Oil & Natural Gas Technology

DOE Award No.: DE- FE0010141

Quarterly Research Performance Progress Report

(Period ending 12/31/2013)

Submitted January 30, 2014

Temporal Characterization of Hydrates System Dynamics beneath Seafloor Mounds: Integrating Time-Lapse Electrical Resistivity Methods and In Situ Observations of Multiple Oceanographic Parameters

Project Period: October 1, 2012 – October 31, 2015

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Prepared for:

The Department of Energy - Methane Hydrates Program
United States Department of Energy
National Energy Technology Laboratory

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Office of Fossil Energy

RESEARCH PERFORMANCE PROGRESS REPORT

Temporal Characterization of Hydrates System Dynamics beneath Seafloor Mounds: Integrating Time-Lapse Electrical Resistivity Methods and In Situ Observations of Multiple Oceanographic Parameters

ACCOMPLISHMENTS:

Major objectives of the project are to:
1) characterize, geophysically, the sub-bottom distribution of hydrate and its temporal variability and,
2) contemporaneously record relevant environmental parameters (temperature, pressure, salinity, turbidity, bottom currents and seafloor microseismicity) to investigate possible links of the variability to climate. In order to achieve these overall objectives, we have identified the following goals:

a) employ the Direct Current Resistivity (DCR) method as a geophysical indicator of hydrates,
b) identify hydrate formation mechanisms in seafloor mounds,
c) detect short-term changes within the hydrates system,
d) illuminate relationships/impacts of local oceanographic and microseismic parameters on the hydrates system and, indirectly, the benthic fauna,
e) monitor fluid/hydrate motion and seafloor instability that these changes might produce.

Accomplishments achieved in relation to these goals include the following (Quarter 1):

- Completion and acceptance of the Project Management Plan; successful "kick-off,"
- Successful completion and testing (at sea) of the I-SPIDER (patent pending), a new deployment and surveying system,
- Beginning of the assembly and evaluation of existing data from the research site at MC118,
- Renovation of the Direct Current Resistivity (DCR) cable in preparation for the September survey.

Accomplishments achieved in relation to these goals include the following (Quarter 2):

- We have used the I-SPIDER, the Integrated Scientific Platform for Instrument Deployment and Emergency Recovery, successfully on three successive cruises both surveying and deploying instruments;
- CMRET's shop and SDI's shop have coordinated effort to build the communications software that will enable us to have live communication with the DCR array while in survey mode;
- We have completed the consolidation of electronics into a single "topside system" that greatly increases our ability to control and monitor at-sea operations;
- We have installed Ultra-short Baseline (USBL) transponders in the hull of the R/V *Pelican* to maintain our exceptional navigation/locating capabilities while at sea;
- We have made significant progress in processing the 2013 multibeam data from MC118;
- We have established a processing protocol for the new polarity-preserving chirp data from MC118;
- We have begun to build the Integrated Portable Seafloor Observatory (IPSO) lander;
- We have made repairs to the damaged resistivity system resulting from the flooding event, summer 2012;
- We have determined what caused the instrument to flood;
- We have devised a solution to the flooding problem;

- We have begun work to devise a means whereby operation of the array can be accomplished autonomously while on the seafloor;
- We have scheduled two cruises for 2014 on the R/V Pelican: April 7-12 and October 3-6.

Accomplishments achieved in relation to project goals include the following (Quarter 3):

- We have completed the survey-mode communications electronics;
- We have upgraded the SSD and I-SPIDER individually and as a tandem system;
- We have selected primary and secondary target sites for the DCR survey and have plotted the survey;
- We have built the IPSO lander frame, researched and ordered instruments and installed them on the IPSO lander;
- We have begun processing the new polarity-preserved chirp data from MC118;
- We have completed repairs to the seafloor DCR system associated with the housing flooding that occurred in July 2012;
- SDI replaced the power and control though-housing connector to the DCR instrument with one that has higher current capacity;
- We have devised a system whereby the DCR system will be controlled remotely while on the seafloor;
- SDI built the Atom control computer and installed it in a pressure housing;
- We have developed/acquired new control software for autonomous operation of the DCR instrument;
- We have built a stand that will hold the DCR instrument electronics and housing end cap in an inverted position while assembling the DCR housing.

Accomplishments achieved in relation to project goals include the following (Quarter 4):

- We have inventoried data from MC118 that has and will continue to inform our survey and deployment strategies;
- We have established a processing protocol for the polarity-preserving chirp data from MC118;
- We have designed and begun acquiring components for the replacement battery system for the IPSO;
- We have completed a paper describing the new resistivity data processing method that will be used to process the targeting data as a 3D data set;
- We have developed a data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor;
- We have submitted a no-cost extension request to complete Year 1 work that has been approved.

