Oil & Natural Gas Technology

DOE Award No.: DE-NT0005668

Quarterly Report

April 2010 to June 2010

Gas Hydrate Characterization in the GoM using Marine EM Methods

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

August 2, 2010

Office of Fossil Energy

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EXECUTIVE SUMMARY We have commissioned the conductivity cell and made calibration runs on ice and a teflon plug. We have also started to explore 1D OCCAM inversions of the Vulcan data at MC 118. Progress is being made on developing an OCCAM inversion for the transmitter navigation. A First Break article was published in June 2010 about the CSEM data collected at MC 118 and GC 955, and we received some positive feed back from readers. Further modifications were made to our Geophysics paper on 2D inversion of hydrate CSEM data, and it has finally been acceptance for publication. We also received reviews of our Geophysical Journal International submission on the Hydrate Ridge data set, and a few revisions need to be made. Progress was also made on a collaborative project with Peter Kannberg and Anne Tréhu of Oregon State University studying a data set collected a year ago at the Pinnacle location on Hydrate Ridge.

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: Preliminary Field Data Interpretation. Completed October 2009.

Task 5.0: Design and Build Conductivity Cell.

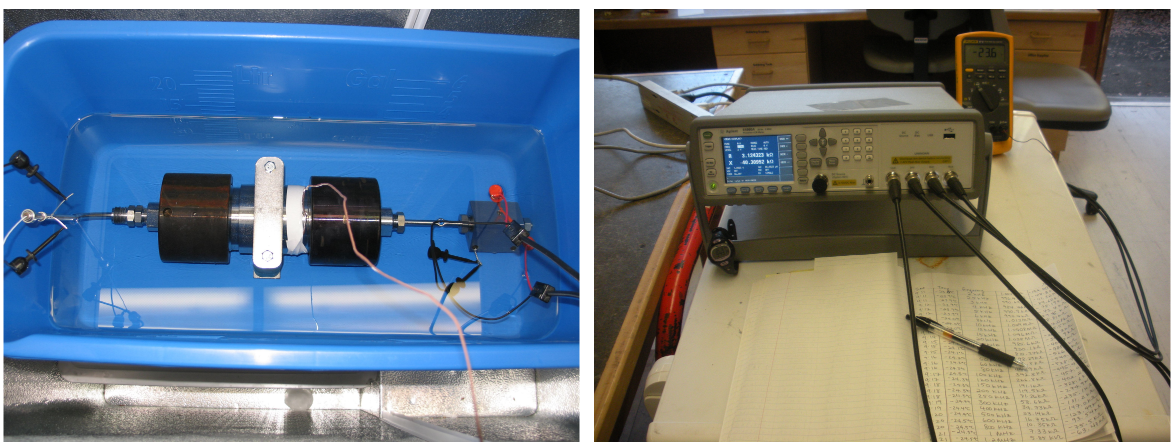

Figure 1: The conductivity cell (left) in an propylene glycol bath with electrical connectors attached to the ends, in the center is a thermistor. To the right is the Agilent LCR meter and a Fluke multimeter for measuring the thermistor sitting on top of the chest freezer.

The conductivity cell has been designed and built, and calibration tests of the cell using water standard have been completed. Figure 1 (left) shows the conductivity cell sitting in a propylene glycol bath within a chest freezer with electrical connectors for the LCR meter (there are another two red connectors to the left that have not been captured in the photo) and (right) the set up for the Agilent E4980A Precision LCR meter and a Fluke multimeter (for reading the thermistor) sitting on top of the standup freezer.

We took HPLC (high performance liquid chromatography) reagent grade water (maximum of 1 ppm contaminants), outgassed it under a vacuum for an hour or so, and froze it slowly (over 10-20 hours) in a teflon sleeve. We filed off the meniscus with a steel file. We loaded the ice puck (about a 1/2 inch height by 1 inch diameter) into the cell with two disks of silver foil as electrodes. These are blocking electrodes, since they are polarizing and don't allow transfer of charge, but they work at high frequencies and there are extensive data in the literature for comparison.

