Electrical Resistivity Investigation of Gas Hydrate Distribution in Mississippi Canyon Block 118, Gulf of Mexico

Prime Recipient
John A. Dunbar
Baylor University
Department of Geology
Waco, Texas

DOE Award Number
DE-FC26-06NT42959

NETL Project Manager
Richard Baker

January 9, 2007
Objectives

Project Objectives

- Evaluate direct-current electrical resistivity (DCR) method for use in hydrate exploration and production.
- Characterize the sub-bottom distribution of hydrate within Mississippi Canyon Block 118, Gulf of Mexico (MC 118).
- Monitor change in hydrate concentration/distribution over time.

Phase Objectives

- **Phase 1**
  - Reconfigure commercial DCR system for ocean-bottom deployment.
  - Evaluate DCR method in survey mode, using bottom-towed configuration.
- **Phase 2**
  - Reconfigure DCR system for fixed, autonomous seafloor operation.
  - Evaluate DCR method in long-term monitoring mode.
Expected Benefits

- Low-cost evaluation of potentially critical technology.
- Expandable to commercial-scale, high-spatial resolution, 3D/4D mapping of hydrate concentration.
- Contribute to fundamental understanding of thermal-gas hydrate systems.
Project Organization

**Baylor University, Waco, Texas (John Dunbar)**
Shear wave seismology, marine seismic acquisition, sub-bottom profiling and electrical methods.

Geophysical data acquisition, processing, and interpretation.
Federal funds $157,256.

**Advanced Geosciences, Inc., Austin, Texas (Mats Lagmanson)**
Commercial DCR systems for engineering, mining, and environmental applications.

Electronic components for DCR system.
Federal funds $58,330.

**Specialty Devices, Inc., Wylie, Texas (Paul Higley)**
Electrical/ocean engineering, marine acoustics, deep-sea ROVs.

Assembly of ocean-bottom DCR system, field deployment.
Federal funds $62,500.
Background
Active-Source Geophysical Methods

Borehole Geophysics

Sonic Logging => Reflection/Refraction Seismology
Induction Logging => Controlled Source EM
Resistivity Logging => Direct Current Resistivity (DCR)

Surface Geophysics
Why Use Electrical Methods to Explore for Hydrates?

- Seismic velocity is sensitive to the presence of hydrate at low saturation, but is less sensitive to changes at high saturation.
- Resistivity changes progressively with the degree of saturation (Archie’s law).
Direct Current Resistivity Method (DCR)
Modern DCR Methods

- **Multi-electrode acquisition**
  - Computer controlled
  - Tens to hundreds of electrodes
  - 8 channels
  - 2D and 3D
  - Land and shallow marine
  - Depths $\leq$ 500 m

- **Tomographic inversion**
  - Poisson’s - equation based
  - Automated
  - 2D and full 3D*
  - PC based*
  - Time-lapse
Shallow Marine DCR System,
Lake Whitney, Texas
Example Inverted DCR Sections from Lake Whitney, Texas
Phase 1: Evaluation for use in Reconnaissance Surveys for Deep-Sea Hydrates

- Task 1.1 – 1.4: Construction prototype seafloor DCR system.
  - Problem: Adaptation of commercial, shallow-marine DCR system for deep-sea application.
  - Risk: Unforeseen technical problems.

- Tasks 1.5 - 1.7: Survey of region of known gas hydrate occurrence.
  - Problem: Avoiding seafloor obstacles, while achieving adequate spatial coverage within target area.
  - Risk: Equipment or logistical failure.
  - Deliverables for Phase 1:
Interior of AGI, SuperSting, DCR Control Module
Instrument Pressure Housing Design
Bellamare, Inc., La Jolla, California
Synthetic Forward Model
200 m thick Hydrate, 56-electrode, 1100 m Array
Inverted Resistivity Section from Synthetic Model
1100 m Array

Iteration = 5; RMS error = 2.99%
Relative Sensitivity Section
1100 m Array
Gas Hydrate Sea Floor Observatory - Mississippi Canyon Block 118
Zero-offset Reflection Profile over Vertical Array Site
Reconnaissance DCR Survey of MC 118
Phase 2: Evaluation of DCR Method for Future 4D Monitoring of Hydrate production

- **Tasks 2.1-2.3:** Reconfigure system for long-term, seafloor operation.
  - **Problem:** Integration of DCR system into site infrastructure.
  - **Risk:** Unforeseen problem in reconfiguring the system.
  - **Critical Milestone:** Semi-autonomous operation by the end of 6/2008.

