Deepwater Methane Hydrate Characterization and Scientific Assessment

DE-FE0023919

Peter Flemings & the UT-GOM[2] Science Team

University of Texas at Austin

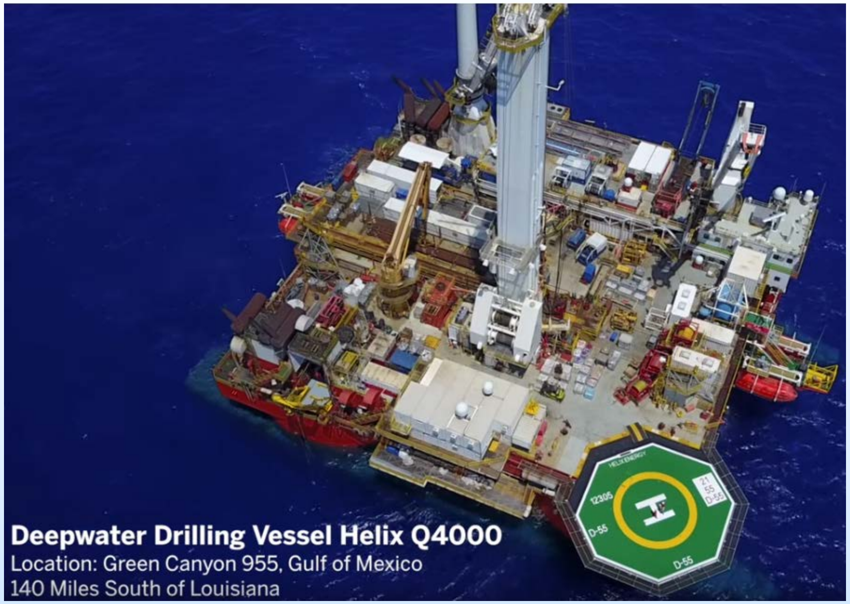
U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 26-30, 2019

UT-GOM2 Team



BOEM Bureau of Ocean Energy Management

University of Washington

University of New Hampshire

U.S. Department of Energy

UTIG Institute for Geophysics

Lamont-Doherty Earth Observatory – The Earth Institute at Columbia University

USGS science for a changing world

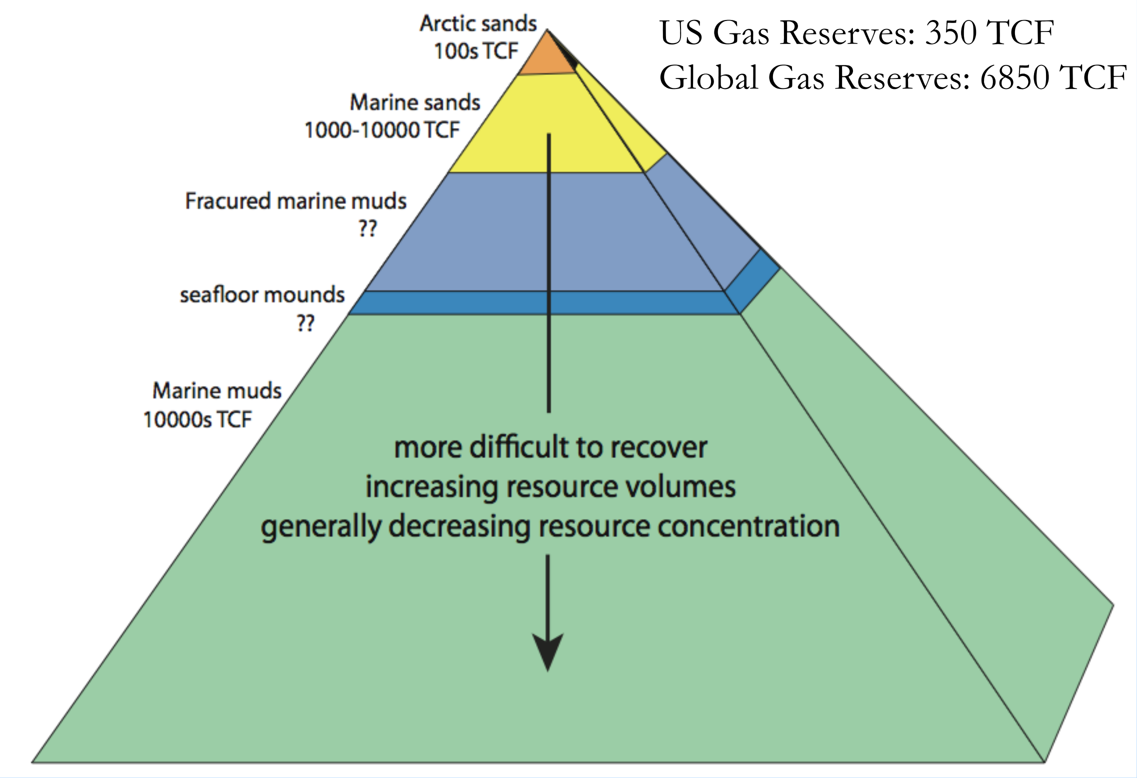
The Ohio State University

University of Oregon

Presentation Outline

- Introduction
- Insights From UT-GOM2-1 Expedition
- Laboratory Results
- UT-GOM2-2 Expedition

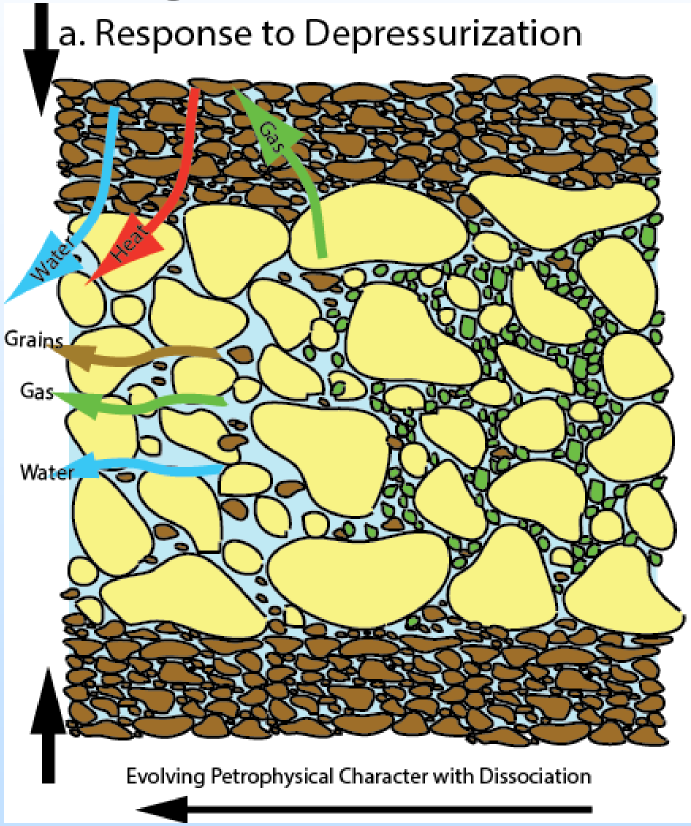
Significant reserves in gas hydrate deposits within coarse-grained systems



(From Fire and Ice, Fall 2006, Boswell & Collett)

The Challenge:
Systems understanding of gas hydrate formation and dissociation in coarse-grained rocks

- Need physical samples to understand fluid and sediment properties
- Marine physical samples never acquired in U.S. program prior to UT-GOM2-1



(Boswell et al., 2016)

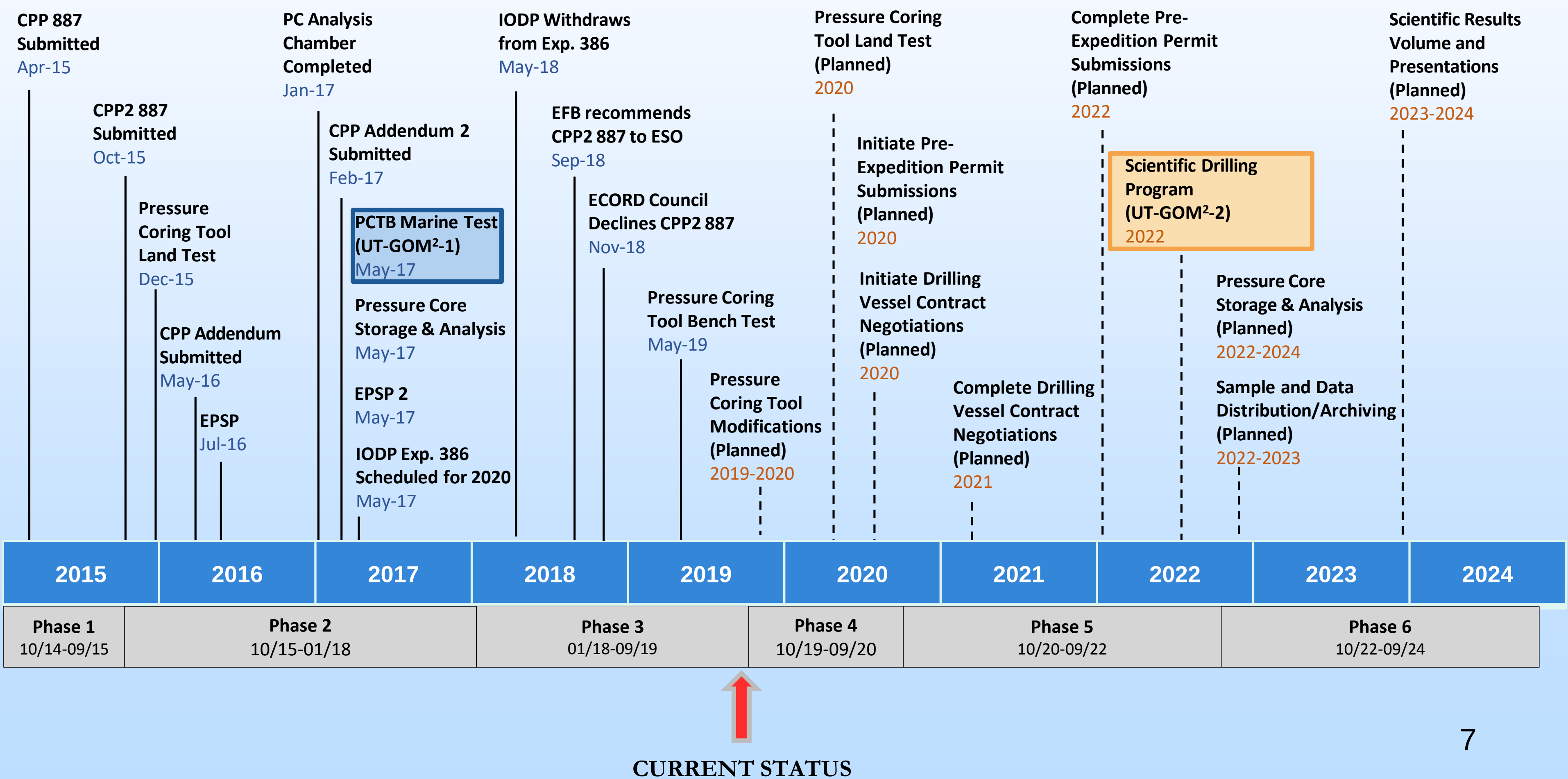
Technical Status

10 year drilling and science program to study coarse-grained methane hydrate deposits

- UT-GOM2-1 Engineering Test (2017)
- UT-GOM2-2 Hydrate Coring Program (2022)

Project Timeline

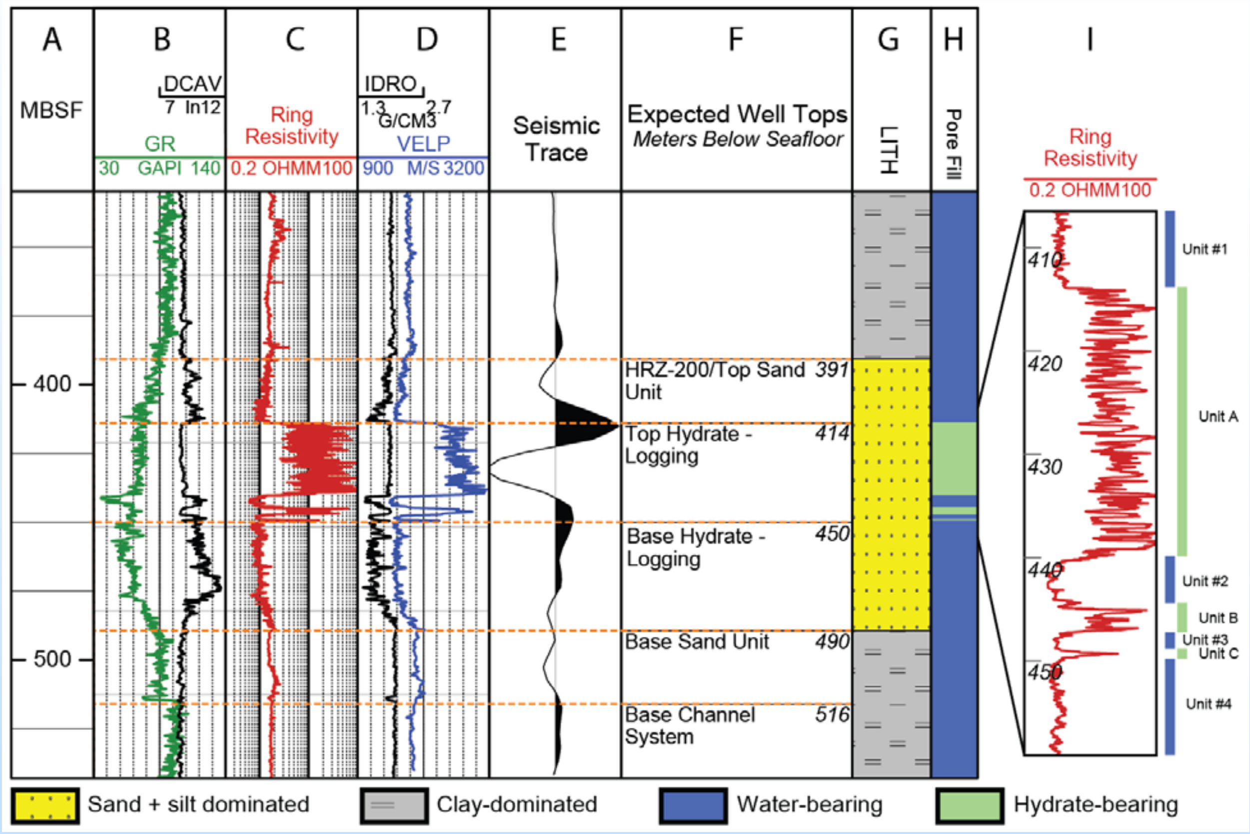
- Previous Tasks/Events shown in blue with solid line
- Future Tasks/Events shown in orange with dashed line