We have inventoried data from MC118 that has and will continue to inform our survey and deployment strategies. These include the following:
1. multibeam (*Okeanos Explorer*); hull-mounted system ~25m resolution; 2011; available online.
2. multibeam of the entire block at 40m above seafloor, 200m spacing; ~1.5m resolution.; acquired in May, 2005, by C&C Technologies; reprocessed most recently in 2011 at MMRI; CMRET owns it.
3. multibeam full Eagle Ray (AUV) survey at 50m above seafloor, 200m line spacing; ~1.5m resolution; Sept-Oct, 2012; only extraneous data removed; belongs to NIUST.
4. multibeam full ER survey of Woolsey Mound at 15m above seafloor, 60m line spacing (.5m resolution); Sept-Oct, 2012; only extraneous data removed; belongs to NIUST.
5. chirp of the entire block at 40m from seafloor, 200m spacing; 10cm resolution; May, 2005, by C&C

Technologies; CMRET owns it.
6. ppchirp full ER survey at 50m above seafloor and 200m line spacing; 10cm resolution; Sept-Oct, 2012; not post-processed; belongs to NIUST.
7. ppchirp full ER survey of Woolsey Mound at 15m above seafloor, 60m line spacing; 10cm resolution; Sept-Oct, 2012; not post-processed; belongs to NIUST.
8. gravity cores; <10m in length; January, 2005;May, 2005; October, 2005; April, 2008; electric logs on representative samples, all logged and described by hand; all logs owned by CMRET.
9. Jumbo Piston Cores (5); 15-18m in length; January 2011; all logged and described by hand. Some electric logs run at Stennis; all logs belong to CMRET.
10. push-cores recovered by the SSD; <.5m; June, 2007; November, 2007; September, 2010; some processed for microbial populations; sent to various Consortium members, i.e. not onsight.
11. full *Mola Mola* photosurvey of key portions of Woolsey Mound; 3m off the seafloor; Sept-Oct, 2012; being mosaicked at NIUST; belongs to NIUST.
12. seismic data from MC118 (high resolution Surface-source-deep-receiver, SSDR).
13. numerous sets of photodata that have been made available to us for a variety of purposes.
13. side-scan from Woolsey Mound; Navy surveys using new AUV: April, 2011.
14. side-scan from about ½ of Woolsey Mound; NR-1; 2007.

We have established a processing protocol for the polarity-preserving chirp data from MC118. Subbottom profiles have been converted and processed for stratigraphic interpretation/analysis. Using a converter developed in-house, the files logged by the subbottom profiler (SBP) in GeoAcoustics condensed format (.gcf) are merged with vehicle log files and exported in a variant of the SEG-Y (.sgy) geophysical data format. Processing and subsequent interpretation can procede using standard seismic tools, such as Kingdom, thereby allowing for analysis of sediment elastic properties and, eventually, the creation of pseudo-3D volumes. The 3D representations can be combined with vehicle-derived bathymetry and backscatter measurements to derive a greater understanding of the seafloor structure. This process will allow selection of the most promising sites for surveys and for deployments of the DCR instrument.

We have designed and begun acquiring components for the replacement battery system for the IPSO. The MMRI/CMRET shop has designed and begun assembling components for construction of the replacement battery that will be needed for the lander recovery and replacement operation scheduled for October, 2014.

We have completed a paper describing the new resistivity data processing method that will be used to process the targeting data as a 3D data set. Baylor graduate student, Tian Xu, and John Dunbar have submitted a paper describing the methods used to process the survey data. The strategy used will be analogous to the binning method applied to marine 3D multichannel seismic reflection data sets. In this approach, individual resistivity readings collected on multiple, irregularly spaced and oriented profiles will be sorted into rectangular bins that subdivide the seafloor. Resistivity readings with the same electrode configuration and offset will be grouped within bins and used to estimate the value of virtual readings made at regularly spaced intervals within the survey area. Once binned to a regular grid of measurements, the data will be inverted to produce a resistivity volume using existing commercial inversion software. This processing strategy has been tested on synthetic datasets of different density generated over idealized 3D anomalies (see Appendix).
Xu, T., Dunbar, J. A., 2013, *Binning method for mapping irregularly distributed continuous resistivity profiling data onto a regular grid for 3D inversion*, Submitted to the Journal of Environmental and Engineering Geophysics, November, 2013.

We have developed a data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor. This system utilizes the new Atom based processor along with previously developed equipment to create a system which can take periodic DCR measurements over a deployment of 6 months. The DCR system to be deployed during the initial cruise was completed and tested. The final system was initialized and put through a series of programmed start and stop and sleep cycles intended to simulate the requirements during the 6 month deployment. By mid-October these tests were completed and the internal battery was put on charge. The system was programmed to sleep until the 2nd day of the cruise at which time final deployment programming was to occur.

Since postponement of the cruise the system was reprogrammed for long-term sleep. Since the system is not connected to its long-term seafloor battery pack, it has been programmed for periodic wake up during which time the internal deployment battery is recharged. We intend to maintain the system in this condition until approximately one month before the planned April cruise date. At this time, a series of pre-deployment checks will be initiated.

We have submitted a no-cost extension request to complete Year 1 work; it has been approved. Several factors contributed to our need to request additional time to complete Year 1 work, primarily the execution of the survey and lander-deployment cruise. The instruments are ready. The primary vehicle, the I-SPIDER is also ready. However, the SSD blew out two thrusters performing a rescue of an AUV in September. Evaluation of the system electronics as well as the thruster electronics revealed flaws in both systems. The MMRI/CMRET has addressed the system issues but Technadyne, manufacturer of the thrusters, has acknowledged the need for a thruster electronics redesign; therefore, the SSD still does not have adequate thruster capabilities to qualify as a reliable ROV. In addition, our group suffered a major personal loss and the sea state in late October would have prevented deployment of the SSD even if it had been in top form. We are rescheduled for April and hope better weather will permit us to complete the cruise tasks and therefore Year 1.

