Oil & Natural Gas Technology

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Quarterly Report

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Gas Hydrate Characterization in the GoM using Marine EM Methods

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EXECUTIVE SUMMARY

A kick off meeting for the DOE-NETL Hydrate Project was held at the DOE-NETL facility in Morgantown, West Virginia on January 6th. The PI (Steven Constable) attended this meeting and presented the goals of the project and a summary of the controlled source electromagnetic (CSEM) data recently collected in the Gulf of Mexico during October 7 – 26, 2008. Discussions during this meeting concluded that a first priority for the project should be to obtain a rapid result from the CSEM data in order to assist the DOE-NETL/JIP in their upcoming spring hydrate drilling compaign. Only two of four sites surveyed, Walker Ridge 313 (WR 313) and Green Canyon (GC 955), are relevant to the JIP drilling campaign and so analysis of Alaminos Canyon 818 (AC 818) and Mississippi Canyon 118 (MC 118) data was delayed for the time being. The WR 313 data was processed first because the CSEM survey targeted most of the proposed JIP wells. The GC 955 data set was considered less important as the CSEM survey was unable to target the proposed JIP wells due to the presence of a drill rig while surveying this location.

Initial analysis of the WR 313 data set commenced in mid-January. The new instrument, Vulcan – a three axis electic field receiver towed in tandem 300 m behind the transmitter – was viewed as the data set that would provide the quickest preliminary result because fixed off-set data does not require the same navigational rigor as data from seafloor instruments. However, fixed offset data represents a new data type for us to process and analyze, and it has taken longer then anticipated to do this. An attempt was made to generate pseudosections from the CSEM data recorded by the twenty seafloor receivers at Walker Ridge but the navigational assumptions used for the transmitter location and orientation (derived from winch wire out and the pressure-depth gauge of the transmitter) were too inaccurate to obtain reliable results. To resolve these navigational issues the near field electromagnetic data need to be processed by a Marquardt inversion program to recover navigation parameters (written as part of Weitemeyer's PhD thesis) and which solves for transmitter orientation and position. This will be the next step in data analysis for all survey locations.

Raw data were distributed to industrial sponsors in February and a presentation was made at our two day annual consortium meeting. An abstract was submitted to the 2009 MARELEC meeting to be held July 6th and 7th in Stokholm, Sweden. An additional meeting at LLNL took place in mid-march to discuss the design of the conductivity cell, and the PI also gave a talk to the climate group there. We had the opportunity to host a number of researchers at Scripps who also collect marine electromagnetic data over gas hydrates (Katrin Schwalenberg of BGR, Hannover, Germany; Martin Sinha of the National Oceanography Centre, Southhamption U.K.; Tada-nori Goto of Kyoto University, Japan; and Yamane Kazunobu, of JOGMEC, Japan), facilitating an open dialogue within this small community

Because of the priority given to getting early results from Walker Ridge and Green Canyon, we have delayed some of the work required to start the conductivity cell construction.

PROGRESS, RESULTS, AND DISCUSSION

Phase 1.

Task 1.0: Project Management Plan. Completed November 5, 2008.

Task 2.0: Technology Status Assessment. This is embodied in the original proposal.

Task 3.0: Collect Marine CSEM Field Data. Completed October 26, 2008.

Task 4.0: Design and Build Conductivity Cell. A meeting took place in mid-March with Steven Constable and Jeff Roberts at LLNL.

Task 5.0: Preliminary Field Data Interpretation.

The WR 313 survey consisted of twenty deployed seafloor receivers placed along an east-west and north-south trending line. The transmitter and Vulcan were towed across these two semi-perpendicular lines as shown in Figure 1. The data from the seafloor instruments and vulcan have been processed. Work in obtaining an accurate model for the transmitter position and orientation is ongoing.

