Deepwater Methane Hydrate Characterization and Scientific Assessment

DE-FE0023919

Peter Flemings & the UT-GOM² Science Team

University of Texas at Austin

U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 13-16, 2018
Presentation Outline

• Introduction
• The UT-GOM2-1 Expedition
• Laboratory Results
Introduction

What is methane hydrate?

\[ CH_4 \cdot 5.75H_2O \]

(Collett et al., 2009)
Methane Hydrate as an Energy Resource

US Gas Reserves: 350 TCF
Global Gas Reserves: 6850 TCF

(from Fire and Ice, Fall 2006, Boswell & Collett)
Production tests of increasing scale in Japan and China

In Gulf of Mexico 4,000 TCF recoverable methane in hydrate sands

2012 US Consumption ~25 TCF
(http://www.eia.gov/tools/faqs/faq.cfm?id=33&t=6).
(Frye 2008)

2017: China completed its first test exploration in the South China Sea on July 9, which lasted 60 days. Total output exceeding 300,000 cu m and daily output surpassed 5,000 cu m/day.

In Gulf of Mexico 4,000 TCF recoverable methane in hydrate sands

20,000 m³/day—2013 (6 days)
8300 m³/day—2017 (24 days)

Chinese technicians check their combustible ice mining equipment during an on-the-spot operation in Shenhu Area in the South China Sea, 320 kilometers southeast of Zhuhai city, Guangdong province. [Photo by Guo Junfeng/China Daily]
Where are we today?

• Massive natural gas reserves trapped in hydrates in the deepwater
• For coastal nations with limited energy resources--a potential domestic energy source to provide energy security today.
• Can we produce environmentally, safely and economically?
• What are the basic flow and mechanical properties of these systems so that we can understand this behavior?
The Challenge: Systems understanding of methane hydrate genesis and dissociation

- At the heart of how we produce
- Need physical samples to develop detailed experimental program
- Marine physical samples never acquired in U.S. Program

Boswell et al., 2016
## Technical Status

7 year ~$94MM ($64MM Federal) drilling and science program to study coarse-grained methane hydrate deposits

- UT-GOM2-1 Engineering Test (2017)
- UT-GOM2-1 ~60 day Coring, in-situ testing program (2020)
UT GOM2-1 Executed Spring 2017

May 2   Mobilize
May 11  Execute
May 23  Demobilize
May 26  Establish shore-based lab
June 3   Complete Operations
UT-GOM2-1 Goals:

- Previous drilling inferred gas hydrate in sands
- Need physical samples to determine petrophysical properties
- Goal: capture pressure cores across hydrate bearing interval:
  - Gas source
  - Pore water composition
  - Sediment texture
  - Hydrate concentration
  - Hydrate Habit
  - Permeability
  - Relative Permeability
## UT-GOM2-1 Expedition Team

### Onboard scientists
- Tim Collett, USGS
- Ann Cook, Ohio State University
- Skyler Dong, University of Texas
- Peter Flemings, University of Texas
- Gilles Guerin, Columbia University
- Melanie Holland, Geotek
- Kevin Meazell, University of Texas
- Joshua O’Connell, University of Texas
- Peter Polito, University of Texas
- Alexey Portnov, Ohio State University
- Manasij Santra, University of Texas
- Peter Schultheiss, Geotek
- Yongkoo Seol, NETL-DOE

### Shore-based scientists
- Ray Boswell, NETL-DOE
- Athma Bhandari, University of Texas
- Rick Colwell, Oregon State University
- Sheng Dai, Georgia Institute of Technology
- Hugh Daigle, University of Texas
- Tom Darrah, Ohio State University
- David DiCarlo, University of Texas
- David Divins, University of New Hampshire
- Nicolas Espinoza, University of Texas
- Matt Frye, BOEM
- Jennifer Glass, Georgia Institute of Technology
- David Goldberg, Columbia University
- Meytal Higgins, ExxonMobil
- Junbong Jang, USGS
- Joel Johnson, University of New Hampshire
- Joel Kostka, Georgia Institute of Technology
- Jung-Fu Lin, University of Texas
- John Pohlman, USGS
- Derek Sawyer, Ohio State University
- Evan Solomon, University of Washington
- Zara Summers, ExxonMobil
- Carla Thomas, University of Texas
- William Waite, USGS
- Cliff Walters, ExxonMobil
- Kehua You, University of Texas