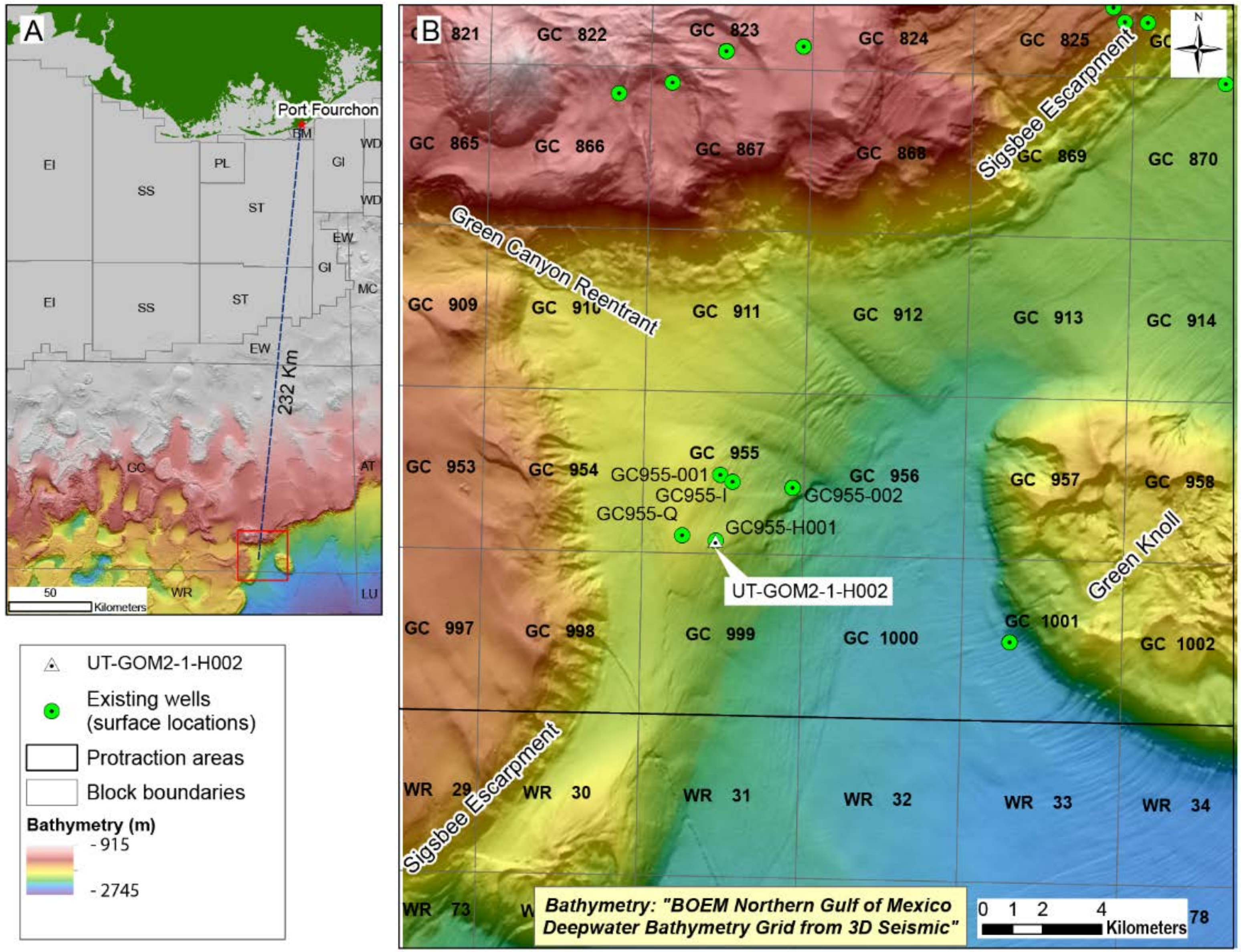


UT-GOM2-1 Goals

Goal: capture pressure cores across hydrate bearing interval:

- Gas source
- Pore water composition
- Sediment texture
- Concentration
- Permeability
- Rel. permeability
- Geomech. Props.





A
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GC 870
Sigsbee Escarpment
Green Canyon Reentrant
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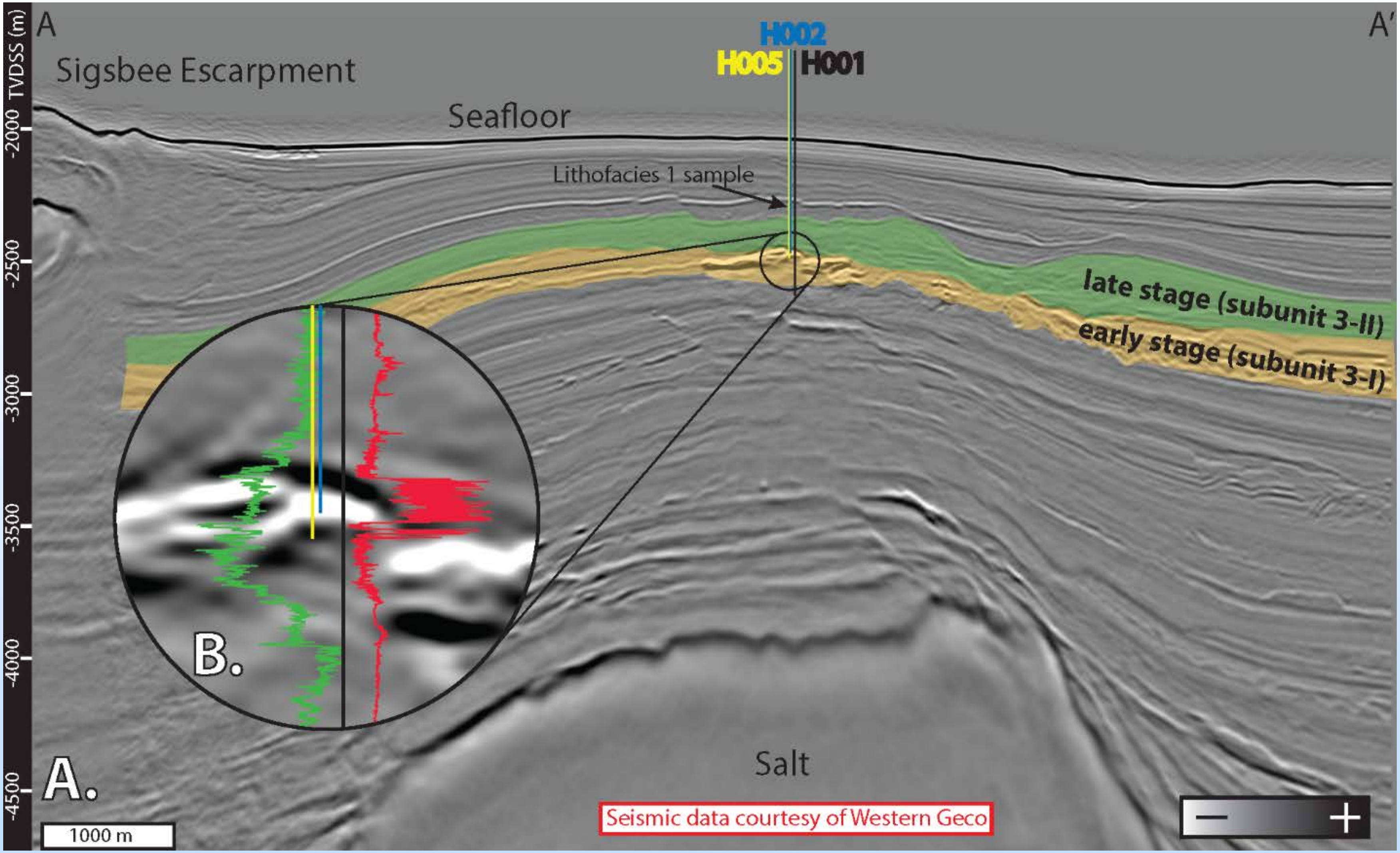
GC955-001
GC955-I
GC955-002
GC955-Q
GC955-H001
UT-GOM2-1-H002
Green Knoll
GC 997
GC 998
GC 999
GC 1000
GC 1001
GC 1002
WR 29
WR 30
WR 31
WR 32
WR 33
WR 34
WR 73
78
Bathymetry: "BOEM Northern Gulf of Mexico Deepwater Bathymetry Grid from 3D Seismic"
0 1 2 4 Kilometers
N
UT-GOM2-1-H002
Existing wells (surface locations)
Protraction areas
Block boundaries
Bathymetry (m)
- 915
- 2745

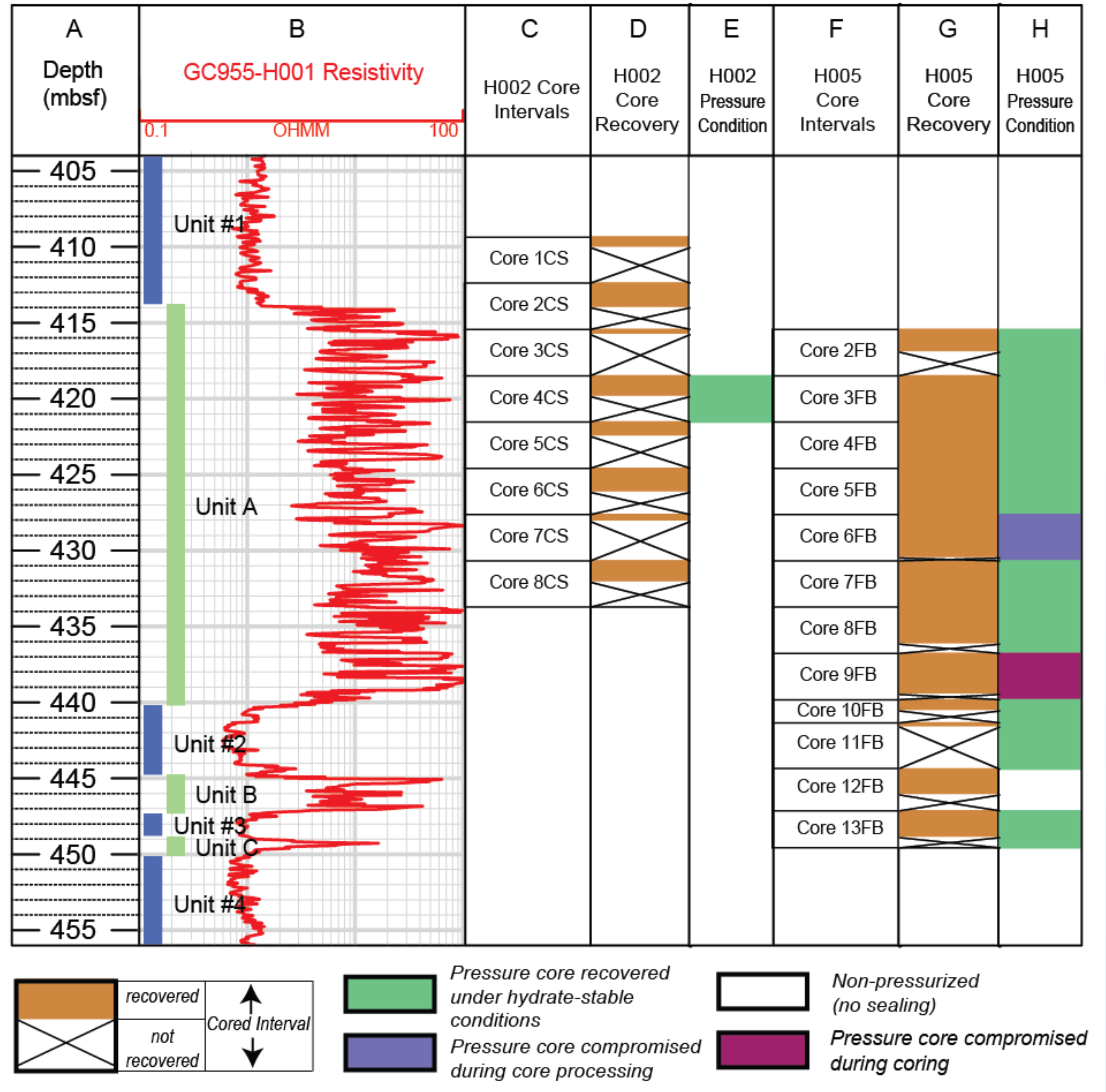


(Meazell et al., in review)

Spud-in for H002 Well

Recovering pressure core

Cored Intervals



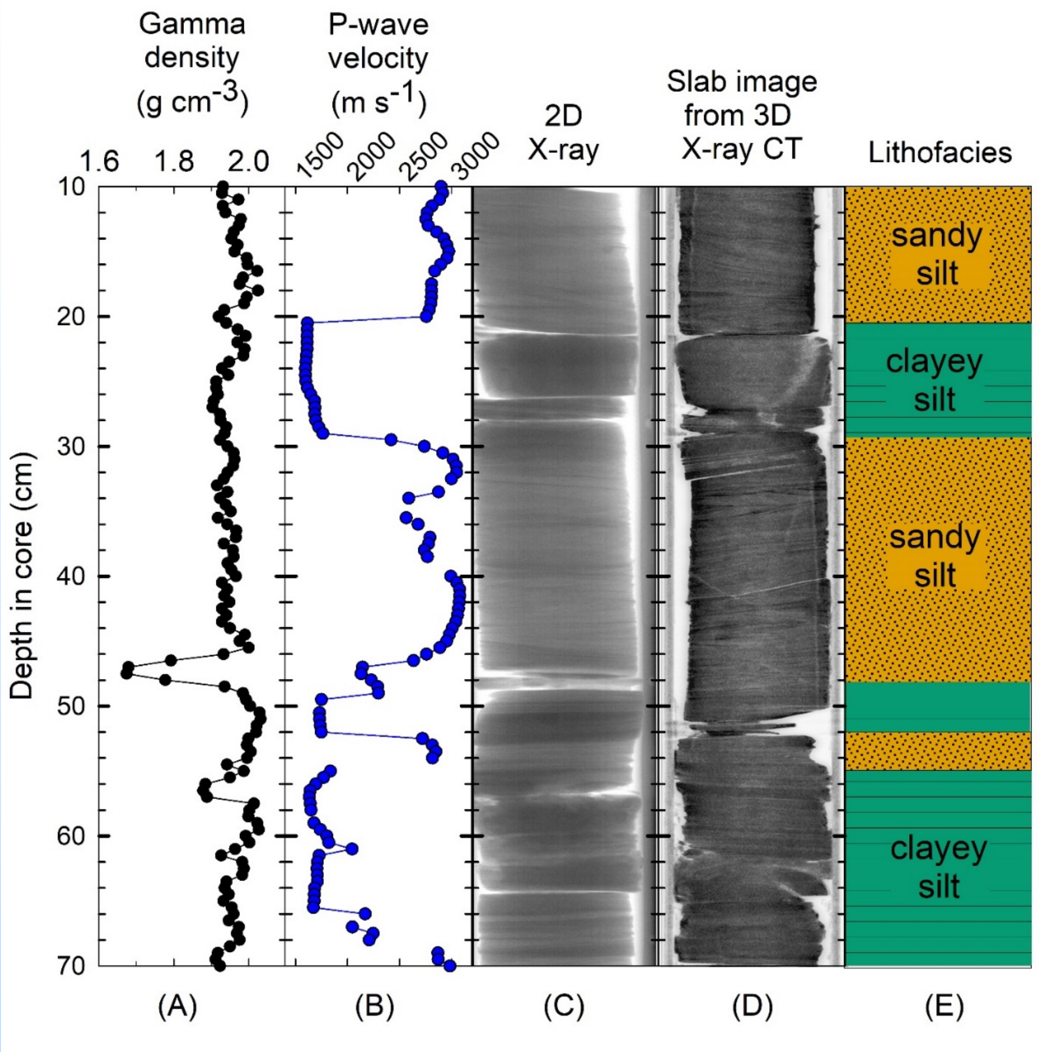
Lithofacies

<u>Sandy Silt</u>

- Interbedded with clayey silt.
  - 10 cm average but up to 1 m.
- low density and high velocity
- Cross-bedding
- Continuous underformed samples.

