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HYDRATE RESEARCH ACTIVITIES THAT BOTH SUPPORT AND DERIVE FROM THE MONITORING STATION/SEA-FLOOR OBSERVATORY, MISSISSIPPI CANYON 118, NORTHERN GULF OF MEXICO

Submitted by:

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PHASE 1 Subcontractors and Tasks for FY 2006:

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Task 2: Seismic Data Processing at the Gas Hydrate Sea-floor Observatory: MC118.

Jeffrey Chanton, Department of Oceanography, Florida State University, Tallahassee, FL 32306
Task 3: Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements

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Bob A. Hardage, Bureau of Economic Geology, John A. and Katherine G. Jackson School of Geosciences, the University of Texas at Austin, University Station, Box X, Austin, TX 78713-8924.
TASK 3: Seismic Data Processing at the Gas Hydrate Sea-Floor Observatory: MC118.

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TASK 4: Geochemical investigations at MC 118: Pore fluid time series and gas hydrate stability.

John Noakes, Scott Noakes, and Chuanlun Zhang, The University of Georgia, Athens, Georgia, and Tim Short, SRI International, St. Petersburg, Florida.
TASK 5: Automated Biological/Chemical Monitoring System (ABCMS) for Offshore Oceanographic Carbon Dynamic Studies.

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TASK 6: Microbial techniques to extract carbon from stored hydrocarbon gases.

Ira Leifer, Marine Science Institute, University of California at Santa Barbara, Bldg. 2, Room 3357, Santa Barbara, CA 93103-5080.
TASK 7: Scoping study using Spatio-Temporal Measurement of Seep Emissions by Multibeam Sonar at MC118.

Paul Higley, Specialty Devices, Inc., 2905 Capital Street, Wylie, TX 75098
TASK 8: Validate high-frequency scatter on SSDR data by acquisition of targeted cores and velocity profiles at MC118 Hydrate Mound.

Sabodh Garg, Science Applications International Corporation, 10260 Point Campus Drive, MS A-3, San Diego, CA 92121.

TASK 9: Recipient shall model carbonate/hydrate mound in Mississippi Canyon 118 using modified version of (THROBS).

PHASE 3 Subcontractors and Tasks for FY 2009:

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TASK 2: Geological and Geophysical Baseline Characterization of Gas Hydrates at MC118, Gulf of Mexico.

Bob A. Hardage, Bureau of Economic Geology, John A. and Katherine G. Jackson School of Geosciences, the University of Texas at Austin, University Station, Box X, Austin, TX 78713-8924.

TASK 3: Near seafloor geology at MC118 using converted shear-waves from 4C seafloor sensor data.

Laura Lapham and Jeff Chanton, Department of Oceanography, Florida State University, Tallahassee, Florida, 32306-4320.

TASK 4: Geochemical investigations at MC 118: Pore fluid time series and gas hydrate stability.

John Noakes, Scott Noakes, and Chuanlun Zhang, The University of Georgia, Athens, Georgia, and Tim Short, SRI International, St. Petersburg, Florida.

TASK 5: Automated Biological/Chemical Monitoring System (ABCMS) for Offshore Oceanographic Carbon Dynamic Studies.

Ira Leifer, Marine Science Institute, University of California at Santa Barbara, Bldg. 2, Room 3357, Santa Barbara, CA 93103-5080.

TASK 6: Quantification of Seep Emissions by Multibeam Sonar at MC118.

Sabodh Garg, Science Applications International Corporation, 10260 Point Campus Drive, MS A-3, San Diego, CA 92121.

TASK 7: Modeling a carbonate/hydrate mound in Mississippi Canyon 118 using modified version of (THROBS).

PHASE 4 Subcontractors and Tasks for FY 2010

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TASK 2: Integration of Multiple Methods of Geological and Geophysical investigations to advance Shallow Subsurface Characterization at MC118.

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TASK 3: Modeling a carbonate/hydrate mound in Mississippi Canyon 118 using modified version of (THROBS).

Laura Lapham and Jeff Chanton, Department of Oceanography, Florida State University, Tallahassee, Florida, 32306-4320.

TASK 4: Geochemical investigations at MC 118: Pore fluid time series and gas hydrate stability.

John Noakes, Scott Noakes, and Chuanlun Zhang, The University of Georgia, Athens, Georgia, and Tim Short, SRI International, St. Petersburg, Florida.
TASK 5: Automated Biological/Chemical Monitoring System (ABCMS) for Offshore Oceanographic Carbon Dynamic Studies.

Ira Leifer, Marine Science Institute, University of California at Santa Barbara, Bldg. 2, Room 3357, Santa Barbara, CA 93103-5080.
TASK 6: Quantification of Seep Emissions by Multibeam Sonar at MC118.

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INTRODUCTION / PROJECT SUMMARY

The Gulf of Mexico Gas Hydrates Research Consortium (GOM-HRC) was organized in 1999, with the goal of establishing a monitoring station/sea-floor observatory (MS/SFO) to investigate the hydrocarbon system within the hydrate stability zone (HSZ) of the northern Gulf of Mexico. The intention has been to consolidate research effort and to equip the MS/SFO with a variety of sensors that will enable more-or-less continuous monitoring of the near-seabed hydrocarbon system and to determine the steady-state description of physical, chemical and biological conditions in its local environment as well as to detect temporal changes of those conditions.

The purpose 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 researchers with an improved 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, now the Bureau of Ocean Energy Management, BOEM) 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, now NOAA/OER (Ocean Exploration and Research) in 2002 via their National Institute for Undersea Science and Technology (NIUST). Some nineteen industries and nineteen universities are actively involved in Consortium/Observatory research; the United States Geological Survey (USGS), the US Navy, Naval Meteorology and Oceanography Command, Naval Research Laboratory (NRL) and NOAA's National Data Buoy Center are involved at various levels of participation. Funded investigations include a range of physical, chemical, and biological studies. Studies of the benthic fauna as a proxy for seafloor hydrocarbon venting comprise a recent addition to the emphasis areas of the Consortium.

The project is administered by the Center for Marine Resources and Environmental Technology (CMRET), the marine arm of the Mississippi Mineral Resources Institute (MMRI) of The University of Mississippi (UM).

EXECUTIVE SUMMARY

In 1999, a consortium of leaders in gas hydrates research in the Gulf of Mexico was assembled for the purpose of consolidating both laboratory and field efforts. 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. The primary purpose of the station is to monitor activity within the zone of hydrate stability 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 developed and assembled components for a station that will monitor physical and chemical parameters of the sea water, seafloor sediments, and shallow sub-seafloor sediments on a more-or-less continuous basis over an extended period of time. Study of chemosynthetic and other benthic communities and their interactions with geologic processes is a component of the Observatory; results will provide an assessment of environmental health in the area of the station including the effects of deep sea activities on world atmosphere and, therefore, weather.

Central to the establishment of the Consortium is the need to coordinate activities, avoid redundancies and promote effective and efficient communication among researchers. Complementary expertise, both scientific and technical, has been assembled; collaborative research and coordinated research methods have grown out of the Consortium and design and construction of most instrumentation for the seafloor station are essentially complete.

In October, 2004, Mississippi Canyon 118 (MC118) (Figure 1) was selected by unanimous consensus of the GOM-HRC at their semiannual fall meeting as the location likeliest to fulfill the research needs and goals of the group. Criteria for selection included evidence of gas hydrates on the sea-floor, active venting and availability. Based upon roughly five years of site evaluations, sensor design, fabrication, testing and data collection and evaluation, selection of the site was followed by MMS placing a research restriction on the unleased block so Observatory research might continue even if the block should subsequently be leased, as is now the case. *MC118 is the only research reserve in the Gulf of Mexico and the Seafloor Observatory is the only such facility in the Gulf.*

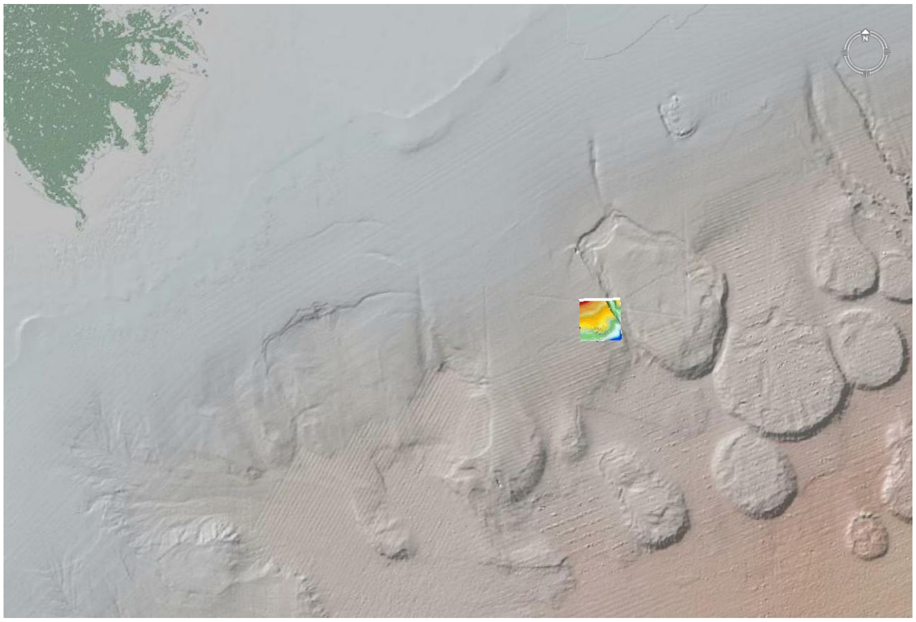


Figure 1. MC118 is located ~30 miles off the toe of birdsfoot delta on the edge of a massive slump.
Since changes in the hydrate stability zone must in some way be measured against an established baseline, a significant effort has been devoted to establishing the baseline geology and chemistry at the site of the MS/SFO at MC118. Characterization and baseline determination commenced in spring, 2005. The First Phase Sea-floor Probe (SFP) installation was completed successfully with two sub-sea-floor arrays emplaced in the sea-floor at MC118; a thermistor array, and a geochemical, pore-fluid chemistry, and pressure sensor array were deployed using the MMS/BOEM gravity-driven SFP. In spite of a variety of delays, including the effects of several severe hurricanes, follow-up surveys and deployments, continue to take place. Geophysicists and geologists at the University of Mississippi and the University of South Carolina (USC) have established that Woolsey Mound, a hydrate-carbonate feature and site of the observatory, lies directly over a rising salt dome, that "master faults" extend from the salt body to the seafloor, that the three crater complexes on the mound each reside on the hanging wall of one of these master faults, that swarms of radial faults intersect these master faults providing a conduit system sufficient to supply hydrocarbon fluids from depth to the seafloor and water column (Figure 2). Moreover, resistivity data, heat-flow and additional geophysical findings suggest that these conduits are alternately open and closed – possibly by hydrate dissociation or dissolution and formation – and that each crater complex appears to represent a different fluid flux regime and a different stage in mound development (Macelloni et al., in prep).

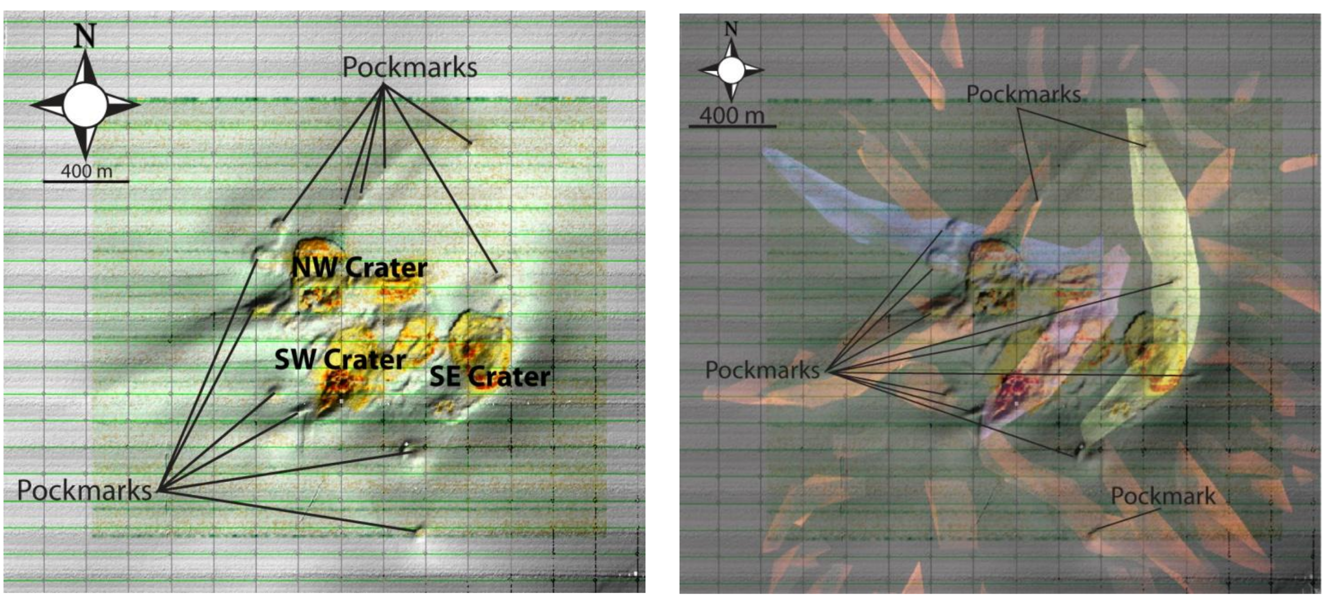


Figure 2. Woolsey Mound at MC118 has 3 distinct crater complexes. The image on the left shows bathymetry and acoustic backscatter (hardgrounds) at the site. To the right, "master faults" – blue, violet, yellow – and shallower, radiating faults – orange – are plotted with this same bathymetry to illustrate surface expression of the fault system.

Experiments designed to assess water-column geochemistry, microbial communities and activities, hydrate host materials, and composition of pore-fluids have been designed and built, and tests run at MC118. Sediments collected from Mississippi

Canyon have been studied for effects of parameters possibly involved in hydrate formation. Laboratory analyses show that smectite clays promote hydrate formation when basic platelets slough off the clay mass. These small platelets act as nuclei for hydrate formation. Experiments show an increasing importance of microbial activities surrounding active vents in promoting the formation and stability of seafloor gas hydrates. Rogers (2001) established a connection between the microbial communities and hydrate formation and recently found through experimental analyses of MC118 microbial consortia that *microbial cell wall material inhibits hydrate formation*, a necessary occurrence for the bacterial cell's survival preventing hydrate formation-heats from being liberated directly onto cell surfaces (Rogers' final report, included in 42877R18). Microbes inhibit hydrate formation, thus enhancing their ability to survive the extreme conditions of the deep sea HSZ.

During this reporting period, the CMRET planned and directed one cruise to MC118 and participated in two NIUST Autonomous Underwater Vehicle (AUV) cruises directed by the NIUST Underwater Vehicles Technology Center (UVTC). The AUV recovered multibeam and polarity-preserved chirp data that will be processed by scientists at the STRC. The multibeam data will be used to produce bathymetry and backscatter images while the chirp data allow us to image, in great detail, the shallowest portion of the subsurface. A cruise report for the July cruise is in prep and will be posted shortly at http://www.mmri.olemiss.edu/Home/Publications/Cruise.aspx. A fall cruise was cancelled due to a break in our fiber-optic cable, necessary to all functions of the cruise. We have now replaced the cable and have spooled and terminated it successfully. Major achievements of the successful cruises include:

1. Deployed and recovered - at MC118 - the newly designed and built calibration mooring, ABIL (Autonomous Benthic Instrument Lander), Figure 3, with Ultra-short Baseline (USBL) transponder, CTD (conductivity-temperature-depth instrument), and the University of Southern Mississippi's (USM's) sonar scanner aboard; Performed calibration for HyPack navigation.
2. Performed lander operations at MC297 (OC26) with the newly upgraded Station Service Device (SSD), Figures 4, 5, 6, 7, and 8, as requested by PI for Ecosystem Impacts of oil and gas inputs to the Gulf - Gulf Recovery Initiative):
    a. video the disposition of the lander (Figure 9);
    b. video the instruments on the lander;
    c. video surroundings for potential CSA (Chimney Sampler Array) deployment sites; and
    d. place chimneys on the seafloor (remove each from the lander and place at a suitable site for determining flux of gas from seafloor sediments, i.e. where bacterial mats are abundant or bubble streams are visible).
3. With the NIUST AUV team (Figure 10), recovered multibeam data from 50m above seafloor for MC118 and MC297 (OC26). MMRI/STRC will process and interpret the data.
4. With NIUST AUV team, recovered multibeam data from 15m above the seafloor, Figure 11, over the western portions of Woolsey Mound at MC118 for a very high resolution bathymetry study. MMRI/STRC will process and interpret the data.
5. With the NIUST AUV team, recovered high resolution photo data from MC118

and MC297 using the *Mola Mola* AUV (Figure 12). *This is the first survey conducted with the Mola Mola with proper navigation*.

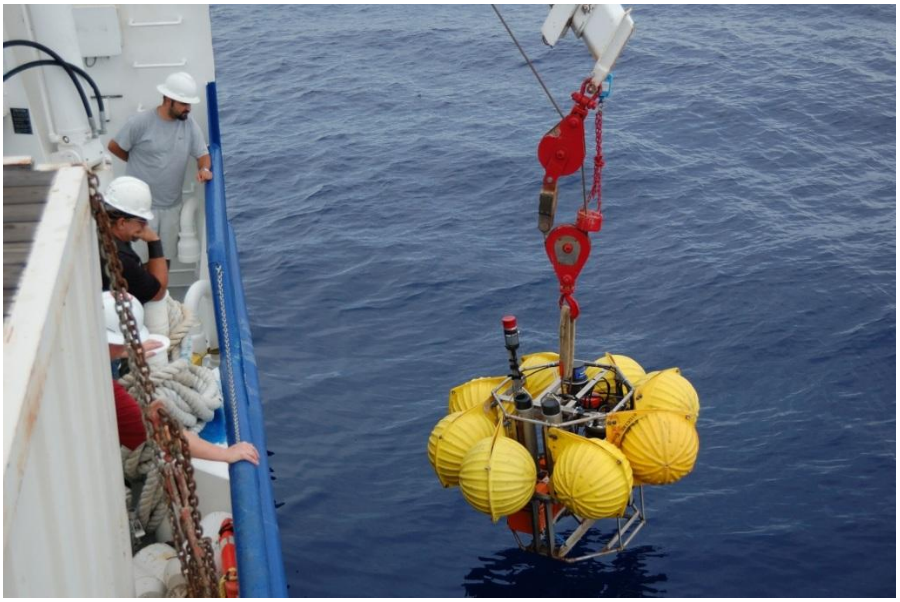


Figure 3. The ABIL is deployed using the Pelican's crane. Note the compact, central, arrangement of instruments - CTD, acoustic releases, battery, transponder - protected by the glass floats in hard-hats. Scanning sonar – red – is located above the other lander components for greater access to its surroundings.

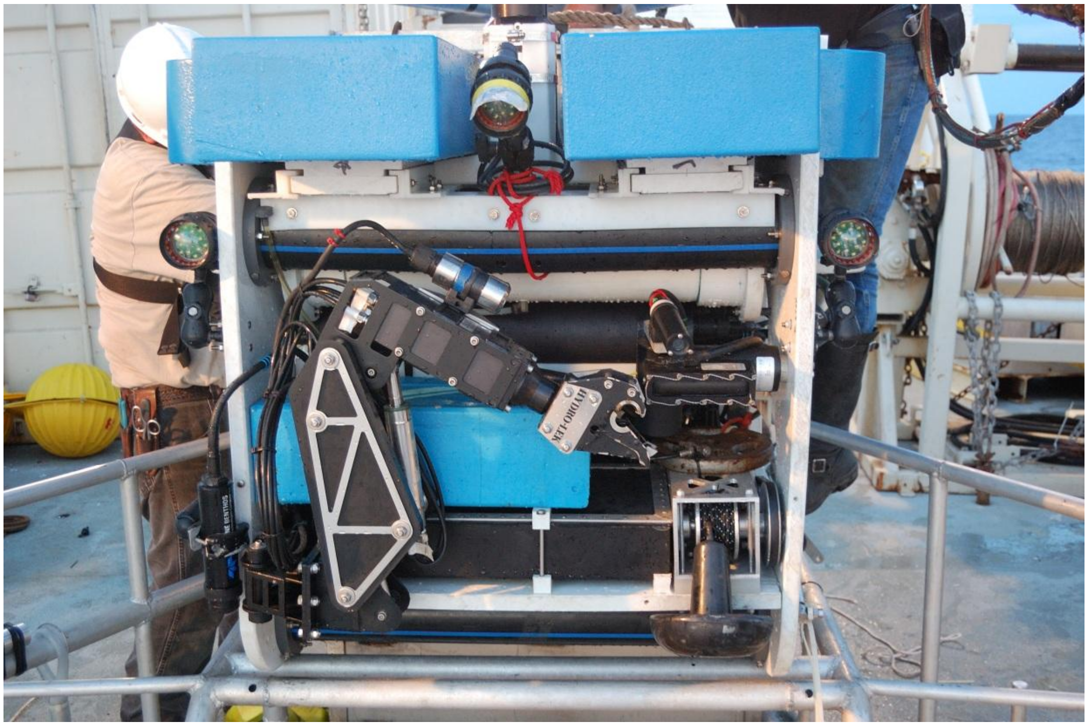


Figure 4. The SSD undergoes a series of ondeck tests prior to every dive. Note the new camera on the manipulator arm, center of image.

