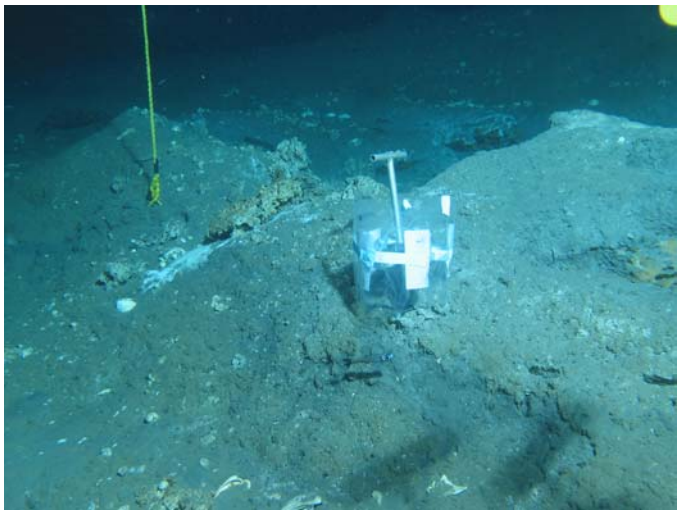

Figure 2: Sea-floor photograph of a bagged peeper at Mandyville. The yellow vertical line off to the left of the picture is marker #1.

Results: Pore-fluids were measured for methane concentrations and stable carbon isotope ratios. Results showed methane concentrations less than 350 uM ~10 cm away from the buried hydrate (Figure 3). These concentrations are below saturation concentrations (~70,000 uM). Methane stable carbon isotope values averaged -58.2 ± 0.4 ‰ from 2 to 10 cm away from the buried hydrate (Figure 4). These values are highly depleted in 13C compared to the isotope value of the hydrate itself, -47‰ (dot-dash line in Figure 4). The concentration and isotope gradient together suggest that the dissolved methane was produced by microbial methanogenesis and that the buried hydrate does not significantly contribute methane to the dissolved phase. This follows the hypothesis that the stability of hydrate is not thermodynamically controlled and that other factors control the kinetics of hydrate dissolution. These preliminary data and hypotheses should be verified or refuted when additional peepers are recovered.

Cruises Results:

July 1-8, 2007, MC 118, Gulf of Mexico. The primary goal of this cruise was to provide time at sea to test the functioning of the Service Station Device (SSD). The cruise plan included picking up seafloor instruments with the SSD. However, due to a variety of developments in the maneuverability of the SSD and of the ship – strong winds at severe angle to the current made for near-impossible station maintenance - we were unable to pick up the peepers, OsmoLander, or PFA box. Additional cruise time in November may be devoted to this need.

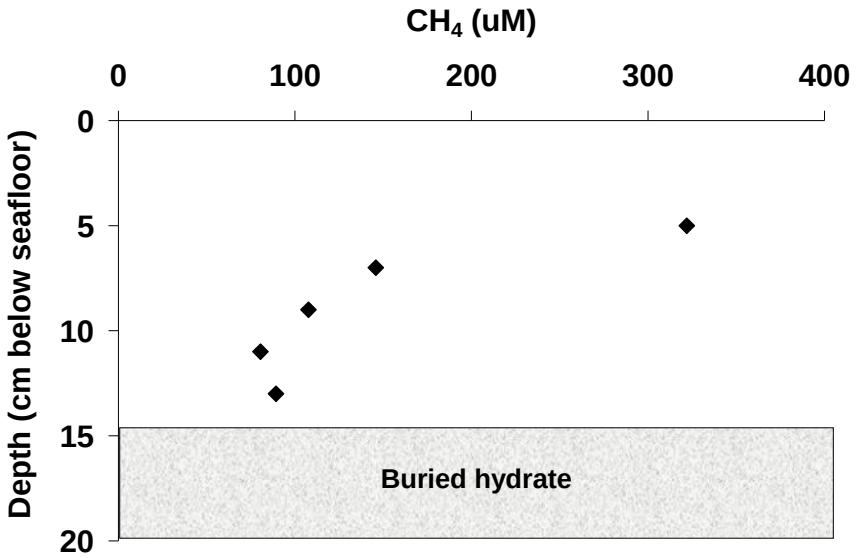

Figure 3: Methane concentrations as gradient away from buried hydrate. Note that at in situ pressure and temperature, saturated methane concentrations are ~70 mM.