Milestone chart: Milestones A and B are complete; Milestone C cannot be completed until the Year 1 cruise sails.

Milestone	**Planned Completion**	**Actual Completion**	**Verification Method**	**Progress/Deviation from Plan**
Milestone A: Target sites selection for IPSO deployment at MC118	9/15/2013	9/17/2013	4 targets identified	2 days
Milestone B: Successful testing of a new Integrated Portable Seafloor Observatory (IPSO).	9/15/2013	9/25/2013	Successful onshore test of IPSO	10 days
Milestone C: Successful deployment of Integrated Portable Seafloor Observatory (IPSO).	9/30/2013		Proper orientation and functioning of IPSO	
Milestone D: Recover data from MC118 with the IPSO	6/2014		IPSO recovered with data	
Milestone E: Complete analysis of temporal characterization of hydrates system dynamics at MC118	3/31/2015		Resistivity and temporal data produce reasonable temporal analysis	
Milestone F: Complete final report and submit to DOE	6/30/2015		Report accepted by COR	

PRODUCTS:

MMRI/CMRET scientists have, since 2005, studied, reprocessed, and analyzed geophysical datasets from the MC118 area (see Q4 accomplishment 1 for inventory of data). They have deployed instruments here since 2005 and have developed a variety of successful methods. These have formed the foundation of the new lander and instrument array to be deployed during the initial cruise for this project.

An abstract was submitted and accepted for development into a full paper for the 2013 Transactions of the Gulf Coast Association of Geological Societies (GCAGS). This paper has been written, reviewed, revised and resubmitted (June). It was presented at the Annual Meeting of the GCAGS in New Orleans in October. Part of the paper includes innovative treatment of multibeam data from acquisition through post-processing and analyses. This constitutes another product, or cluster of products, in the form of maps of the research site. These are being used in all stages of the project including the planning of the cruises and selection of target sites for data-collection and potential deployment sites for the resistivity array. Additional products include:

- Lutken, C. B., D'Emidio, M., Macelloni, L., Lodi, M., Ingrassia, M., Pierdomenico, M., Asper, V., Woolsey, M., Jarnagin, R., Diercks, A., 2013, *Challenges in imaging the deep seabed: examples from Gulf of Mexico cold seeps,* Transactions of the Gulf Coast Association of Geological Societies, New Orleans, October 6-8.
- A paper describing the new resistivity data processing method that will be used to process the targeting data as a 3D data set has been written and submitted for publication:
  Xu, T., Dunbar, J. A., 2013, *Binning method for mapping irregularly distributed continuous resistivity profiling data onto a regular grid for 3D inversion*, Submitted to the Journal of Environmental and Engineering Geophysics, November, 2013.
- Post-processing of polarity-preserved chirp data acquired in 2012 from Woolsey Mound (MC118) is underway. When processing is complete, this dataset will be used along with simultaneously-acquired multibeam data (already processed) to refine and reinforce selection of target sites for the resistivity active study and for sites at which to deploy the resistivity array.
- A submission to G-3 has been made, reviewed and returned for revision, revised and resubmitted. The resubmission has been accepted for publication:
  Wilson, Rachel M., Leonardo Macelloni, Antonello Simonetti, Laura Lapham, Carol Lutken, Ken Sleeper, Marco D'Emidio, Marco Pizzi, James Knapp, and Jeff Chanton, *Subsurface methane sources and migration pathways within a gas hydrate mound system, Gulf of Mexico.*

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

During this quarter, personnel from the University of Mississippi and from both subcontracting organizations participated in the project. Their contributions are as follows:

Name: Carol Lutken
Project Role: PI, University of Mississippi
Nearest person month worked: 0 (1 week)
Contribution to Project: Lutken worked with the MMRI shop to describe and acquire parts and repairs for the SSD and then to reschedule the work for repairs following the rescue of the NIUST photo-AUV. She continues to work with D'Emidio to analyze subsurface data available from MC118. She compiled information for and wrote the quarterly progress report. She worked with the DOE COR to propose and write the request for the No-Cost Extension to Year 1 of the project. She executed all communications between participants and with DOE and LUMCON and made arrangements to postpone the October cruise and reschedule the work for the April, 2014 dates.

Name: Marco D’Emidio
Project Role: Scientist, University of Mississippi
Nearest person month worked: 0 (1 week)
Contribution to Project: D’Emidio worked with electronics and computing engineers at NIUST to finalize the ppchirp format and processing. He is working to complete the processed ppchirp dataset prior to the April deployment cruise.

Name: Matt Lowe
Project Role: Marine Systems Specialist, University of Mississippi
Nearest person month worked: 0 (2 weeks)
Contribution to Project: Lowe is the Chief of shop operations at MMRI/CMRET. During this quarter, he and the shop team completed the design and integration plan for the replacement battery systems for the IPSO lander. He continues to mastermind improvements and repairs to the ROVs. He is engaged in upgrading electronics and the thruster systems of the SSD.

Name: Steven Tidwell
Project Role: Research Associate, University of Mississippi
Nearest person month worked: 0 (2 weeks)
Contribution to Project: Tidwell is the MMRI/CMRET shop technician with a degree in geological engineering and expertise in machining and electronics as well as computer software. During this quarter, he worked to define and collect components that will be needed to construct the replacement battery for the IPSO.