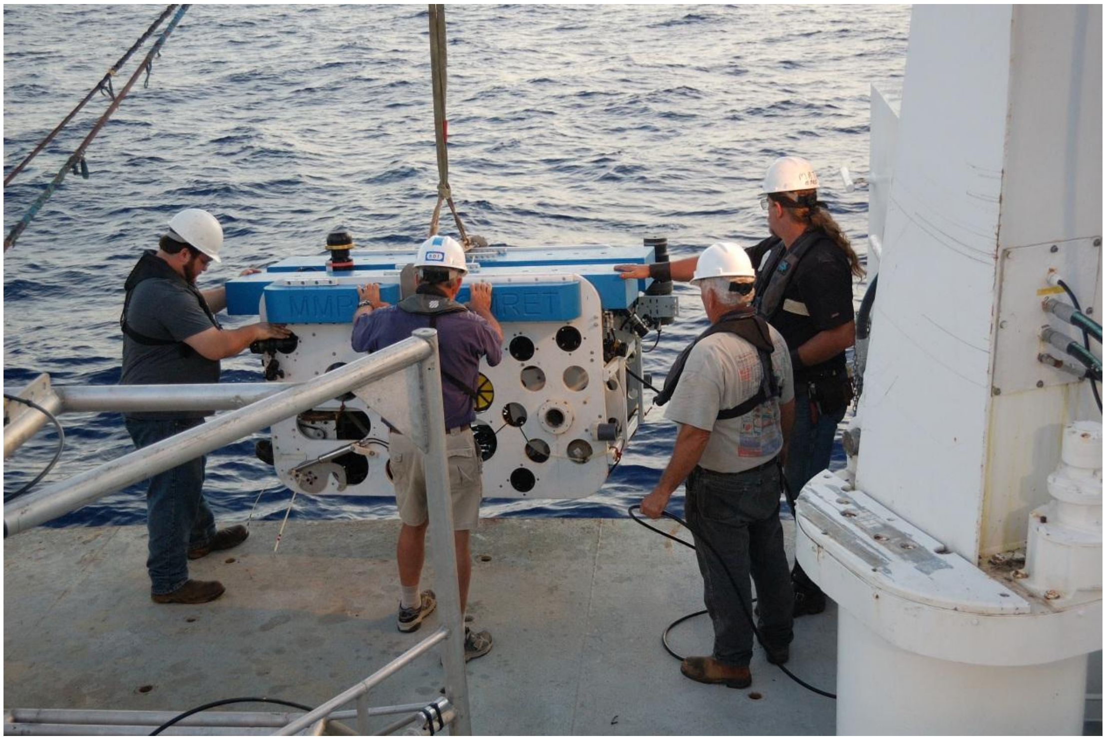


Figure 5. As part of the pre-dive preparations, the SSD undergoes a dunk test prior to its initial dive. This test will determine what adjustments need to be made to the vehicle's ballast and trim, so that its travel in the water-column will be stable and its responses predictable.

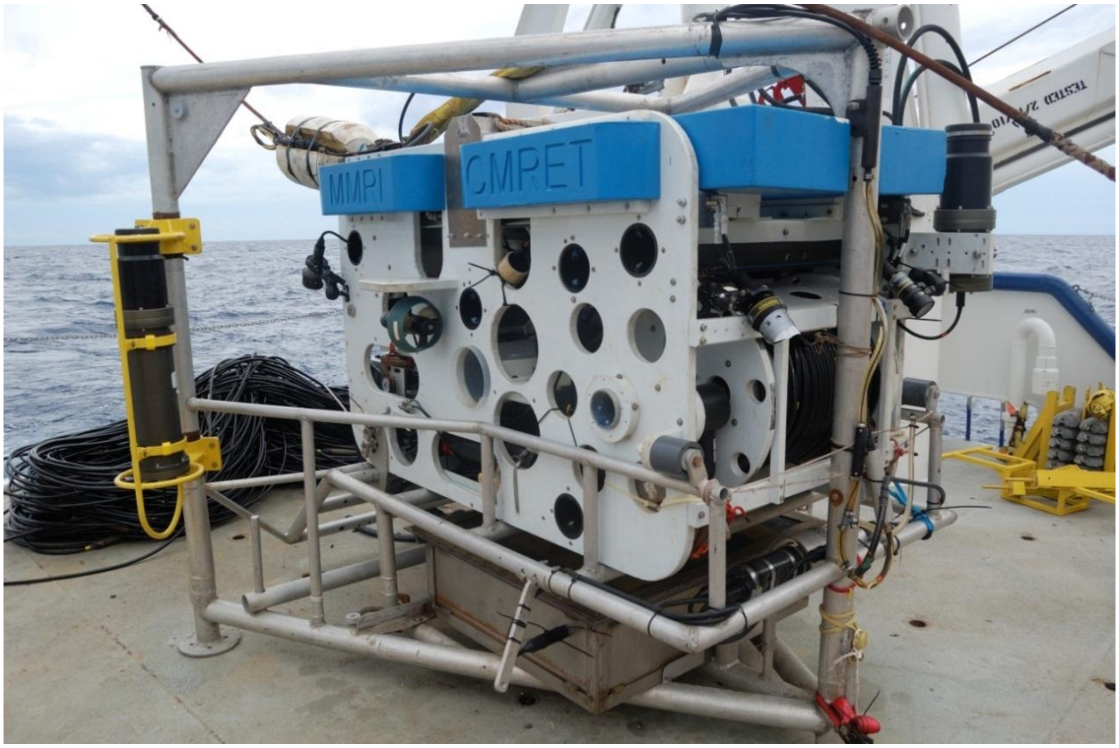


Figure 6. While the Pelican motors to the target, the SSD, complete with upgrades, resides in its cage, ready to dive.

Figure 7. The SSD team effects a smooth vehicle recovery.

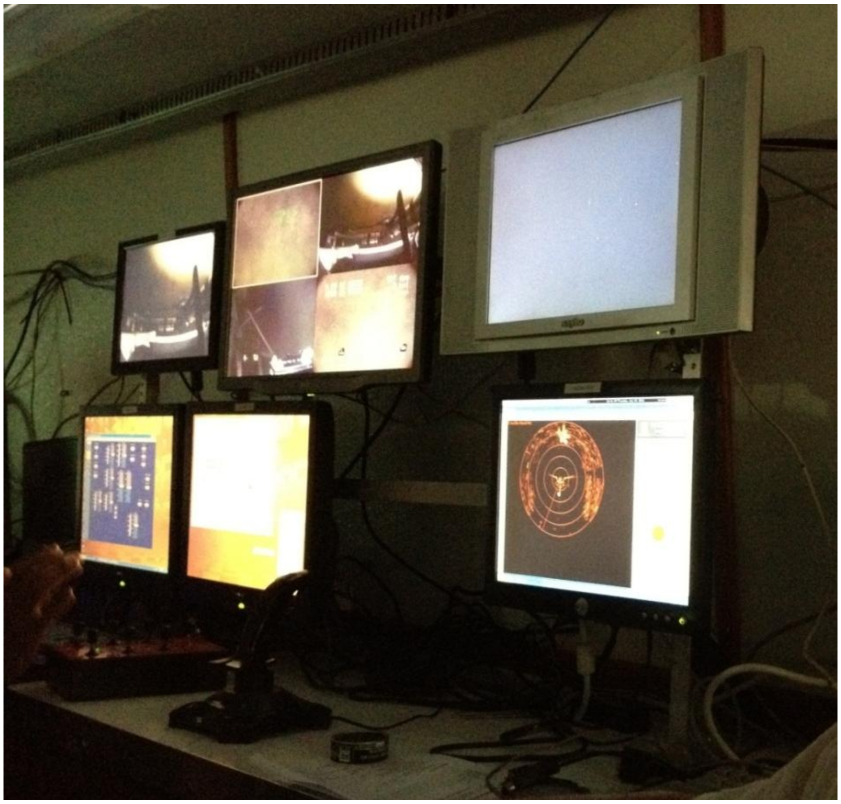


Figure 8. The SSD feeds back a variety of information to the vessel via fiber-optic cable feed: photographic data from multiple cameras, sonar, and information about its location and attitude. Its power comes from a battery built into the vehicle which doubles as a clump-weight.

Figure 9. The ECOGIG lander, built by the MMRI/CMRET shop, was located 115m from the location given the navigation. Using the SSD's sonar and multiple camera capabilities, we were able to locate the lander, then survey its position, document the orientations of the instruments and remove the chimneys (grey cylinders in the front of the image on the right) and place them on the seafloor where the seafloor showed signs of gas emissions (bacterial mat, pitted surfaces).

Figure 10. The AUV team prepares to launch the Eagle Ray AUV from the Pelican's maindeck via the launch and recovery system (LARS), designed and built specifically for it.

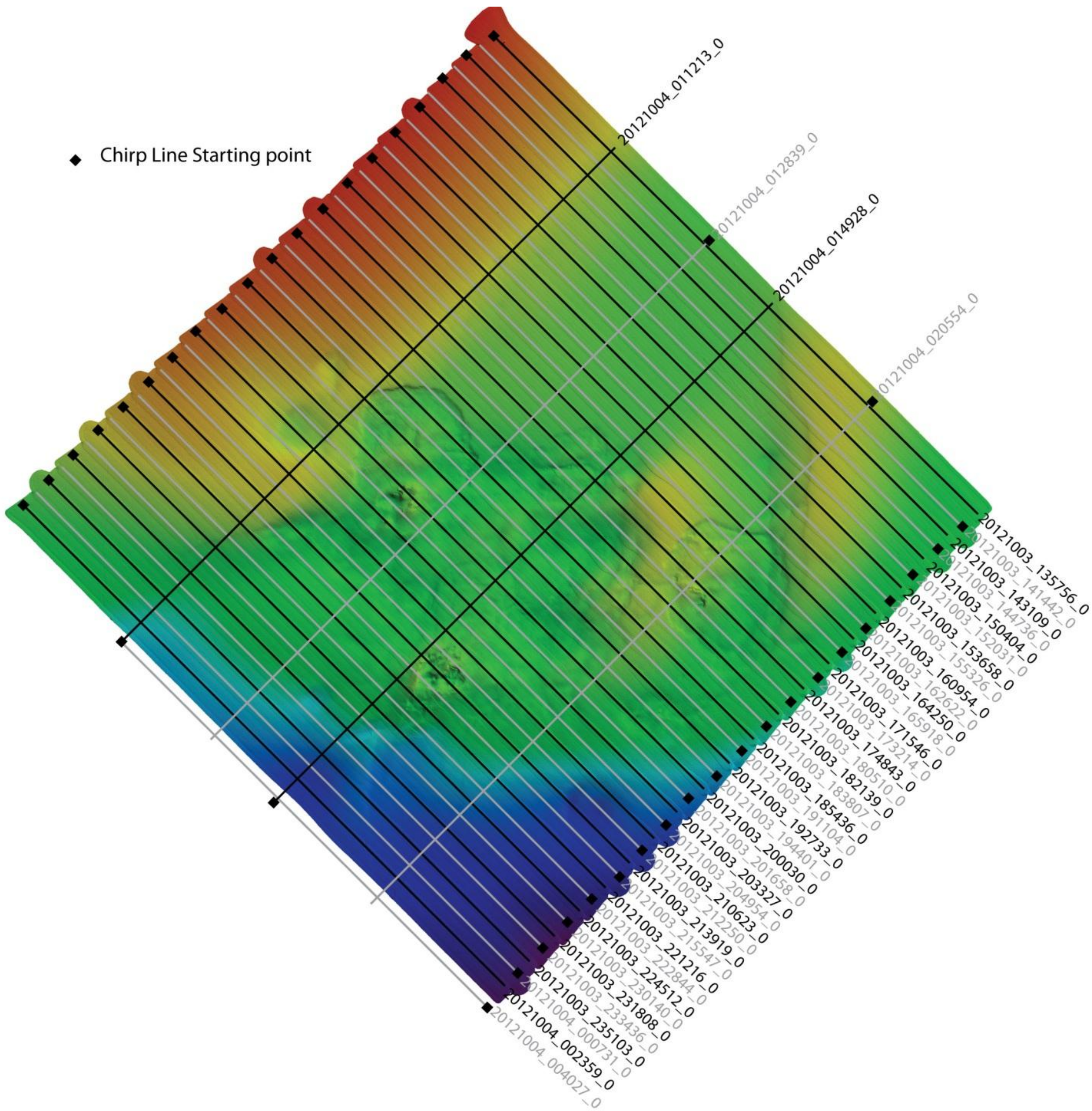


Figure 11. The plot of the high resolution multibeam survey conducted from the Eagle Ray AUV. Polarity-preserving chirp sonar was run simultaneously with multibeam (plotted here over the unprocessed resulting bathymetry). The AUV flew 15m above the seafloor. Survey line spacing is 60m; resolution is 25cm.

Figure 12. The AUV team prepares to launch the Mola Mola photo-AUV from the Pelican's upper deck.

MONITORING STATION SYSTEMS STATUS SUMMARY

Geophysical Sensor Systems/Geology

Geophysical studies as well as coring efforts have been used to define the baseline geology at the Observatory site. Multibeam swath bathymetry and chirp sonar systems on the C&C Hugin 3000 AUV have been used to define seafloor morphology and bottom reflectivity (see Figure 13) and high resolution chirp sub-bottom profiling. With meticulous reprocessing of the data, extremely detailed images of the seafloor and ~60-70m profiles of the subseafloor have been made. These very high resolution images are placed in a regional context that we are now updating using the *Okeanos Explorer* multibeam data acquired late in 2011. In addition to *Okeanus* data, new NIUST UVTC *Eagle Ray* AUV surveys have been acquired that include multibeam (from which new bathymetry and backscatter images are being generated by MMRI/CMRET/STRC) and a new polarity-preserving chirp subbottom survey (see Phase 4, Task 2 of this report). A surface-source deep-receiver system or SSDR (single channel seismic profiling with resolution improved via source-signature processing), has been used to complete a 3x3km survey of the hydrate/carbonate mound at MC118 (officially named after the late Dr. Bob Woolsey, MMRI/CMRET Director, and founder of the Consortium and of the Hydrates Monitoring Station/ Seafloor Observatory project). The resultant 109 profiles of very high resolution seismic data have undergone processing - including the application of Empirical Mode Decomposition (EMD) described by Battista et al. (2007) - to create a 3-D model of the mound. This dataset is capable of imaging features associated with gas hydrates – chimneys, fracture porosity, etc. – hundreds of meters below the seafloor. An industry dataset, acquired by TGS-NOPEC has been evaluated by geophysicists and geologists in the Consortium in order to extend the range of baseline information from the MS/SFO site to the deeper subsurface and the source(es) of hydrocarbons and fracturing at depth. In addition, Consortium geophysicists have acquired Controlled-source Electro-Magnetic (CSEM) data adjusted for shallow hydrate targets and a Direct Current Resistivity data set to produce high resolution images beneath the mound. Although the CSEM data have not yet been processed and evaluated, they are expected to show distribution of hydrates and 3-D structures such as dipping faults to ~200m beneath the seafloor. Results of the analyses of the resistivity data show likely hydrate concentrations associated with areas of faulting and fractures (conduits for migrating fluids) and suggest that these pathways for hydrocarbon migration open but, at least in some cases, subsequently fill with hydrate and become blocked to further fluid migration and perhaps reopen or open elsewhere, forming seafloor features such as pockmarks and seafloor seeps and vents (Figure 2). These findings were corroborated by a 2011 jumbo piston coring effort that recovered hydrate from sites identified from the survey. Additional resistivity studies are planned that will improve the resolution of the initial efforts and may identify areas of greater/lesser hydrate concentrations.

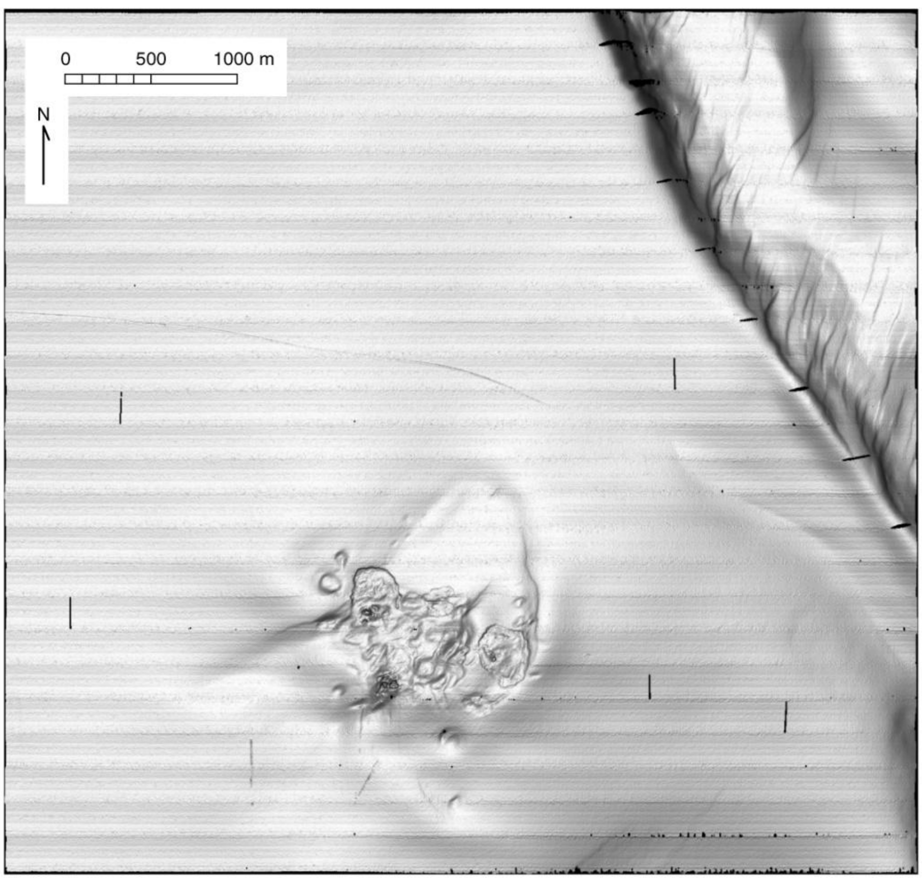


Figure 13. Multibeam image of Mississippi Canyon 118. Data acquired by C&C technologies and reprocessed by The University of Mississippi and University of Rome, La Sapienza.

In the spring of 2012, a heat-flow study was conducted across the mound that also supports these findings. In addition, polarity-preserved chirp data from the 2005 AUV survey have been extracted by C&C Technologies and provided to the UM team for incorporation into the existing geophysical data library. With multiple resolution datasets and meticulous processing and interpretation, we have been able to construct a continuous record that extends from the salt structures – and deep petroleum reservoir potential - at depth through the shallow section and on to the seafloor. An example of this approach appears as Figure 14 and is explored in detail in Simonetti et al., 2011.

Geophysical systems designed and built for permanent installation at the Observatory include a vertical water-column array (VLA) of sensors to determine sub-bottom structure and materials and an orthogonal cross of horizontal line arrays (HLAs) of sensors. Advantages of the HLAs include utilization of surface noise produced by noise-generating ships of opportunity providing P-wave energy for the hydrophones of the vertical and horizontal arrays. Further, the composite vertical and horizontal arrays can be used in experimental work with natural ambient sound, such as ship noise or wind-driven wave noise, as a passive seismic energy source. The planned addition of accelerometers to the suite of seafloor sensors – dependent upon additional project funding - would enable passive monitoring via microseisms. These events, known to occur frequently in the region, are produced by ubiquitous salt movements as well as by deeper, basement-related seismic events. They can be recorded and possibly related to various observed phenomena at the study site such as pore-fluid migration and large scale episodic fluid venting.

Seismic data-processing software has been developed at Exploration Geophysics Laboratory (EGL) of the Texas Bureau of Economic Geology (BEG) that is structured to optimize P-P and P-SV image resolution in the immediate vicinity of 4-component (4C) seafloor-based seismic sensors. In April, 2011, an Ocean Bottom Seismometer (OBS) experiment was conducted over a portion of Woolsey Mound to collect 4C data that will enable researchers to establish the shear features/characteristics of the shallow subsurface. Passive data were also collected via the OBSs and are being evaluated by the University of California-San Diego (UCSD) for their utility in monitoring the HSZ. A recent publication summarizes the work done by the (UCSD group). (see Phase 4, Task 2, this report for the status of this challenging effort). Additional 4C work is planned following the deployment of the HLAs. Software has already been written but is being modified for this experiment. In addition, inversion of the seismic data with the resistivity data is anticipated as a possible next step in geophysical characterization of this site.

Currently the completed water-column VLA, with the seabed HLA horizontal cross, is awaiting installation. The HLA's are complete and were successfully pressure-tested at Southwestern Research Institute in February, 2010, to 1000m water depth equivalents. Several attempts to deploy these ponderous arrays have not been successful and the recovery of the ROV (Remotely Operated Vehicle)-Assisted Recovery Device or ROVARD and the pop-up buoy, April, 2012, have been made in an effort to explore a lander-deployment of at least one of the arrays as a test of the concept.