### Management/Administration
- Anisa Abdulkader, University of Texas
- Jac Erengil, University of Texas
- Tessa Green, University of Texas
- Colleen Morgan, University of Texas
- Jamie Morrison, University of Texas
- Katherine Perry, University of Texas
- Steve Rosen, University of Texas
- Judy Sansom, University of Texas
- Carla Thomas, University of Texas

### Education/outreach
- Anton Caputo, University of Texas
- Drew Ott, Desolate Films

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Huge thanks to UTIG, UT Legal Affairs, Risk Management, and Purchasing Offices
Making up BHA

Spud-in for H002 Well
Recovering pressure core
What are pressure coring tools?

http://www.jamstec.go.jp/cdex/e/developtec/coring/category03/

01 – Flemings, et al., GOM2: Prospecting, Drilling and Sampling Coarse-Grained Hydrate Reservoirs in the Deepwater Gulf of Mexico
• 12 successful pressure cores in main hydrate reservoir
Lithofacies

**Lithofacies 2**
- Interbedded with lithofacies 3.
- Low density (2.05-2.1 g/cc) and high velocity (3000-3250 m/s)
- Ripples and/or cross-bedding.
- Most continuous underformed samples.

**Lithofacies 3**
- Interbedded with lithofacies 2
- High density (~1.9g/cc) and low velocity (~1700 m/s)
- Generally massive and more deformed
PCATS – X-ray CT

Lithofacies 2
‘Sand’ is ‘sandy silt’ (Meazell, in prep)

- Clay: d(0.5) = 13 μm
- Sand: d(0.5) = 48 μm

Facies 3

Grain size bin (μm)

Frequency (%)
Hydrate Concentration ($S_h$)

Examples from ~20 cm length sections

- H005-1FB-3 (lithofacies 1)
- H005-4FB-2 (lithofacies 2)
- H005-4FB-5 (lithofacies 3)

$S_h=87\%$
$S_h=32\%$
$S_h=0.5\%$
### Hydrate Concentration ($S_h$)

**Core H005-04FB**

<table>
<thead>
<tr>
<th>Core depth (cm)</th>
<th>A: Gamma density</th>
<th>B: P-wave velocity</th>
<th>C: X-ray</th>
<th>D: Lithofacies</th>
<th>E: Sh</th>
<th>F: Grain size</th>
<th>G: Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>H: C1/C2</th>
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<tr>
<td>10</td>
<td>1.5 G/CM³</td>
<td>1500 M/S 3500</td>
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<td>87</td>
<td>44</td>
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</table>

**Legend:**
- Yellow: Lithofacies 2
- Gray: Lithofacies 3
Really Dry Gas

- Nearly pure methane
- Ethane < 200 ppm

Ongoing gas analyses
- Methane $\delta^{13}C$ and $\deltaD$
- Noble gases
- Clumped methane isotopes $\Delta^{18}$
Ongoing Experimental Analysis: UT Pressure Core Center

(a) Pressure Core Chamber and Mini-PCATS

(b) K0 Permeameter
K0 Permeability Measurement

- Tests pre- and post-dissociation
- Consolidation at Hydrostatic stress
- Consolidation K0 condition
- 3 permeability tests per stress state

(22 consolidation tests & 61 perm tests)
Initial Permeability Measurements

- Effective permeability (Sh=0.8): ~$10^{-2}$ mD to ~$10^{-3}$ mD pre-dissociation
- Absolute permeability: ~0.5 mD to $10^{-2}$ mD post-dissociation
- Mudrock layer in sample may drive low permeability measurement
Initial Permeability Measurements

(3) Result of Compressibility

Consolidation Timing:

- **Pre-dissociation:**
  1) Consolidation under hydrostatic stress
  2) Consolidation under K0 conditions
     
     Compressibility index $C_c = 0.09$

- **Post-dissociation:**
  3) Consolidation under K0 conditions
  4) Unloading and reloading under K0 conditions
     
     Compressibility index $C_c = 0.15$
Lessons Learned

– Extensive resources must be allocated to project management
– Permitting process is exhaustive and requires enormous focus and commitment.
– Must have strong institutional support (bonding, permitting, contracting, insurance).
– Pressure coring is still a developing technology:
  • Must bench and field test all equipment prior to going to sea.
  • Cannot make even minor changes after field testing
– Laboratory testing of pressure cores is a time-intensive process continually pressing the boundaries of technology
– Permitting process should begin earlier.
Synergy Opportunities