We loaded the cell and the first measurements were noisy. After a day or so the measurements were much better, which suggests that we need to have the ice "anneal" for a day or so in the freezer. We decided not to spend time learning how to operate the LCR meter over a GPIB interface using a computer, since it is not unreasonable to make the measurements manually. Initial measurements below were made in a chest freezer between -10 and -20^oC in air. The air temperature in the freezer varies a lot as the chiller switches in and out. To stabilize the temperature we strapped the thermocouple to the outside of the cell and immersed it all in propylene glycol.

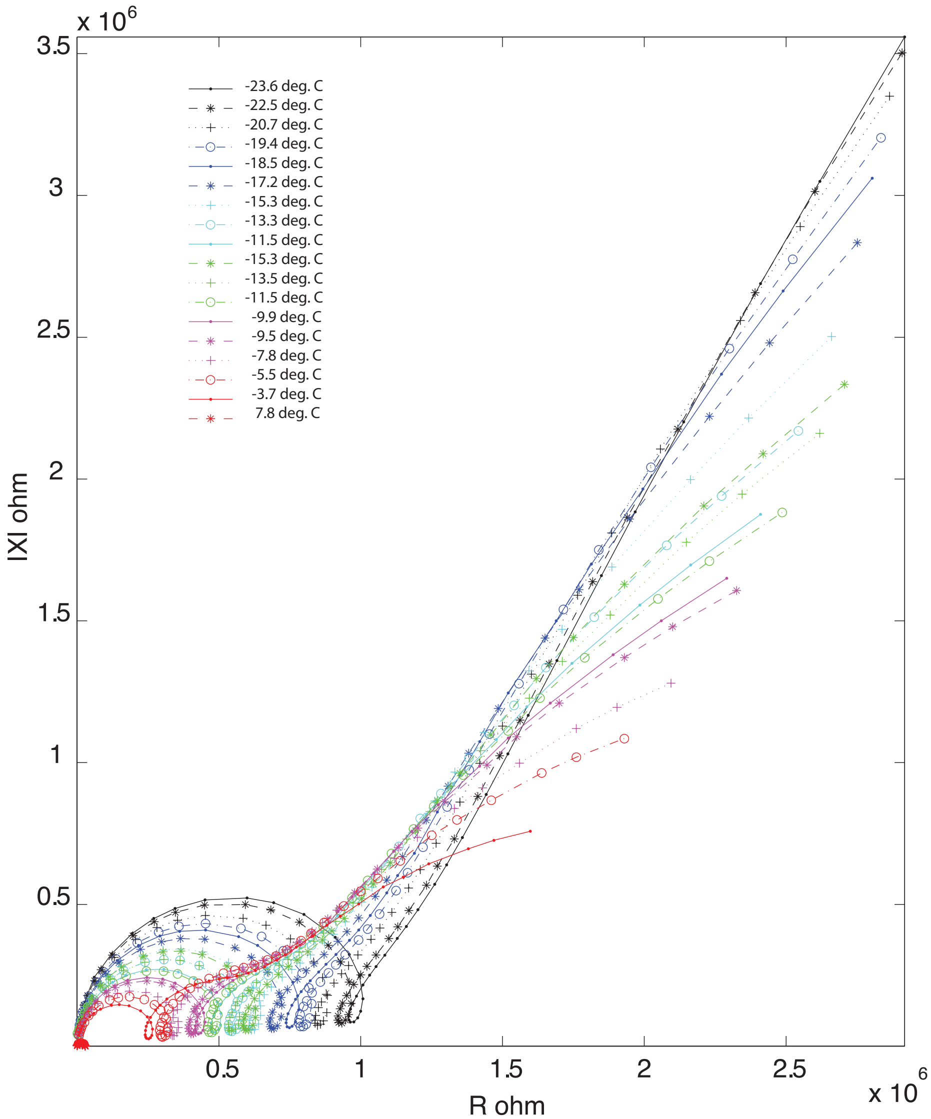

Figure 2: Calibration runs on ice at varying temperatures within a propylene glycol bath.