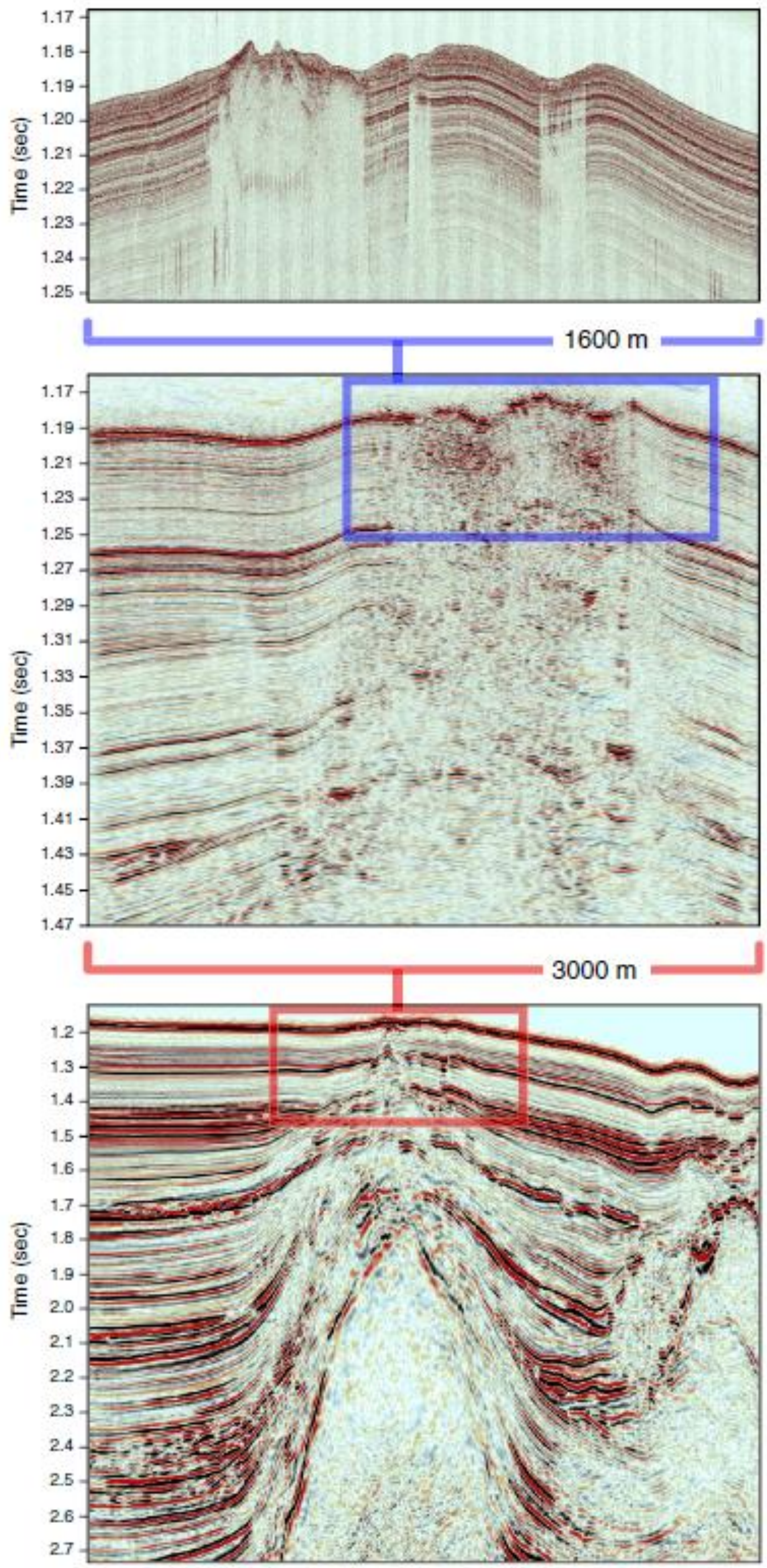


Figure 14. Three resolutions of seismic data were used to evaluate the subsurface at Woolsey Mound. The top profile was acquired using a chirp subsystem profiler of ~8kHz frequency and 10cm resolution. The middle profile was acquired using a shallow- source-deep- receiver system of ~1.5kHz frequency and 1m resolution. The bottom profile was extracted from industry 3D data of ~50Hz frequency and 50m resolution. Note difference in scales and coverage highlighted by the boxed areas.

Additional geophysical studies are either complete, underway or in the planning stages. The additional recent AUV multibeam surveys present the possibility of performing time-series analyses of seafloor changes at the Observatory site, including the evolution of chimneys, gas vents, sediment accumulations and changes in hydrate outcroppings. A June 2009 multibeam survey was run simultaneously with Woods Hole Oceanographic Institution's (WHOI) Mass spectrometer, Tethys. During this survey, Tethys detected methane spikes in areas where multibeam data indicated the possible presence of a seep that had not been evident in the 2005 survey. This critical find verifies the utility of these systems, particularly when used in concert. A new SSDR survey will serve the same purpose but will address changes in the subsurface, including the HSZ. Mounting a hydrophone on the *Eagle Ray* and placing the receiver nearer the seafloor would eliminate cable strum, improving the data as well as extending the range of usable data deeper into the subsurface by increasing the arrival time of the surface ghost. Although we continue to work with Geoacoustics on problems in the software that supports the Polarity Preserving/Discriminating Chirp sub-bottom profiler system, results of the initial successfully navigated survey are promising. The goal of this technology is to enable researchers to discern reflectors related to near-bottom geologic features - including shallow gas horizons - to depths of approximately 50m. A particular benefit is its frequency compatibility with the AUV multibeam swath bathymetry mapping system, permitting simultaneous operation.

An additional industry data set acquired by Western Geophysical Company was purchased in 2010 and delivered in early 2011. Researchers at the USC and the UM have worked together to unravel the complex deep geology of Woolsey Mound; this additional dataset has already allowed these teams to identify previously unidentified structures and features, such as gas pockets that do not appear in the TGS-NOPEC data - adding a time dimension to the deep regional structure. Amplitude variation with offset (AVO) can be applied to this data set to discriminate between fluid and solid material in pore fluids, the latter providing evidence of hydrate. This survey, which includes 12 sec records, also includes about 30% of the data into bordering blocks for full lateral coverage of the observatory block.

Construction of speed of sound probes to accompany CMRET's 10m coring capability is underway and will be used at targeted locations in an attempt to define a seismic signal for hydrate, something that has eluded hydrate workers to the present. Target locations have been identified based on the noise/scatter of signal noted in SSDR data collected from particular locations at MC118, from identification of resistivity anomalies and from detailed study of the morphologic features apparent in the extremely detailed seafloor images produced by meticulous processing of the multibeam backscatter and bathymetry, and corroborated in the chirp data. CMRET has also constructed a site reconnaissance camera (SRC, Figure 15) to inspect seafloor locations of interest prior to coring and/or deployment of landers and sensors on the seafloor.

Jumbo Piston Cores (JPCs) were collected by Consortium geologists and geochemists working with TDI Brooks, International aboard the R/V *Brooks McCall.* Five cores of roughly 12-15m length were collected from sites selected using a combination of geophysical surveys from the area and core histories. Sites of high resistivity readings were given priority as were sites where seafloor expression of gas expulsion and faulting are evident on multibeam images. Hydrates were recovered in the bottom 2 meters of the core from the site of highest resistivity readings (Figure 16). A newly acquired IR camera was used for the first time on this cruise and proved to be quite successful in predicting both high and low heat within unopened cores (Figure 17). This technique is being explored further and refined for use in future coring efforts as hydrate is known to dissociate rapidly upon recovery while temperature gradients may remain for longer periods. This area was targeted in the heat-flow study and found to have the highest heat-flow of the 13 measured sites on Woolsey Mound, a clear indication of fluids migrating through the fracture and to the seafloor.

Figure 15. The Site Reconnaissance Camera, or SRC, designed and built at the MMRI shop – with input from researchers and assistance from the NIUST shop – will make its marine debut in March, 2013. Cameras, lights, and USBL navigation will provide the ability to "see" specific locations on the seafloor. The SRC will be used to verify and investigate seafloor features and instruments prior to coring, while deploying instruments, or making recoveries.

Figure 16. After 2 hours on deck, hydrate can still be observed in the bottom sections of JPC-001. The core contained hydrate layers, nodules, blades, grains and granules in extremely fine-grained host material.

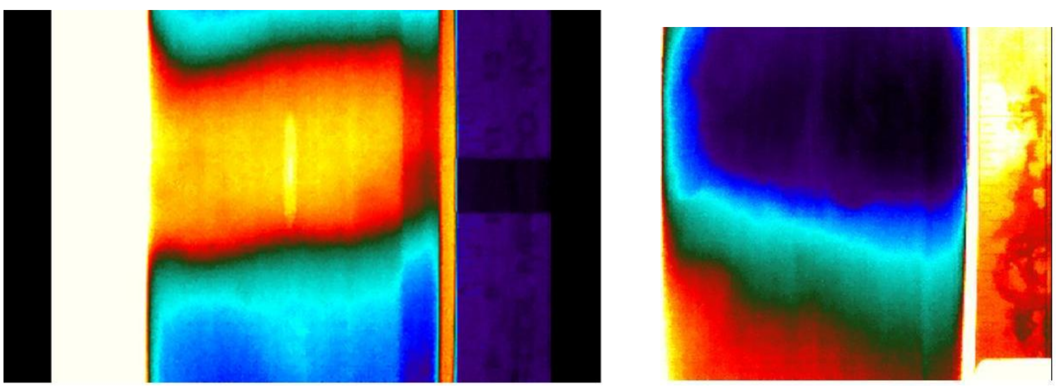


Figure 17. Images from the IR camera highlight areas of anomalous temperature. In the example at left, a void space in the unopened core shows as warmer (warmer color). In the example to the right, a hydrated section shows as cooler (cooler color).

Geochemical Sensor Systems

Experiments designed to assess water-column geochemistry, microbial communities and activities, hydrate host-materials, bubble streams and composition of pore-fluids have been designed, built and tests run at MC118. Sediments collected from Mississippi Canyon have been studied for effects of parameters possibly involved in hydrate formation. Laboratory analyses show that smectite clays promote hydrate formation when basic platelets slough off the clay mass. These small platelets act as nuclei for hydrate formation. Experiments show an increasing importance of microbial activities surrounding active vents in promoting the formation and stability of seafloor gas hydrates. Experimental analyses of MC118 microbial consortia (Phase 3, Task 6, below) have shown the intriguing finding that *microbial cell wall material inhibits hydrate formation*, a necessary occurrence for the bacterial cell's survival, as it prevents hydrate formation-heats from being liberated directly onto cell surfaces. Microbes inhibit hydrate formation, thus enhancing their ability to survive the extreme conditions of the deep sea HSZ.

Evolution of geochemical sensor systems has helped define the baseline as well as the direction of geochemical research at MC118. Early in the history of the Observatory project, a 200m water-column oceanographic line array (OLA) was planned to monitor hydrocarbon pore-fluids venting from the surficial sediments in the vicinity of hydrate mounds and transiting the lower water column. As experience and an improved understanding of the hydrocarbon system and hydrography of the lower water column have emerged, a more comprehensive approach has been developed. The OLA (NETL/NOAA), has been modified to a 60m length and designed to monitor the benthic boundary layer, hence the designation Benthic Boundary Layer Array (BBLA). This array was deployed successfully in March of 2009 and recovered in June. Three months of water-column chemistry were recovered. The BBLA was refitted to include a Contros methane sensor on the bottom node and redeployed at MC118 in September, 2010 and recovered in April, 2011. This dataset has received cursory evaluation and appears to include water-column indications of the Deepwater Horizon spill of April, 2010. Unfortunately, the Contros methane sensor failed after less than 24 hours at depth (1000m). The BBLA was redeployed in June, 2011; in October, 2011, the WHOI optic modem was used successfully to *transfer data remotely from the BBLA to the ship*. This is the first instance of remote data transfer via optic modem and demonstrates the potential of this system. The BBLA was again recovered in April, 2012 for re-batterying and instrument maintenance. The newest dataset, collected over nearly a full year are being evaluated by a visiting scholar, hired to evaluate, process and interpret the geochemical data from the MS/SFO, primarily that recovered using the BBLA.

A small barrel-like, chimney sampler array (CSA), (NOAA/NIUST), outfitted with sensors that collect chemical data related to hydrate formation/dissociation, was fabricated by STRC subcontractors and tested in shallow water. The prototype unit was deployed and tested at MC118 in September, 2006, using the Johnson SeaLink (JSL) manned submersible submarine. A modified and expanded version of this sensor system was deployed on the MMRI/CMRET-designed ROVARD at MC118 in September, 2010 and was recovered in June, 2011. Failure of the METS (methane sensor) truncated collection after 3 weeks. An upgraded system was deployed in October (Figure 18) and collected in April, 2012. Although the METS again failed, it had been routed to a different circuit, allowing the other sensors to continue to collect very high resolution geochemical data, as displayed in Figure 19. Once the BBLA data-evaluation is complete, an attempt will be made to merge the datasets from these two arrays.

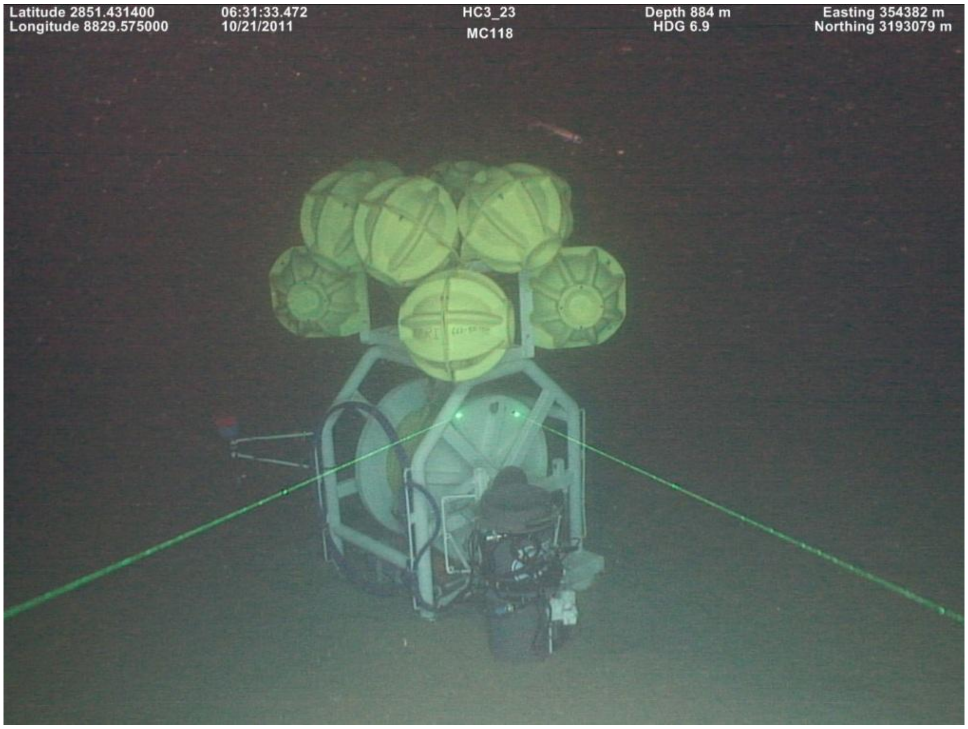


Figure 18, The ROVARD, with CSA, as seen from the ROV, Holiday, during an October, 2012, NRDA cruise.

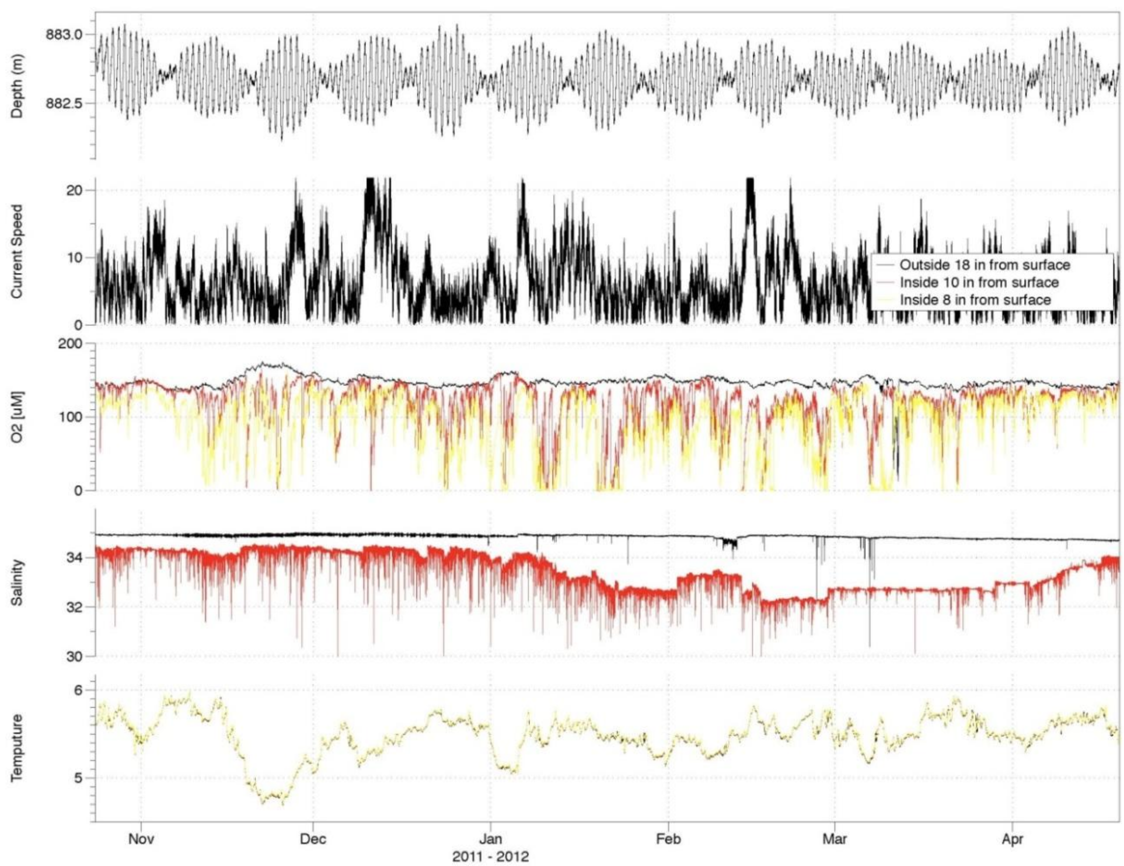


Figure 19. Water-column data collected with the CSA over a six-month deployment on the seafloor at Woolsey Mound.

The pore-fluid sampling array (PFA) was designed to sample and analyze pore-fluid chemistry of the shallow, near-seabed HSZ. The first PFA was completed in time for deployment during a May, 2005 cruise using a 10m SFP in much the same way as the thermistor array (TA) was emplaced. The osmo-sampler retrievable section was recovered on the September 2006 JSL dive along with the TA data-logger. Smaller pore-fluid samplers have been deployed using a variety of methods and expand the lateral coverage of pore-fluid geochemistry at the Observatory. Recovered water samples have since been processed yielding valuable data on the pore fluid chemistry representative of its location. The PFA design and its sampling success prompted the fabrication of a second PFA to expand the lateral coverage of the pore fluid investigation to additional areas of interest. A second unit was installed during the April 2008 cruise, penetrating a fracture zone within 3m of a 10m gravity core site which yielded significant hydrates (gravity corer and PFA precision guided by ultra-short base-line (USBL) navigation system). Smaller pore-fluid collecting devices or “peepers” were among the sensors deployed on the MMRI/CMRET-designed ROVARD that was recovered in June, 2011. Additional replacement osmoboxes as well as smaller pore-fluid sampling units - landers and peepers – have been deployed at MC118 and elsewhere (see Final Report for Phase 4, Task 4, 42877R24, Appendix B). This device is also under consideration for adaptation to collect microbial growth information.

The Noakes Lander with Automated Biological/Chemical Monitoring System (ABCMS) was used quite successfully in October, 2011, to evaluate several sites under consideration for installment of the CSA. The Noakes system - which now includes a downward-looking camera - operated for 9 hours recovering visual data continuously and samples of water-column suspended material, on demand. Although the membrane induction mass spectrometer (MIMS) did not function, the electronics to and from it did. The membrane component of the MIMS failed and although several replacement membranes were fabricated onboard, none survived the rigors of emplacement into the MIMS (see Phase 4, Task 5). This System is scheduled for a repeat trial, with MIMS, in April, 2013, as is the University of California, Santa Barbara (UCSB) 3-D sonar rotator.

Biological Experiments and Monitoring

The importance of microbial activity to the production and stability of hydrates has been acknowledged by Consortium researchers since the early discussions of the MS/SFO. The possibility of adding a microbial component to the station was discussed for several years prior to the addition of microbial researchers to the Observatory project via NIUST. Four projects were funded and provided ship time with the Consortium beginning in September, 2006, with deployment of experiments on the seafloor with the JSL. Their work continues using the NOAA/NIUST specially designed ROV, station service device (SSD), for deployment and recovery. The Consortium (via NIUST) has provided the microbial team with access to the site by making a portion of Consortium-requested ship time and ROV/SSD submersible time available for their use. Microbial collectors have been deployed and several sampling efforts have succeeded in beginning to elucidate the microbial activities at the observatory site. In this way, the MS/SFO becomes a three-way observatory providing geophysical, bio-geochemical, and microbial data from the sea-floor, eventually on a continuous, near real-time basis.

This additional dimension has greatly expanded the utility of this multi-disciplinary facility and improved our ability to investigate and model the interrelated physical, chemical and biological processes at work at this active carbonate - hydrate mound complex, complete with dynamic hydrocarbon fluid venting.

In 2009, serious attention began to be given to the macrofauna at MC118. Through collaborations with other researchers and the efforts of new student interns, we are beginning to unravel the history of the fauna on the seafloor, their ecology and history and how these factors reveal the venting history at MC118. Four submersible cruises to MC118 in 2010-11 revealed much more diversity and complexity on the seafloor than previously known. Additional cruises and projects, mostly carried out through affiliates of the CMRET, occurred through the end of 2011 with the CMRET providing maps, bathymetry, locations of seafloor instruments, hazards, etc. to researchers from a variety of institutions, participating in Deep Water Horizon recovery work at MC118. In 2012, UVTC and STRC cooperated on a *Mola Mola* AUV cruise that included a photo-survey of the western craters at MC118. The high definition photos reveal the seafloor and its inhabitants in incredible detail, as illustrated in Figures 20, 21, 22. Figure 23 illustrates the distribution of seafloor types - as determined from video and sampling – including hardground at MC118, where biota are found in abundance.

Figure 20. Bacterial mats and clams form part of a complex community on the seafloor at MC118.