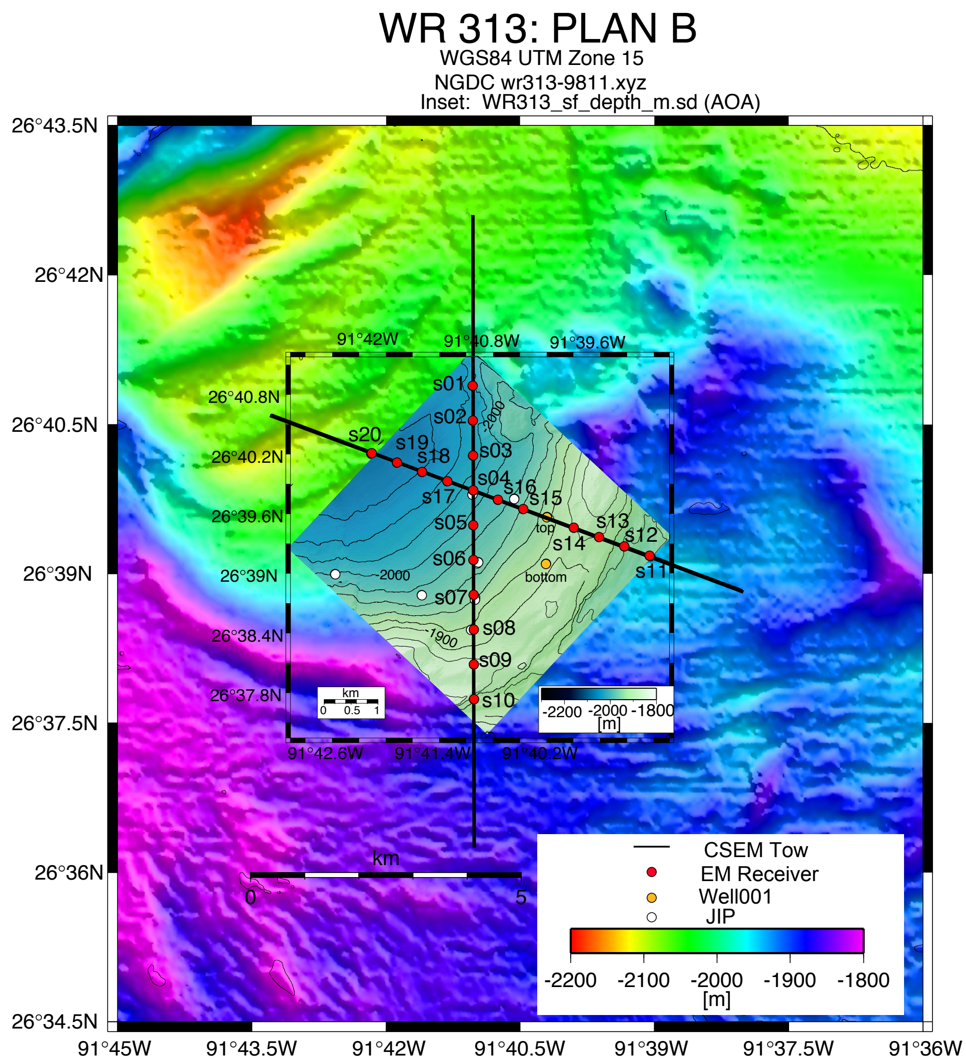

Figure 1. Map of WR 313 CSEM hydrate survey, with the twenty receiver locations and two tow lines: east-west tow and north-south tow.

During the four GoM surveys we were working to develop a new transmitter navigation system (the "Barracuda"), a recently built instrument meant to provide very accurate navigational data for the transmitter by triangulating using ranges from two surface towed GPS/ radio acoustic units. Unfortunately the Barracuda navigation system was not fully functional until the last survey (MC 118), which means that to obtain accurate transmitter navigation for the other surveys we will have to process the near field electromagnetic data using a total field navigation program (written as part of Weitemeyer's PhD thesis) which inverts for transmitter position and orientation. This work was expected to take more time than we had available in order to assist the JIP, and so we used winch wire out and pressure/depth data from the transmitter to approximate position and orientation.