The Agilent LCR meter is used to make resistance (R, real component) and reactance (X, imaginary component) measurements over a frequency range of 20 Hz to 2 MHz using an applied voltage of 1 V (2 V was also used, and give similar results, but to avoid the possibility of exceeding the breakdown voltage most runs used the smaller voltage of 1 V). These types of measurements were repeated at different temperatures and Cole-Cole plots are shown in Figure 2. The are three main features present in all of the measurements below 0^oC:

(1) The high frequency portion that is a well-formed semi-circle is presumably from Debye relaxation and almost certainly contains the system capacitance. This can be determined by CNLS (complex nonlinear least square) equivalent circuit fitting of the data. It can be temperature sensitive (Jeff Roberts, pers. comm.). The peak of the circle also gives the Debye relaxation time, which for pure ice at -10^oC is around 5x10^{-5} s. We have yet to model and quantify this behavior, but the cell appears to be performing reasonably.

(2) The low frequency portion looks like a Warburg impedance response and is expected for this set-up (Jeff Roberts, pers. comm.).

(3) The curly-cue is often interpreted as dissolution, corrosion, or thin-film response (Jeff Roberts, pers. comm.).

We allowed the ice to melt and made a measurement on the confined water, and have also tested the cell with a Teflon disc as a sample to estimate the system response. We are concerned by the low in-phase resistance of the Teflon blank, and plan to repeat this measurement after removing the cell from the glycol bath. Figure 3 shows the teflon disk runs and the water runs with an equivalent circuit model for each case. The values of the resistors and capacitors and Warberg impedance are still to be modeled.

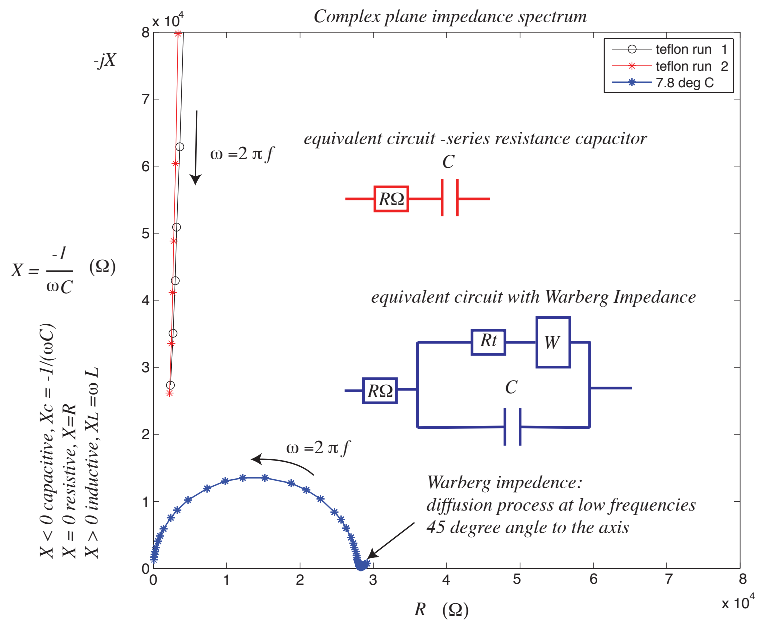

Figure 3: Calibration runs on teflon disc at -23^oC (run 1), -15^oC (run 2), and confined water. An equivalent circuit model has been labeled for the teflon as a series resistance capacitor and for the water as an equivalent circuit (series resistor with a parallel resistance capacitor) with a Warberg Impedence. Equivalent circuit sketched is from Cogger and Evans (1999). Note that only a few frequencies are plotted for the teflon disc (600 Hz to 2 MHz).

References: Cogger, N.D. and N.J. Evans. 1999. An Introduction to Electrochemical Impedence Measurements. Technical Report No. 6 Part No. BTR006. Solartron Limited.

Petrenko V.F. and R.W. Whitworth. [2006] Physics of Ice. Oxford University Press Inc. , New York.

Task 6.0: Make Hydrate and Hydrate/Sediment Conductivity Measurement. The task is scheduled for next quarter and later this year.