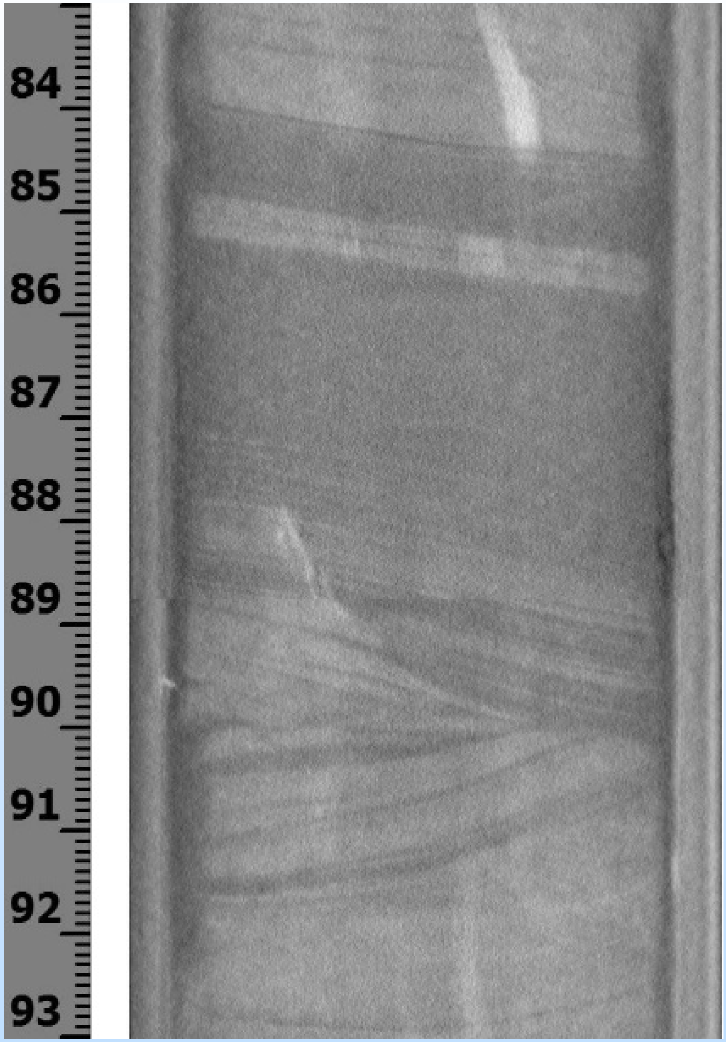
<u>Clayey Silt</u>

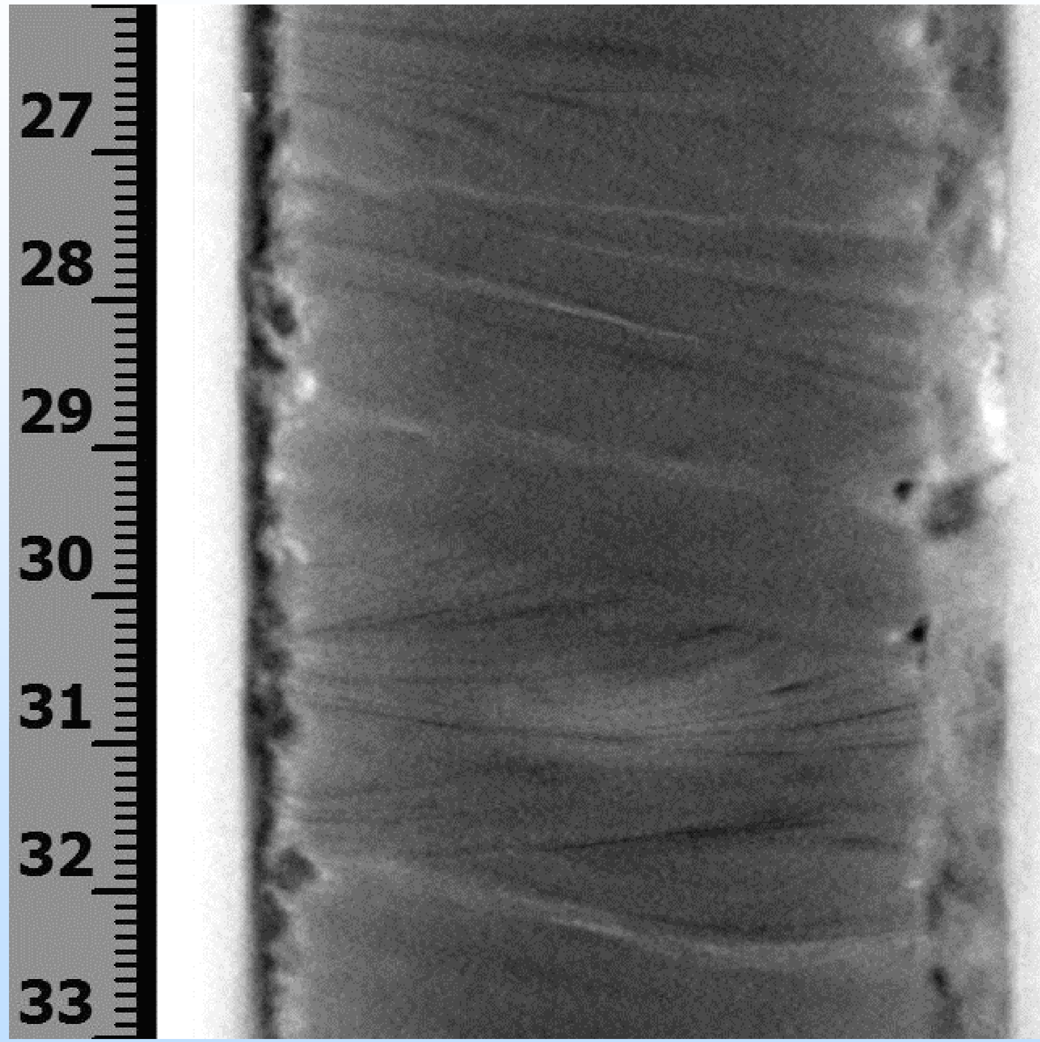
- Interbedded with sandy silt
  - 3 cm average
- High density and low velocity
- Generally massive and more deformed



(Phillips et al., in review)

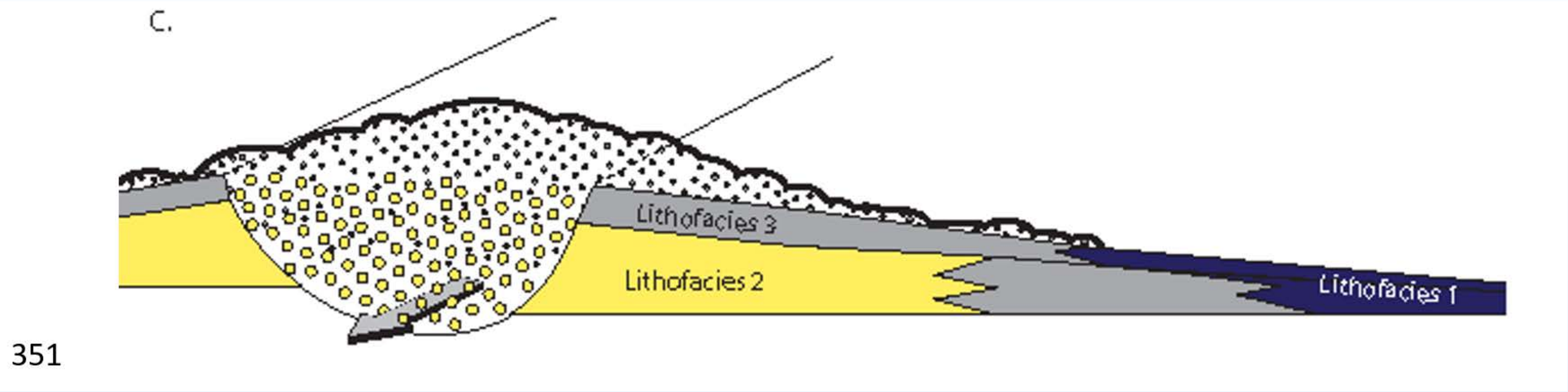
Sandy Silt



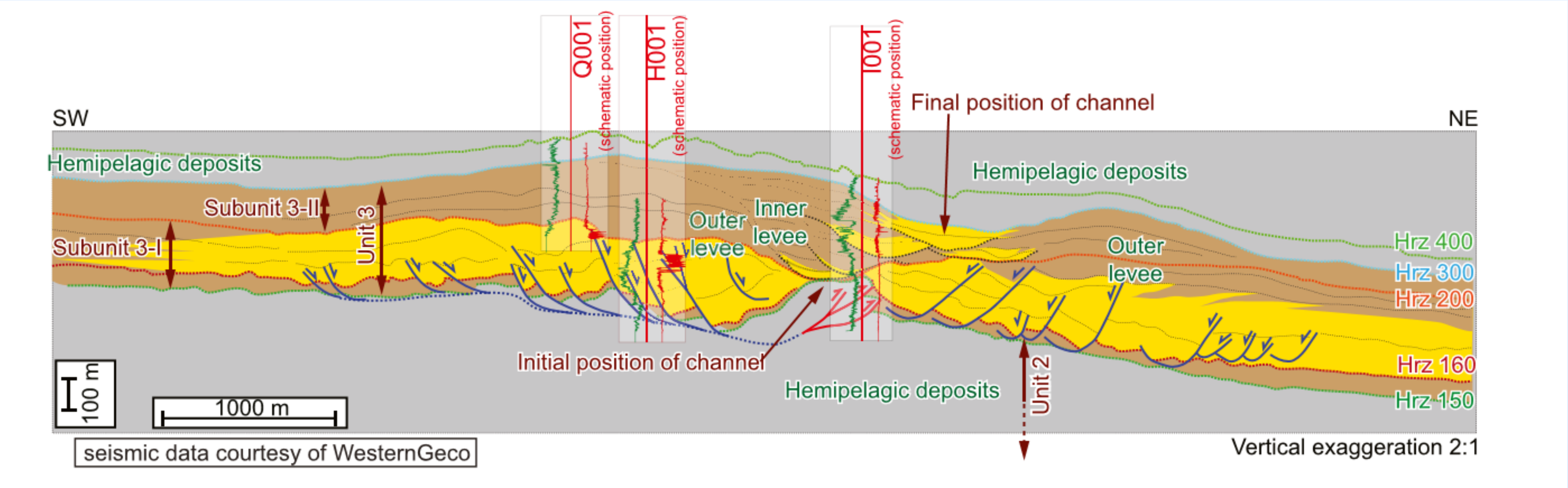


PCATS – X-ray CT

Depositional Model for GC-955



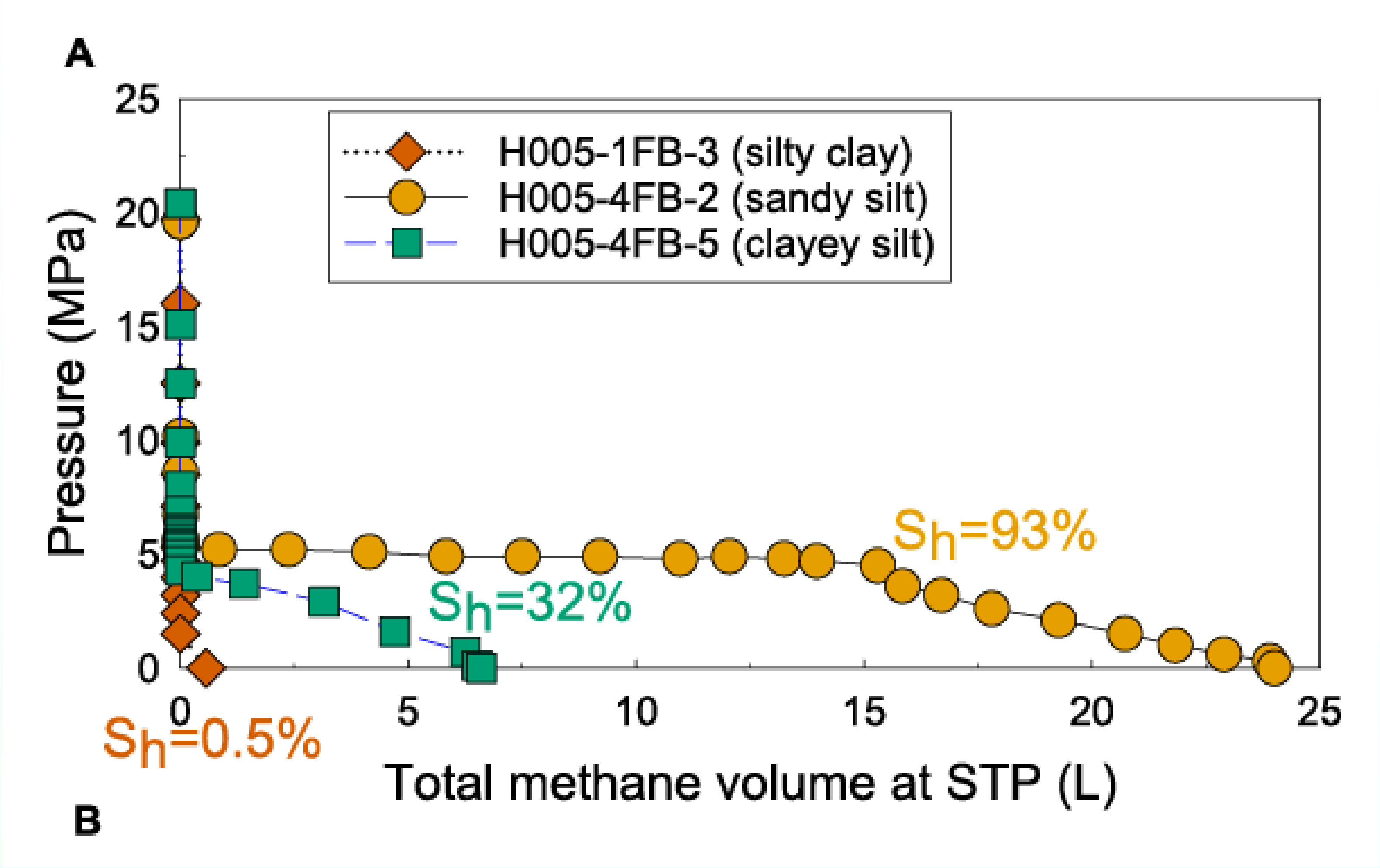
(Meazell et al., in review)



(Santra et al., in press)

Hydrate Concentration (S_h)

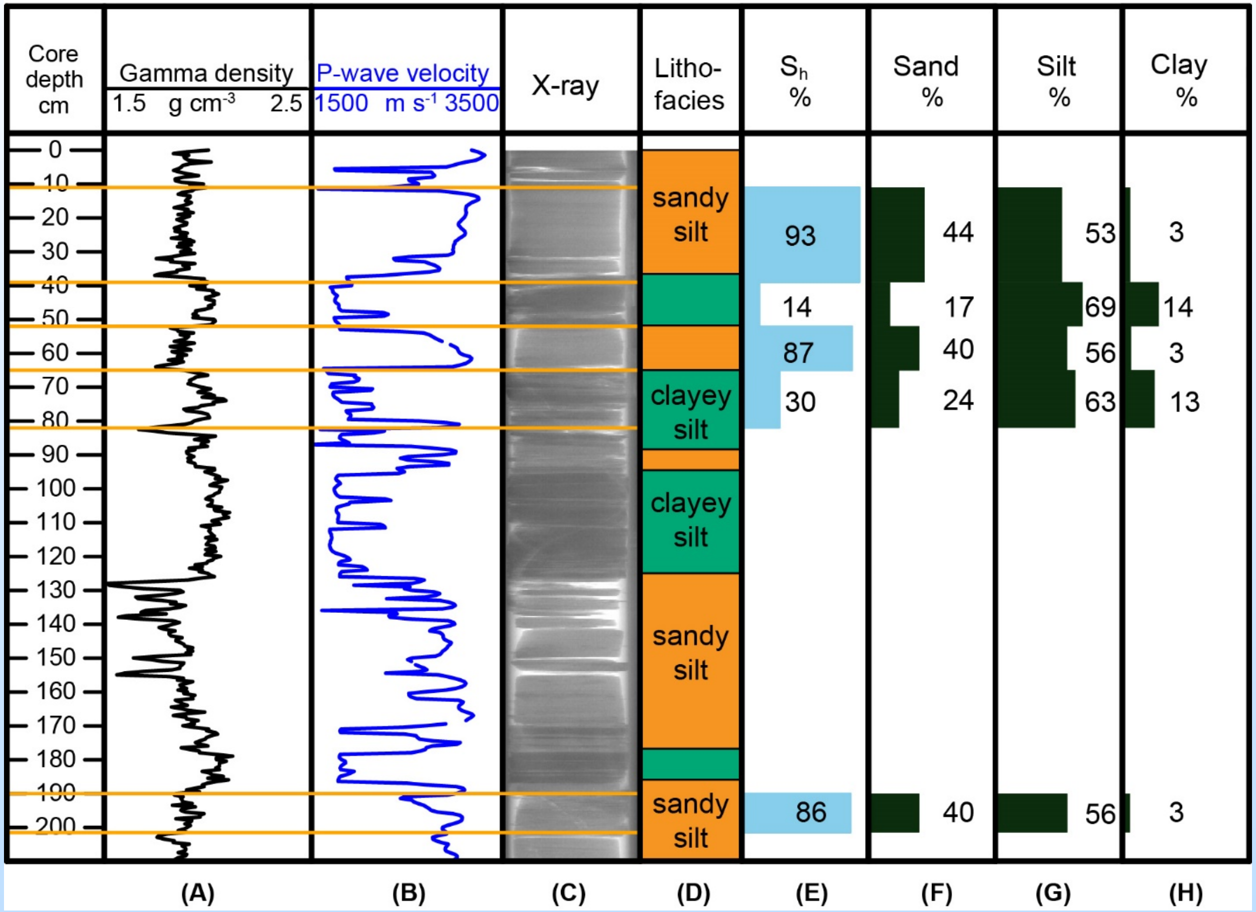
Examples from ~20 cm length sections



(Flemings et al., in review)