– We are a global resource that supports research into hydrate system
  • Technical Advisory Group reviews sample requests.
  • Samples to NETL, USGS, JOGMEC (Japan)
  • Open Shared testing of pressure coring tools with Japan
Project Summary

– Key Findings

• Interbedded clayey silt and silty sand at cm to m scale.
• ‘Sand’ is ‘sandy silt’
• 90% hydrate saturation in silty sand; lithology controlled.
• Really dry gas
• In situ salinity is near seawater
• Permeability (1 sample with a mudstone layer in it!)
  – Effective permeability (Sh=0.8) : ~10-2 mD to ~10-3 mD pre-dissociation
  – Absolute permeability: ~0.5 mD to 10-2 mD post-dissociation
Project Summary

– Steps Forward: UT GOM2-2
  • Explore for new hydrate location
  • Drill and Core 2nd depositional environment (sheet sands)
  • Perform in-situ testing (permeability, pressure).
  • Acquire high technology logging suite across hydrate
  • Full suite of pressure coring and standard coring to capture downhole behavior.

– Steps Forward: International Experimental Program
  • Systematic analysis of hydrate petrophysics through U.S. and international partners.
Appendix

– These slides will not be discussed during the presentation, but are mandatory.
Benefit to the Program

• This effort will acquire and analyze the petrophysical properties of hydrate-bearing coarse grained reservoirs.

• It will address the question of how to produce them environmentally, safely and economically.

• Specifically, it will determine what are the basic flow and mechanical properties of these systems so that we can understand this behavior?
Project Overview
Goals and Objectives

• Describe the project goals and objectives in the Statement of Project Objectives.
  – How the project goals and objectives relate to the program goals and objectives.
  – Identify the success criteria for determining if a goal or objective has been met. These generally are discrete metrics to assess the progress of the project and used as decision points throughout the project.
• Project Team
  – **The University of Texas Institute for Geophysics** is the prime contractor, responsible for leading development and execution of all scientific, technical, and logistical aspects of the project.
  – There are five sub-recipients on this project:
    • **Ohio State University**: Site characterization and technical science lead
    • **Oregon State University**: Microbiology lead
    • **University of New Hampshire**: Lithostratigraphy lead
    • **University of Washington**: Organic and inorganic geochemistry lead
    • **Lamont-Doherty Earth Observatory**: Wireline logging and logging-while-drilling lead
• Project Advisory Group
  – The Project Advisory Group is responsible for guiding technical project decisions. This group includes members of the Project Team, BOEM, USGS, DOE, and industry.

**Organization Chart**

- **Project Team**
  - Matt Frye
    - Chief, Resource Evaluation Division
  - Bill Shedd
    - Supervisor
      - Resource Analysis

- **BOEM**

- **USGS**
  - Tim Collett
    - Senior Scientist

- **DOE**
  - Jared Ciferno
    - Director, Strategic Center for Natural Gas and Oil
  - Rick Baker
    - Project Manager
      - NETL
  - Ray Boswell
    - Hydrates Advisor
      - NETL
Gantt Chart

PHASE 1: Oct 2014 – Sep 2015

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<td>M1C: Site Location and Ranking Report</td>
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<td>Task 3.0: Develop Pre-Expedition Operational Plan</td>
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<td>M1D: Preliminary Field Program Operational Plan Report</td>
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<td>Task 4.0:Complete IODP CPP Proposal</td>
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<td>M1F: Demonstration of a viable PCS tool (Lab Test)</td>
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Gantt Chart

PHASE 2: Oct 2015 – Jan 2018
Gantt Chart

PHASE 3: Jan 2018 – Sep 2019
## Gantt Chart

**PHASE 4: Oct 2019 – Sep 2021**

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<td>Write Phase 3 Report</td>
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Bibliography


Bibliography


Bibliography


- Meazell, K., & Flemings, P.B. (2016). The depositional evolution of the Terrebonne basin, northern Gulf of Mexico. Presented at 5th Annual Jackson School Research Symposium, University of Texas at Austin, Austin, TX.


Bibliography


Bibliography


Bibliography


End of presentation