Name: John Dunbar
Project Role: Co-I, Baylor University
Nearest person month worked: 1 (3 weeks)
Contribution to Project: Dunbar has worked with Xu to define the processing of resistivity data collected during survey mode. This will determine the final site selection for deployment of the DCR instrument for a 6-month period. He also worked on the final testing of the seafloor monitoring system.

Name: Tian Xu
Project Role: Graduate student, Baylor University
Nearest person month worked: 2 (8 weeks)
Contribution to Project: Xu worked with Dunbar to define the processing of resistivity data collected during survey mode. This will determine the final site selection for deployment of the DCR instrument for a 6-month period. Xu is the primary author on the paper resulting from this work.

Name: Paul Higley
Project Role: Co-I, Specialty Devices, Inc.
Nearest person month worked: 0 (0 weeks)
Contribution to Project: Higley instructed the electronics and programming staff who developed the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor.

Name: Scott Sharpe
Project Role: Electronics specialist, Specialty Devices, Inc.
Nearest person month worked: 0 (0 weeks)
Contribution to Project: Sharpe instructed the electronics and programming staff who developed the

data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor.

Name: SDI Technical staff
Project Role: Electronics and technical support, Specialty Devices, Inc.
Nearest person month worked: 4 (15 weeks)
Contribution to Project: Worked with Higley and Sharpe to develop the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor.

Name: SDI Programmer staff
Project Role: Electronics and programming support, Specialty Devices, Inc.
Nearest person month worked: 1 (5 weeks)
Contribution to Project: Worked with Higley and Sharpe to develop the data acquisition and communication and control system to allow long term deployment of a DC resistivity array on the sea floor.

IMPACT:

In September, the I-SPIDER and SSD were used together to rescue a $600,000 NIUST photo-AUV that had become unresponsive on the seafloor. Due to the Herculean effort put forth by the MMRI shop team, we were put behind in our other projects, including this DCR effort. However, benefits of this set-back are that the SSD will have upgraded thrusters and electronics prior to the next trip. So now in addition to its functions of reconnoitering seafloor deployment sites, providing visuals on bubble streams and benthic communities, carrying instruments and landers to the optimal/selected site and releasing the payload on command, it has added AUV/instrument emergency recovery. It has been used alone and in concert with other systems and is the ROV of choice for the DCR survey. This system is designed to reduce risk to equipment in a hazardous environment and to improve a researcher's chances of recovering data and to recover data from the precise location or environment targeted. It will be used in this project to emplace instruments/arrays in premier locations and to conduct surveys that include visual data matched precisely to location and to other datasets.

The survey and deployment efforts of the resistivity instrument via the I- SPIDER will be guided by the use of seafloor imagery in-hand. We have extended the amount of processed high resolution multibeam data relevant to this project and are moving into backscatter extraction for the 2012 dataset. During this quarter, the ppchirp data conversion capability has been completed, so we should begin producing and analyzing shallow-subbottom profiles soon. We anticipate that the shallow profiles will be able to be collated with hydrate sampled and detected via resistivity surveys and hope that will lead to its use as a prospecting tool for shallow hydrates.

Government, survey companies, seismic data-acquisition companies, other research facilities and hydrocarbon companies and their support industries rely upon seafloor imagery to site, survey, build, operate and decommission seafloor structures. With more detailed information from the seafloor and shallow subseafloor, including the hydrate stability zone (HSZ), these operators can achieve their goals in a safer and more efficient manner. They can also use the improved definition to focus on preferred sites and eliminate sites without characteristics that recommend others, saving needless expense and reducing risk.

Students and interns have long been a vital part of our projects. The methods that we have developed and that we are developing and are using, have been tested and some of them developed by students. We encourage these students to participate at all levels and expect at least one student to go to sea with us on every cruise in this project, as part of the scientific crew. We hope to have at least one student as a participant in the geological effort of this project and to add a student/intern as part of our shop team.

The collaboration of our shop with the NIUST shop has continued to be productive. Their expertise in electronics has enabled us to duplicate the electronics box and to make spare cards for the I-SPIDER so that when we do go to sea next, we will not be shut down if one of these functions goes down. We are doing our best to predict and prepare for any and all problems that may arise when we are at sea.

CHANGES/PROBLEMS:

Changes to this project that have been made this quarter derive from the changes in our schedule related to the demands made on our ROVs, to weather and to personal losses that impacted the availability of team members for the October cruise. As the scheduling of time and tasks at sea has changed, so our work schedule, spending schedule and achievements schedule will change. Our first cruise has been shifted to the first week in April (previously scheduled for the second cruise). Our lander and DCR instrument are ready and the DCR housing has passed the pressure testing Go/No-Go requirement. There have not been changes in approach since the addition of the I-SPIDER to our "fleet" of ROVs available to the project. Delays in our ability to execute the fall cruise were the major cause for our no-cost extension request that has been granted. Some changes that are currently being addressed are:

- The I-SPIDER has now been operated successfully on five cruises as a survey and deployment tool as well as a rescue vehicle, performing excellently in every case. We plan for the upgraded Station Service Device ROV to be available as an option for use in concert with the I-SPIDER. Particularly for survey mode, we hope to accomplish the projects goals using the I- SPIDER, primarily because we will be able to monitor the survey, visually, as it is happening, thus avoiding hazards while acquiring the ability to match seafloor environment with resistivity anomalies. Should the SSD not be ready in April, we will proceed without it.
- Dunbar has rebudgeted his student, making use of teaching assistant funds so that student support for this project will still cover the student throughout the cruise and data-collection/processing segments of the project.
- Our cruise schedule has shifted. With no additional cost to the project, we will spread our time out to be sure to be prepared to go to sea while staying within the confines of the original budget.