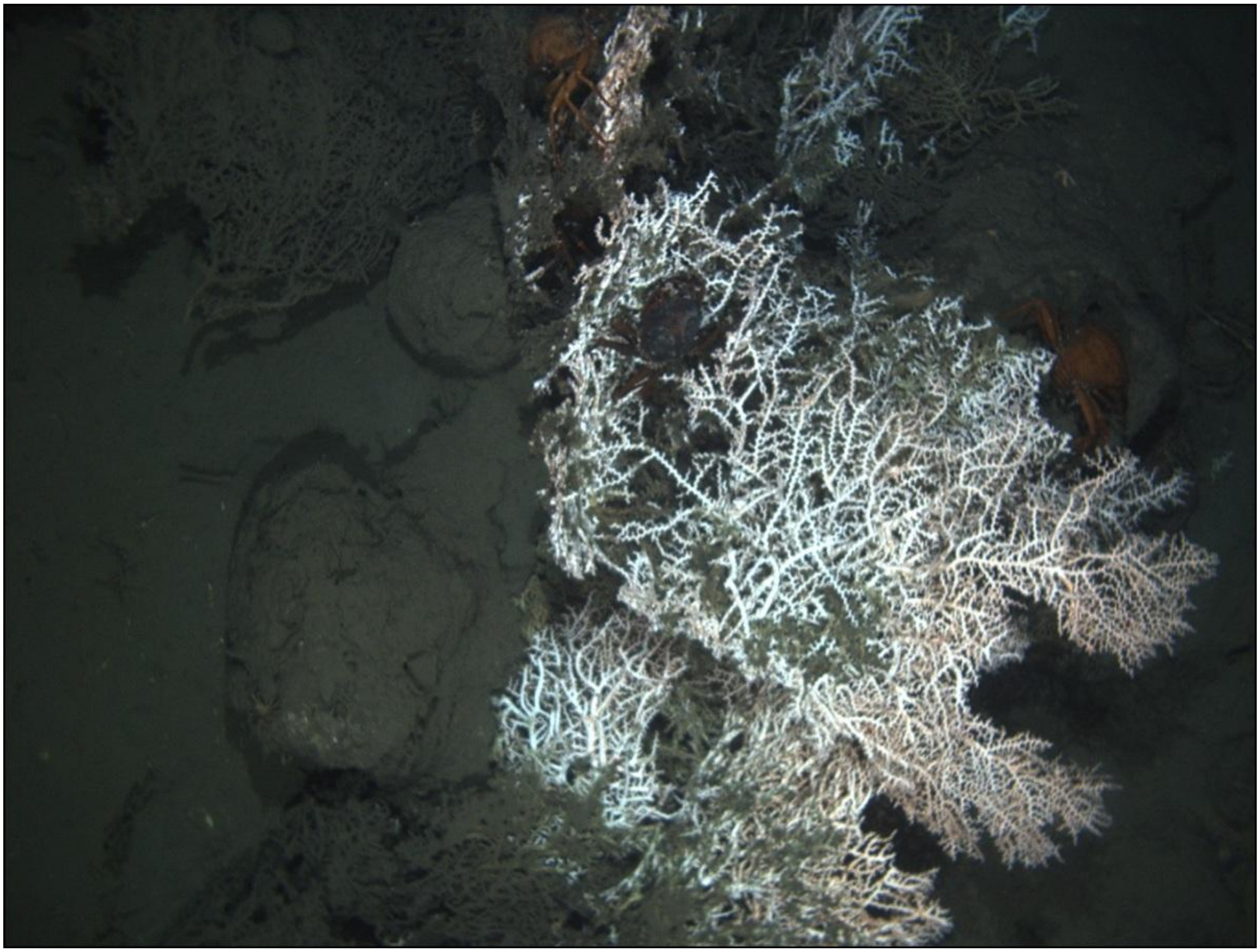


Figure 21. Deep Sea Corals at MC118. Reefs provide habitat, recruitment and nursery functions for a range of deep-water organisms including commercial fish species. Deep sea corals may provide windows into past environmental/ecological conditions. This colony of Madrepora oculata, or zig-zag coral, is a rare find in the Gulf.

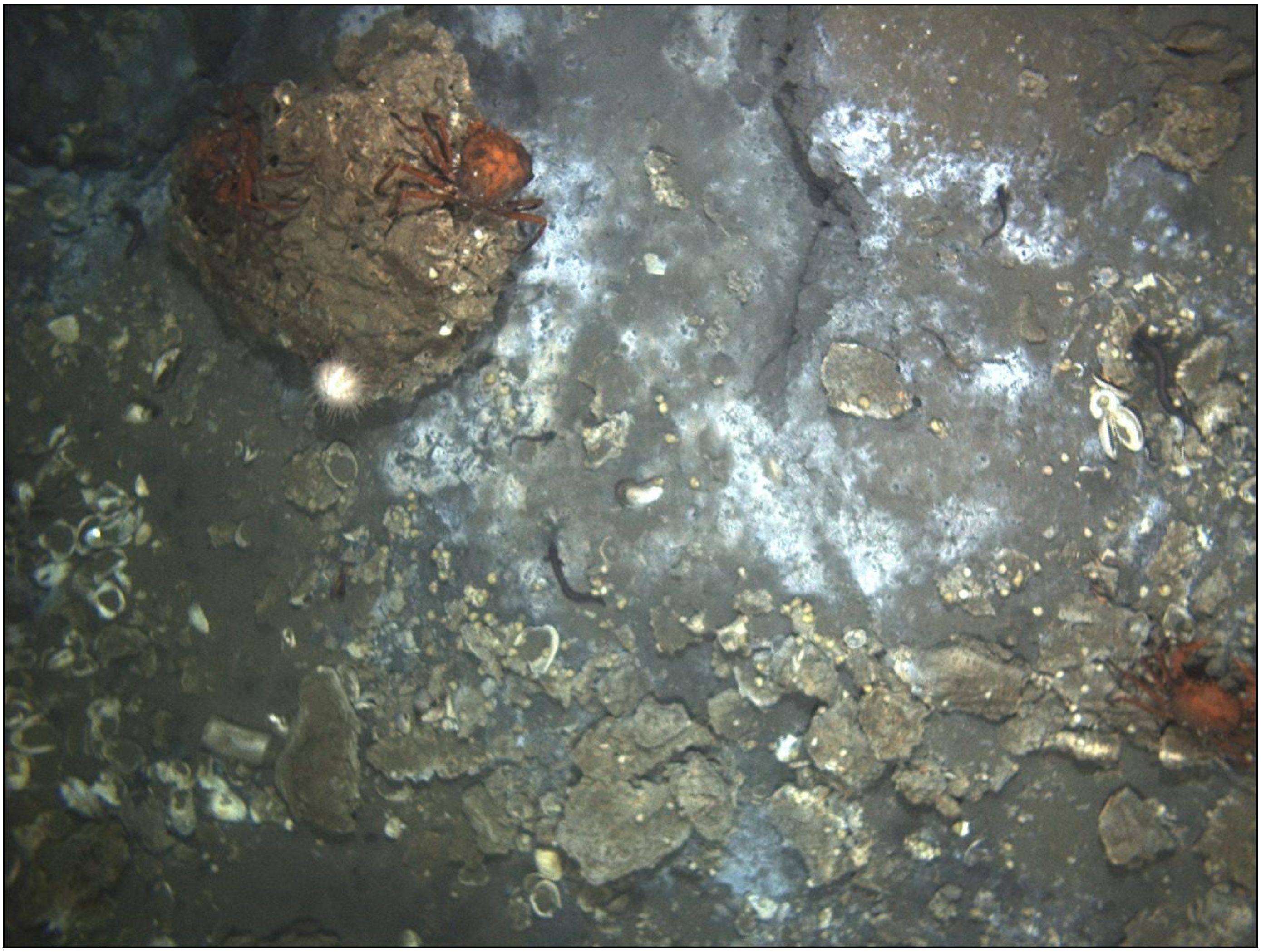
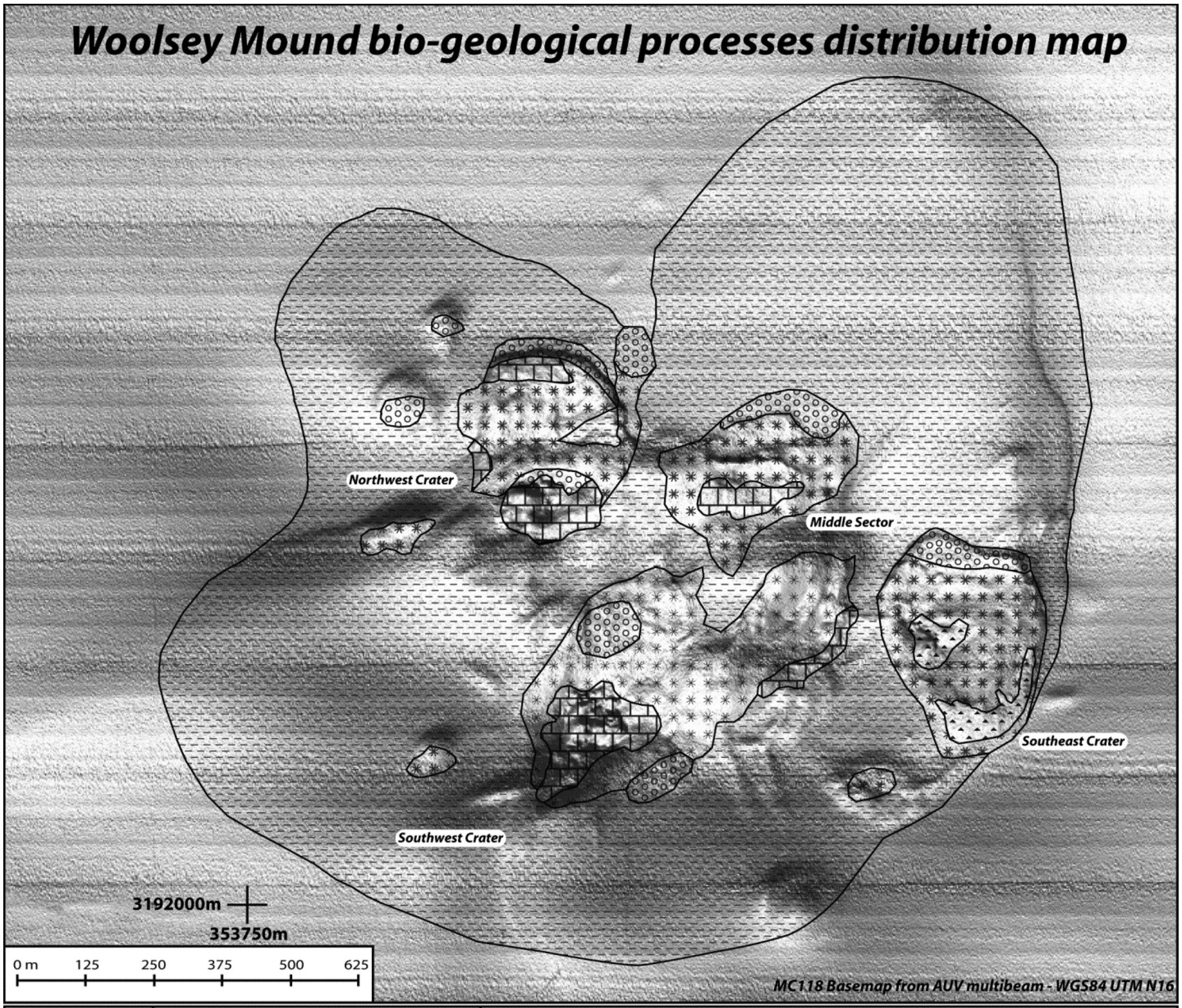


Figure 22. Abundant life is found at the crater complexes on Woolsey Mound. Fish, crabs, echinoderms, chemoautotrophic snails and abundant bacterial mat have been and continue to be reported, and where possible, mapped over the mound.



Pattern	Seabed type(s)	Features
	A: Soft-Smooth	Epipelagic mud with no organisms
	B: Soft-Rough	Epipelagic mud with few organisms
	C: Hard-Smooth	Bioclastic deposits (bioclastic fraction more than 50%)
	D: Hard-Rough	Carbonate outcrops
	E: Smooth-Mud	Bacterial mat(s) - (*Beggiatoa sp*)

Figure 23. A conceptual model of the spatial distribution of biogeological process throughout the Woolsey Mound. Major morphological units, sediment types and biological habitat are mapped, based upon video data, classes of acoustic backscatter anomalies and, where available, sediment core data. The model provides regionalization of the biogeological processes occurring at the mound and highlights significant differences within the three complexes (from Macelloni et al., 2013).

Vehicle/Support Systems
Several vehicles and other support systems serve to make deployments and recoveries possible at the MS/SFO. The SSD, ROVARD, Rochester fiber-optic cable, pop-up system and probes are included in this category. The integrated data power unit (IDP) and the data-recovery system (DRS), designed primarily to facilitate data-recovery, are being redesigned to accommodate the HLAs. The vehicles are described, briefly, below.

Station Service Device (SSD), NOAA/NIUST; The SSD is a specially designed ROV system for use on level-two-equipped, non-dynamically positioned vessels (available at a much lower day rate than a level one) for the purpose of deploying station sensors and support equipment (see Figures 4-7). Battery change-out and general maintenance are also among the SSD tasks. The system differs from conventional ROVs in that, instead of being suspended in the usual manner, it works off a clump-weight/pressure compensated battery (its power supply), lowered to the sea-floor. A small, specially designed ROV is maneuvered from the clump-weight platform, powered by the battery and controlled *via* an umbilical, within a limited working radius (50m), but sufficient to carry out the required tasks of the station. Significant development of this system has taken place and its versatility continues to be apparent: From its first mission in 2007 - when it recovered microbial experiments from the seafloor - to its current capability of collecting targeted push cores, by virtue of its navigation capabilities and multiple cameras the SSD continues to be adapted to Consortium researchers' needs. During the June, 2009 cruise, over 30 hours of resistivity data were acquired using the SSD as the transport for the 1100m towed cable (the first time such a survey has ever been attempted with an ROV). In April, 2010, the SSD successfully carried equipment on the seafloor to the node designed to accommodate the HLA data-loggers, deployed an array spool, collected push-cores and collected many hours of seafloor video images. In September, 2010, the ROV worked in tandem with the ROVARD lander to install geochemical chimney sampler arrays at specific, high value sites on the seafloor.

Extensive upgrades to the SSD were designed to enable it to function at greater depths (up to 2,000m) and with increased maneuverability. A new camera, lights and optical multiplexers for improved imaging and reconnaissance capabilities have been installed. As mentioned earlier, the July, 2012 cruise tested these systems at 1,600+m and the vehicle functioned nearly flawlessly. A report on the upgrades appears as Appendix A to this report.

Autonomous Underwater Vehicle (AUV), NOAA/NIUST: The AUV *"Eagle Ray",* acquired from ISE (International Submarine Engineering) and operated via a cooperative venture between NOAA, and NIUST, has completed sea trials of its basic operating, navigation and seafloor mapping systems and has progressed to working vehicle status. I has now conducted several seabed mapping projects. The ISE design is capable of operating to depths of 2200m and is equipped with a large instrument pay load capacity, making the vehicle ideal as a test platform for a variety of sensors. The MMRI division of NIUST, Seabed Technology and Research Center, STRC, is responsible for, among other things, developing new tools and sensors for the AUV, particularly systems applicable to the exploration of seafloor occurrences of gas hydrates and hydrocarbon seeps and vents. In late June, 2009, the *Eagle Ray* carried the Woods Hole Oceanographic Institute's (WHOI) mass spectrometer during its survey of the near-seabed (6m above seafloor) water column geochemistry at the MC118 test site. Also in progress is the adaptation of the CMRET, shallow-source/deep-receiver (SSDR; BOEM) high resolution seismic system (deep receiver component) for installation on the AUV which will greatly improve stability, near seafloor operation, data acquisition to subbottom depths of 500-700m, navigation accuracy, noise reduction and reduction of survey time by a factor of four. A polarity-preserving chirp system, has been designed, built and installed on the *Eagle Ray*. A test cruise was executed in July, 2011, data recovered and evaluated for performance of the software (Phase 4, Task 2). A landmark cruise was conducted in September-October, 2012 during which *complete multibeam and polarity-preserving chirp surveys – including a high-resolution survey conducted at 15m above seafloor – returned data of unparalleled detail* (see Phase 4, Task 2.3). The MMRI-NIUST team continues to work with Geoacoustics to improve the polarity-preserving chirp software and processing development.

G. Mola Mola AUV, NOAA/NIUST: This vehicle (Figure 24) is designed primarily as a visual survey tool. The *Mola Mola's* primary capability is to photograph the seafloor on a continuous basis. Mosaics of the seafloor can then be made from the series of still photographs. In July, The *Mola Mola* performed photosurveys, complete with superior navigation (necessary for mosaicking as well as population and ecological studies) over two blocks in Mississippi Canyon. Four missions returned photos of extraordinary detail. Lower resolution renderings of some of the photos appear as Figures 20-22. A complete photomosaic of the Woolsey Mound remains a goal of the STRC/UVTC team.

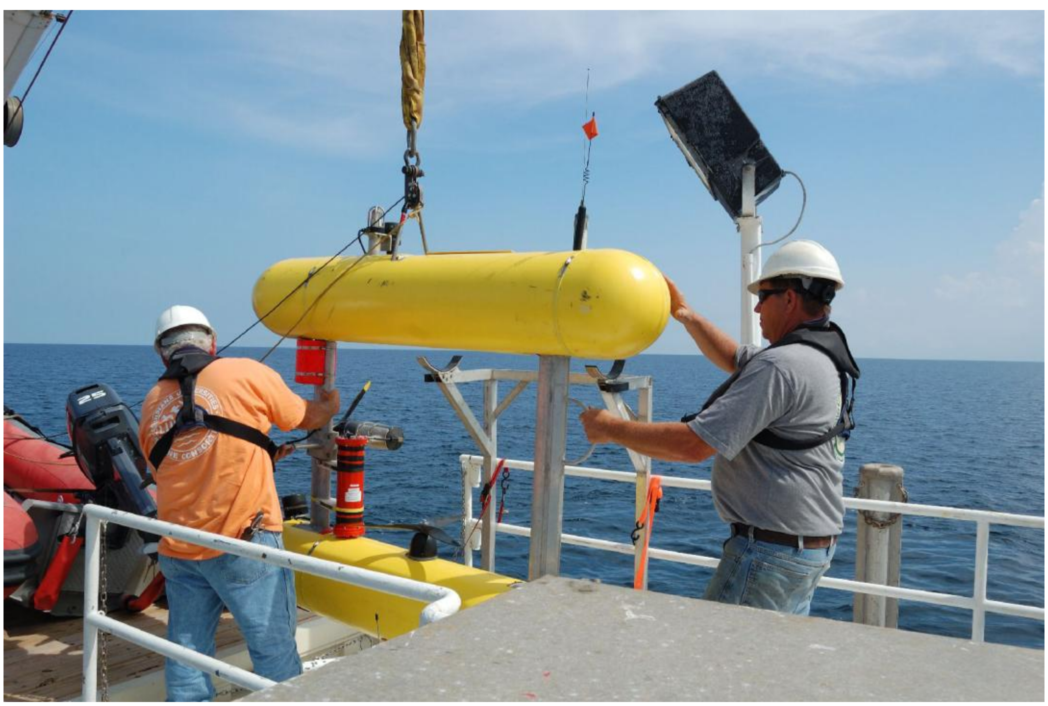


Figure 24. MMRI Electronics Technician, Larry Overstreet, and Research Systems Specialist, Brian Noakes (right), prepare the* Mola Mola *for deployment.

H. The Rochester fiber-optic cable. This piece of equipment is vital to all our operations that require live-streaming of information from the seafloor to the support vessel. The functions of the SSD, for example, depend upon the live connection to the lab for operations: lights, cameras, ballast, pitch, roll, manipulator arm, etc. Since the failure of the original Rochester Cable in September, we have acquired a new, three-fiber replacement, .750" diameter and 3600m in length, for access to 2,000m water depth. Several subcontractors have developed their systems to function with this powerful system: University of Georgia's lander, UCSB's sonar scanner, the SSD, the SRC,

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EXPERIMENTAL/ RESULTS AND DISCUSSION

PHASE 1 Tasks for FY 2006:

Task 1: Design and Construction of four Horizontal Line Arrays
This task is complete. Although the HLAs are still not deployed at the Observatory site, they are complete and ready for deployment, thus satisfying the obligation of SDI, the subcontractor. However, SDI has agreed to continue to work with MMRI toward the eventual goal of deployment of all arrays. The next possible effort is scheduled for September, 2013.

Task 2: Seismic Data Processing at the Gas Hydrate Sea-floor Observatory: MC118.
This task has been completed: software has been written, tested on data from another hydrates location, and awaits data from the MS/SFO.

Task 3: Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements
The Final Report for this task, supported in all four Phases, is found in the GOM-HRC's Technical Progress Report to DOE, 42877R24.

Task 4: Noise-Based Gas Hydrates Monitoring.
This task is complete.

PHASE 2 Tasks for FY 2008:

TASK 1: Project Management Plan
This task is complete.

TASK 2: Processing and Interpretation of TGS-NOPEC Geophysical Company Industry Seismic Data and Integration with Existing Surface-Source/Deep-Receiver (SSDR) High Resolution Seismic Data at MC118, Gulf of Mexico.
This task includes processing and interpreting industry seismic data collected and provided by TGS-NOPEC, Inc. Geophysical Company and integrating them with existing Surface-source/ Deep-receiver (SSDR) high resolution seismic data at from Mississippi Canyon Block 118, Gulf of Mexico (GOM), in order to image and understand the complex geologic structures at the Observatory site and how they relate to gas

hydrate formation and dissociation. This work has been focused on the (1) refinement of the structural interpretation of the TGS-NOPEC seismic data, (2) interpretation and mapping of the high-amplitude reflectors identified as possible bottom simulating reflectors (BSRs), (3) integration of this dataset with the high-resolution SSDR single-channel seismic data, (4) preparation and submission of a proposal to the Integrated Ocean Drilling Program (IODP), and (5) initiation of a thorough analysis of the rock physics properties of the inferred gas hydrates at the study site.

The characterization of the subsurface geology – particularly the structure of the carbonate-hydrate mound and how it relates to and impacts hydrate formation and dissociation – has been essentially completed. Integration of the data from the nearby ARCO-1 deep well was a major accomplishment of this phase. The proposal submitted to the IODP supports this effort and has progressed to the full proposal stage but is not expected to develop into a project until 2013, at the earliest. The proposal is to drill borehole(s) to define the subsurface geology at MC118 and to provide the ability to monitor the subsurface at the site, continuously, into the future.

To date, findings of this effort support the inferences that the structure, stratigraphy and thermal and fluid-flow architecture at MC118 are dominated by salt structures, the mound having evolved in association with a crestal fault system that formed over a domed salt body. Depth conversions have been performed and horizons on TGS records correlated with picked horizons in the ARCO-1 well. Amplitude vs. offset (AVO) analysis was performed on one of the TGS inlines. The results included the identification of an interpreted accumulation of free gas beneath the base of gas hydrates. A request for an additional seismic line in raw form – one that crosses the middle of the mound - was made to substantiate this find and to determine how wide-spread the reflector might be. TGS agreed to provide the line.