Task 7.0: Modeling and Inversion of Field Data. 1D forward modeling has been completed for the entire CSEM data set: ocean bottom electromagnetic receivers and the Vulcan receiver. In some cases the next steps should be 2D forward modeling, particularly where there may be both bathymetric and more complex geologic features. One could argue that this includes all of the CSEM tow lines collected. However, MC 118 has very little bathymetric change across the CSEM tows (probably less then 30 m), and while it does have a salt diapir at about 300 m below the seafloor (McGee et al., 2008), the towed Vulcan data are likely sensing structures no deeper then 300 m (based on the 300m transmitter-receiver offset). Thus 1D OCCAM frequency inversions are probably valid and a good way to explore the data further, and these are in progress. This is very labor intensive as each each transmitter-receiver pair with all of the frequencies recorded constitute a single inversion (amounting to well over 500 inversions for just the Vulcan data at MC 118). We focused our first inversion efforts to selected 'on target' and 'off target' locations based on the frequency pseudosections. The frequency apparent resistivity pseudosections at MC 118 were derived from the total electric field amplitude rather then individual components because the compass failed for this survey. Frequency inversions using the total electric field amplitude have been run above the SE crater ('on target'), giving a half-space resistivity of about 1.15 Ωm, and then off the SE crater ('off target') to the east which resulted in an half-space resisitivity of about 0.6 Ωm. These resistivity values are in close agreement to the frequency pseudosection resistivities presented previously.

In order to understand the limitations of the total electric field amplitude data some synthetic tests are being untertaken. Synthetic inversions on the total electric field amplitude indicate that we need to include higher frequencies (above about 45 Hz) to resolve a 50 m thick 2 Ωm layer buried 50 m below the seafloor using only total electric field amplitude data. We do not have frequencies much about 45 Hz for the Vulcan data, and our navigation is a limiting factor for higher frequencies above 15.5 Hz. However, using frequencies below 15.5 Hz , as was done in making the apparent resistivity pseudosections, we have the problem that in the 10 to 20 Hz range the dipole electric field becomes non-linear (i.e. a 2 Ωm half-space and and 3 Ωm half-space cross in an amplitude-frequency plot) and so the inversion has difficulty. If we used values less then 10 Hz we can only resolve a half-space resistivity – the same results we saw with real data. In order to resolve any other details of structure the individual components Ex, Ey and Ez need to be used. The inclusion of phase data will also help, which means we need to resolve a 3.5 degree phase discrepency at the fundamental frequency.

There are a couple of possible paths to be taken: refine the navigation of the transmitter with an OCCAM inversion (work in progress); start to run 2.5D forward models with the MARE2DCSEM code of Li and Key (2007); continue to understand the inversion sensitivities of Vulcan data and obtain 1D OCCAM frequency inversions for all of the Vulcan data collected.

References:

Key, K. [2009] 1D inversion of multicomponent, multifrequency marine CSEM data: Methodology and synthetic studies for resolving thin resistive layers. Geophysics, 74(2) F9-F20.

Li and Key [2007] 2D marine controlled-source electromagnetic modelling: Part 1- An adaptive finite element algorithm. Geophysics, 72(2) WA51-WA62.

McGee, T., Woolsey, J.R.,Lapham, L., Kleinberg, R.,Macelloni, L., Battista, B., Knapp, C, Caruso, S., Goebel, V., Chapman, R. and 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 2008.

Task 8.0: Estimate Quantitative Hydrate Volumes from Field Models and Laboratory Studies. This task commences later this year.

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. Constable attended the SEG meeting and the Vulcan data was well received with the potential for further research in developing Vulcan systems for third parties. Version 1.0 of the transmitter navigation was distributed to sponsors in early December. At our annual Seafloor Electromagnetics Consortium meeting held March 17 and 18, 2010 Vulcan results at MC 118 were presented and well received. Processed data was distributed to sponsors at the end of March 2010.

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

CONCLUSION. The conductivity cell has been build and tests on ice have been conducted. Initial 1D inversions on Vulcan data have begun.