While this kind of preliminary analysis worked well for our previous Hydrate Ridge survey, in this case it did not work as well, in part because during the Hydrate Ridge survey we also collected acoustic relay data by pinging to the seafloor receivers as the transmitter was towed across the survey area. However, we found that acoustic pings

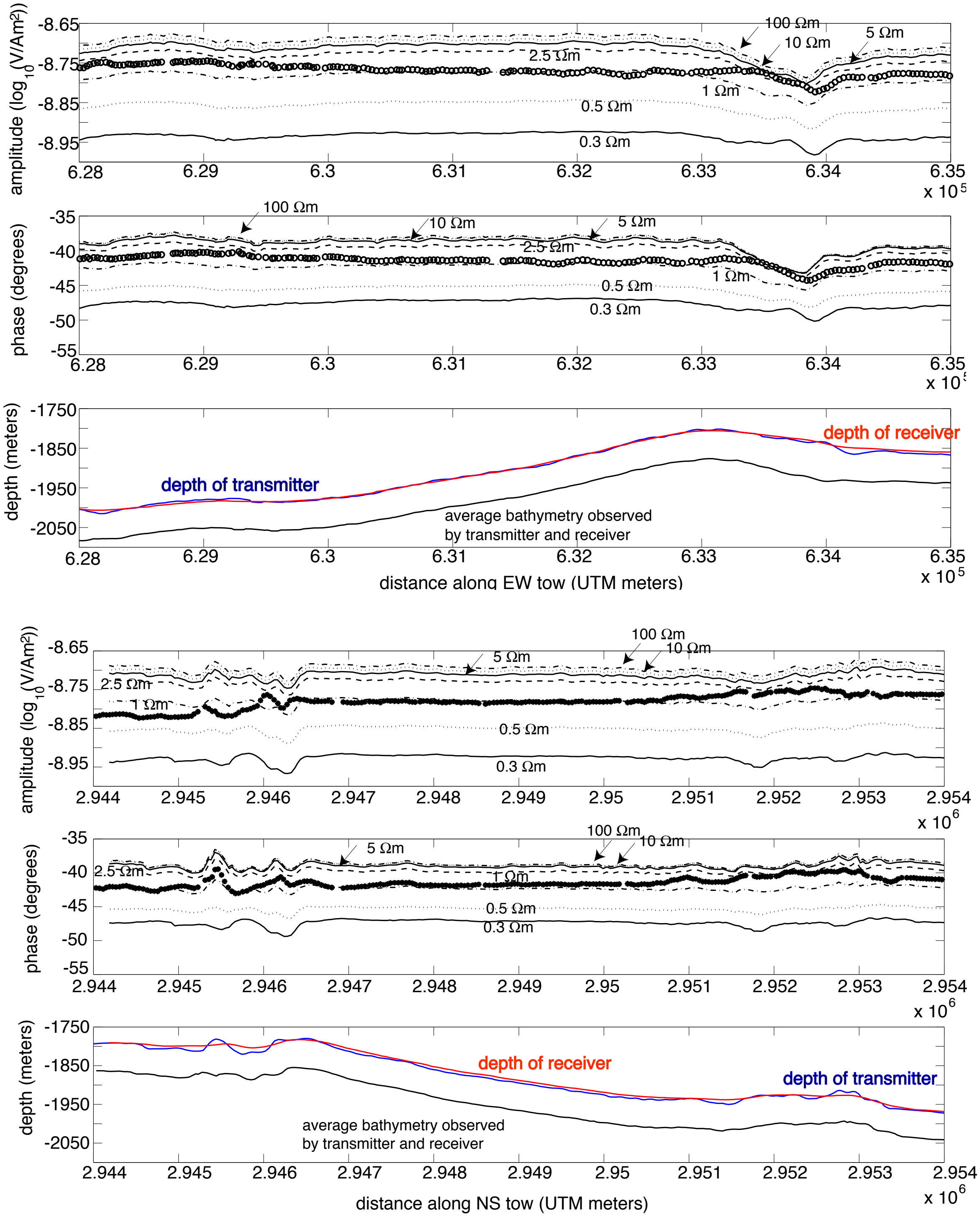

Figure 2. The in-line amplitude and phases for 1D forward models (lines) and data (dots) at a frequency of 1.5 Hz shown for the east-west and north south tow. Although only one frequency is shown here, this analysis was done for all seven frequencies to obtain apparent resistivities.

introduced noise onto the electric and magnetic field data recorded by the receivers, and so during the GoM surveys we avoided acoustically ranging on receivers. Vulcan, our new fixed offset towed receiver, does not require as much navigational rigor as the seafloor instruments, and so processing data from this instrument was given priority to try and get an early result.