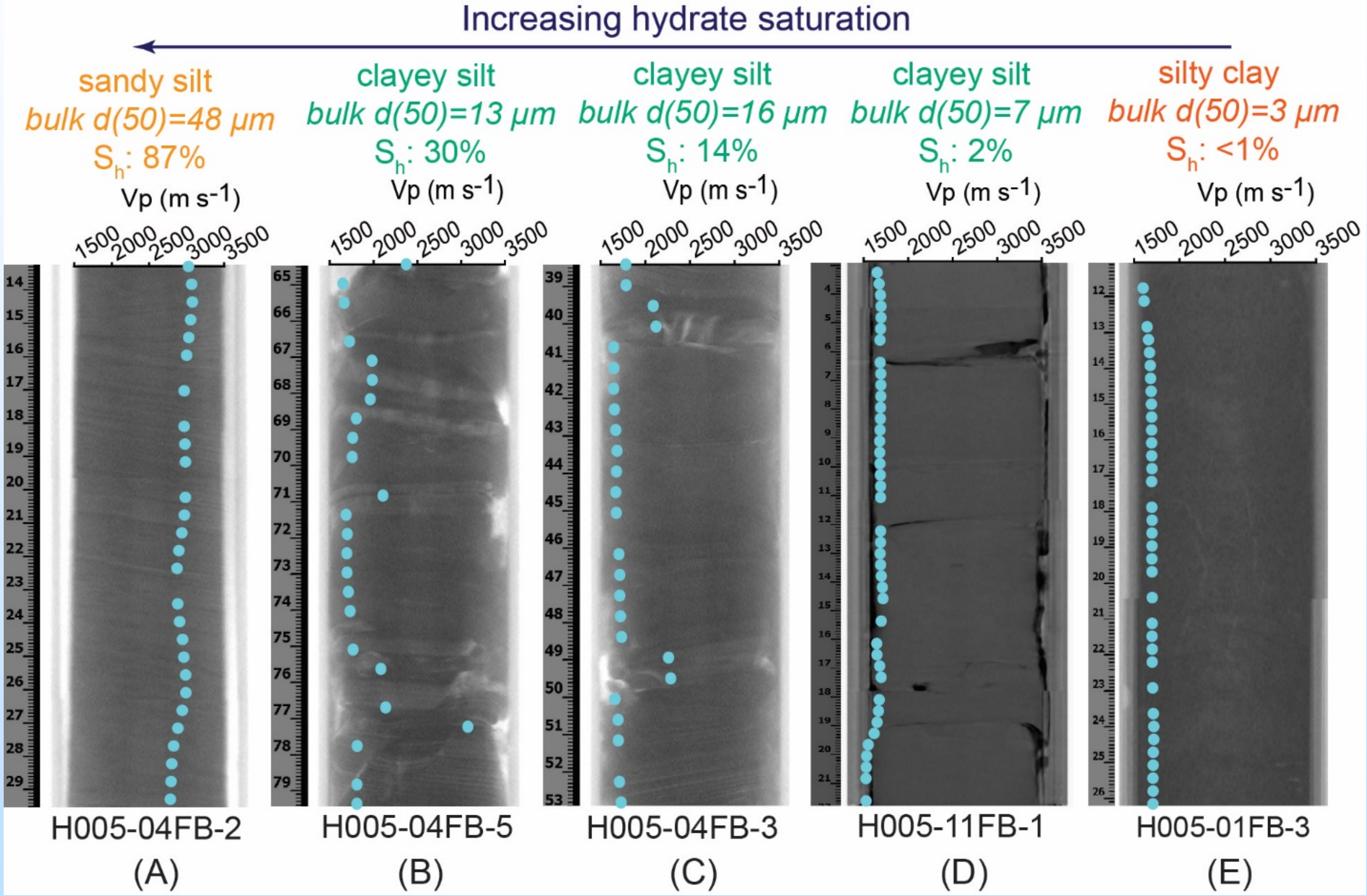
Hydrate Concentration (S_h)

Core H005-04FB



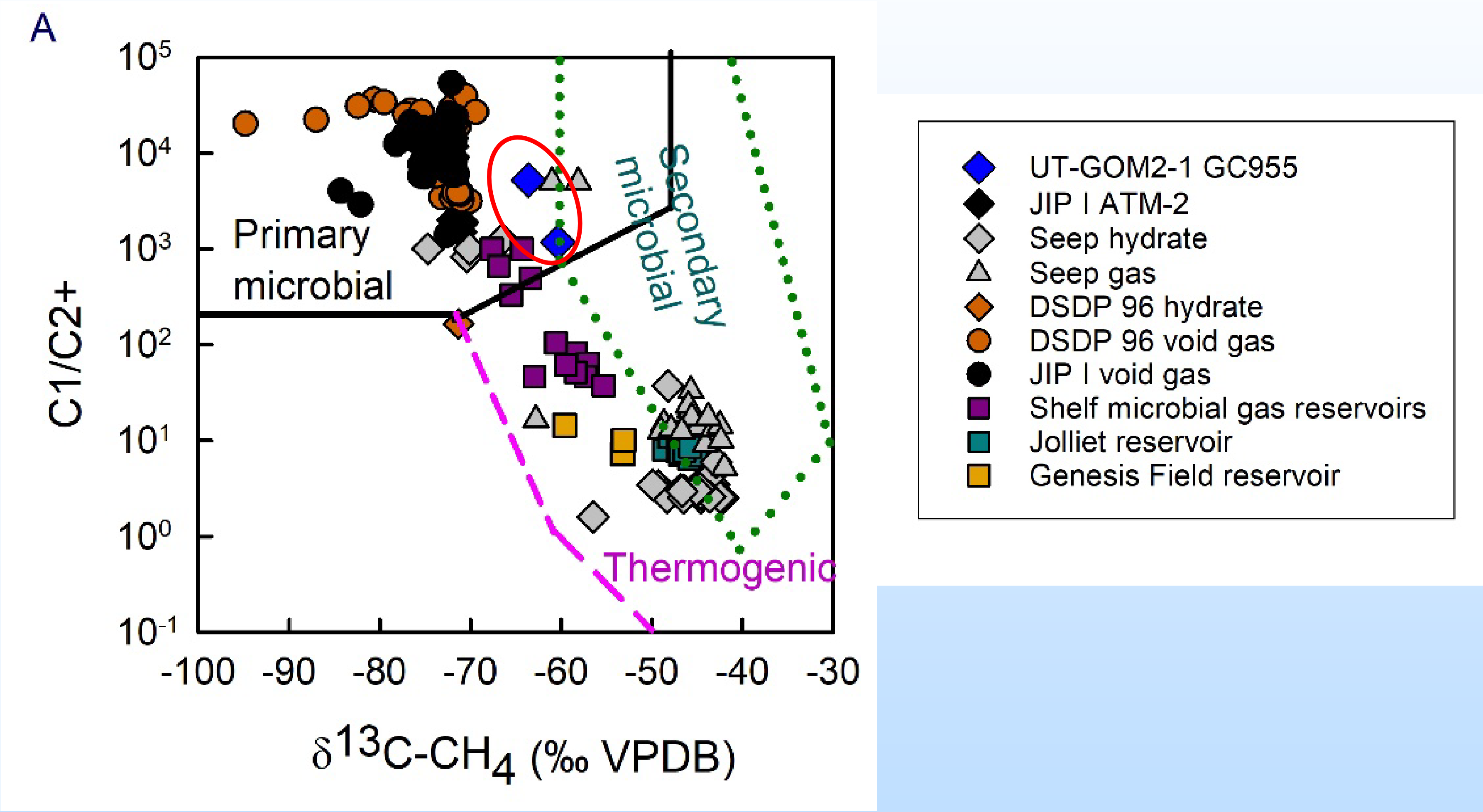
(Phillips et al., in review)

All Hydrate in Sandy Silt



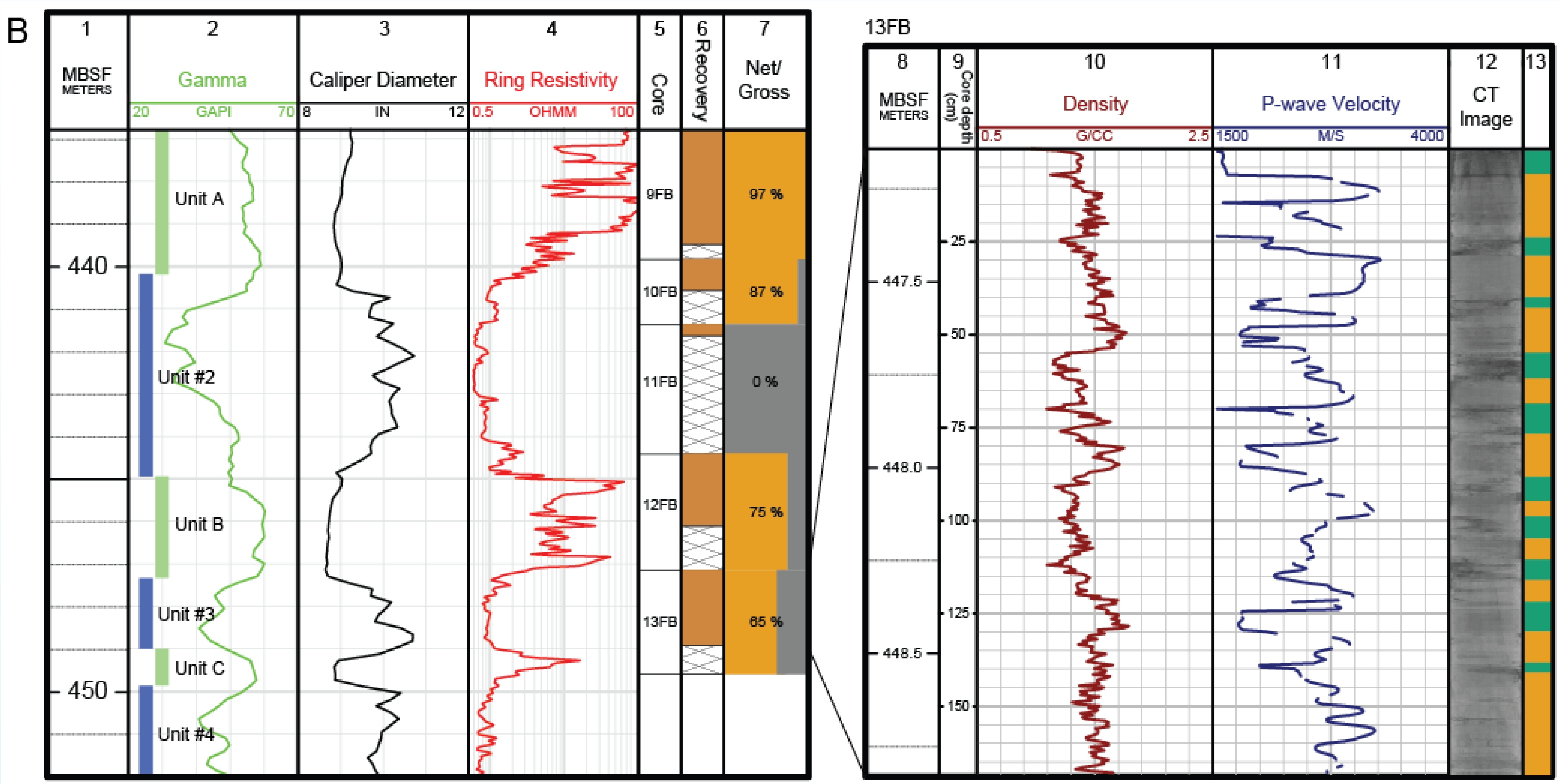
(Phillips et al., in review)

Gas interpreted to be microbial in origin with possible trace thermogenic



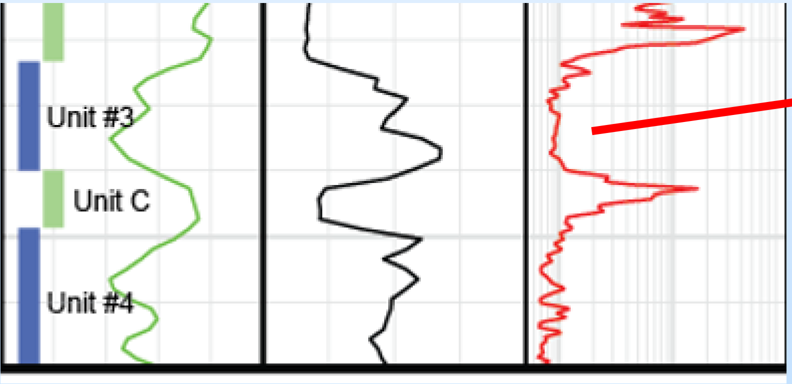
(Phillips et al., in review)