SPECIAL REPORTING REQUIREMENTS:

None noted.

BUDGETARY INFORMATION:

The expenses incurred during this quarter have been charged to both direct charges and cost-sharing. Subcontractors Higley and Dunbar have also charged time to the project as noted in the expenditure of time report. Higley's subcontract has been issued so charges – including some for work perfomed in Q1, Q2 and Q3 - have been made to it. Please see the budget report spread sheet, below.

DOE Hydrates FY12 DE-FE0010141 Baseline Reporting by Quarter	Budget Period 1								Budget Period 2								Budget Period 3			
	Quarter 1 - Corrected		Quarter 2		Quarter 3		Quarter 4		Quarter 1		Quarter 2		Quarter 3		Quarter 4		Quarter 1		Quarter 2	
	1/1/13 - 3/31/13		4/1/13 - 6/30/13		7/1/13 - 9/30/13		10/1/13 - 12/31/13		1/1/14 - 3/31/14		4/1/14 - 6/30/14		7/1/14 - 9/30/14		10/1/14 - 12/31/14		1/1/15 - 3/31/15		4/1/15 - 6/30/15	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total
Baseline Cost Plan																				
Federal Share	127,121	127,121	127,120	254,241	209,200	463,441	127,120	590,561												
Non-federal Share	36,912	36,912	36,912	73,824	36,912	110,736	36,912	147,648												
Total Planned	164,033	164,033	164,032	328,065	246,112	574,177	164,032	738,209												
Actual Incurred Cost																				
Federal Share	-	-	8,592	8,592	86,331	94,923	201,745	296,668												
Non-federal Share	22,599	22,599	5,770	28,369	12,584	40,953	-	40,953												
Total Planned	22,599	22,599	14,362	36,961	98,915	135,876	234,791	370,667												
Variance																				
Federal Share	127,121	127,121	118,528	245,649	122,869	368,518	(74,625)	293,893												
Non-federal Share	14,313	14,313	31,142	45,455	24,328	69,783	36,912	106,695												
Total Planned	141,434	141,434	149,670	291,104	147,197	438,301	(70,759)	367,542												

Appendix A.
Preparation for processing initial reconnaissance DCR data

There will be two phases of work during the upcoming cruise to MC118 in April, 2014. The goal of the initial phase will be to locate a suitable resistivity anomaly for long term monitoring. This will be done by collecting multiple, closely spaced, resistivity profiles across a fault trace along which high resistivity anomalies were observed in the 2009 reconnaissance survey of the site. Ideally, the profiles would be 1 km long and spaced approximately 50 m apart along the trace of the fault trace. These profiles will be processed in real time, as the electrode array is being repositioned for the next profile. Profiles will be collected in this way until a suitable monitoring target is identified. Once this task is complete, the DCR system will be retrieved, reconfigured for the autonomous monitoring operation, and redeployed over the chosen target. Once the initial deployment cruise is complete, we plan to reprocess the initial targeting data as a 3D swath volume. This will provide a 3D resistivity image of the targeted anomaly to serve as a context within which to interpret the repeat 2D profiles collected during monitoring. The 3D resistivity swath will also test the potential value of collecting such data sets over entire seafloor mounds in the future.

During this quarter graduate student Tian Xu and John Dunbar completed a paper describing the new resistivity data processing method that will be used to process the targeting data as a 3D data set. The strategy used will be analogous to the binning method applied to marine 3D multichannel seismic reflection data sets. In this approach, individual resistivity readings collected on multiple, irregularly spaced and oriented profiles will be sorted into rectangular bins that subdivide the seafloor. Resistivity readings with the same electrode configuration and offset will be grouped within bins and used to estimate the value of virtual readings made at regularly spaced intervals within the survey area. Once binned to a regular grid of measurements, the data will be inverted to produce a resistivity volume using existing commercial inversion software. This processing strategy has been tested on synthetic data sets of different density generated over idealized 3D anomalies (Figures 1 - 3) and to process resistivity data collected in a water reservoir on Maui, Hawaii (Figures 4 and 5).