COST STATUS

Table 1: Project costing profile for Budget Period 1, Quarter 4

Time period	Cost share	DoE Plan	DoE Actual
April 2010	$0	$8000	$7684
May 2010	$0	$8000	$7684
June 2010	$0	$8000	$7684
Totals	$0	$24000	$23052

Salaries:

Karen Weitemeyer, a post-doctorate scholar during the budget review period, charged April, May and June salaries.

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 5.0, work completed. Critical milestone for tasks 6, 8, 9, 10.

Milestone 7: Generate merged EM/navigated data set. Task 4.0, work completed. Critical milestone for tasks 7, 8, 9, 10.

Milestone 8: Construct conductivity/pressure cell Task 5.0, work completed. Critical milestone for tasks 6, 8, 9, 10.

Milestone 9: Make calibration tests of cell using water standard Task 5.0, work completed. Critical milestone for tasks 6, 8, 9, 10.

Milestone 10: Install cell in Menlo Park and make initial hydrate measurements Task 5.0, work not yet started. Critical milestone for tasks 6, 8, 9, 10.

Milestone 11: Preliminary interpretation of field data Task 4.0, work completed.

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

Milestone 13: Produce Phase 1 Report Tasks 1-5, completed 2 November 2009. Task 4 given a 6 month extension.

ACCOMPLISHMENTS

• Collection of the Marine CSEM Field Data

• Conductivity cell completed.

• Processing of the data is completed.

• Two Fire in the Ice article were published one in 2009 and the other in 2010.

• Participated in a "Spot Light on Research" article for Fire in the Ice in 2009.

• Raw data and processed data have been distributed to sponsors (2009, 2010).

• Generated merged transmitter navigation with the CSEM data using the Total field navigation program and distributed this version to the sponsors in early December 2009.

• Generated pseudosections for the 0.5 Hz and 6.5 Hz CSEM data transmissions for all 14 tows of the 4 surveyed areas in the Gulf of Mexico 2010.

• Generated pseudosections for Vulcan at MC 118, GC 955, AC 818, and WR 313 and preliminary interpretations of the data, 2010.

• First Break article published this June (2010).

• Completed calibration tests of cell using water standard.

PROBLEMS OR DELAYS The design and construction of the conductivity was given a six month extension. The conductivity cell has been commissioned and calibration runs on ice have been conducted. We need to review and repeat calibration measurements on a teflon plug. Improvements to the transmitter navigation are ongoing. 1D OCCAM inversions on Vulcan type data will require inverting the individual components, Ex, Ey and Ez rather then using the total electric field amplitude, to do this the phase data needs to be reexamined and for MC 118 the yaw, pitch and roll of the receiver needs to be modeled as the compass failed for this survey.

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.

• Talked at the 2009 MARELEC Meeting - 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

• Submitted the second quarter report April 2009.

• Australian show and tell, and 2 talks

Karen Weitemeyer delivered a presentation at two venues in Canberra, Australia:

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

• Submitted the third quarter report July 2009.

Steven Constable delivered a presentation in Japan:

Marine Electromagnetic Methods for Mapping Gas Hydrate

• Submitted the Phase 1 report October 2009.

• AGU Poster presentation December 2009

Karen Weitemeyer and Steven Constable

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

• DoE Atlanta Hydrate Meeting January 25-29 Talk and Poster

Karen Weitemeyer and Steven Constable

Applying Marine EM Methods the Gas Hydrate Mapping

• Fire in the Ice article published March 2010.

Test of a new marine EM survey method at Mississippi Canyon 118, Gulf of Mexico

• SIO Seafloor Electromagnetics Consortium annual meeting, La Jolla, CA - March 17-18, 2010

Karen Weitemeyer and Steven Constable delivered a presentation:

Results from the GoM gas hydrate studies

• Processed Data distributed to sponsors late March, 2010 and early April, 2010.

• First Break Article published this June (2010).

Mapping shallow geology and gas hydrate with marine CSEM surveys

• Submitted an extended abstract to attend the 20th Electromagnetic Induction Workshop Giza, Egypt September 18-25, 2010 .

Mapping gas hydrates and shallow sedimentary structure in the Gulf of Mexico using marine controlled source electromagnetics

Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-NT0005668."

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