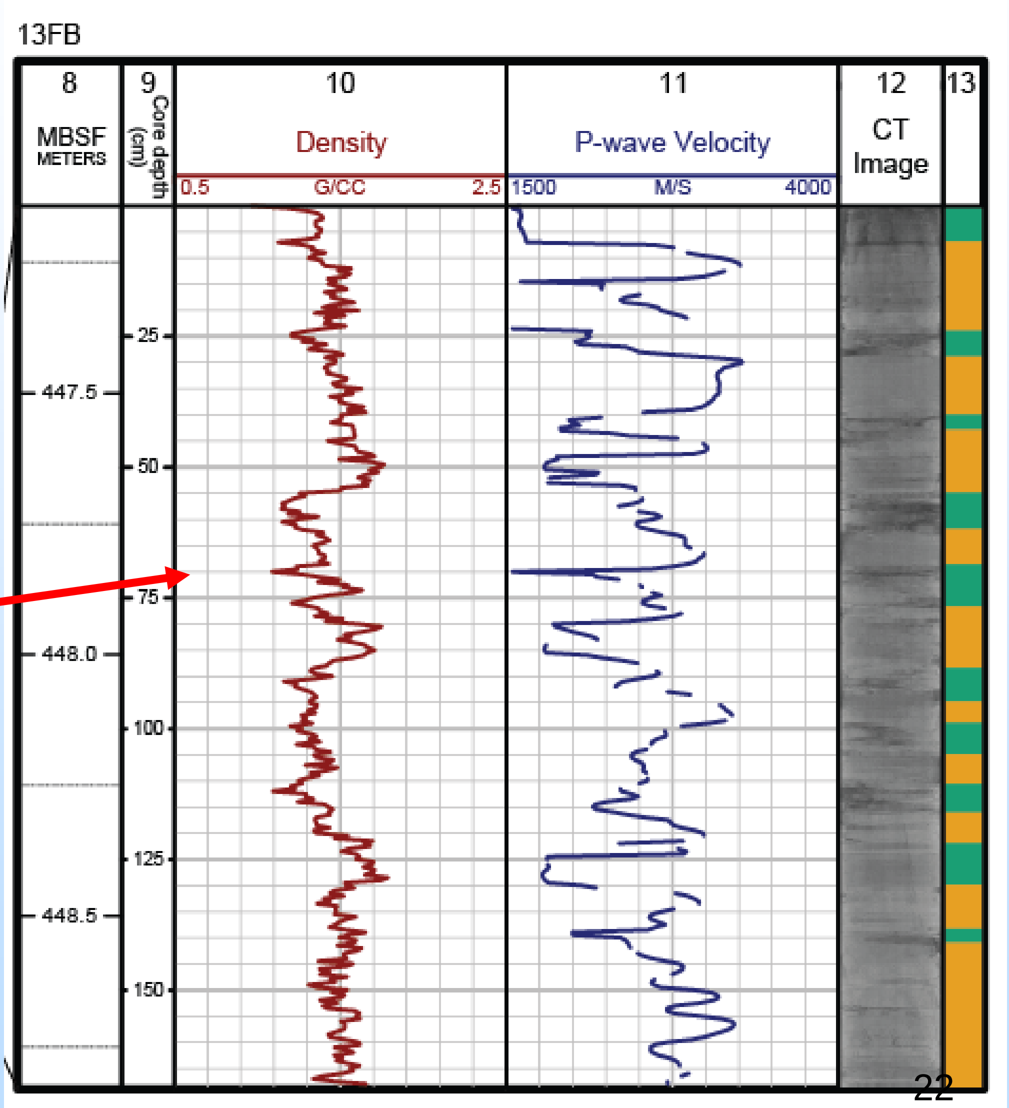
Reservoir Bounding Units



Water-Bearing Interval

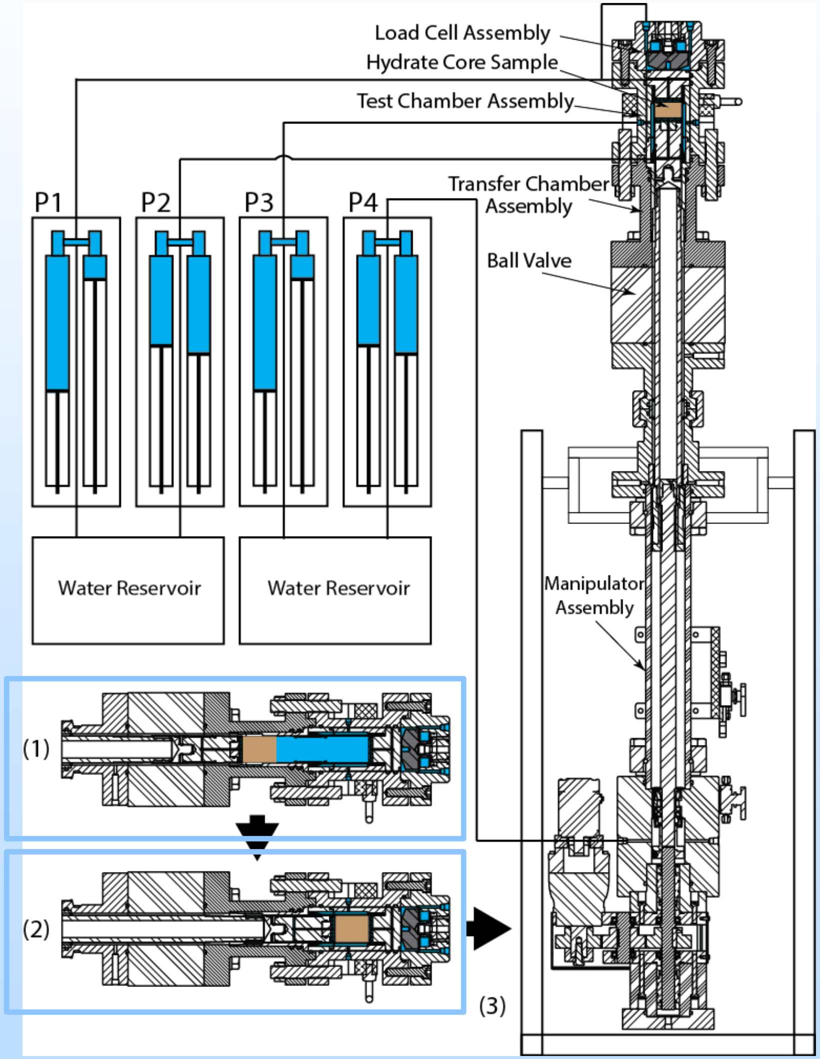
Low net to gross hydrate bearing sandy silts that have undergone washout?





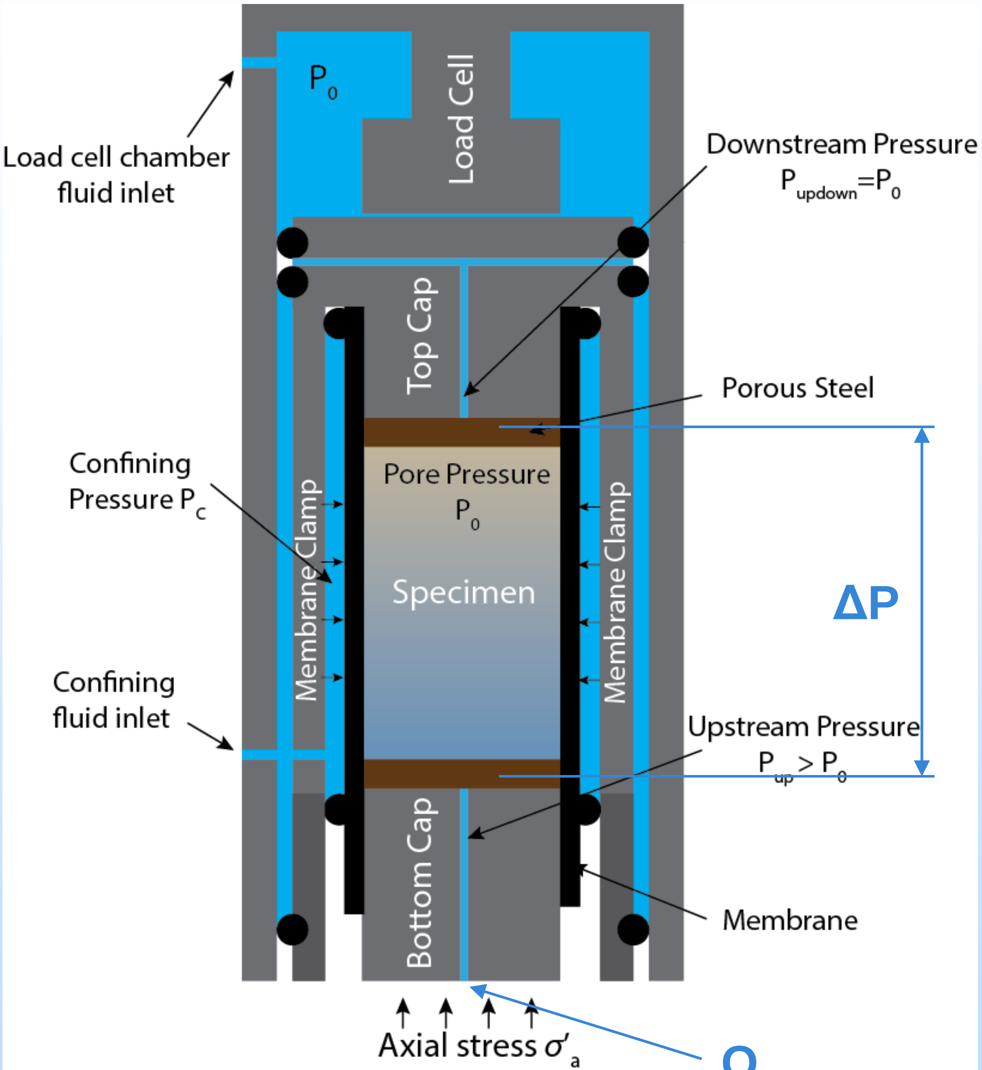
Analysis of Pressure Cores

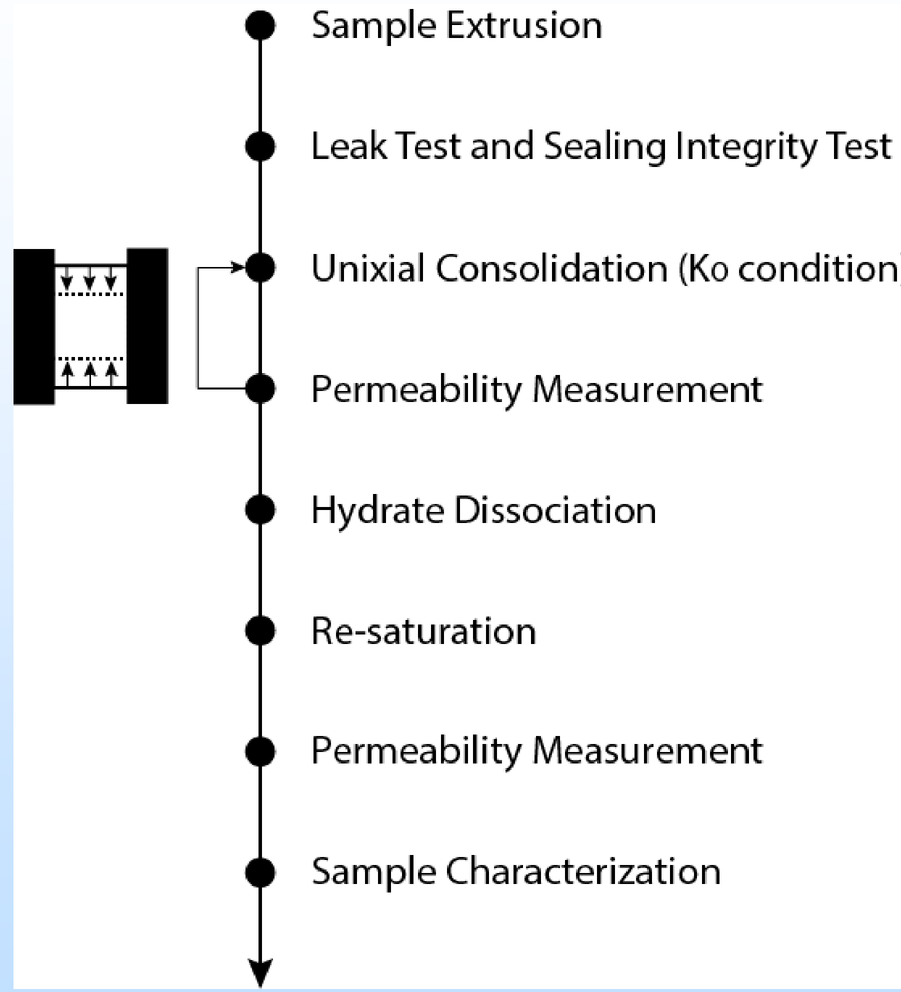
Operations on permeameter



Analysis of Pressure Cores

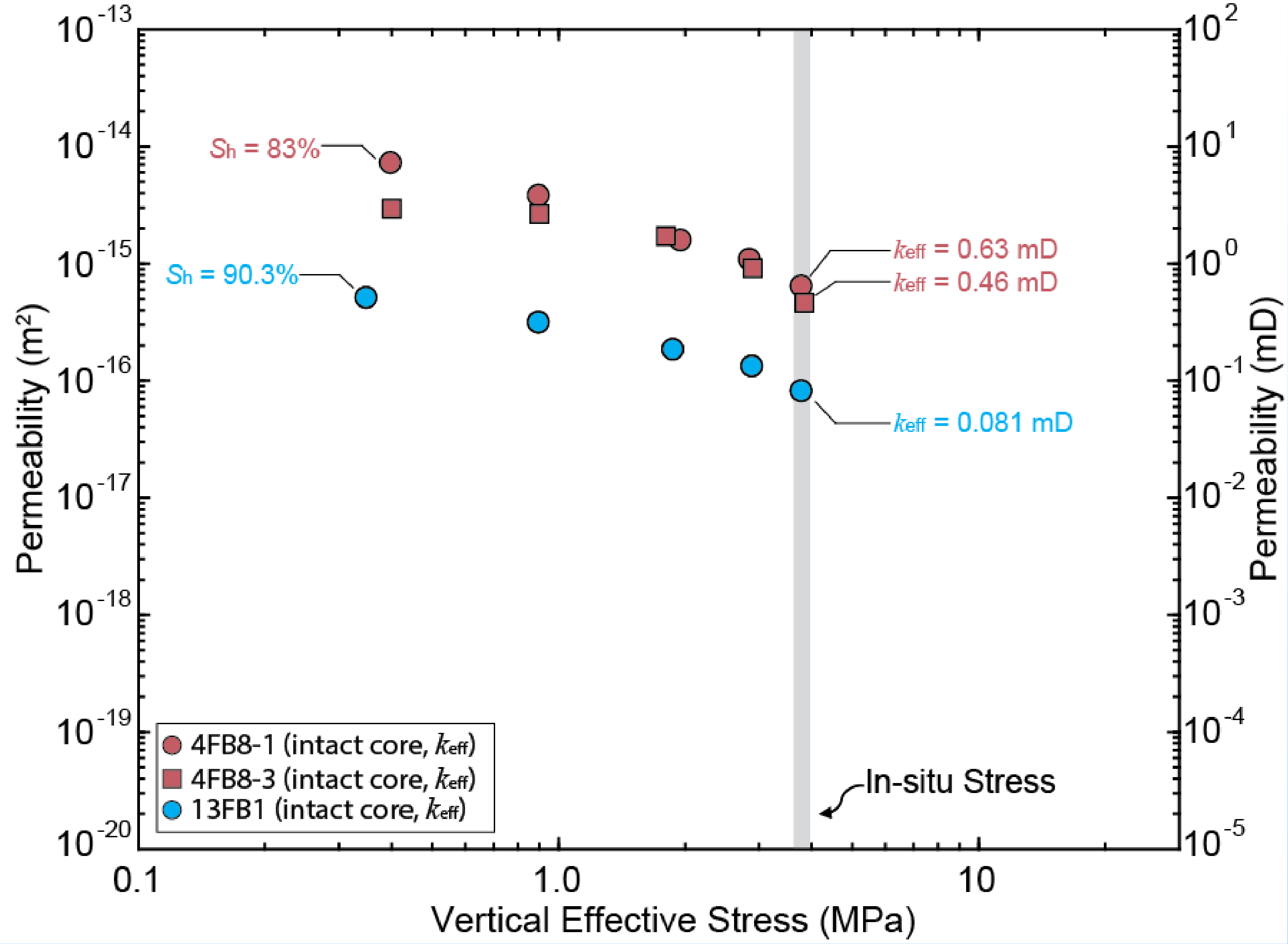
Testing procedures





Water Permeability: $k_w = \dfrac{Q \cdot \mu \cdot L}{A \cdot \Delta P}$

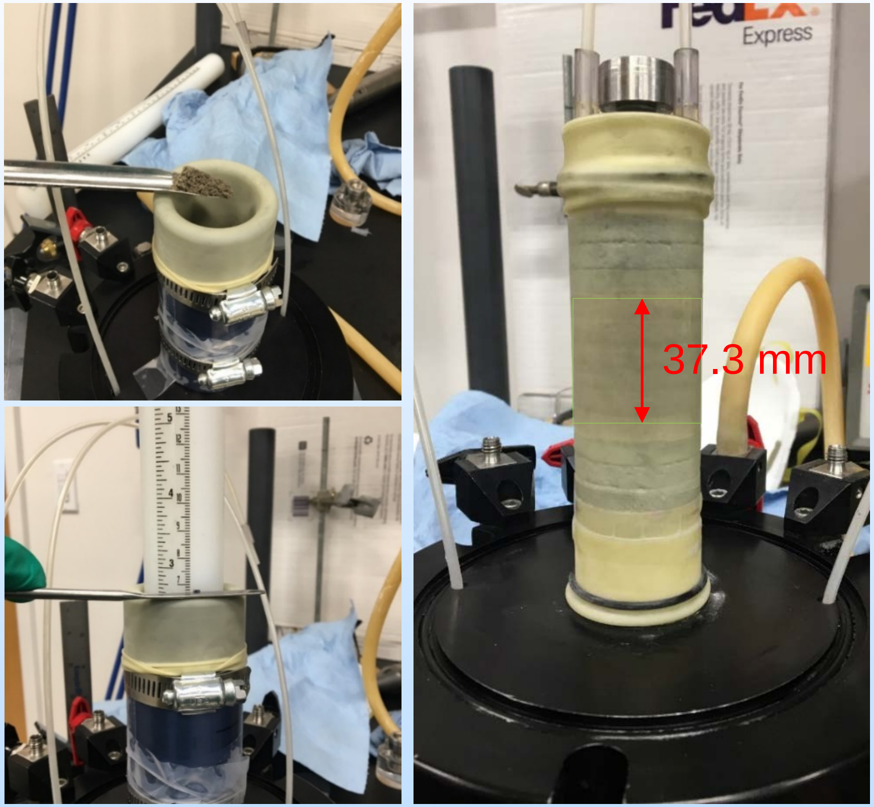
Effective Permeability Estimate: 0.1-0.6 md (1 to 6 e^{-16} m^2)