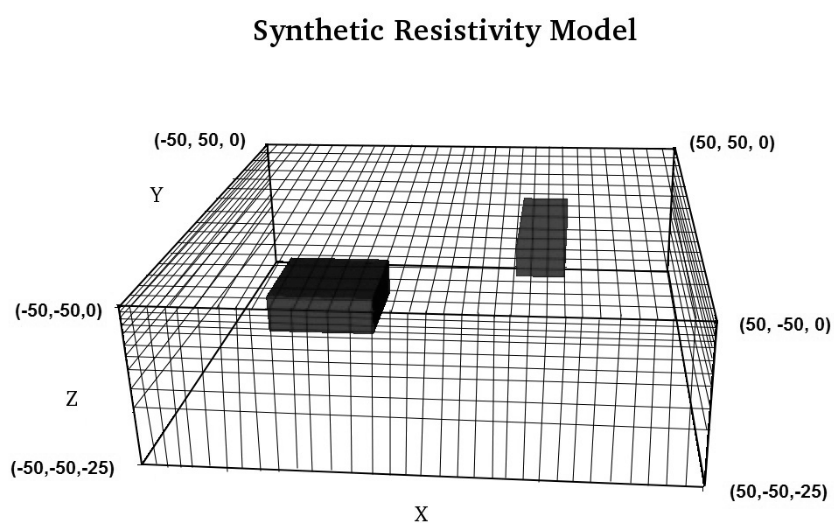

Figure 1. Synthetic resistivity model used to test 3D resistivity data binning method. Model dimensions are in meters.

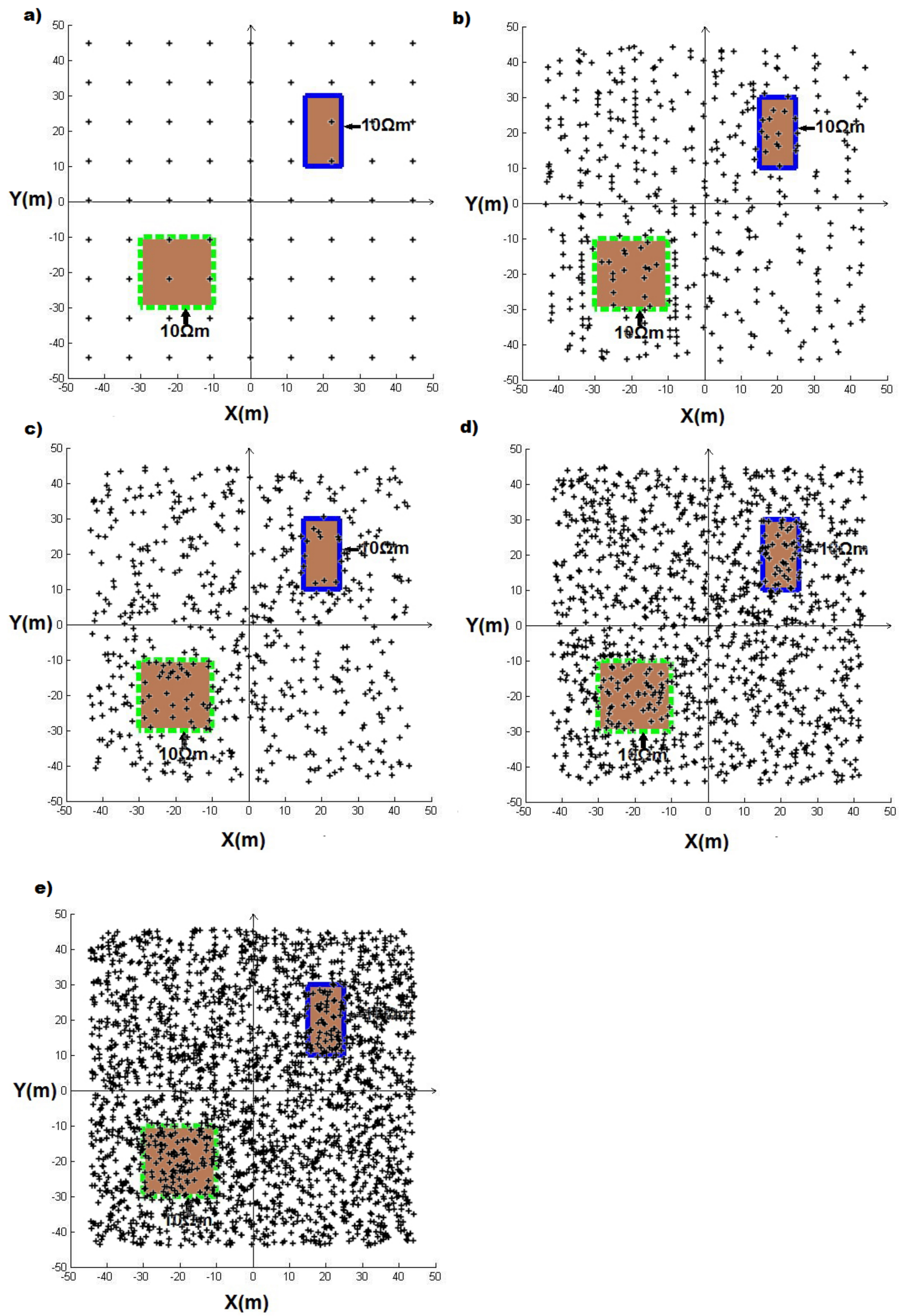

Figure 2. Locations of synthetic resistivity data. Synthetic data set of different data density collected over the model shown in Figure 1.