The amplitude and phase data for Vulcan across the east-west and north-south lines are shown in Figure 2 along with the bathymetry profile across the two tows and the depths to the transmitter and towed receiver. The 1D Dipole forward modeling code of Key (2009) was used to model the electric fields for each transmitter (X,Y,Z, dip, azimuth from north) and the receiver (X,Y,Z, dip, pitch, azimuth from north) position over seafloor half-space models of various resistivities (0.3, 0.5, 1, 2.5, 5, 10, 100 Ωm). A stratified seawater layer is used based on the conductivity data recorded by the transmitter. Seven frequencies were selected that have the largest signal spread over a decade (0.5, 1.5, 3.5, 6.5, 13.5, 23.5, 33.5 Hz). Frequencies above 33.5 Hz appear to be too noisy to be useful and so were not considered in this analysis.

The amplitude and phase of the forward models (Figure 2) show effects associated with bathymetry and variations in the height of the transmitter relative to the receiver. These same effects are evident in the field data. While there are some inconsistencies in the phase data which we have yet to understand, the amplitude data can be used to make a preliminary apparent resistivity image of the Vulcan data.

The electric field data at each data point can be fit to a half-space resistivity value from the 1D forward models using an interpolation to match the data, yielding apparent resistivity values across the tow lines for the seven frequencies considered (shown in Figure 3). The apparent resistivities can be mapped into a pseudo-depth by using the skin depth attenuation; high frequencies will map shallower and low frequencies will map deeper, allowing us to image the heterogeneity across the two tow lines. We have not put a depth scale on the figure since such imaging projections do not provide quantitative depths. A 1D frequency inversion will be carried out to obtain an accurate depth scale when the inconsistency in the phase data is resolved. Meanwhile, the crossing point of the north-south and east-west tows are consistent, which is encouraging.

At this stage we would be reluctant to interpret the results shown in Figure 3. While it appears that there are areas of increased resistivity at the east and west ends of the east-west tow, the highest resistivities are associated with bathymetric highs and the associated variations in transmitter and Vulcan tow depth. We are concerned that small navigational errors are being projected into the apparent resistivity calculations, and so further work is needed.

The seafloor receivers were also processed, merged with the current navigational data, and 1D forward modeled in order to generate pseudosections of the EW and NW tows at WR 313. Unfortunately, the in-tow and out-tow psuedosections are inconsistent and do not provide us with any interpretable results, probably because of an inadequate model for the transmitter location and orientation.

Lessons learned so far:

1. A point dipole approximation is not accurate in forward modeling of higher frequencies at the short fixed offsets used for Vulcan.

2. The vertical depth variations from the transmitter, tail of the transmitter antenna, and the receiver are all needed to compute the apparent resistivities for Vulcan data.

3. It cannot be assumed that the inline component of the data is uncorrupted by the cross line and vertical components of the electric fields, and so all of the navigation parameters for Vulcan (roll, pitch, and heading) must be used to rotate the model data into the same reference frame as the collected data.

Task 6.0: Make Hydrate and Hydrate/Sediment Conductivity Measurement. This task is scheduled for later this year and Budget Period 2.

Task 7.0: Modeling and Inversion of Field Data. Some 1D forward modeling of the WR 313 data is underway refer to Task 5.0 for details. The bulk of this task is scheduled for Budget Period 2.