University of South Carolina (USC) researchers began deriving an impedance volume from the TGS seismic data to be used in porosity calculations and in calculations of gas hydrate saturations.

In their request for continued funding for this project, USC included funds to purchase an additional, deeper, 3-D dataset from WesternGeco. A final report of findings for all phases of this task can be found in the GOM-HRC's Technical Progress Report to DOE, 42877R24, with a summary of resulting publications in Phase 3, Task 2 of this report.

TASK 3: Seismic Data Processing at the Gas Hydrate Sea-Floor Observatory: MC118.

This task is continued into Phase 3.

TASK 4: Geochemical investigations at MC 118: Pore fluid time series and gas hydrate stability.

The Final Report for this task, supported in all four Phases, is found in the GOM-HRC's Technical Progress Report to DOE, 42877R24.

TASK 5: Automated Biological/Chemical Monitoring System (ABCMS) for Offshore Oceanographic Carbon Dynamic Studies.

The University of Georgia (UGA) and SRI International (SRI) research team has developed a unique survey instrument capable of surveying the methane rich seafloor and collecting biomass and suspended sediment samples on demand. This project is extended into Phase 4 and progress is covered more fully in that section of this report.

TASK 6: Microbial techniques to extract carbon from stored hydrocarbon gases: Exploring Extent of Microbial Involvement in Seafloor Hydrate Formations/Decompositions and Establishing that Mechanism

This task continues into Phase 3.

TASK 7: Scoping study using Spatio-Temporal Measurement of Seep Emissions by Multibeam Sonar at MC118.

The multibeam scanning sonar project is continued under Phase 4 and progress is reported in that area of this report.

TASK 8: Validate high-frequency scatter on SSDR data by acquisition of targeted cores and velocity profiles at MC118 Hydrate Mound.

Development of a Shallow Sediment Velocity Probe (SSVP) for use in the Gas Hydrates Research Consortium Sea Floor Observatory Program at MC118.

Introduction

A need for improved knowledge of sediment characteristics as part of the studies of the Gas Hydrates at the MC118 site prompted a desire to measure the velocity of sound through these sediments. The successful installation of the Pore Fluid Array and Temperature Array with sensors installed to depths below the bottom of nearly 10 meters at MC118 opened the possibility of installing acoustic sensors on a similar probe as a method of measuring sediment velocity.

Background

The concept includes developing a series of acoustic sensors that can be attached to this type of a probe, survive the installation trauma and operate at sufficient depths to allow this concept to work. This also requires developing a data acquisition package that can survive these conditions and is capable of driving and communicating with acoustic sensors to achieve a measurement accuracy sufficient to meet the needs of the studies at MC118. SDI has offered to include this development as part of an ongoing electronics package development aimed to provide rapid acoustic shallow water sediment measurement capability.

The sediment probe being designed by SDI is being adapted to also serve as an attachment to an MMRI sediment coring device. The MMRI sediment coring device is intended to collect core samples of gas Hydrates or Hydrate bearing sediments in the Woolsey Mound portion of MC118. Inclusion of the sediment probe on this coring device presents the opportunity to collect a vertically graduated sample of the speed of sound, temperature and shear strength of Hydrate bearing sediments simultaneously with the collection of a core sample of this material. This application of the SDI sediment probe, as married to the MMRI sediment coring device, will be the 1st use of the sediment probe. This use is scheduled for the July 2013 MMRI cruise to MC118.

Activities during this period

Progress on the development of the sediment probe during this period has been centered on adapting the sediment probe to the MMRI gravity core. The MMRI gravity core is being equipped with a USBL and the electronics package for the sediment probe. A string of hydrophones and temperature sensors has been designed to attach to the outside of the core barrel of this gravity core. An acoustic sound source and an accelerometer are included in the sediment probe electronics housing. The sound source is used for the speed of sound measurements and the accelerometer is dual purpose. It detects bottom contact and measures the deceleration rate. The bottom contact serves to trigger a time series of temperature measurements and a time delayed series of speed of sound measurements. The deceleration rate is used to determine the shear strength of the material through which the probe penetrates.

An MMRI drawing of the gravity core has been used as the basis for the sediment probe attachment. The details of mounting the probe to the core barrel and the electronics to the gravity core weight structure have been refined.

The necessary steps to complete the probe development and prepare it for a field test include completing the hydrophone tube construction and completion of the wiring for the hydrophones and temperature sensors within this tube and mounting this probe to the MMRI gravity core. The battery pack for this sensor has been included in the electronics housing eliminating the need for an external battery pack. The external battery pack was originally planned for the stand-alone sediment probe where multiple insertions and retrievals were planned before recovering the system to the boat.

Design Overview and Progress

The sediment probe attachment to the MMRI gravity core consists of a 10 meter long pipe with imbedded hydrophones and temperature sensors and an electronics package attached between fins on the core driving weight. The sediment probe electronics package will be positioned such that the acoustic source transducer can be installed in the end plate of the electronics package and have a clear view of the seafloor adjacent to the core barrel. The sediment probe electronics package includes the controller/data logger, a sensor interface and A/D converter, an accelerometer sensor, temperature sensor interfaces, the battery power supply and the acoustic source.

The operational plan for use with the gravity core includes lowering the sediment probe/ coring device to a depth of 30 to 50 meters above the sea floor, using the USBL system to navigate the sensor to the desire location, free-falling the sediment probe/gravity core into the seafloor, detecting the bottom insertion with the accelerometer sensor, leaving the probe in place for a suitable time to measure sediment velocity distribution and temperature profile along the probe length and having the ship winch pull the probe free of the sea floor and recovered to the deck.

Schedule
The present development plan should allow the sediment probe to be used at sea during the July 2013 cruise

TASK 9: Recipient shall model carbonate/hydrate mound in Mississippi Canyon 118 using modified version of (THROBS).

This preliminary examination of the hydrate phase at MC118 implies that it will be necessary to develop a multi-component simulator in order to model the observed gas and hydrate phase compositions at the Hydrate Mound. The computer program (CSMHYD.exe) developed by Dendy Sloan (Colorado School of Mines) was used to establish the appropriate stability curve, i.e., hydrate dissociation pressure as a function of temperature and salinity.

Since the vent gas at the Hydrate Mound is mostly methane, it was decided to use the methane PVT properties for the “equivalent” gas phase. Other required hydrate properties (e.g. density, compressibility, thermal expansion coefficient, specific heat, heat of formation) were estimated based on published data.

THROBS was modified (January to April 2009) to include the stability curve for Structure II hydrate as deduced from the computer Program (CSMHYD.exe).

SAIC has performed parametric calculations to examine the following aspects of hydrate formation/decomposition at Hydrate Mound:

1. Gas influx rates required for hydrate formation.
2. Effect of salinity on hydrate distribution.
3. Effect of temperature gradient
4. Conditions required the co-existence of 3-phases (hydrate, gas, liquid) and for gas venting at the sea-floor.

This project continues into Phase 4.

TASK 10. Administrative oversight of the Monitoring Station/Sea-floor Observatory Project.

Administration of the Consortium is the responsibility of the University of Mississippi and includes formal Project Proposals to federal funding agencies, Technical Progress Reports, Final Project Reports, informal monthly updates, reports of Consortium meetings, cruise reports, participation in national meetings, organizing meetings between researchers, organizing and participating in program reviews, organizing and participating in research activities, including research cruises. This responsibility was completed for FY08 with the completion and acceptance of the year-end report to DOE, 42877R12. Further administrative duties and responsibilities are addressed in Phase 4.

PHASE 3 Tasks for FY 2009:

TASK 1: Project Management Plan

This task is complete.

TASK 2: Geological and Geophysical Baseline Characterization of Gas Hydrates at MC118, Gulf of Mexico

Temporal evolution of the gas hydrate system at Woolsey Mound *via* time-lapse seismic monitoring.

Introduction

Cold seeps constitute the major source of hydrocarbons in seawater worldwide (National Academy of Science, 2002). In cold seep environments, methane (CH4) is naturally leaked from the lithosphere into the hydrosphere, and ultimately to the atmosphere (Leifer and Boles, 2005). Such methane vents sustain rare ecosystems at the seafloor and may contribute to ocean acidification and global warming (Bangs et al., 2011). Therefore, understanding the dynamics involved in marine hydrocarbon seeps is crucial to quantifying their potential impact on ocean biogeochemistry and climate.

As cold seeps rely upon hydrocarbon gas availability, they are often associated with gas hydrate systems, particularly in deep water settings where temperature and pressure are optimal for gas hydrate to form and accumulate in sediments. In such circumstances, transitory formation of gas hydrates would modulate the continuous release of hydrocarbons in the oceans.

We present data from Woolsey Mound, a hydrate/carbonate mound associated with a fault-controlled cold seep in the continental slope of the Northern Gulf of Mexico. Here, thermogenic gas hydrate accumulations along active faults, nucleating from the underlying salt dome and intermittent seafloor hydrocarbon vents, coexist. The aim of our study is to understand the nature and, most importantly, the short-term mechanisms governing gas hydrate accumulation, destabilization and subsequent methane venting into the water column.

Results

New results from quantitative time-lapse seismic monitoring (or 4-D seismic imaging) conducted using two sets of 3-D standard seismic data acquired three years apart, suggest that the upward migration of deep-sourced hydrocarbons and brines along the faults may be the primary short-term control in the destabilization of gas hydrates (Simonetti et al., *in preparation*). Such a hypothesis would be plausible considering that the fault network not only provides the main migration pathways for rising thermogenic hydrocarbons (Macelloni et al., 2012) but also constitutes the reservoir for gas hydrates (Simonetti et al., *in review*). The main results of our 4-D analyses can be summarized as follows:

- The subsurface of Woolsey Mound shows significant changes in amplitude anomalies (or acoustic impedance) within a three-year time scale;
- These temporal anomalies are spatially associated with the major faults that intersect the seafloor;
- Since the major faults constitute the migration pathways for deep-sourced hydrocarbons, we suggest that changes in acoustic response, through time, are the result of actively migrating thermogenic hydrocarbons within the gas hydrate system;
- As the major faults constitute also the gas hydrate reservoirs, we speculate that gas hydrates may be repeatedly destabilized by transiting thermogenic hydrocarbons within the system in a very short time scale (3 years);
- Gas hydrates may be considered critically stable in active cold seep systems like Woolsey Mound, their stability through time depending primarily on the vigor of the hydrocarbon flux through the gas hydrate system.

The above results will be shortly submitted to the Geophysical Research Letters AGU Journal. A manuscript has been submitted to the Journal of Marine and Petroleum Geology and it is currently being reviewed.

The full final technical report for this project appears in the GOM-HRC's semiannual technical report to DOE 42877R24.

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Simonetti A., Knapp, J.H., Sleeper, K., Lutken, C.B., Macelloni, L., and Knapp, C.C., (2012), Spatial Distribution of Gas Hydrates from High-Resolution Seismic and Core Data, Woolsey Mound, Northern Gulf of Mexico. *Marine and Petroleum Geology* (in review).

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TASK 3: Seismic Data Processing at the Gas Hydrate Sea-Floor Observatory: MC118.

The previous technical report, 42877R24 addressed three aspects of the Ocean Bottom Seismometer data treatment: data quality evaluation, survey geometry sorting, and separation of the seismic wavefield. Due to the death of Dr. McGee and the departure of Dr. Macelloni, the MMRI/CMRET does not have a resident geophysicist available to complete this project. We have, therefore, entered into negotiations with long-time collaborator, Vaughn Geobel of Lookout Geophysical Company to complete this task. He is familiar with the project and is in close communication with Dr. Macelloni, so that the transfer of information can be as clean and efficient as possible. He will first evaluate the data for consistency and then present an estimate of time required to finish the job.

TASK 4: Geochemical investigations at MC 118: Pore fluid time series and gas hydrate stability.

The Final Report for this task, supported in all four Phases, is found in 42877R24.

TASK 5: Automated Biological/Chemical Monitoring System (ABCMS) for Offshore Oceanographic Carbon Dynamic Studies.

The University of Georgia (UGA) and SRI International (SRI) research team has developed a unique survey instrument capable of surveying the methane rich seafloor and collecting biomass and suspended sediment samples on demand. This project is extended into Phase 4 and progress is covered in that section of this report.

TASK 6: Microbial techniques to extract carbon from stored hydrocarbon gases: Exploring Extent of Microbial Involvement in Seafloor Hydrate Formations/Decompositions and Establishing that Mechanism

This task is complete with the final report already having been submitted in the July-December, 2010 (42877R18) reporting period. In brief, these results include the MSU team's findings that indigenous microbes play an important part in the nucleation, accumulation, and dissociation of near-surface hydrates, that microbial techniques can be used to extract carbon from stored hydrocarbon gases—i.e., to assist in the production of the occluded hydrocarbon gases, and most recently, the intriguing finding that microbial cell wall material inhibits hydrate formation, a necessary occurrence for the bacterial cell's survival, as it prevents hydrate formation-heats from being liberated directly onto cell surfaces. ***They found the hydrate inhibitor to be peptidoglycan, a chemical common in microbial cell walls.*** Data were gathered showing this water-insoluble peptidoglycan polymeric compound, to be increasingly effective as an inhibitor - to hydrate formation - by increasing its surface area through cell lysing. A smaller, water-soluble, molecular component of the peptidoglycan polymer was tested and shown to retain hydrate-inhibiting properties. In tests comparing with a methanol standard, this water-soluble, glycan strand performed better in delaying gas hydrate formation (i.e., longer induction times) than similar amounts of methanol, the current industry standard used to inhibit hydrate formation in pipelines.

TASK 7: Scoping study using Spatio-Temporal Measurement of Seep Emissions by Multibeam Sonar at MC118.

The multibeam scanning sonar project is continued under Phase 4 and progress is reported in that area of this report.

Task 8: Administrative oversight of the Monitoring Station/Sea-floor Observatory Project.

Administration of the Consortium is the responsibility of the University of Mississippi and includes formal Project Proposals to federal funding agencies, Technical Progress Reports, Final Project Reports, informal monthly updates, reports of Consortium meetings, cruise reports, participation in national meetings, organizing meetings between researchers, organizing and participating in program reviews, organizing and participating in research activities, including research cruises. This responsibility was completed for FY09 with the completion and acceptance of the year-end report to DOE, 42877R18. This responsibility continues through the life of the project and a compilation of administrative duties and responsibilities is presented in Phase 4, Task 7.

Task 9. Project Summary Updates:

These appear as Task 8 in Phase 4.

PHASE 4 Tasks FOR FY2010

TASK 1: Program Management Plan

This task is complete.

Task 2: Integration of Multiple Methods of Geological and Geophysical investigations to advance Shallow Subsurface Characterization at MC118, site of the Gulf of Mexico Hydrates Research Consortium's Seafloor Observatory

The focus of this task is to collect, assemble, integrate, and interpret multiple geo-datasets that have been/will be collected to investigate the characteristics of the hydrocarbon system at the site of the Seafloor Observatory being installed by the Gulf of Mexico Hydrates Research Consortium at MC118.

Progress has been made in data acquisition as well as in integration of datasets. However, completion of this task must, necessarily, follow completion of the collection and consolidation of all datasets for the six subtasks. Progress on each is as follows:

Subtask 2.1. Recipient shall contract heat-flow data collection surveys across the hydrate mound area at MC118.

This study was completed and reported upon in the previous technical progress report, 42877R24. The purpose of the study was to determine the thermal properties impacting the Observatory site and thus provide information regarding the general extent of hydrate stability as well as specifics regarding the role(s) of major faults in functioning as conduits for fluids migrating from depth to the seafloor, and which faults are open conduits and which are not.

A summary paper has been written and is being circulated among the co-authors prior to submission to a peer-reviewed Journal. This paper addresses the distribution of heat-flow in the carbonate complex at Woolsey Mound. The heat-flow values and hydrate compositions obtained from samples collected during a 2002 submersible dive and from core samples collected during the January, 2011 Jumbo Piston Coring cruise were used in the compositional simulator developed by SAIC (Phase 4,Task 3) to model the hydrate stability zone.

Subtask 2.2. Recipient shall contract to have giant piston cores collected from areas of interest at the Observatory site. This subtask was completed and a report of activities (42877R22) made during a previous reporting period.

Subtask 2.3. Recipient shall process and interpret the polarity-preserving chirp data collected with the AUV-borne system, to define the shallow geometry of the fluids/gas pipe system and integrate these results with the geological (core analyses) and geophysical data.

The Polarity Preserving Chirp (PPC) sub-bottom profiling system was successfully integrated into the *Eagle Ray* AUV and the first sea trial was executed in July, 2011. A partly successful cruise was made in May, 2012, during which some data were obtained from Ewing Banks. Then, in September-October, 2012, a NIUST cruise to MC118 and MC297 returned very successful data from this system. Software challenges remain but this cruise returned multiple surveys at different altitudes and definition, all with superior navigation and profile data that can be correlated to the multibeam data acquired during the same cruise. In some cases, both systems were run simultaneously, without serious impediment to either dataset. We continue to work with the vendor to solve remaining software difficulties and the vendor continues to be most cooperative.

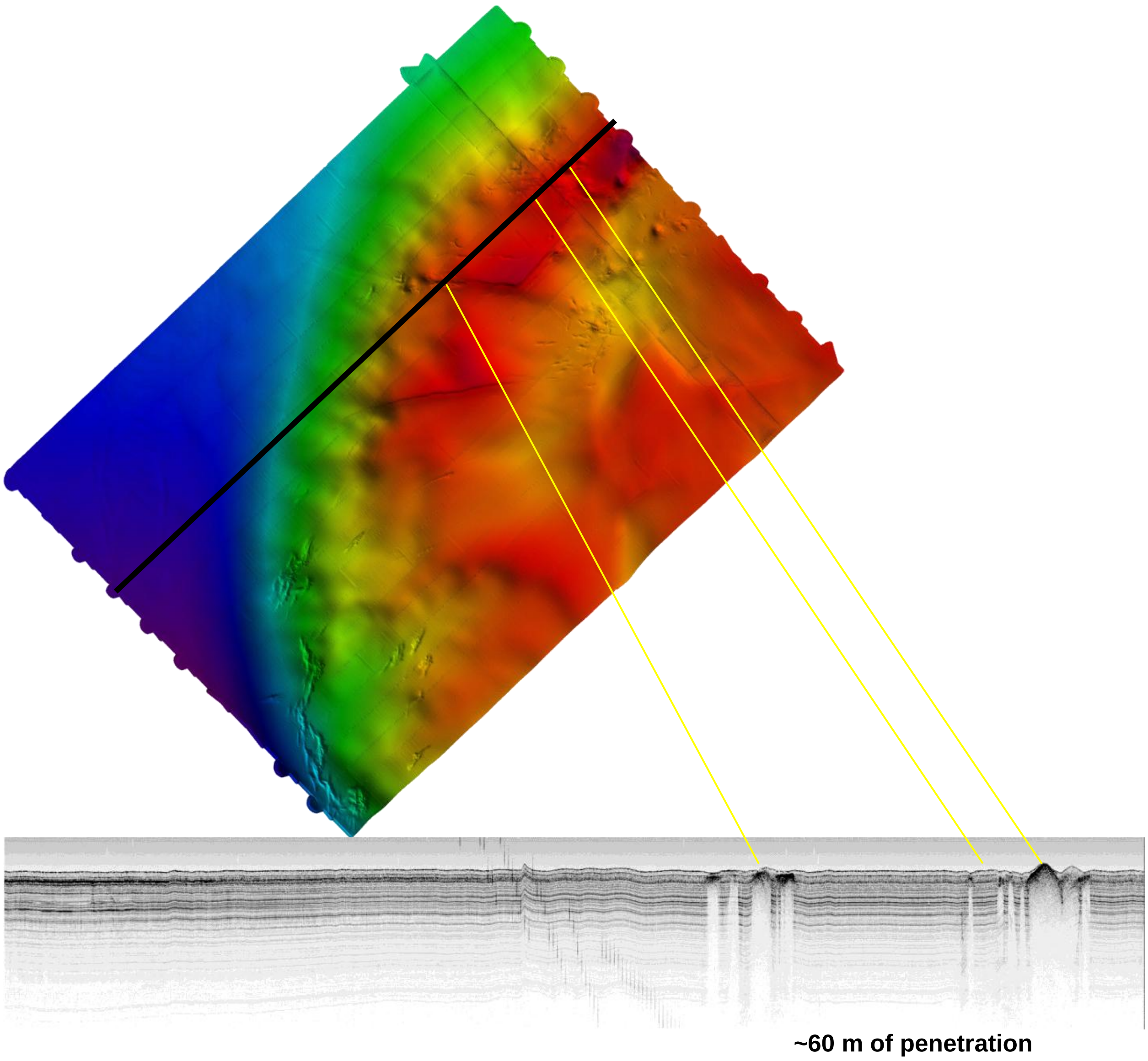

Figure 25. Polarity-Preserving chirp line correlated with seafloor bathymetry collected with the Eagle Ray AUV.

Subtask 2.4 The recipient shall perform sedimentological, lithological, paleontological and geophysical analyses of the newly recovered cores (Phase 4, subtask 2.2) and shall integrate the results with previous core studies. The University of Southern Mississippi core-logging team opened, photographed and described the cores from the JPC cruise during the summer of 2011. Electric log analyses were performed at Stennis Space Center's office of NAVOCEANO. A summary of the lithostratigraphy appeared in the previous Technical Progress Report (42877R24) The biostratigraphic/time analysis is anticipated in the near future.

Subtask 2.5 Recipient shall collect solid outcropping gas hydrates and/or authigenic carbonate/hydrates samples at the MC118 Observatory site using the existing pressure-chamber sampler in conjunction with the STRC ROV. The construction of the small pressure vessels is complete and they have been fitted to the SSD Remotely Operated Vehicle (ROV). The CMRET/SDI/STRC team will attempt to complete this task in March or September, 2013 when cruises are scheduled aboard Louisiana Universities Marine Consortium's (LUMCON's) R/V *Pelican*.