(Fang et al., AAPG Bulletin, in preparation)

Intrinsic Permeability of Reconstituted Sandy Silt

Undercompaction

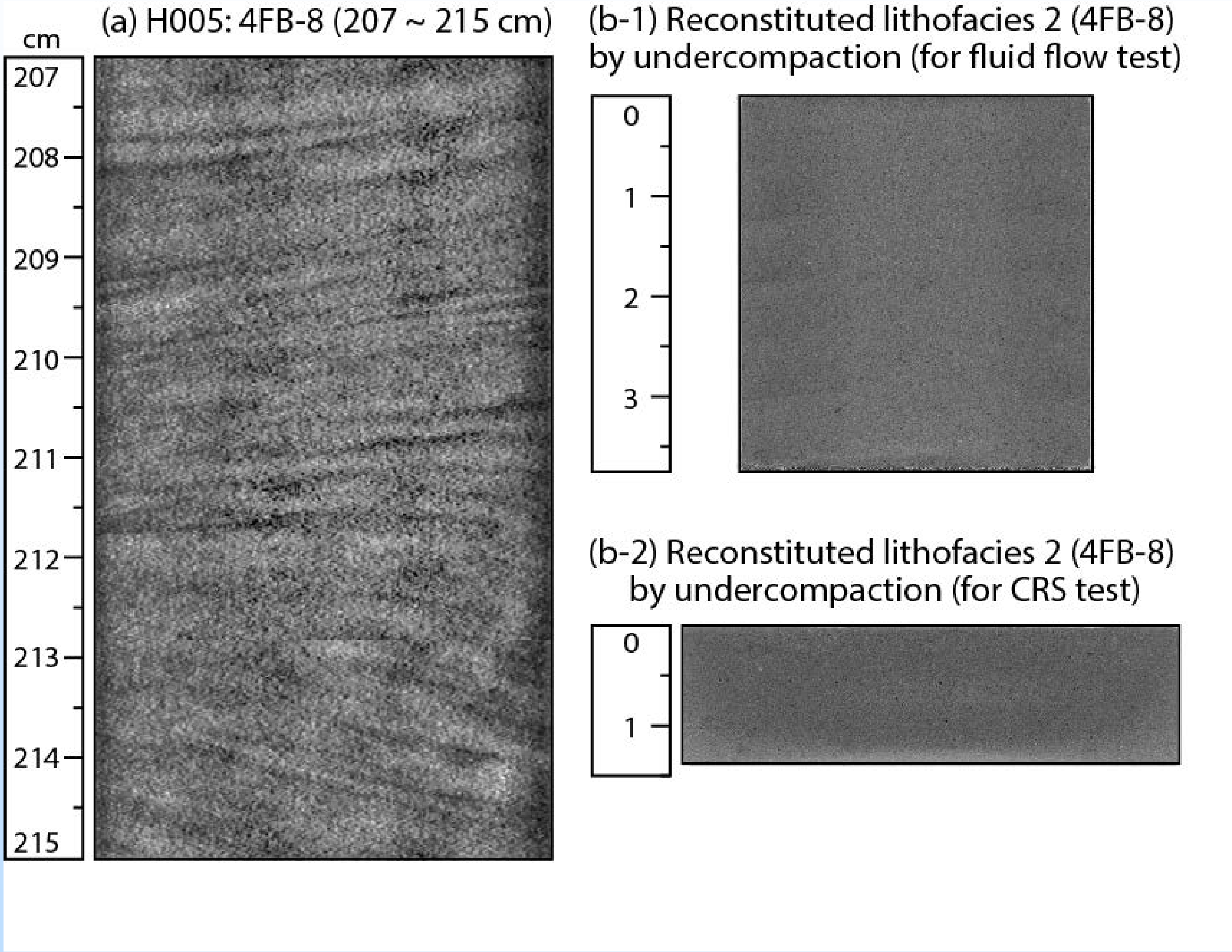


Coarse sandy soils or non-plastic material

Sandy silt

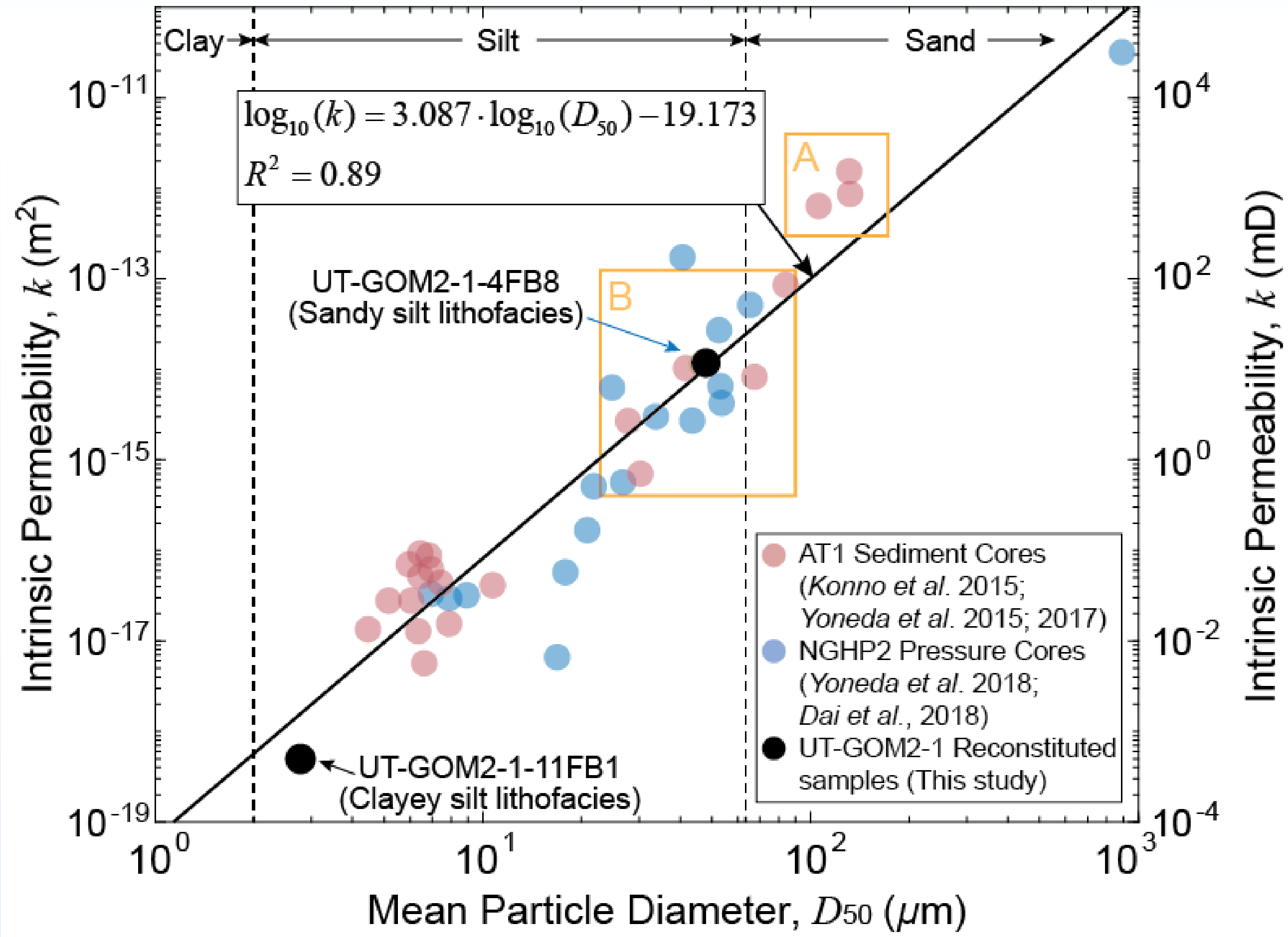
Intact vs. Reconstituted Sandy Silt

Sandy silt



(Fang et al., AAPG Bulletin, accept pending revisions)

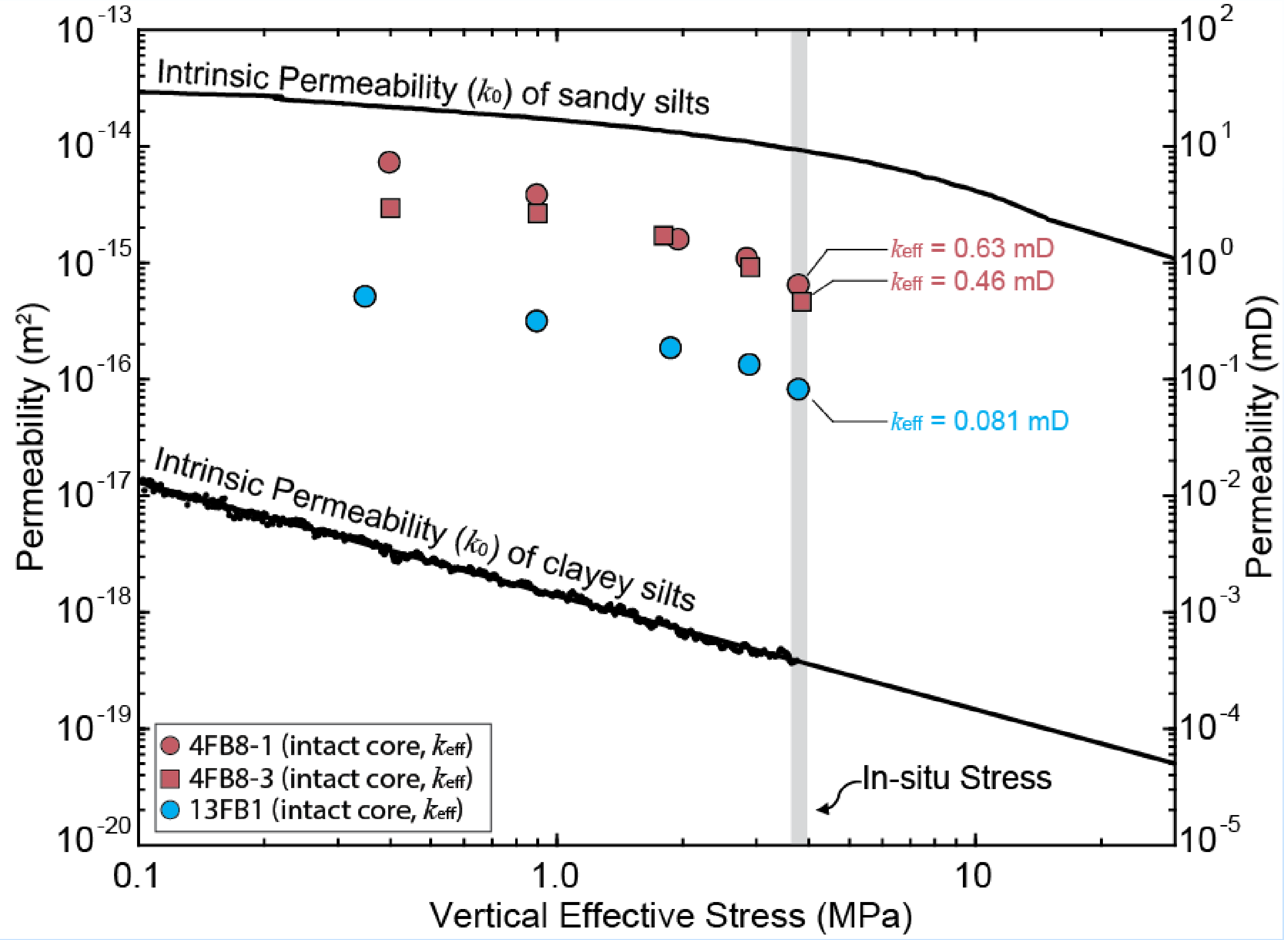
In comparison with other hydrate reservoirs



- Sandy silt: 11.8 mD (1.18×10^{-14} m^2) at in-situ effective stress (3.8 MPa)
- Clayey silt: 3.84×10^{-4} mD (3.84×10^{-19} m^2) at in-situ effective stress (3.8 MPa)

(Fang et al., AAPG Bulletin, accept pending revisions)