- **Tasks 2.4-2.6:** Long-term monitoring.
  - **Problems:** Power, data storage, data retrieval.
  - **Risks:** Equipment failure during long-term deployment.
  - **Critical Milestone:** Analysis of monitoring data complete by end of 9/2009.
Phase 2: Long-term Fixed Monitoring
Data will be accessed at the sea surface on acoustic command using a custom-made device dubbed the “Big M”.
# Project Budget

## Phase 1 schedule and expenditures.

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Requested Amount</th>
<th>Baylor U Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1 – Bottom-Towed DCR Survey of MC 118</strong>&lt;br&gt;October 2006 – Mar. 2008</td>
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<tr>
<td>Task 1.3</td>
<td>Jan. - June 07, Adaptation of DCR System.</td>
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<tr>
<td>Components for AGI SuperSting R8 IR</td>
<td>35,000</td>
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<tr>
<td>56 graphite electrodes and connectors from AGI</td>
<td>8,560</td>
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<tr>
<td>Construction of bottom-towed array by SDI</td>
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<td>Pressure Housing and Assembly by SDI</td>
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<td><strong>Task 1.4</strong> April-June, 07 Test of Seafloor DCR System</td>
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<td><strong>Task 1.5</strong> July-Dec., 07 Bottom-Towed DCR Survey of MC 118</td>
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<td><strong>Task 1.6</strong> Oct. 07– Mar., 08, Analysis of DCR Survey Data</td>
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<tr>
<td>Salaries</td>
<td>7,141</td>
<td>21,742</td>
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<tr>
<td>Travel</td>
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<td>Publication charges</td>
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<tr>
<td>Fringe benefits</td>
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<td><strong>Total direct cost Phase 1</strong></td>
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<td>Overhead</td>
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<td><strong>Phase 1: totals</strong></td>
<td>133,640</td>
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### Project Budget

**Phase 2 schedule and expenditures.**

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<td>January 2008 to August 2009</td>
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**Task 2.1 April-June, 2008, Remote Operation DCR Monitoring System**

- Remote control unit for SuperSting System: 14,770
- Seabed platform by SDI: 9,500
- Cabling to central seabed power and data storage: 3,000

**Task 2.2 April-June, 2008, Re-configuration of DCR System for Long-Term Monitoring**

- Remote control unit for SuperSting System: 14,770
- Seabed platform by SDI: 9,500
- Cabling to central seabed power and data storage: 3,000

**Task 2.4 June-Dec. 2008, Deployment of Long-Term Monitoring DCR System**

**Task 2.5 Jan. – Sept. 2009, Participation in Periodic Data-Retrieval Cruises**

**Task 2.6 Jan.-Sept.2009, Analysis of DCR Long-Term Monitoring Data**

**Task 2.7 July-Sept. 2009, Final Report**

**Salaries.**

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**Travel.**

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**Publication charges**

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**Fringe benefits**

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**Total direct cost for Phase 2**

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**Overhead**

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**Phase 2: totals**

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**Project totals**

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<td>278,166</td>
<td>68,885</td>
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Commercial-Scale Exploration DCR System

Specifications
- Peak Current: 6 amps
- Channels: 100 - 200
- Streamer Length: 2 - 3 km
- Penetration: 400 - 600 m
- Continuous Survey Speeds: 4 - 5 knots
Commercial-Scale 4D, DCR Monitoring System

Specifications
- Static 3D array
- 100s of channels
- 1000s of electrodes
- Image on daily basis