Subtask 2.6. The recipient shall refurbish 4C nodes, donated by CGG Veritas for deployment and use in shear experiments as defined in Phase 2 task 3, and Phase 3 task 3.

This subtask was rewritten and rebudgeted from 3 years of DOE awards to the CMRET. It now reads:

Phase 3, Task 3: Near seafloor geology at MC118 using converted shear-waves from 4C seafloor sensor data (Subcontractor: John Collins, Woods Hole Oceanographic Institution)

This task is complete. The data have been delivered to CMRET in both SEED and SEGY formats and CMRET has, after inspecting the data, copied and delivered a set to UT-Austin (Hardage) for 4-C analyses and to enable them to fulfill the FY08 subcontract. In addition a copy of the data was delivered to UCSD (Gerstoft) for analysis of ambient noise in the data. A full report of cruise activities is available at the MMRI website: http://mmri.olemiss.edu/Home/Publications/Cruise.aspx

As noted earlier, UT's responsibilities have been largely transferred to the University of Mississippi. UM continues to work with UT and UCSD to complete the analyses of the Ocean Bottom Seismometer (OBS) data. Most recently, Um has entered into a tentative agreement with Lookout Geophysical Co. to complete the data analyses and preliminary interpretation of the data for this task. Progress on this subtask is discussed further under Phase 3, Task 3.

Publications deriving, at least in part, from work described in this task:

Lutken, Carol, Ken Sleeper, Greg Easson, Leonardo Macelloni, Gene Smith, 2012, *The GOM GAS HYDRATES SEAFLOOR OBSERVATORY: Producing Science for National and Global Management Decisions,* AGU Science Policy Conference 2012, Washington, DC, April 29-May 2.

*Macelloni, Leonardo, Antonello Simonetti, James H Knapp, Camelia C Knapp, Carol B Lutken. *Multiple resolution seismic imaging of a shallow hydrocarbon plumbing system, Woolsey Mound, Northern Gulf of Mexico Gulf of Mexico.* Marine and Petroleum Geology.

Macelloni, L., M. D'Emidio, A. Simonetti, J. Dunbar, C.B. Lutken, 2012, *Geophysical evidence of shallow hydrates formation and accumulation at Woolsey Mound (Mississippi Canyon Block 118),* Ocean

Sciences Annual Meeting, Salt Lake City, February 19-24.
Macelloni, Leonardo, Charlotte Brunner, Simona Caruso, Carol Lutken, Marco D'Emidio, Laura Lapham, 2012, *Spatial distribution of seafloor biogeological and geochemical processes as proxies of fluid flux regime and evolution of a carbonate/hydrates mound, northern Gulf of Mexico*, Deep Sea Research, Part 1, in press, Manuscript Number: DSR1-D-12-00118R1.
Pizzi, Marco, Leonardo Macelloni, Lutken Carol B., Marco D'Emidio, 2012, *Temporal Evolution of MC118 Woolsey Mound seep activity: constraints from analysis of small-scale salt-induced sediment deformation,* GRC "*Natural Gas Hydrates System*", Ventura, CA, March 18-23, 2012.
Simonetti, Antonello, James H. Knapp, Camelia C. Knapp, Carol B. Lutken, 2012, *4d seismic imaging of a thermogenic gas hydrate system in the northern Gulf of Mexico (Woolsey Mound, MC118),* The Gordon Research Conference on Natural Gas Hydrate Systems, Ventura, California, March 18th-23rd
Wilson, R.M., L.L. Lapham, C. Martens, J.P. Chanton, H. Mendlovitz, ,K. Sleeper, M. Reidel, 2012*, Time-series methane monitoring in gassy sediments and the benthic boundary layer,* Ocean Sciences Annual Meeting, Salt Lake City, February 19-24.
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In Press:
Carrière, Olivier and Peter Gerstoft, in press, *Deepwater subseafloor imaging using active seismic interferometry*, Geophysics.

Submitted:
Simonetti, Antonello, James H. Knapp, Kenneth Sleeper, Carol B. Lutken, Leonardo Macelloni, Camelia C. Knapp, *Spatial Distribution of Gas Hydrates from High-Resolution Seismic and Core Data, Woolsey Mound, Gulf of Mexico,* submitted to Marine and Petroleum Geology.
In prep:
Macelloni, L, Lutken, C. B., Garg, S., Simonetti, A., D'Emidio, M., Wilson, R., Sleeper, K., Lapham, L., Lewis, T., Pizzi, M., Knapp, J., Knapp, C., Brooks, J. and McGee T.M., Geothermal regime and hydrate stability zone of woolsey mound (northern Gulf of Mexico): a transient, thermogenic, fault-contolled hydrate system
Wilson, Rachel, Leonardo Macelloni, Antonello Simonetti, Jeffrey Chanton, Jim Knapp, Laura Lapham, Carol Lutken, Ken Sleeper, Charlotte Brunner, Chris Martens, Marco D'Emidio, Integrating geochemical profiles with seismic surveys to identify subsurface methane sources and migration pathways

TASK 3: Modeling a carbonate/hydrate mound in Mississippi Canyon 118 using modified version of (THROBS).

Introduction

The hydrate mound in Mississippi Canyon Block 118 (MC 118), as described by *McGee et al.* (2008), contains mostly Structure II thermogenic hydrates formed by gases upflowing along a nearly vertical fault system extending from a salt diapir that underlies several hundred meters beneath the hydrate mound. The surface of the hydrate mound is characterized by several crater clusters; these crater clusters have been grouped into three major complexes based on topographic relief and gas venting (*McGee et al.,* 2008). At present, the SE complex exhibits no venting activity; the NW complex has moderate activity, and the SW complex shows moderate to high venting activity. Venting activity has likely changed over time. In addition to variable venting activity over time, the following observations are relevant to the modeling of hydrates at this site:

1. Salinities as high as 5 times that of sea-water have been recorded around the vents in the NW complex. High salinity and gas venting suggests the presence of 3-phase conditions (gas + hydrate + liquid).
2. Chemical composition of vent gas is different from that of the hydrate. It has been suggested that the difference is due to molecular fractionation (*Sassen*, 2006). Treatment of this aspect will require a “compositional” simulator.
3. Presence of multiple BSRs. It is possible that this is due to the existence of gas hydrates that are stable to greater depths (higher temperatures?) than that encountered above the “shallowest” BSR. Clearly, a compositional simulator is needed for modeling this phenomenon.
4. Acoustic wipeout zones, observed in seismic profiles, have been interpreted to indicate the possible presence of free gas (“chimney” flow) and/or other inhomogeneities (e.g. carbonate/hydrate blocks in the sediments). Modeling of chimney flow and/or other inhomogeneities can only be done by a multi-dimensional hydrate simulator.

Prior to the start of Year 1 (2008-2009) of SAIC effort, our hydrate simulator (THROBS) was restricted to one-dimension and Structure I methane hydrate. It was recognized that THROBS will have to be generalized in several respects in order to treat the phenomena of interest. Required changes include:

1. Incorporation of the stability curve and other hydrate properties (heat of melting, hydration number, and thermomechanical properties) for structure II hydrates.
2. Replacement of methane gas equation-of-state (EOS) and gas solubility relationship by an EOS and solubility curve that reflects the gas composition.
3. Development of a multi-dimensional version of THROBS.

Given the fiscal constraints, SAIC undertook a limited research effort during the first year (2008-2009). Specifically, we incorporated structure II hydrate stability curve and relevant properties (item 1 above) into THROBS simulator. The gas mixture forming the hydrate was represented as a single gas. The modified THROBS simulator was used to model (1) the hydrate distribution above the shallowest BSR, (2) presence of high salinity fluids within the hydrate stability zone, and (3) gas venting at the sea-floor. The work performed during Year 1 is described in a report by Garg and Pritchett (S. K. Garg and J. W. Pritchett, Modeling Studies of Hydrate Mound, Mississippi Canyon 118, Gulf of Mexico, Report submitted to the University of Mississippi, September 2009).

As previously mentioned, a “compositional” (i.e. multi-gas) simulator is needed to account for the various gas components present in MC 118 hydrates; such a treatment for the gas composition is necessary for modeling phenomena such as molecular fractionation and multiple BSRs. During Year 2 (2009-2010), we initiated the development of a multi-component (methane, ethane, and propane) simulator. Because of funding limitations, this effort had to be spread over a couple of years. The work was divided into two parts, i.e. (1) development of a computationally efficient multi-component equation-of-state (i.e. PVT behavior of 3-gas components, water, and salt; phases will include hydrate and precipitated salt as solid phases, water with dissolved gases and salt as a liquid phase, and a gas phase), and (2) modification of the simulator to accommodate the new equation –of-state.

In preparation for the extension of the approach to treat multidimensional problems, SAIC completed the adoption of the existing (single gas) THROBS equation-of-state for use in the multidimensional STAR simulator. Test calculations have verified that, with the new STAR/HYDCH4 constitutive description, the two codes (THROBS and STAR) produce identical results when used to solve 1-D problems. Since the MC118 site analysis will eventually require a multidimensional treatment, this is a necessary step in the development. With the existing THROBS constitutive description incorporated into STAR, it is now possible to carry out preliminary multidimensional studies and we are in a better position to proceed toward the final goal of a multidimensional, multi-component modeling capability. A description of STAR/HYDCH4 was provided in a previous letter report (July 2010).

The work during Year 3 (2010-2011) mainly consisted of developing a multi-component equation-of-state (i.e. PVT behavior of 3-gas components, water, and salt; phases will include hydrate and precipitated salt as solid phases, water with dissolved gases and salt as a liquid phase, and a gas phase) for incorporation into STAR and/or THROBS simulators. The progress made tthrough the end of June 2011 was described in a previous letter report (July 2011).

Work performed during the report period
Contract Matters

The SAIC subcontract for Year 3 with the University of Mississippi was finalized towards the end of September, 2010. A no-cost extension until the end of June, 2012 was granted in the fall of 2011. An additional no-cost extension until the end of July 2013 was received during the current report period.

Technical Progress

During 2011, work was continued on debugging and testing the new equation-of-state package (HYDGAS). As reported in January 2012 letter report, the contract funds were nearly exhausted (around 97% of the total) by the end of 2011. Since the remaining amount is insufficient to complete this HYDGAS package, a decision was made in January 2012 to suspend this effort pending the availability of additional support. Effort is continuing on identifying additional resources that may become available for this work. If we are successful in obtaining additional support, we will complete the HYDGAS package, and perform preliminary calculations to characterize the effect of a gaseous mixture on hydrate formation at the Hydrate Mound.

In June 2012, SAIC was informed by the University of Mississippi that recently very accurate heat flow data were collected at 15 sites in and around MC118. We have used the completed HYDGAS correlations to compute the base of the hydrate stability zone (for 100% methane gas, and a mixture of methane, ethane and propane) at these 15 sites. This work will be included in a multi-author paper to be submitted to a peer-reviewed journal. A draft of the latter paper is currently undergoing author review and revisions.

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Garg, S.K., Pritchett, J.W., Katoh, A., Baba, K., Fuji, T. (2008), A mathematical model for the formation and dissociation of methane hydrates in the marine environment, Journal of Geophysical Research, Vol. 113, B01201, doi:10.1029/2006JB004768.

Garg, S.K., Pritchett, J.W. (2011), Modeling Studies of Hydrate Mound, Mississippi Canyon Block 118, Gulf of Mexico, Proceedings of the 7th International Conference on Gas Hydrates (ICGH 2011), Edinburgh, Scotland, United Kingdom, July 17-21, 15 pp.

McGee, T., Woolsey, J.R., Lapham, L., Kleinberg, R., Macelloni, L., Battista, B., Knapp, C., Caruso, S., Goebel, V., Chapman, R., Gerstoft, P. (2008), Structure of a Carbonate/Hydrate Mound in the Northern Gulf of Mexico, Proceedings of the 6th International Conference on Gas Hydrates (ICGH 2008),Vancouver, British Columbia, Canada, July 6-10, 10 pp.

TASK 4: Biogeochemical investigations at MC 118: Pore fluid time series and gas hydrate stability. Final Report Fiscal years 2006-2012

Integrating geochemical and geophysical studies to characterize the sulfate methane transition zone of a complex carbonate hydrate mound in Northern Gulf of Mexico

Including Phase 1, TASK 3: Coupling of Continuous Geochemical and Sea-floor Acoustic Measurements (Subcontractor: Florida State University, FSU). This task is complete and a final report appeared as Appendix B to the previous technical report, 42877R24.

Manuscripts in Preparation:

Wilson, Rachel, Laura Lapham, Michael Riedel, and Jeff Chanton. Time-series in situ methane concentrations from sediment porewaters overlying a hydrate outcrop

Lapham, Laura L., Rachel M. Wilson, Brian J. Anderson, Nagasree Garapati, Ian R. MacDonald, Jeff P. Chanton. Gas hydrate dissolution rates quantified with laboratory and seafloor experiments

Wilson, Rachel, Leonardo Macelloni, Laura Lapham, Antonello Simonetti, Jim Knapp, Camelia Knapp, Carol Lutken, Ken Sleeper, Charlotte Brunner, Marco D'Emidio, and Jeff Chanton. Integrating geochemical profiles with seismic surveys to identify subsurface methane sources and migration pathways

Lapham, L., R. Wilson, J. P. Chanton, C. Paull, and M. Riedel, Temporal variability of in situ methane concentrations in gas hydrate bearing sediments near Bullseye Vent, In preparation for Global Biogeochem. Cycles.

TASK 5: Automated Biological/Chemical Monitoring System (ABCMS) for Offshore Oceanographic Carbon Dynamic Studies: Development of the Marine Lander Survey Vehicle for Gas Hydrate Research

The new MIMS (Membrane Induction Mass Spectrometer) was completed in late August and transported to Athens, GA, for a final pressure test prior to deployment in the Gulf of Mexico. The MIMS was placed in UGA's test chamber and brought to pressure to simulate a 1000 m deployment (Figure 26). The MIMS was outfitted with a small "clean" sample bag to prevent any internal contamination from the pressure chamber. The MIMS was able to stream data while under simulated depth.

During September 2012, the Lander and MIMS were transported to Cocodrie, LA for deployment at the MC118 Hydrates site in the Gulf of Mexico. The Lander was set up on the deck of the R/V *Pelican* with the optional rosette attached (Figure 27). A complete system test was performed using a direct line fiber optic cable to ensure that the Lander could communicate with the filtering mechanism, video, and rosette. Next, the MIMS was installed on the Lander. An additional system test was performed to ensure that the MIMS was communicating with the Lander. After several tests, the system was ready for deployment. However, the MMRI/CMRET fiber optic deployment cable on the RV *Pelican* was experiencing problems. After considerable testing, it was determine that the cable had a major break too far into the cable to repair.

While the fiber optic cable was being evaluated, SRI and UGA personnel continued testing the MIMS on the Lander. Several simulations were executed to ensure that the Lander could communicate with the MIMS even while all systems were being operated. It was determined that the MIMS could stream data while the filtration was in process and the video streaming.

Since the Lander could not be deployed using the ship's fiber optic cable, it was decided to return to Athens on September 26. The Lander was partially dismantled for storage with the intention of redeploying it during the Consortium-scheduled April 10-15, 2013 R/V *Pelican* cruise.

Figure 26. Preparing MIMS for pressure testing (above, left).

Figure 27. Lander with optional rosette water sampler (left).

TASK 6: Quantification of Seep Emissions by Multibeam Sonar at MC118.
The lander, sonar, rotator, and associated electronics were readied for deployment in September, 2012, including spending a day at Ole Miss working on ROVARD communication and interfacing.

Atmospheric measurements – We now have hydrogen and UHP air gas generators to run our gas chromatographs so no pressure bottles are need on board the *Pelican*. We are now achieving sub-ppb accuracy with a 10 to 15-minute repeat time for BTEX and other higher n-alkane and n-alkene volatile organic hydrocarbons, as well as a Los Gatos Research greenhouse gas analyzer, which will allow us to measure methane and carbon dioxide with 1 ppb accuracy at 10 Hz. This suite of gas measurements will allow us to fingerprint plumes observed in the air above MC118 with regards to sources including offshore facilities and subsurface rising plumes, as were discovered during the HYFLUX experiment.

We also have a working ThermoElectron Dynacal that allows calibration BTEX and higher n-alkanes at sub-ppb levels.

Part 1 of the manuscript describing methane measurements during the drive from California to Cocodrie, Louisiana, 2010 is now in press, revisions to Part 2 should soon be complete. Mobile full suite gas measurements are planned for the drive-to and return-from Cocodrie, Louisiana, 2013.

The bubble model has been improved further to address temperature profiles, including fixing a number of bugs. Additional improvements have been made in simulations of Type II hydrate effects through collaboration with Jonathan Levine (Colorado School of Mines). These simulations have been used to explain the persistence of bubbles observed in the HYFLUX experiment for a bubble plume from MC118. These have been added to the manuscript-in-progress with planned submission in a few months.

Results from these improved simulations were presented at the Pergamon workshop in Ghent, Belgium, November 6, 2012.

Progress also was made in analyzing the data from the HYFLUX experiment, whose funding ended a few years ago. Specifically, oil and gas droplet fluxes from GC600 were analyzed, and written up, and are ready for publication, allowing for comparison of MC118 fluxes. A contribution from a second cruise author is pending.

Task 7: Administrative Oversight of the Monitoring Station/Sea-floor Observatory Project.
Administration of the Consortium is the responsibility of the University of Mississippi and includes formal Project Proposals to federal funding agencies, Technical Progress Reports, Final Project Reports, informal monthly updates, reports of Consortium meetings, cruise reports, participation in national meetings, organizing meetings between researchers, organizing and participating in program reviews, organizing and

participating in research activities, including research cruises. For this reporting period, these include:

- Technical semiannual progress report 42877R24 covering progress of DOE-funded projects as well as additional Consortium accomplishments for the time period January 1 – June 30, 2012, was completed and submitted to DOE during this reporting period. Regular monthly reports documenting progress of subcontractors and the Consortium in general have been less formal, taking the form of email and telephone updates.
- Final Reports have been submitted and accepted from UCSD, USC, MSU and FSU.
- Personnel changes have been many. Tom McGee, MMRI/CMRET Geophysicist and founding member of the GOM-HRC died in February, 2012, leaving a great void in our scientific staff. Leonardo Macelloni, Geologist/Geophysicist, who has worked with the Consortium and MS/SFO since 2003, took a job in industry. Although he is still an active participant in Consortium projects, his activity is, necessarily, reduced and sporadic. Ken Sleeper, Geologist and STRC Program Manager since 2005 left the MMRI/STRC in July, 2012. It will be difficult, perhaps impossible to replace the talent and devotion of these scientists.
- In October, we welcomed Visiting Scholars Francesca Marra and Alessandra Conti, Marine Geoscientists, from the University of Rome, La Sapienza. They will be working with data already in-hand: Francesca will be working on BBLA and possibly data from additional geochemical sensors/arrays and Alessandra will process and interpret AUV multibeam data, correcting for noise, navigation errors and extracting bathymetry and backscatter from which she will produce images that will be used in morphological, biological and geological studies.
- An additional funding possibility through DOE, NETL, FY 2012 Methane Hydrate Program, Funding Opportunity Number: DE-FOA-0000668, arose in March. The UM team, together with Consortium members from Baylor University and SDI, developed and submitted a proposal to develop a surveying resistivity capability in response to this opportunity. ***The UM-Baylor-SDI submission was successful***, but at December's end was still being negotiated. Amount of funding and effort have been negotiated successfully but the nature of the UM match is under discussion and DOE continues to investigate whether or not the WesternGeco data is acceptable cost-share.
- UM-led publications in peer-reviewed journals are listed in the Publications section of this report and include two new publications and another in preparation.
- UM Consortium scientists planned, contracted for and executed a research cruise to MC118, site of the GOM-HRC MS/SFO, aboard the R/V *Pelican*, July 16-20, Major achievements of this cruise include:
    - Deployment and recovery of the newly designed and built calibration mooring, ABIL, with USBL transponder, CTD (conductivity-temperature-depth instrument), and the University of Southern Mississippi's (USM's) sonar scanner aboard; Collected data and performed calibration for navigation.
    - Performed lander operations at MC297 (OC26) with the newly upgraded SSD as requested by ECOGIG GRI-I, including:

a. video disposition of the ECOGIG lander at an unsurveyed site, MC297;
b. video instruments on the lander;
c. video surroundings for potential CSA deployment sites; and
d. place chimneys on the seafloor (remove each from the lander and place at a suitable site for determining flux of gas from seafloor sediments, i.e. where bacterial mats are abundant or bubble streams are visible).

- A cruise report for the July cruise will soon be found at http://www.mmri.olemiss.edu/Home/Publications/Cruise.aspx.
- MMRI/CMRET/STRC participated in a UVTC cruise to MC118 and MC297. The data collected on this very successful cruise is being processed by MMRI/CMRET/STRC scientists. Achievements of this cruise include:
- Multibeam and polarity-preserving chirp surveys run from the *Eagle Ray* AUV, 50m above the seafloor for MC118 and MC297 (OC26). MMRI/STRC will process and interpret the data.
- A multibeam and polarity-preserving chirp survey run from the Eagle Ray AUV, 15m above the seafloor, for high resolution bathymetry, backscatter and shallow sub-bottom studies, over Woolsey Mound at MC118 for very high resolution bathymetry, backscatter and shallow sub-bottom studies. MMRI/STRC will process and interpret the data.
- High resolution photo survey recovered data from MC118 and MC297 using the *Mola Mola* AUV. This is the first survey conducted with the *Mola Mola* with proper navigation and returned photos of extremely high quality.
- 4-C data have undergone preliminary analyses. With the death of one geophysicist and the departure of the other, we are negotiating with Lookout Geophysical, Inc., our supplier for many years of software amendments and advice for custom processing of seismic data, to finish the job.
- Although incomplete, SAIC has used the model they are developing to approximate the base of hydrate stability at MC118 using some geochemical data from the seafloor arrays and the heat-flow data from the March study.
- Upgrades to the SSD have now been tested at sea and found to be satisfactory.
- Leonardo Macelloni, Marco D'Emidio, Carol Lutken and newly arrived Visiting Scholars Francesca Marra and Alessandra Conti attended the 62nd Annual Convention of the Gulf Coast Association of Geological Societies (GCAGS) in Austin, Texas, in October to attend the meeting and to participate in the awards ceremony in which the Consortium-authored paper, *Spatial Distribution of seafloor bio-geological and geochemical processes as proxy to evaluate fluid flux regime and time evolution of a complex carbonate/hydrates mound, northern Gulf of Mexico,* by Leonardo Macelloni, Simona Caruso, Laura Lapham, Carol Lutken, Charlotte Brunner and Allen Lowrie, received the Second place 2010 Grover E. Murray Best Published Paper Award.
- A September cruise was scheduled to take our newly-built site reconnaissance camera (SRC) and the ABCMS and scanning sonar landers to MC118 for short-term deployments, surveying and recovery. Unfortunately, this cruise had to be cancelled due to a break in our fiber-optic cable. This cable is necessary to receive information from the landers during deployments. However, through diligent research and rebudgeting of our BOEM award, we were able to purchase

a new, multiple-fiber cable from Rochester Cable Co. It is slightly smaller in diameter and a few 100s of meters shorter than the old cable but the specs are higher.