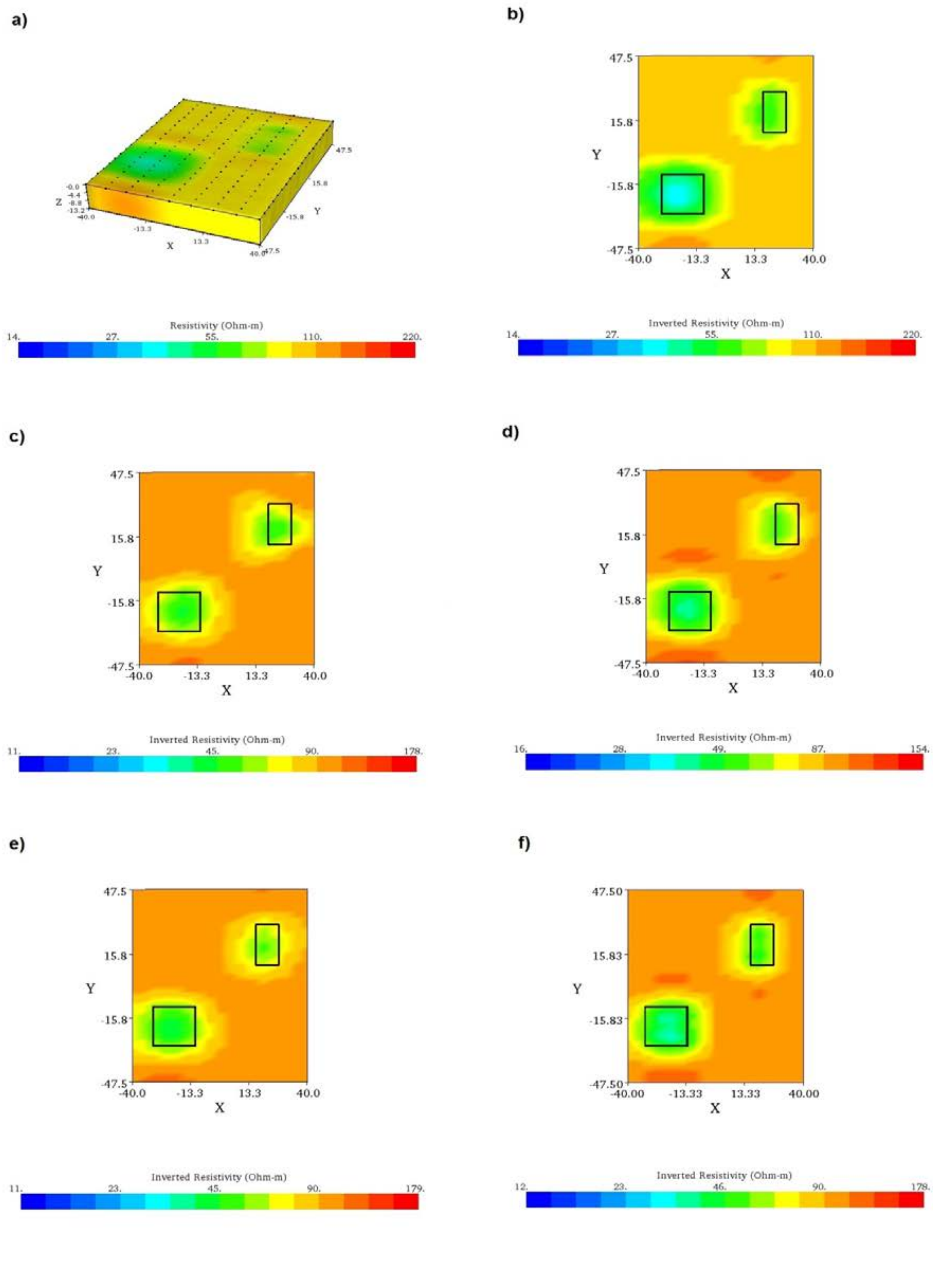

Figure 3. Inverted resistivity volumes for synthetic data sets shown in Figure 2.