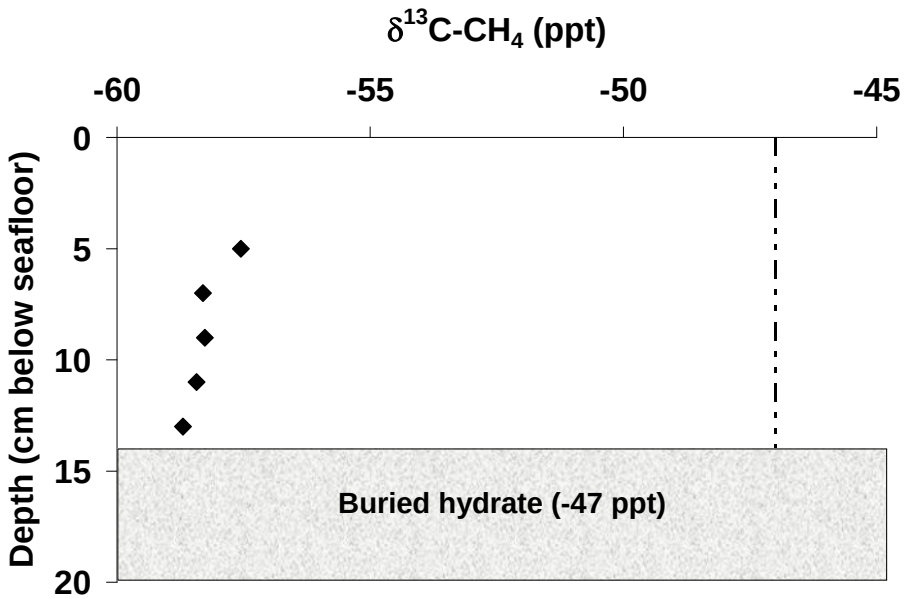

Figure 4: Methane isotopes as gradient away from buried hydrate. Note that buried hydrate has a $\delta^{13}C$-CH_4 value of -47 ppt (as indicated with dot-dash line).

EXPERIMENT TO GENERATE SHEAR WAVES IN THE SEA FLOOR AND RECORD THEM WITH A HORIZONTAL LINE ARRAY

PROGRESS REPORT

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July 23, 2007

EXPERIMENT TO GENERATE SHEAR WAVES IN THE SEA FLOOR AND RECORD THEM WITH A HORIZONTAL LINE ARRAY

The integration and application of the Input/Output Corporation's (I/O) three axis accelerometer sensor to the Horizontal Line Array is desirable as the resolution, accuracy and low frequency response of this accelerometer sensor is superior to that of marine 3-axis geophone sensors. The application of this sensor to the Sea Floor Observatory has required adapting the communications system used in its normal seismic application to the communications requirements of the Sea Floor Observatory. I/O developed this sensor as part of a highly integrated seismic system which can collect data from tens of thousands of these sensors every 10 to 20 seconds. This requires very fast data transmission which I/O has developed a data interface that is both proprietary and elegant. The adaptation of portions of this data transmission scheme and repackaging of this data collection scheme was a significant challenge to the integration of the sensors into the SFO data retrieval system.

In an effort to simplify the data communications and control electronics I/O developed an SCI circuit card with a proprietary custom IC which combines the functions of a large amount of the custom circuitry in the recording truck. The efforts in the Spring of 2007 centered on utilizing this new approach to the problem. Both I/O and SDI wrote software to finally resolve this communications problem. The SCI card communicated directly with the present ALI cards following a software upgrade to the ALI cards. I/O completed the software upgrade in April. During May of 2007 SDI integrated the updated ALI circuitry and the new SCI card with communications software for system test and data collection. The power requirement of this system is now 12 vdc and 48 vdc. The 12 vdc will be generated from the PCB and with the modification of the PCB design in 2007 to 48 vdc from 24 vdc the 48 vdc can now be supplied to the data collection array without further conversion.