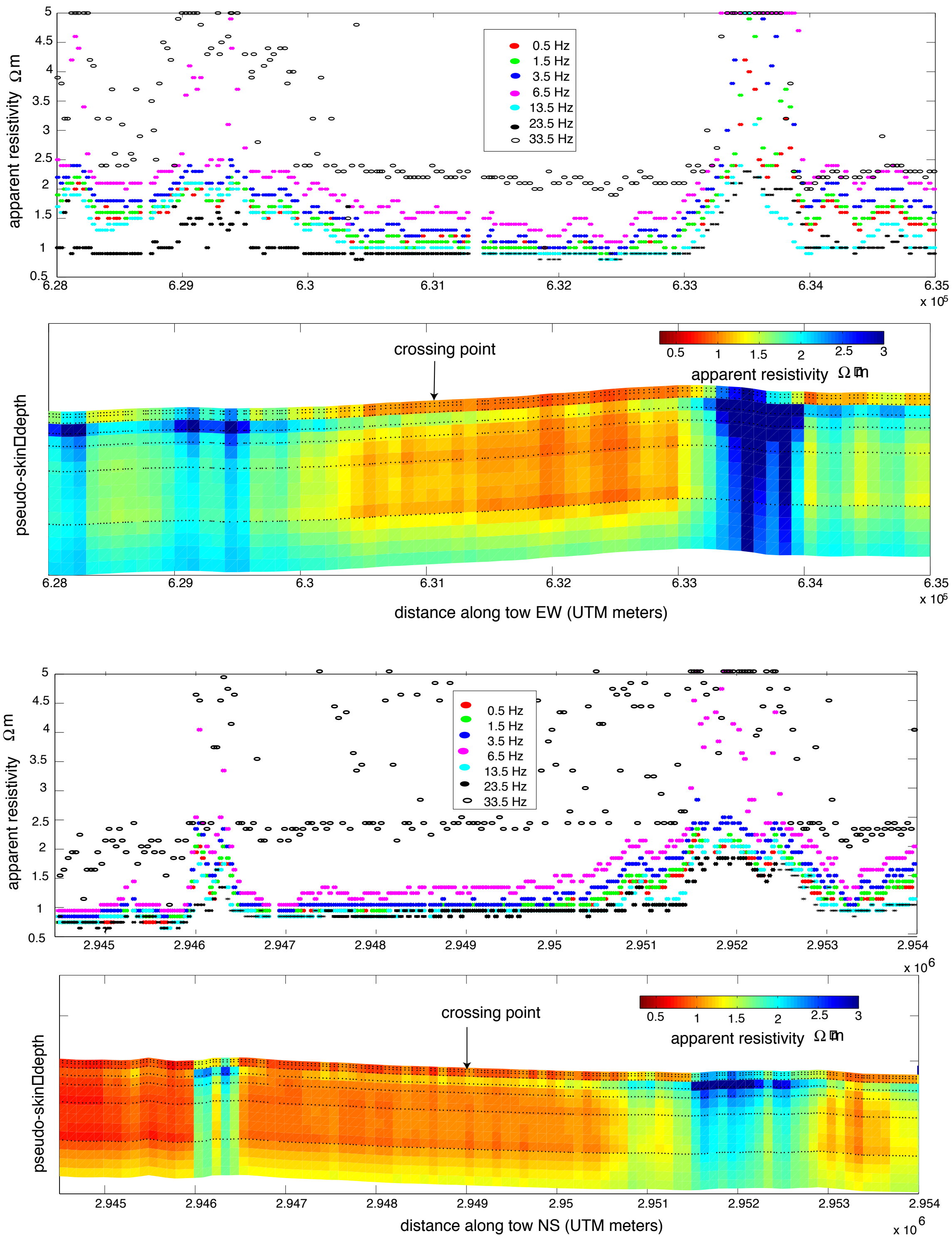

Figure 3. Amplitude 1D forward modeled apparent resistivity values for the north south and east west tows for frequencies 0.5, 1.5, 3.5, 6.5, 13.5, 22.5, and 33.5 Hz. The skin depth of the frequencies can be used to project the resistivites into an approximate depth. Future work will involve 1D OCCAM inversions across the tow line.

Task 8.0: Estimate Quantitative Hydrate Volumes from Field Models and Laboratory Studies. This task is scheduled for Budget Period 2.

Task 9.0: Technology Transfer. The data have been distributed to the sponsors (February, 2009) and preliminary results were presented at the Seafloor Electromagnetics Consortium annual meeting March 18 and 19, 2009. A meeting with Ken Greene of Exxon Mobil (March 20, 2009) took place with a discussion of possible collaboration in the near future.

Task 10.0: Final Publication. This task is scheduled for Budget Period 3.

CONCLUSIONS

The desire to produce a quick result for the DoE/NETL JIP drilling timeline led us to attempt a less rigorous treatment of the data, which in our opinion has proven to be inadequate. This quarter has been a useful period for learning the complexities of Vulcan-type CSEM data, but it is clear that reliable results will not be obtained until we carry out total field navigation to obtain an accurate location and orientation for the transmitter. This will be our next priority.