- Advances in data-processing this period have been noteworthy. Marco D'Emidio has taken on the task of processing the polarity-preserving chirp data. This has included many conversations and back-and-forth communications and software trials to get the processing we need. As can be seen in the report for Phase 4, Task 2.3, the data, recovered via AUV, are quite good. Marco is also working with Alessandra on processing multibeam bathymetry and backscatter from the *Eagle Ray* cruises. Francesca is striving to build a contextual database for Woolsey Mound and to place the processed BBLA data within it.

Task 8. Project Summary Updates:

Periodic website updates are the responsibility of the CMRET together with DOE. Publications are added to the Consortium list as they appear or as notification is received and a list of recent publications accompanies this report.

The Consortium website continues to be expanded and updated though there is much information still awaiting posting. Unfortunately, reductions in personnel as well as funding have necessitated shifting personnel from this important task to other more pressing duties. It is a goal of the CMRET to get many of the older reports, logs and other data posted. Geological and geophysical pages for the website include core locations and descriptions, cruise reports, meeting presentations, online geophysical data collected by the CMRET, reports of meetings and many maps derived from Consortium effort.

Several new peer-reviewed publications have come out in the six months covered in this report. The heat-flow report is nearing submission for publication. We have submitted a proposal to NSF for funding to do coastal work that, if funded, should help keep our projects alive. Fortunately, the new DOE award should soon be in place. We continue to be involved in ECOGIG work, designing, building and deploying landers at selected sites in the northern Gulf, and processing AUV data recovered by NIUST UVTC.

CONCLUSIONS

This report covers the accomplishments of the six-month period from July 1 through December 31, 2012, of funding of Cooperative agreement Project #DE-FC26-06NT42877, 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: one cruise to deploy and test a new lander, test an upgraded SSD, locate and service a GRI-I instrumented lander, and the attempt to conduct a resistivity survey has been made; the cable that failed and resulted in an aborted September cruise has been replaced. Polarity-preserved chirp data are being evaluated and much progress made towards their complete processing with a cooperative vendor, Geoacoustics (Konigsburg). Industry data have been analyzed and integrated with high-resolution data validating a capability to merge multiple datasets to predict hydrate in the shallow subsurface with greater accuracy than any known single method can provide. Innovative data processing techniques and approaches are being employed to evaluate seismic datasets, both standard and Consortium-developed, and an improved image of the subsurface structure of the carbonate-hydrate mound at MC118 is emerging. HLA configuration and deployment challenges continue and we continue to develop new deployment and recovery approaches and techniques to overcome them. A preliminary hydrate 3-gas model is approaching completion and has been used with actual MC118 data to predict the range of hydrate stability at our observatory site. Manuscripts have been submitted and resubmitted and, in some cases, accepted and published in peer-reviewed journals. Every effort has been – and will continue to be – made to maximize Consortium members' access to and benefit from the cruises scheduled for 2013 though without additional resources these will be curtailed. New funding sources continue to be sought. Additional efforts to monitor developments resulting from the vast amounts of hydrocarbons spilled into the seawater at MC252 are ongoing, with Consortium researchers are making significant findings/contributions to unraveling that developing predicament. Funding through DOE will continue through an award to conduct simultaneous resistivity and oceanographic studies.

ACRONYMS AND ABBREVIATIONS

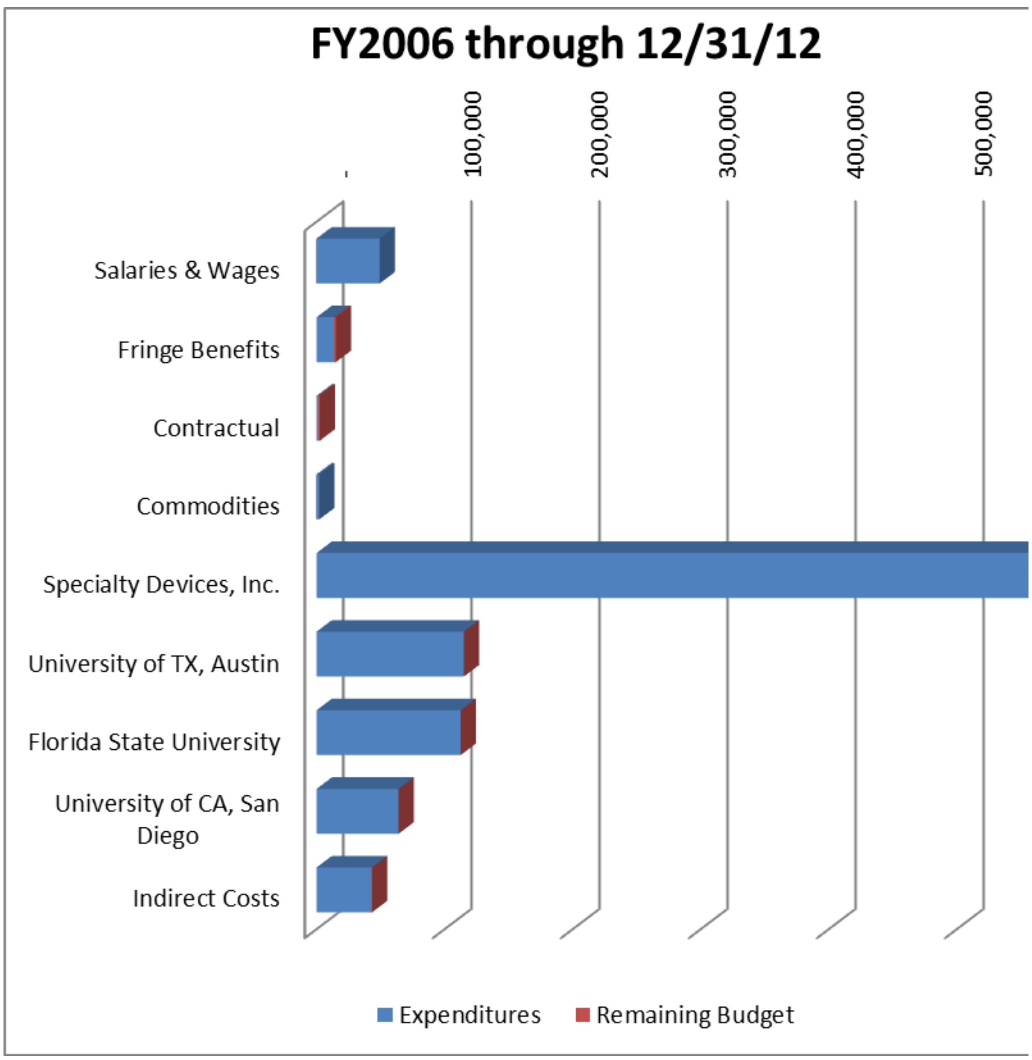
1-D	one-dimensional
3-D	3-dimensional
4-C	four component
ABCMS	Automated Biological Chemical Monitoring System
ABIL	Autonomous Benthic Instrument Lander
AUV	autonomous underwater vehicle
AVO	amplitude vs. offset
BBLA	Benthic Boundary Layer Array
BEG	Bureau of Economic Geology (University of Texas)
BOEM	Bureau of Ocean Energy Management
BSR	bottom-simulating reflector
C&C	Chance and Chance
CGGVeritas	Compagnie Générale de Géophysique (CGG) and Veritas
CMRET	Center for Marine Resources and Environmental Technology
CMSHYD	stand-alone computer program; Sloan's statistical thermodynamic approach
CSA	Chimney Sampler Array
CSEM	Controlled-source Electro-Magnetic
CTD	Conductivity, Temperature, Depth
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of the Interior
DRS	Data Recovery System
ECOGIG	ECosystem impacts of Oil and Gas Inputs to the Gulf
EGL	Exploration Geophysics Laboratory

EMD	Empirical Mode Decomposition
EOS	equation-of-state
FY	Fiscal Year
GOM	Gulf of Mexico
GOM-HRC	Gulf of Mexico-Hydrates Research Consortium
GRI	Gulf Recovery Initiative
HF	heat flow
HLA	horizontal line array
HRC	Hydrates Research Consortium
HSZ	Hydrate Stability Zone
HYDGAS	new hydrate equation-of-state
IDP	Integrated Data Power Unit/Interconnection and Data Recovery device
IR	Infrared
ISE	International Submarine Engineering
JPC	Jumbo Piston Core/Coring
JSL	Johnson SeaLink
LARS	
LUMCON	Louisiana Marine Consortium
MC	Mississippi Canyon
METS	methane sensor
MIMS	membrane introduction mass spectrometer
MMRI	Mississippi Mineral Resources Institute
MMS	Minerals Management Service
MS/SFO	monitoring station/sea-floor observatory
NAVOCEANO	U.S. Naval Oceanographic Office
NETL	National Energy Technology Laboratory
NIUST	National Institute for Undersea Science and Technology
NOAA	National Oceanographic and Atmospheric Administration
NRDA	Natural Resource Damage Assessment
NRL	Navy Research Laboratory
NURP	National Undersea Research Program
OBS	ocean bottom seismometer
OER	Ocean Exploration and Research
OLA	Oceanographic Line Array
P-wave	compressional wave/pressure wave
PFA (=PCA)	pore-fluid array
P-P	P-wave mode (P wave down and P wave up)
PPC	polarity-preserving chip subbottom profiling system
P-SV	converted-shear mode (P-wave to SV-shear wave conversion)
PVT	pressure-volume-temperature
RMS	root mean squared
ROV	remotely operated vehicle
ROVARD	ROV Assisted Recovery Device
R/V	Research Vessel
SAIC	Science Applications International Corporation
SDI	Specialty Devices, Inc.

SFO	Sea Floor Observatory
SFP	Sea Floor Probe
SRC	Site Reconnaissance Camera
SRI	SRI, International
SSD	Station Service Device
SS/DR	Surface-Source Deep Receiver
SSVP	shallow sediment velocity probe
STAR	SAIC's multidimensional simulator
STAR-HYDCH4	Constitutive descriptor
STRC	Seabed Technology Research Center
TA	thermistor array
TGS-NOPEC	geophysical data (2-D, 3-D) acquisition company
THROBS	SAIC's hydrate simulator
UCSB	University of California, Santa Barbara
UCSD	University of California, San Diego
UGA	University of Georgia
UM	University of Mississippi
USBL	ultra-short baseline navigation system
USC	University of South Carolina
USGS	United States Geological Survey
USM	University of Southern Mississippi
UT	University of Texas
UVTC	Underwater Vehicle Technology Center
VLA	vertical line array
WesternGeco	Western Geophysical Company
WHOI	Woods Hole Oceanographic Institution

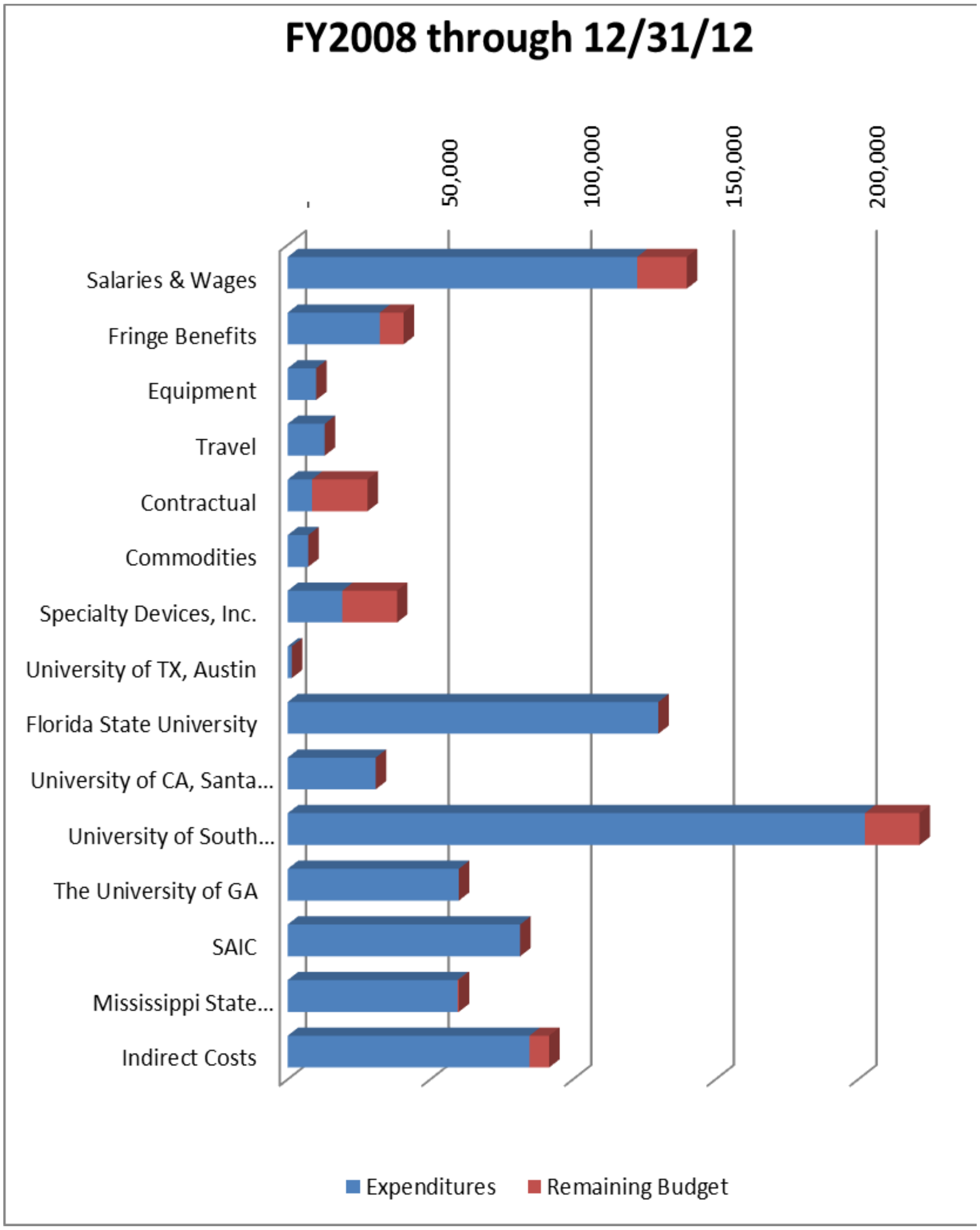
COST STATUS

As can be seen in the figures and tables that follow, Phase 1 (FY06) and Phase 3 (FY09) funds are essentially spent. We are working to zero out the few line-items with balances remaining. Funds remaining in Phase 2 (FY08) are primarily the SDI speed of sound probe and USC. USC has invoiced us for the remaining salary but has not yet accounted for their cost-share so we are working with them to get that resolved. The speed of sound probe is due to go to sea in July so that account should be spent out soon after that cruise. Remaining contractual funds are to support SDI's participation in cruises. The salary and fringe will be expended in the preparation and execution of the April and July cruises. Significant funds remain in Phase 4 (FY10). The 4C experiment has funds remaining to serve as analysis support. With a new contractor in place to do the analyses, we will resolve this funding anomaly. UCSB and UGa will spend out their accounts assuming all goes according to plan on the April cruise and follow-up. The no-cost extension through July, 2013, should see most work completed. We are striving to complete the project by that time.



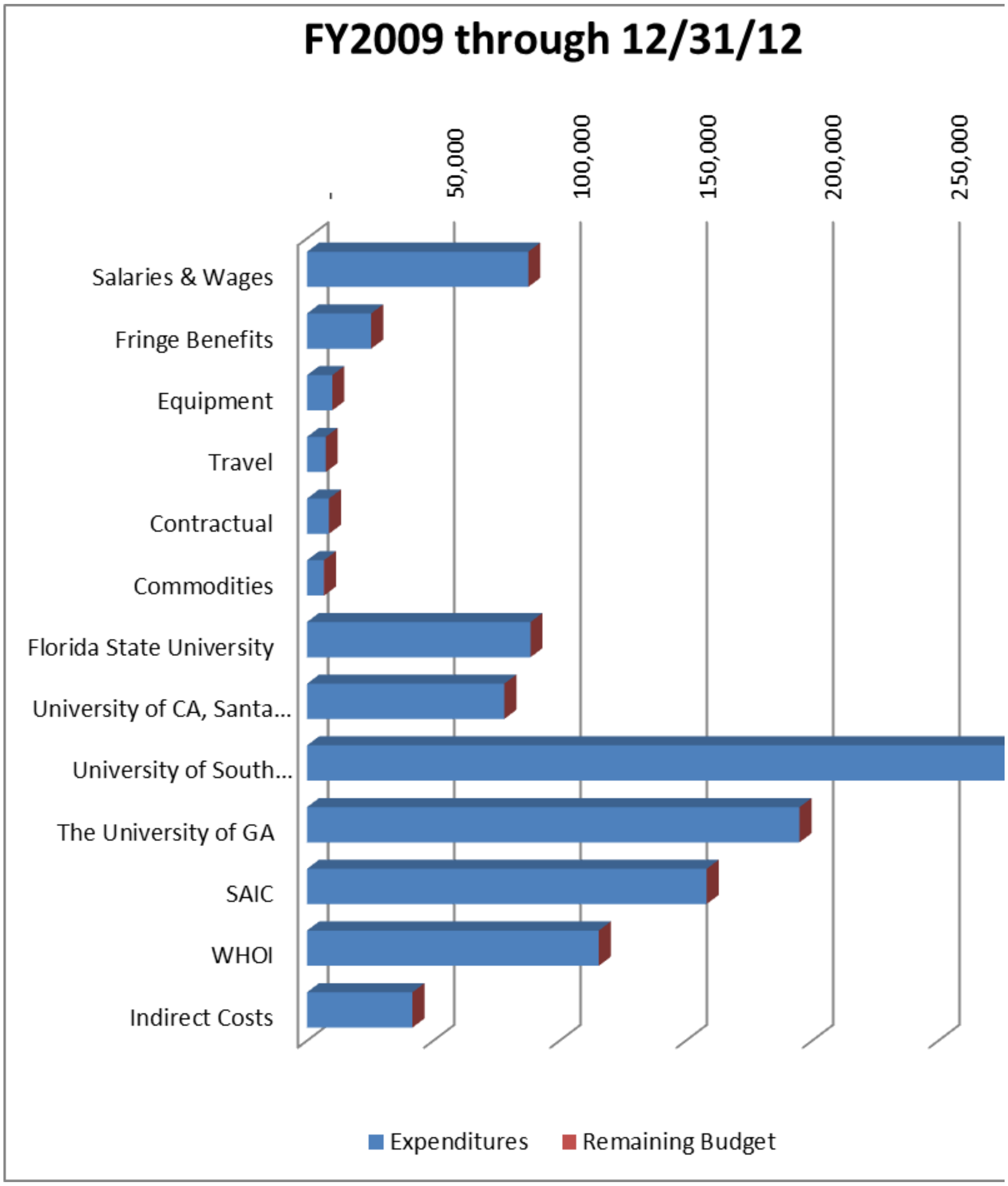
Mississippi Mineral Resources Institute
DOE DE-FC26-06NT42877
Funding Status as of 12/31/12

FY2006	Expenditures	Remaining Budget
Salaries & Wages	49,309	(229)
Fringe Benefits	13,471	1,646
Contractual	1,026	1,474
Commodities	2,176	(2,176)
Specialty Devices, Inc.	559,912	-
University of TX, Austin	114,979	21
Florida State University	112,520	-
University of CA, San Diego	64,113	-
Indirect Costs	43,155	187
Total	960,661	923


FY2008 through 12/31/12
-
50,000
100,000
150,000
200,000
Salaries & Wages
Fringe Benefits
Equipment
Travel
Contractual
Commodities
Specialty Devices, Inc.
University of TX, Austin
Florida State University
University of CA, Santa...
University of South...
The University of GA
SAIC
Mississippi State...
Indirect Costs
Expenditures
Remaining Budget