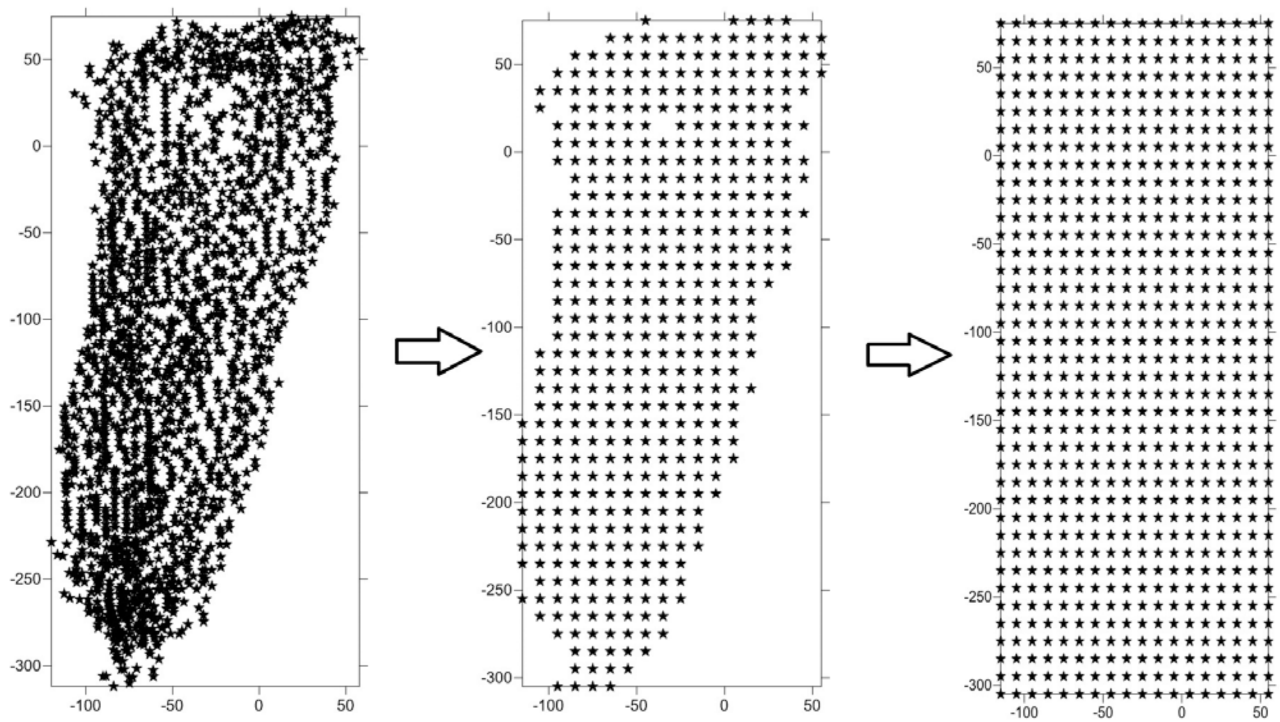

Figure 4. Binning of field data collected in a water reservoir on Maui, Hawaii. The dimensions of the reservoir are in meters.

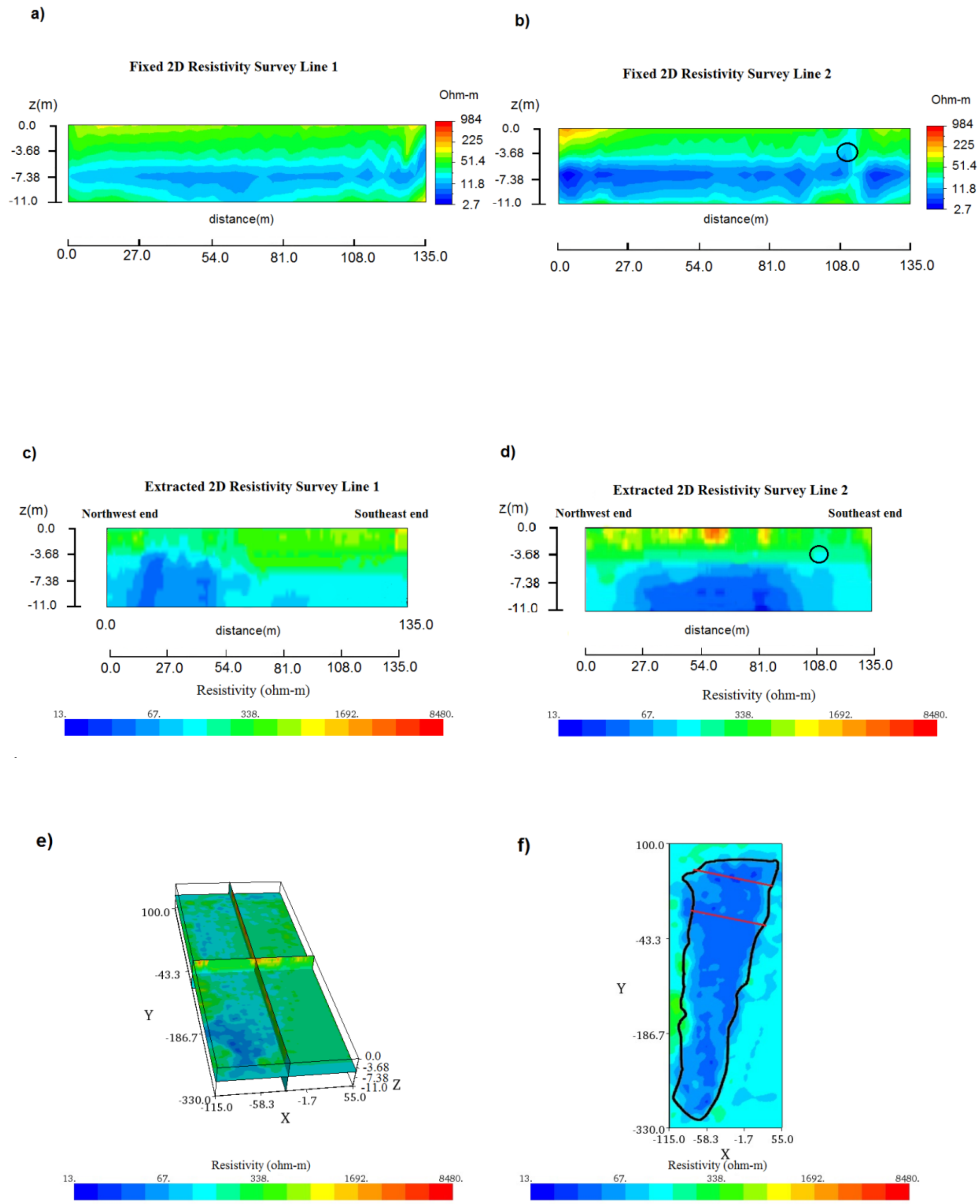

Figure 5. Views of 3D inverted resistivity volume from binned resistivity field data. The spatial pattern and density of resistivity data are shown in Figure 3. Dimensions are shown in meters.