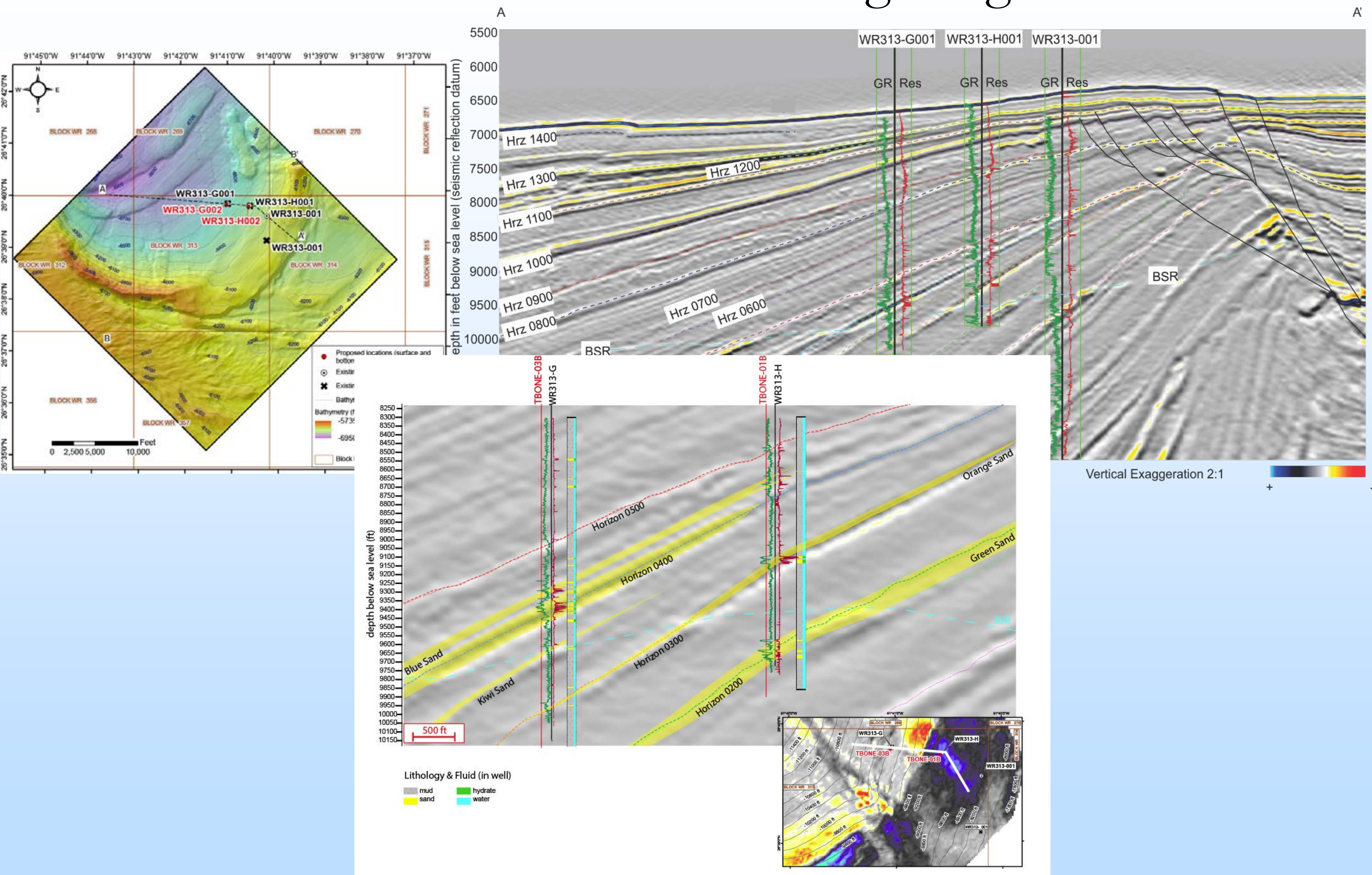
Effective (~0.5 md) vs. Intrinsic (~12 md) Permeability



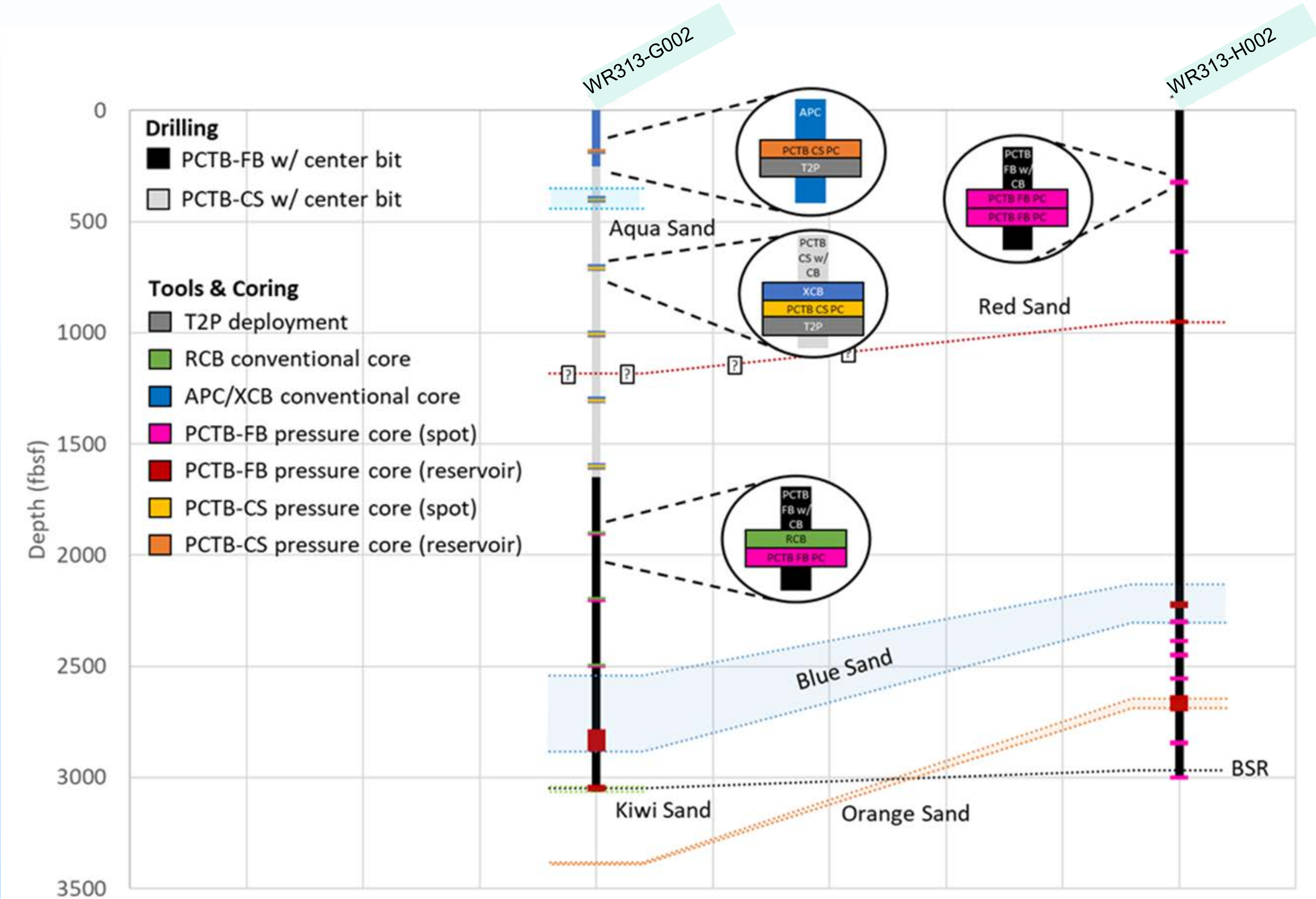
(Fang et al., AAPG Bulletin, in preparation)

- Intrinsic permeabilities of sandy silt and clayey silt lithofacies provide end members of the permeability in GC 955 hydrate reservoirs.

2022: UT-GOM2-2 Scientific Drilling Program: WR 313



Pressure & Conventional Coring & Pressure and temp.



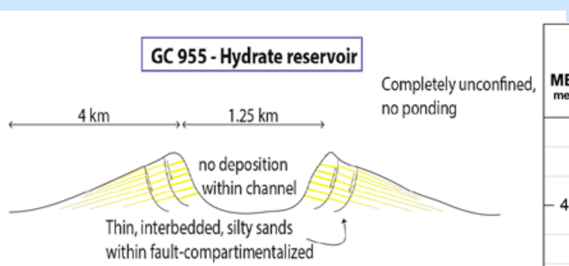
GOM2-2 Research Questions

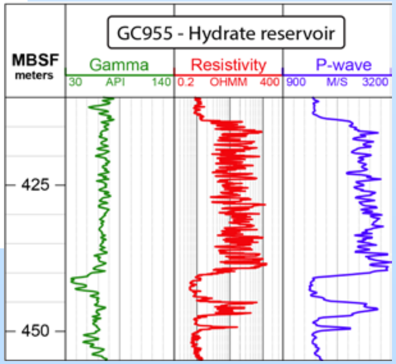
1. **Reservoir Properties** (we have sampled 1 marine sand hydrate reservoir)

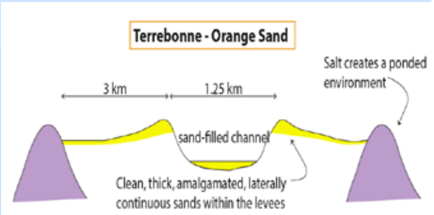
k, ϕ, S_h, m_v, X → *Reservoir Simulation* → *Production Design,*

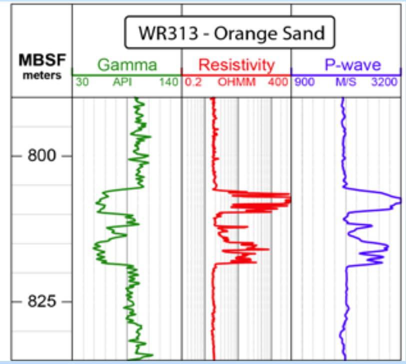
A. More characteristic of producible reservoir

B. Multiple reservoirs at different thermodynamic and stress states









GOM2-2 Research Questions

1. **Reservoir Genesis and Exploration Model**
   A. Geochemical & sedimentary profiles from seafloor to base hydrate stability zone
      1) Gas Source (thermogenic vs. biogenic)?
      2) Is gas sourced locally or is transported long distances?
      3) What is the microbial activity? What are the methanogenesis kinetics?

   B. Evolutionary model to predict basins most likely to form concentrated reservoirs in coarse-grained systems
      A. Role of biogenic vs. thermogenic source, burial history, and fluid flow in generating deposits
      B. Critical to understanding

         hydrate system but also all shallow gas systems

Lessons Learned from UT-GOM2-1

- 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), Georgia Tech
  - Open Shared testing of pressure coring tools with Japan

Project Summary

- Key Findings
  - Interbedded clayey silt and silty sand at cm to m scale.
  - 90% hydrate saturation in silty sand
  - Microbial origin
  - Permeability
    - Effective permeability (S_h=0.9) : ~0.5 md
    - Absolute permeability: ~12 md

Project Summary

- Steps Forward: UT GOM2-2
  - Explore for new hydrate location
  - Drill and Core 2nd depositional environment (sheet sands)
  - 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

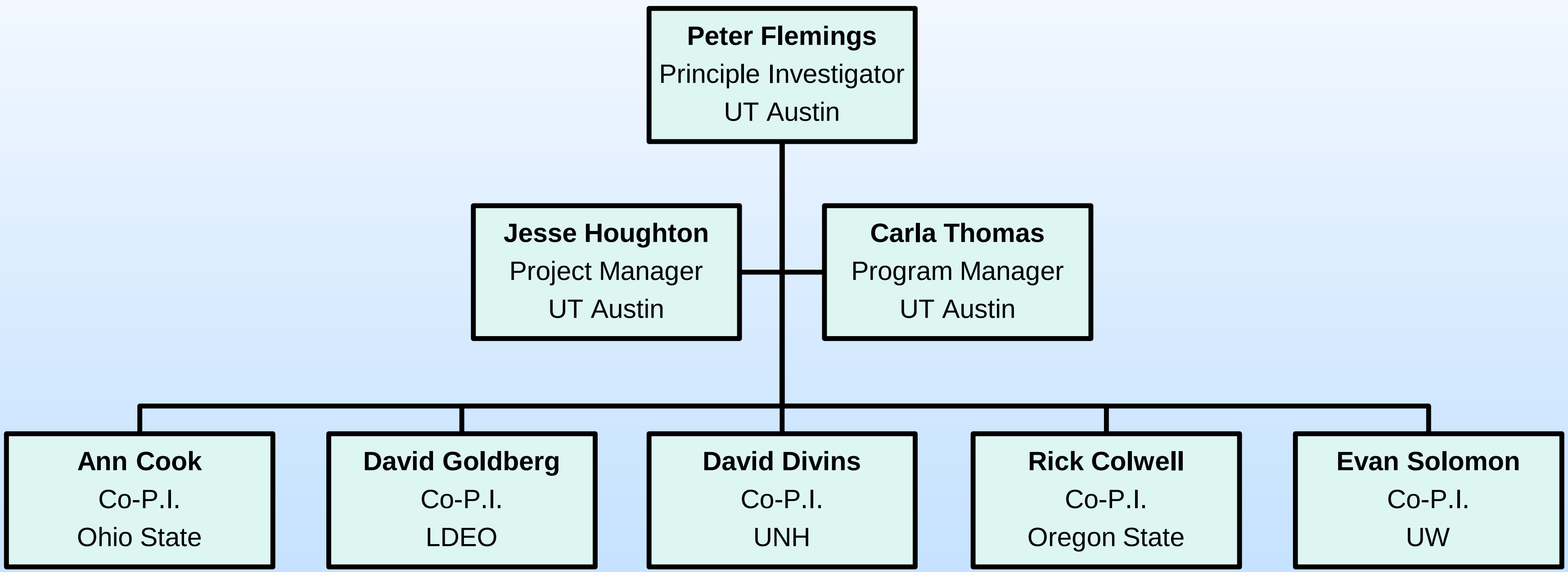
Goals and Objectives

- 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.

Organization Chart

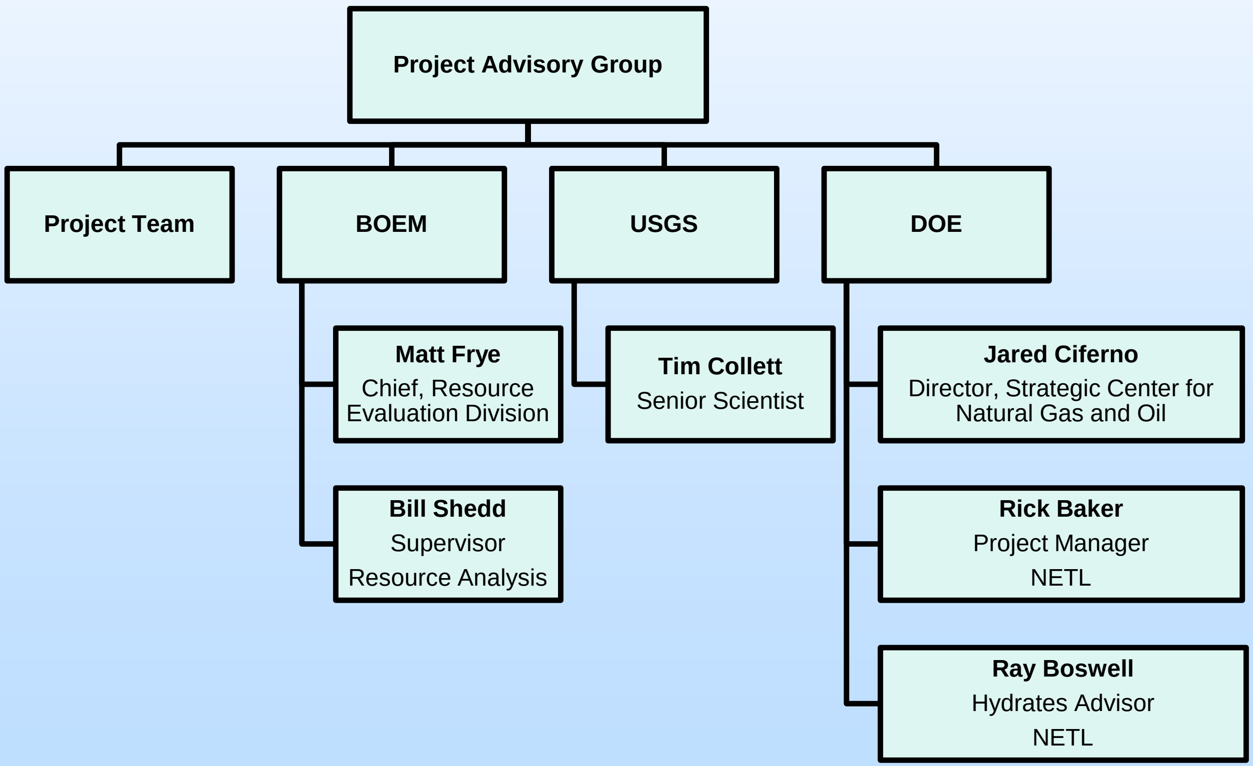
- Project Team
  - **The University of Texas Institute for Geophysics** is the prime contractor, responsible for leading development and execution of all scientific, technical, and logistical aspects of the project.
  - There are five sub-recipients on this project:
    - **Ohio State University**: Site 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