The new SCI circuitry and new software cured the last of the major problems preventing the performance of a test of this technology in a format that will lend itself to installation on the sea floor. The new combination of cards and software was packaged and tested at sea with the MMRI Sled combination S and P wave source in June.

The in-water test was performed with successful recovery of accelerometer shear data generated from the MMRI developed seismic gun shear sled. This test was conducted in Biloxi, Mississippi using the University of Mississippi's R/V Kit Jones as the shooting boat and a second boat was utilized as the recording boat. The test included using multiple accelerometer sensors coupled with hydrophone sensors to simulate the sensor packages to be used on a down-hole array or the earlier planned horizontal line arrays. The shear phones were installed on the sea floor with three methods of handling the coupling of the sensor to the soft mud sea floor. One sensor array was lowered to the bottom and slightly pressed

into the mud bottom, one array was encased in a compartmentalized sand bag as developed by ARCO Exploration Company and one sensor array was installed and pressed approximately 2 ½ feet into the seafloor as is planned to be done by a sled-borne plow system. Multiple data lines were shot using various shot point offsets and shot spacing. The shear data exhibited excellent signal to noise ratios with the shear data from the I/O sensors appearing to have better signal to noise ratio than that from the hydrophones. Mechanical packaging was designed for housing the accelerometers and the data collection interface electronics for these accelerometers but has not been implemented as there may be the opportunity to reduce the electronics physical size in the near future.

Considerable support was received from Input/Output Corporation in Houston, Texas in the development of the software to function with the Input/Output electronics with both the SDI developed software package to address the SCI/ALI electronics interface and a software package from I/O becoming available on the same day. Both software packages performed well with the I/O package providing better graphics displays during data collection and the SDI package lending itself better to the planned DATS data collection platform. Further discussions with Input/Output management has lead to the possibility of further refinement of the electronics to better suit the application of the Sea Floor Observatory. These refinements will removing unnecessary functions on each circuit board and reduce the overall dimensions of the circuit boards. The reduced size will greatly affect the size of the pressure housing needed for installation at the depths of the Sea Floor Observatory.

ACRONYMS

4-C	four-component
ALI	A-Link interface (Input/Output's combination of units; accelerometer pseudo-ethernet communications interface and timing device)
AUV	autonomous underwater vehicle
BCS	Barrodale Computing Services, Ltd.
C	carbon
CH4 (=CH_4)	methane
cmbsf	centimeters below sea-floor
CMRET	Center for Marine Resources and Environmental Technology
CO2 (=CO_2)	carbon dioxide
DATS	Data Acquisition and Telemetry System
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of the Interior
EGL	Exploration Geophysics Laboratory
FY	Fiscal Year
GOM	Gulf of Mexico
GOM-HRC	Gulf of Mexico-Hydrates Research Consortium
HLA	horizontal line array
HRC	Hydrates Research Consortium
HSZ	Hydrate Stability Zone
IC	integrated circuit
IDP	integrated data power unit
I-O; I/O	Input-Output Corporation
JIP	Joint Industries Program
mbsf	meters below sea-floor
MC	Mississippi Canyon
mM	millimolar
MMRI	Mississippi Mineral Resources Institute
MMS	Minerals Management Service
MS/SFO	monitoring station/sea-floor observatory
M/V	merchant vessel
uM	micromolar
NETL	National Energy Technology Laboratory
NIUST	National Institute for Undersea Science and Technology
NOAA	National Oceanographic and Atmospheric Administration
NURP	National Undersea Research Program
OBC	ocean-bottom cable
PFA (=PCA)	pore-fluid array
Ppt	parts per thousand
P-wave	compressional wave
ROV	remotely operated vehicle
R/V	Research Vessel

SCI	serial communications interface
SDI	Specialty Devices, Inc.
SFO	Sea Floor Observatory
SFP	Sea Floor Probe
SSD	Station Service Device
SS/DR	shallow-source/deep-receiver
S-wave	shear wave
US	United States
USGS	United States Geological Survey
vdc	volts direct current
VLA	vertical line array
VSP	vertical seismic profile