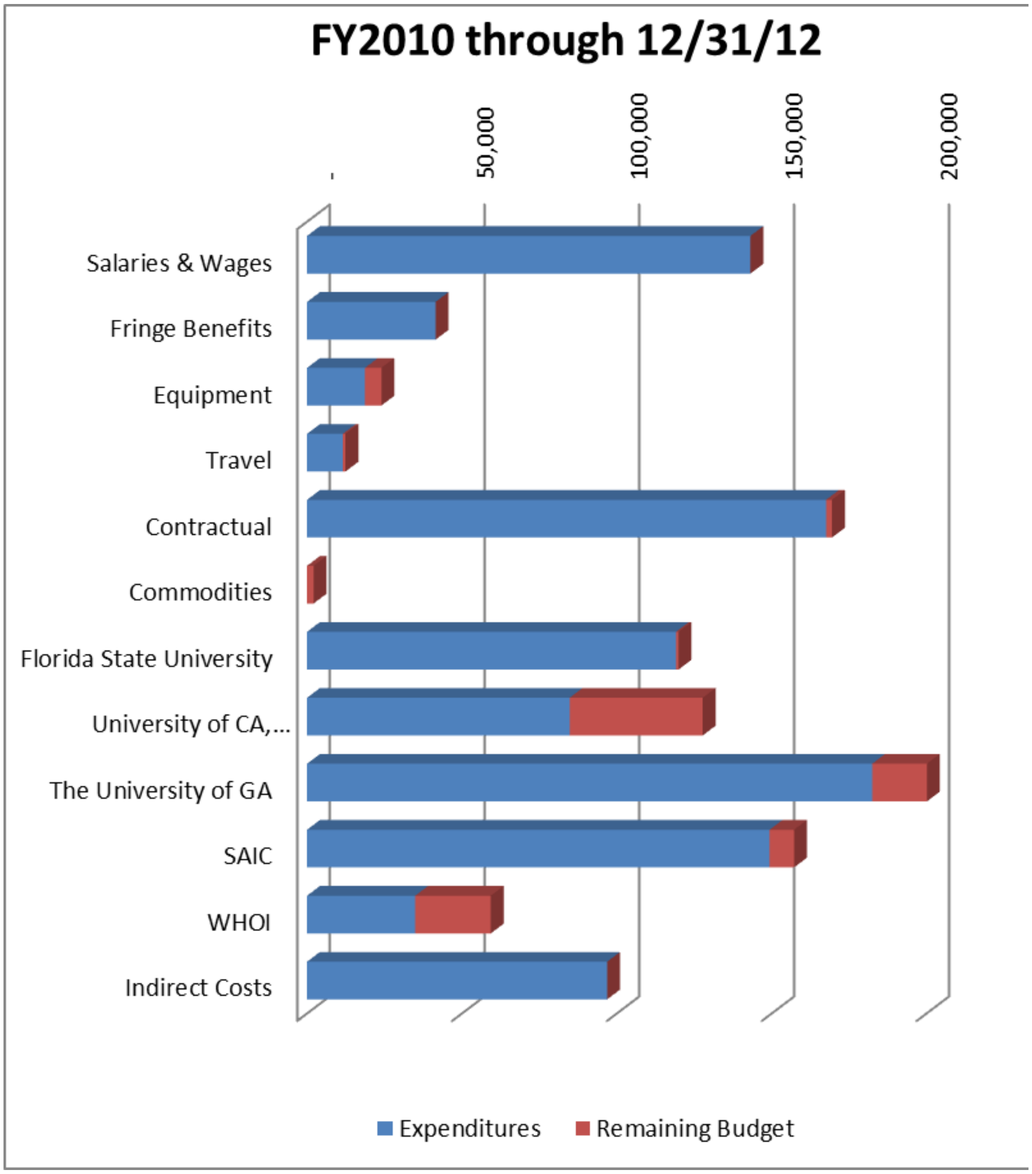
Mississippi Mineral Resources Institute
DOE DE-FC26-06NT42877
Funding Status as of 12/31/12

FY2008	Expenditures	Remaining Budget
Salaries & Wages	122,483	17,428
Fringe Benefits	32,276	8,344
Equipment	10,000	-
Travel	13,000	-
Contractual	8,500	19,500
Commodities	7,215	-
Specialty Devices, Inc.	19,168	19,168
University of TX, Austin	1,445	-
Florida State University	129,972	-
University of CA, Santa Barbara	30,881	-
University of South Carolina	202,336	19,180
The University of GA	60,000	-
SAIC	81,527	-
Mississippi State University	59,539	463
Indirect Costs	84,774	6,889
Total	863,116	90,972


FY2009 through 12/31/12
-
50,000
100,000
150,000
200,000
250,000
Salaries & Wages
Fringe Benefits
Equipment
Travel
Contractual
Commodities
Florida State University
University of CA, Santa...
University of South...
The University of GA
SAIC
WHOI
Indirect Costs
Expenditures
Remaining Budget

Mississippi Mineral Resources Institute
DOE DE-FC26-06NT42877
Funding Status as of 12/31/12

FY2009	Expenditures	Remaining Budget
Salaries & Wages	87,602	-
Fringe Benefits	25,405	-
Equipment	10,000	-
Travel	7,400	-
Contractual	8,717	2
Commodities	6,697	70
Florida State University	88,508	-
University of CA, Santa Barbara	78,118	-
University of South Carolina	284,899	-
The University of GA	195,029	-
SAIC	158,252	-
WHOI	115,550	-
Indirect Costs	41,775	-
Total	1,107,952	72


FY2010 through 12/31/12
-
50,000
100,000
150,000
200,000
Salaries & Wages
Fringe Benefits
Equipment
Travel
Contractual
Commodities
Florida State University
University of CA,...
The University of GA
SAIC
WHOI
Indirect Costs
Expenditures
Remaining Budget

Mississippi Mineral Resources Institute
DOE DE-FC26-06NT42877
Funding Status as of 12/31/12

FY2010	Expenditures	Remaining Budget
Salaries & Wages	143,151	-
Fringe Benefits	41,514	-
Equipment	18,696	5,304
Travel	11,549	851
Contractual	167,582	1,918
Commodities	-	2,108
Florida State University	119,127	854
University of CA, Santa Barbara	84,787	42,956
The University of GA	182,465	17,656
SAIC	149,341	7,918
WHOI	34,926	24,402
Indirect Costs	96,895	-
Total	1,050,033	103,967

MILESTONE STATUS

Milestones identified in the Project Management Plan are discussed below and related to their status.

Milestone 1: *Complete the baseline characterization of the subsurface at the Observatory site, MC118 for presentation to the panelists at the DOE Merit Review.* *Complete Seismic Analysis of data from MC118 including defining features that relate to the occurrence of gas hydrates.*

Baseline character of the Observatory site at MC118, as revealed in several seismic data sets is complete. Three different resolution datasets have been evaluated and integrated. Jumbo piston cores, heat-flow data, and polarity-preserving chirp data have been recovered and are being integrated and evaluated. We have yet to complete the hydrate vessels for collection from the SSD and we have yet to complete the biostratigraphic analysis of the cores, but we definitely have a much clearer view of the surface and subsurface at MC118 than we did in 2010 when this proposal was tendered. We have, at last, recovered a photo survey of the western craters of the Woolsey Mound in order to complete our surface structures and benthic faunal analyses. We have also acquired a high resolution multibeam and polarity-preserving chirp survey of Woolsey Mound and vicinity and are working on the processing possibilities and interpretation. Chemical surveying has added valuable information to the site baseline characterization and we now have a student analyzing the BBLA seafloor array data.

Milestone 2: Recover instruments from the seafloor and analyze data for baseline geochemistry and microbiology for the model (Task 9).

All landers have been recovered. CMRET began analyses of the BBLA data in the summer of 2012 and now has a Visiting Scholar dedicated to the completion of this task.

Milestone 3: Deploy horizontal line arrays, connect them to the data recovery system and collect test data from the data-logger. *All components of the deployment have been tested successfully.* Deployment strategy has been redesigned to include a lander for delivery of the arrays, one-at-a-time to the seafloor. This will likely not occur until fall, 2013.

Milestone 4: Complete installation of all Observatory components and collect geophysical data for input into model (Task 9). Due to deployment logistics, this milestone will necessarily follow the deployment of the horizontal arrays. However, time-series geochemical data from the BBLA and CSA are now being processed and evaluated. Heat-flow, pore-fluid and JPC have been made available to modeling efforts.

Milestone 5: Complete additional surveys – SSDR, Mass spectrometer (STRC-funded), multibeam (NIUST-funded) to provide important updated baseline seismic data prior to the commencement of true monitoring. The multibeam and mass spectrometer surveys are complete. We have received a complementary update in the multibeam from the Navy C&C along with very high resolution side-scan sonar data from MC118. We will use our 2005 survey to calibrate a new AUV they are testing for the Navy. The hydrophone array – necessary for the SSDR survey with the AUV-borne receiver - in Phase 2 of development by NOAA has been tabled for the moment, until the NOAA-NIUST budget is reinstated.

Milestone 6: **Complete 4C survey and analyze data for new software:** This dataset has been collected and delivered to subcontractors for analyses. UM has taken the lead in evaluating the active-source data. With the departure of the lead on theis project. However, we are negotiating a contract with Lookout Geophysical CO. to complete the task.

Milestone 7: Establish a "final" model of the observatory site, from which changes can be determined and monitoring established. The initial phases of the modeling effort are complete. Real data are now being incorporated into the final model. Unfortunately, funds are exhausted so this project remains incomplete though SAIC researchers are seeking additional funds to enable them to complete it. If funds sufficient to complete the model are not secured, the approximation of the base of hydrate stability, determined in this reporting period, can surely serve until additional funds are found.

New Milestones – and status - from FY10 Program Management Plan

Milestone 5: Collect and evaluate giant piston cores from the MC118 Sea Floor Observatory. This Phase 4 milestone is tied to Task 2 and is estimated to be complete in July, 2013. This task is essentially complete. The cores have been collected, logged and described and a report of their lithostratigraphy completed (APPENDIX A, previous report, 42877R24). We hope to get a complete biostratigraphic analysis by the end of July.

Milestone 6: Collect heat-flow data from MC118. This Phase 4 milestone is tied to tasks 2 and 3 and is estimated to be complete by March, 2012. This task is complete.

Milestone 7: Collect and evaluate additional gravity cores to complete sedimentation model, support geochemical and geophysical (structural) characterization of MC118. This Phase 4 milestone is tied to Tasks 2, 3 and 4 and is estimated to be complete by July, 2013. This task has slid as two cruises had to be cancelled in light of certification issues with the vessel and failure of our equipment. We have rescheduled to coordinate coring with speed of sound probe testing. This cruise is now anticipated to occur in July, 2013.

Milestone 8: Integrate geophysical datasets with geochemical and biological data. This Phase 4 milestone is tied to tasks 2 and 3 and is partly complete but ongoing. This task is in progress and results thus far have contributed significantly to numerous evaluations of MC118, most significantly the selection of sites for both the JPC and heat-flow cruises as well as our gravity coring cruise. An updated habitat map, tentatively tied to the shallow high resolution seismic and acoustic data was presented at the 2011 International AAPG in Milan and was awarded a "top ten" poster status for the entire meeting. We intend to continue this novel approach to seep evaluation with the new Visiting Scholars.

Milestone 9: Purchase and learn to operate an Infrared camera for the purpose of distinguishing hydrates in unopened cores. This Phase 4 milestone is tied to task 2 and is estimated to be complete by April, 2011. This task is complete. The camera was used on the JPC cruise. Initial results were very promising and significant work has been done to improve the carriage and scale display. The goal is to use it on our coring cruise to identify which cores and sections are likeliest to contain hydrates and/or exhibit gas expansion.

Milestone 10: Collect and analyze hydrate and "slime"(= protective ? biofilm) at hydrate outcrops in an effort to explain the existence and persistence of hydrate in seawater undersaturated for methane. This Phase 4 milestone is tied to tasks 2 and 4 and is estimated to be complete by September, 2013. Pressure chambers have been designed and built with this goal in mind but not installed on a vehicle, either the SSD or the SRC. Installation will follow a March ECOGIG cruise that will require the SSD.

Milestone 11: Recover additional pore-fluid time-series via additional instrument (PFAs, osmolander, peepers) deployments and recoveries. This Phase 4 milestone is tied to task 4 and is estimated to be complete by October, 2012. We have deployed several systems of pore-fluid collection. Peepers were collected via the ROVARD. Analyses counterindicate this collection technique as the collection bags leaked. However, series of pore-fluids have been collected via cores and a variety of instruments. Although we will continue to try to retrieve the osmoboxes that remain, this task is complete. The technology won a spot as an ECOGIG PI for Dr. Lapham

Milestone 12: Deploy the ABCMS lander in upgraded configuration including video, lights reduced-size mass spectrometer, and altimeter. This Phase 4 milestone is tied to task 5 and is estimated to be complete by April, 2013. This milestone was achieved in October, 2011, with the exception of the mass spectrometer functions. Its scheduled participation - with a new MIMS unit - in the Consortium cruise to MC118 had to be changed from September, 2012, when the cable failed, to April, 2013.

ACCOMPLISHMENTS

Major accomplishments of this reporting period include:

Dive of the SSD to 1,600+m on which all upgrades proved successful: recovery of imagery that verified lander and instrument locations and orientations, removing instruments from lander and carrying them to select seafloor locations;

Recovery of AUV multibeam and polarity-preserving chirp data from both 50m and 15m above seafloor for MC118;

Processing strategies established for multibeam and polarity-preserving chirp data from MC118.

Arrival of two Visiting Scholars from the University of Rome with expertise in processing and interpreting data such as we have in-hand;

Consortium members have produced several journal papers and received a major award For a GCAGS paper;

Recovery of geochemical data and sediment samples from the near-seabed and shallow seabed – BBLA and CSA and ROVARD;

Replacement of the damaged fiber-optic cable for use at-sea.

PROBLEMS/DELAYS

The majority of delays in the program derive from challenges presented by weather, working at 900m water depth and/or shortage of funds and personnel. In September, our fiber-optic cable that had worked so well since 2005, failed, causing the trip to be cancelled. Electronics at depth will always be challenging. The SDI/CMRET team continues to work diligently to overcome these challenges. The electronics of the SSD have been completely overhauled and the vehicle pressure-tested successfully (to 2,000m equivalency) at Southwest Research Institute in San Antonio; the vehicle performed magnificently in July. We acknowledge, however, that additional difficulties in the future are part of working in extremely challenging environments.

Both the cruise we contributed to and the one we ran we conducted this reporting period, were extremely successful. Landers have been recovered and are being reconfigured to accommodate a different configuration of instruments. Because we have saved some ship time by cutting cruises short, and by cancelling the September cruise when the cable failed, we have funds to support two cruises in 2013. We have taken on, for pay, other marine research work, particularly lander work, in order to keep our capabilities moving forward.

A major difficulty for the CMRET is loss of personnel. Tom McGee, our Senior Scientist/Geophysicist and charter member of the Consortium died unexpectedly in February. Due to lack of funding into the future, Leonardo Macelloni, our lead on many aspects of Consortium overall scientific effort, resigned to accept a position with Western Geco, effective in July. Our Project Manager for STRC, Ken Sleeper, has accepted a position with the UM Office of Research and Sponsored Programs, effective August 1. Our shop has been cooperating with the NIUST shop as both groups are short-handed and we benefit from complementary expertise, but we have not replaced the two experienced personnel lost from the shop in the last two years.

PRODUCTS

Important products of this reporting period are:

1. Successful pressure-testing and subsequent performance of the SSD, locating and servicing a seafloor lander at 1,600m water-depth,
2. Recovery of multiple datasets via AUV;
3. Completion of the Site Reconnaissance Camera;
4. Replacement and successful spooling and termination of the Rochester Cable;
5. Progress Report from January - June, 2012,
6. Publications in peer-reviewed Journals,
7. Capabilities shared with other researchers and institutions.

RECENT PUBLICATIONS BY CONSORTIUM MEMBERS:

2012

*Macelloni, Leonardo, Antonello Simonetti, James H Knapp, Camelia C Knapp, Carol B Lutken. *Multiple resolution seismic imaging of a shallow hydrocarbon plumbing system, Woolsey Mound, Northern Gulf of Mexico Gulf of Mexico.* Marine and Petroleum Geology.

2013

*Macelloni, Leonardo, Charlotte Brunner, Simona Caruso, Carol Lutken, Marco D'Emidio, Laura Lapham, 2013, *Spatial distribution of seafloor biogeological and geochemical processes as proxies of fluid flux regime and evolution of a carbonate/hydrates mound, northern Gulf of Mexico*, Deep Sea Research, Part 1, in press, Manuscript Number: DSR1-D-12-00118R1.

In Press:
Carrière, Olivier and Peter Gerstoft, 2012, *Deepwater subseafloor imaging using active seismic interferometry*, Geophysics.

Submitted:
Simonetti, Antonello, James H. Knapp, Kenneth Sleeper, Carol B. Lutken, Leonardo Macelloni, Camelia C. Knapp, *Spatial Distribution of Gas Hydrates from High-Resolution Seismic and Core Data, Woolsey Mound, Gulf of Mexico*

In prep:
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APPENDIX A
STATION SERVICE DEVICE ROV
R/V PELICAN
JULY, 2012
OC-26 in MC-297 (and MC118?)

The SSD had a successful cruise July, 2012, when it dove deeper than ever before and moved more equipment on the seafloor than ever before. The mission was part of the ECOGIG oil spill project administered by NIUST. The speicfic operations called for the SSD to dive on a lander fabricated by MMRI's shop and equipped with ECOGIG instruments and to place select instruments on the seafloor, adjacent to the lander. The operation is similar to missions with the MMRI ROVARD lander during which instruments were placed with the SSD at the Woolsey Mound research reserve, MC118. The current mission, however, was executed in signifacantly deeper water (1600m vs 900m).

The SSD has undergone a major overhaul in order to provide a more robust and deeper-diving vehicle. Rapid reponse funds, made available from the Northern Gulf Institute, were awarded in the wake of the Deepwater Horizon oil spil to upgrade the vehicle to explore seafloor conditions in water depths up to 2000m. To meet this goal, nearly every system on the SSD has been improved and/or modified including the electrical, hydraulic, ballast, and instrument packages (sonar, alitmeter, cameras, and lights). Efforts continue to increase the reliability of the vehicle by isolating individual circuits and by building in fail-safe systems.

Specific upgrades include:

- New pressure vessels for scanning sonar, main electronics bottle, electrical power bottle, hydraulic telemetry bottles, and electrical actuators on the winch drum.
- New hydraulic system with enlarged telemetry system to accommodate additional hydraulic systems (including open circuits for future upgrades). A fail-safe system is under development and close to completion that will release the hydraulic system in the event of a vehicle fault (allowing the vehicle to be recovered even if attached to an asset on the seafloor at the time of failure – without damage to the seafloor asset or the vehicle).
- New syntactic foam, which provides increased buoyancy and payload capacity, operated by new upgrades to the hydraulic system. New, retrievable drop-weight system (the yo-yo) added for lifting and repositioning heavier payloads on the seafloor.
- New circuit protection added to isolate key electrical and optical communications systems. New circuit boards added to increase the number of video feeds. New DVR system to capture and display multiple video feeds simultaneously.
- New camera mounted on the arm, which, in conjunction with repositioning of existing cameras, provides a 3D view of items of interest and subsequent manipulation with the arm. Additional cameras and lights are close to completion which will provide an even broader view of seafloor operations.

ROV Operations:
On July 18, 2012, the SSD was launched from the R/V*Pelican* in Mississippi Canyon federal lease block 297. Early in the morning of July 19, 2012, the SSD landed at 1616mbsl within 8m to the SE of the lander. The lander was located at 28°42.20819'N, 88°21.61232'W approximately 115m to the SE from the reported location. The high resolution, scanning sonar on the SSD was critical for locating the lander. Even with the sonar, a dedicated search operation was required. The lander was found to be in good condition, in an upright position, with pore-fluid probes just at the seafloor. The Chimney Sampler Arrays were positioned as deployed except one of the plastic floats on one of the chimney had collapsed and debris from the float littered the area near the lander. The SSD was flown out to the lander were it did a short video survey of the lander and the instruments. Then the SSD handily removed the Chimney Sampler Arrays and placed one approximately 7m to the SE and one 3m to the SSE of the lander. The new camera system made the operations of releasing and grabbing the CSA a nearly effortless task compared to the former, 2D view under which this operation has been executed in the past. The increase payload of the second CSA (with the collapsed float) posed no problem for the SSD. The "yo-yo" retrievable drop weight was deployed and the SSD had more than enough lift to move the array. The SSD was recovered and a short transit was made to MC118 for the reminder of the cruise.

The upgrades and success of the cruise are attributable to our ROV team which includes UM marine systems specialists working with USM undersea vehicle engineers and the ROV design team at SDI. The small operating footprint of the SSD means that it can operate from smaller, less costly vessels and still have enough deck and bunk space left for science missions.

Figure A1. Matt Lowe (right), MMRI, and Paul Higley (left), SDI, on the backdeck of the R/V Pelican preparing the SSD for a post-upgrades float test.

Figure A2. SSD operations monitor shows multiple cameras displayed in real time. All video is recorded for later examination, site verification, and study.

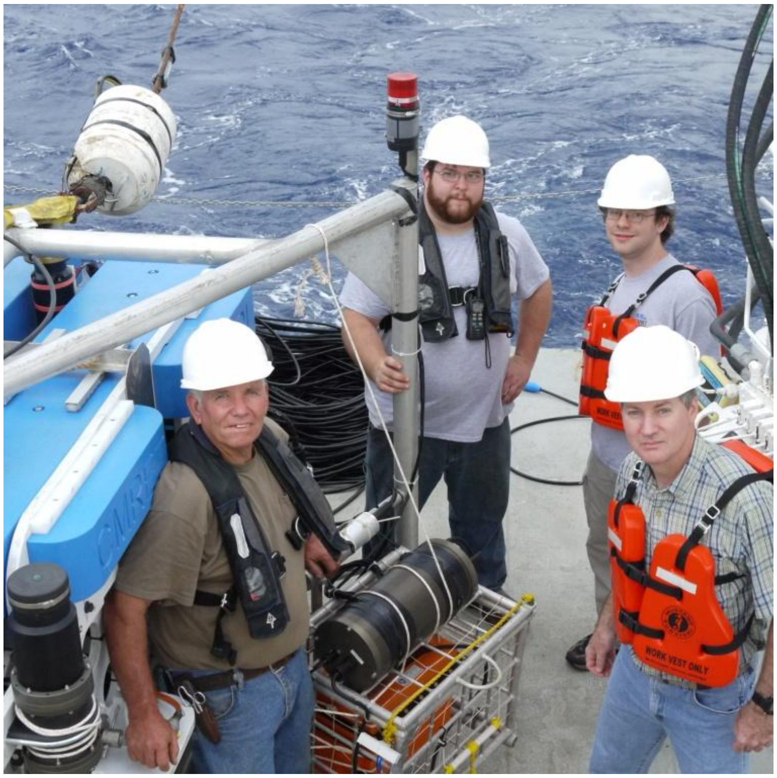

Figure A3. Some of the proud SSD ROV team, from left to right, Larry Overstreet, Steven Tidwell, Max Woolsey, and Roy Jarnagin.

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