COST STATUS

Table 1: Project costing profile for Budget Period 1, Quarter 2

Time period	Cost share	DoE Plan	DoE Actual
January 2009	$25,306	$9,784	$7,432
February 2009	$0	$9,784	$34,723
March 2009	$0	$9,784	$7,466
Totals Q2	$25,306	$29,352	$49,621

Table 2: Cumulative costing profile

Time period	Cost share	DoE Plan	DoE Actual
Totals Q1	$528,141	$499,378	$481,123
Totals Q2	$25,306	$29,352	$49,621
Totals	$553,447	$528,730	$530,384

MILESTONE STATUS

Milestone log for Budget Period 1.

Milestone 1: Revised Project Management Plan. Task 1.0, completed 3 November, 2008.

Milestone 2: Submission of Technology Status Assessment. Task 2.0, embodied in the original proposal.

Milestone 3: Preparation of marine instrumentation for shipping. Task 3.0, completed 30 September, 2008. Equipment was tested in the laboratory and trucked to Fort Lauderdale. Critical milestone for tasks 5,7,8,9,10.

Milestone 4: Carry out field program in GoM. Task 3.0, completed 26 October, 2008. Field program was completed more than successfully, with one extra survey area covered and 15 more stations than proposed. Critical milestone for tasks 5,7,8,9,10.

Milestone 5: Produce initial cruise report Task 3.0, completed 30 January, 2009.

Milestone 6: Design conductivity and pressure cell. Task 4.0, work underway. Critical milestone for tasks 6, 8, 9, 10.

Milestone 7: Generate merged EM/navigated data set. Task 5.0, work underway. Critical milestone for tasks 7, 8, 9, 10.

Milestone 8: Construct conductivity/pressure cell Task 4.0, work underway. Critical milestone for tasks 6, 8, 9, 10.

Milestone 9: Make calibration tests of cell using water standard Task 4.0, work not yet started. Critical milestone for tasks 6, 8, 9, 10.

Milestone 10: Install cell in Menlo Park and make initial hydrate measurements Task 4.0, work not yet started. Critical milestone for tasks 6, 8, 9, 10.

Milestone 11: Preliminary interpretation of field data Task 5.0, work underway.

Milestone 12: Webpage updated Task 9.0, January 30 2009.

Milestone 13: Produce Phase 1 Report Tasks 1-5, to be completed 31 July 2009.

ACCOMPLISHMENTS

• Collection of the Marine CSEM Field Data

• Conductivity cell design underway.

• Processing of the data is underway.

• A Fire in the Ice article was published.

• Participated in a "Spot Light on Research" article for Fire in the Ice.

• Data distributed to sponsors.

PROBLEMS OR DELAYS

The design and construction of the conductivity cell is progressing more slowly then anticipated. This is in part due to our attention being diverted to obtain a quick result for the JIP hydrate drilling campaign.

PRODUCTS

• Revised Project Management Plan.

• A project website was set up:

    http://marineemlab.ucsd.edu/Projects/GoMHydrate/index.html

    Cruise Report is available for download.

• Project Summary:

    project summary outlining project goals and objectives on the NETL project Web site.

• Collection of Marine CSEM data in the Gulf of Mexico:

    Data distributed to sponsors early February.

• Fire in the Ice article published Winter 2009.

• NETL kick off meeting, Morgantown, WV - January 6, 2009

The PI delivered a project overview presentation.

• Submitted a 2009 MARELEC abstract - Stockholm, Sweden - July 7-9 2009

The PI will present a talk entitled *Applying marine EM methods to gas hydrate mapping*

• Submitted the first quarter report February 2 2009.

•Invited talk at LLNL mid-march

Steven Constable delivered a presentation:

Marine Electromagnetic Methods for Mapping Gas Hydrate

• SIO Seafloor Electromagnetics Consortium annual meeting, La Jolla, CA - March 18-19, 2009

Karen Weitemeyer delivered two presentations:

Marine EM for gas hydrate studies, with first results from the Gulf of Mexico

Using Near field data to navigate controlled source electromagnetic data

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