Organization Chart
Project Team



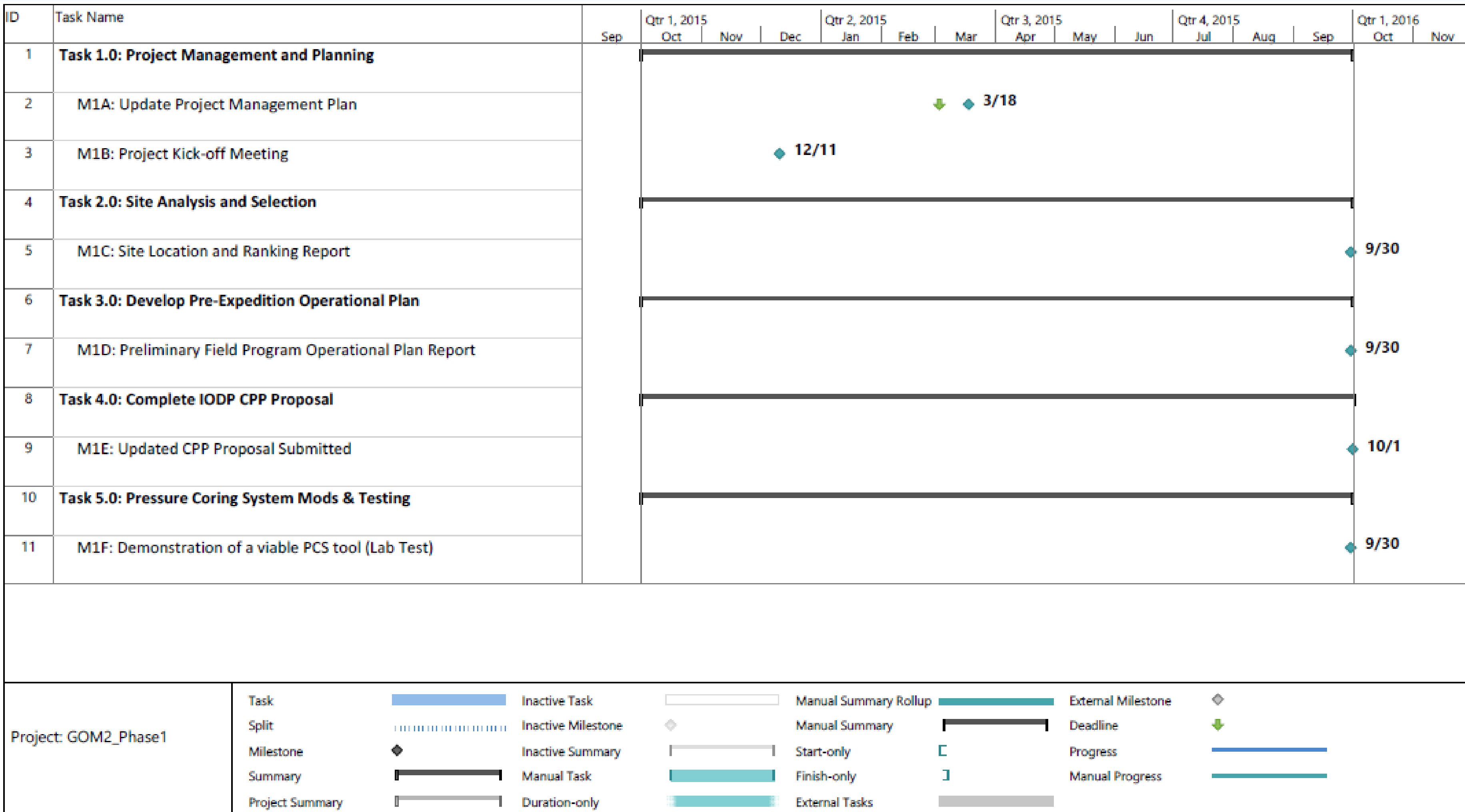
Organization Chart
Project Advisory Group

- The Project Advisory Group is responsible for guiding technical project decisions. This group includes members of the Project Team, BOEM, USGS, DOE, and industry.



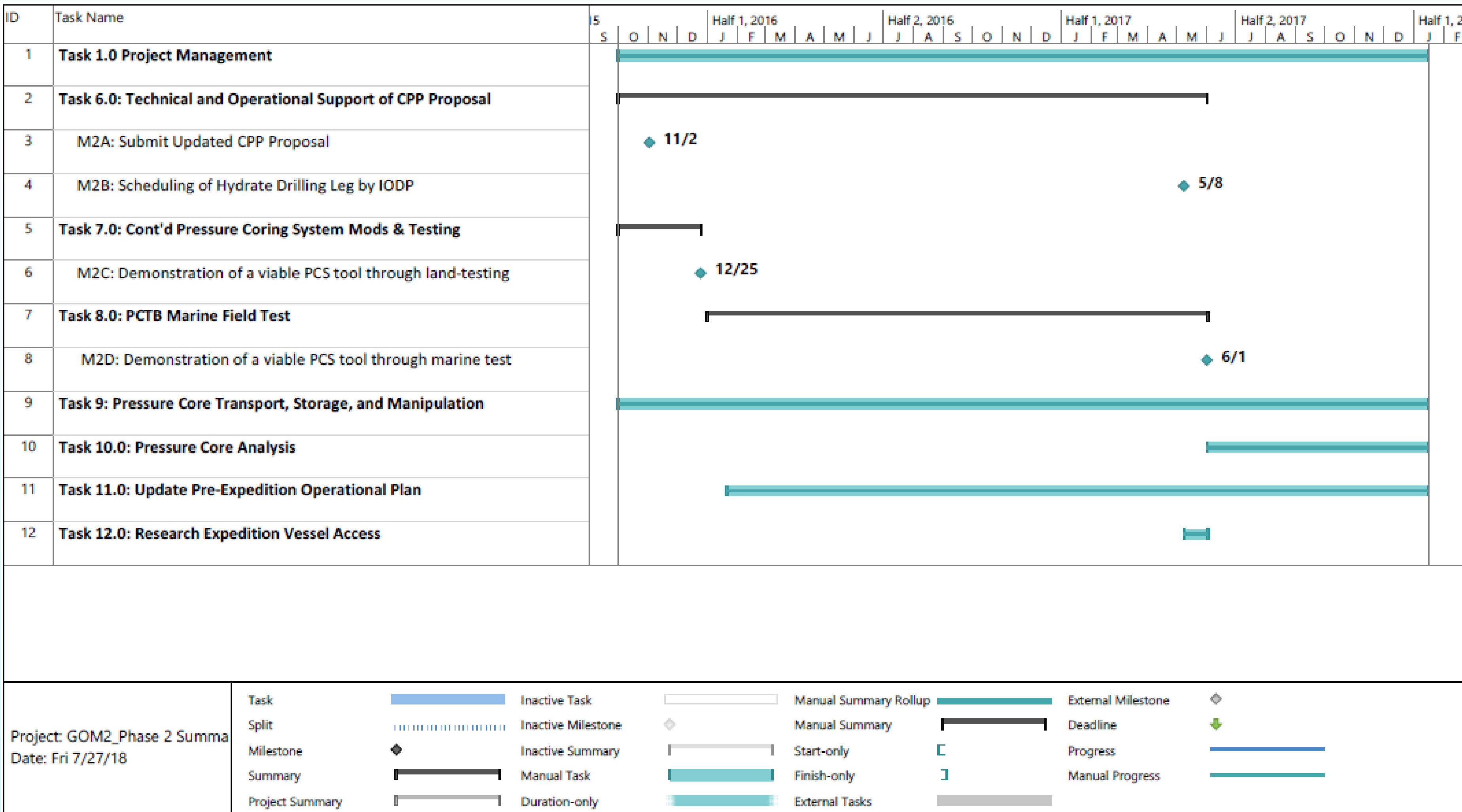
Gantt Chart

PHASE 1: Oct 2014 – Sep 2015



Gantt Chart

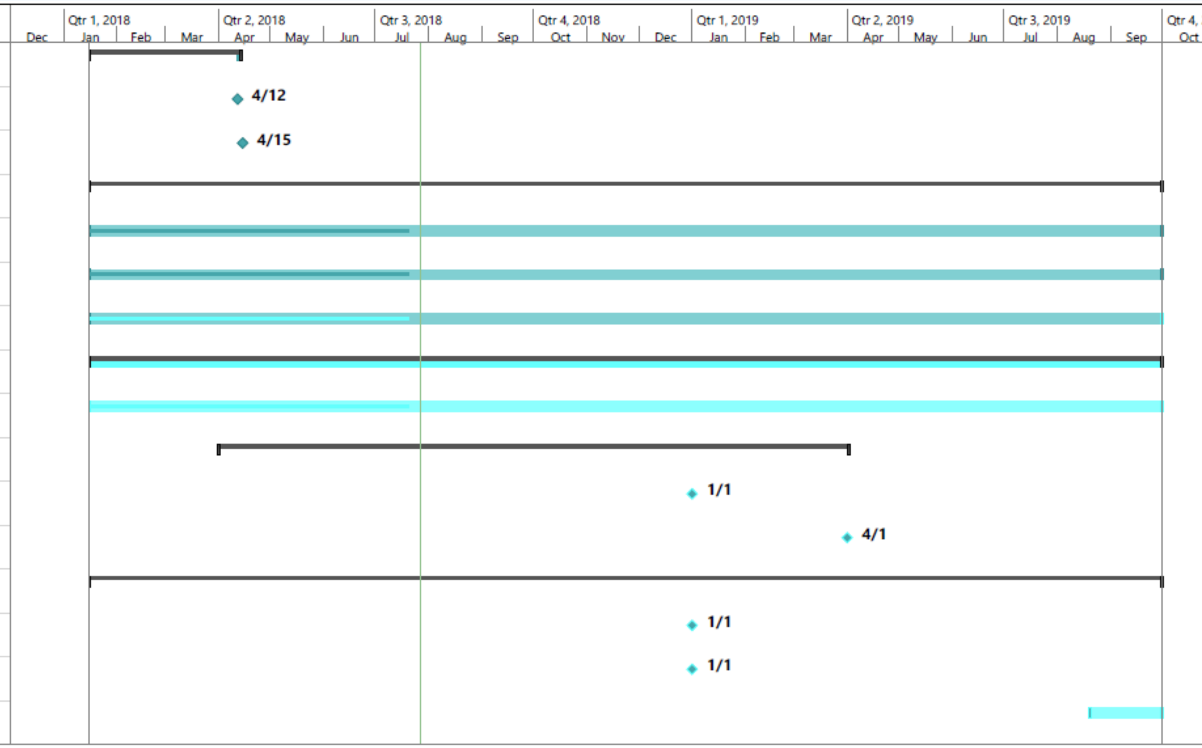
PHASE 2: Oct 2015 – Jan 2018



Gantt Chart

PHASE 3: Jan 2018 – Sep 2019

ID	Task Name
1	**Write Phase 2 Report**
2	M2E: Update Operational Plan
3	M2F: Document results of BP2/Phase 2 Activities
4	**PHASE 3**
5	**Task 1.0: Project Management and Planning (Cont'd)**
6	**Task 6.0: Technical and Operational Support of CPP Proposal (Cont'd)**
7	**Task 9.0: Pressure Core Transport, Stg., and Manipulation (Cont'd)**
8	**Task 10: Pressure Core Analysis (Cont'd)**
12	**Task 13.0: Maintenance and Refinement of Pressure Core Transport, Storage, and Manipulation**
13	**Task 14.0: Performance Assessment, Modifications, and Testing of DOE Pressure Coring System**
14	M3A: Demonstration of a viable PCS tool for hydrate drilling: Lab Test
15	M3B: Demonstration of a viable PCS tool for hydrate drilling: Land Test
16	**Task 15.0: Field Program Preparations**
17	M3C: Complete Refined Field Program Operational Plan Report
18	M3D: Completion of required Field Program Permits
19	**Budget Period 3 Go/No-Go Decision Point**



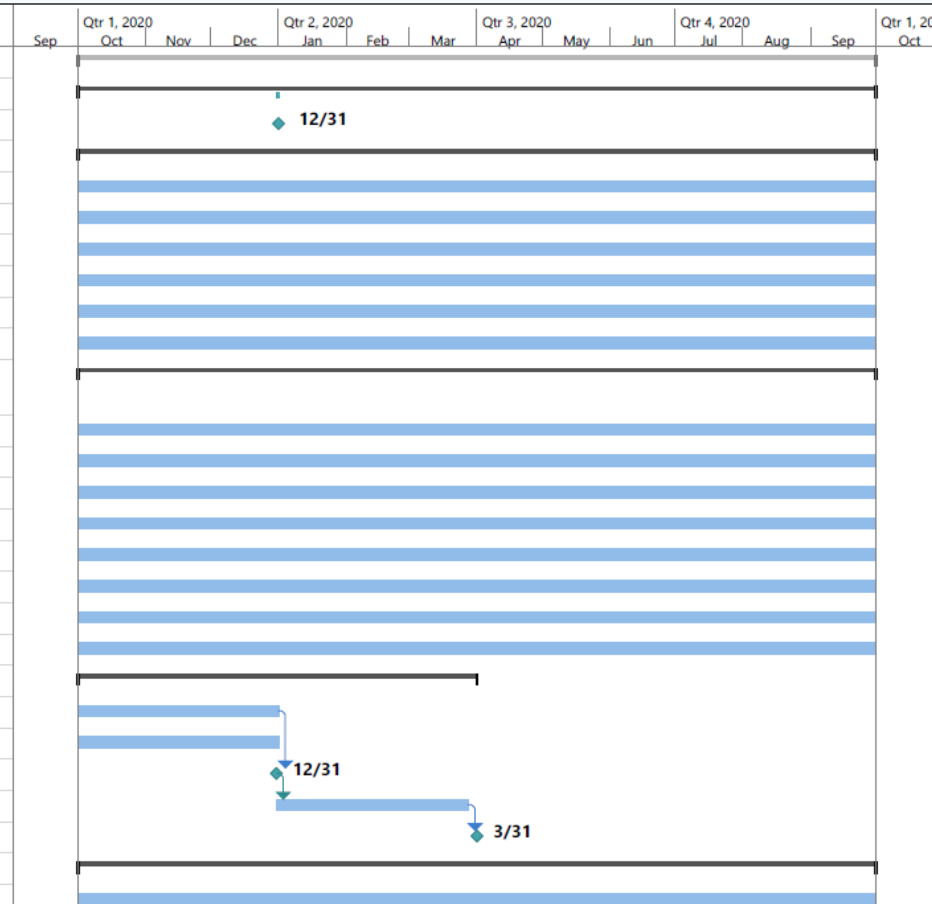
Project: GOM2_Phase3_2018_FI
Date: Fri 7/27/18

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Gantt Chart

PHASE 4: Oct 2019 – Sep 2020

ID	Task Name	Start	Finish
0	**BUDGET PERIOD 4**	**Tue 10/1/19**	**Wed 9/30/20**
1	**Task 1 - Project Management and Planning**	**Tue 10/1/19**	**Wed 9/30/20**
2	*M4A - Document Results of BP3 Activities*	*Tue 12/31/19*	*Tue 12/31/19*
3	**Task 10 - Core Analysis**	**Tue 10/1/19**	**Wed 9/30/20**
4	*Subtask 10.4 - Continued Pressure Core Analysis (UT-GOM2-1)*	*Tue 10/1/19*	*Wed 9/30/20*
5	*Subtask 10.5 - Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-*	*Tue 10/1/19*	*Wed 9/30/20*
6	*Subtask 10.6 - Additional Core Analysis Capabilities*	*Tue 10/1/19*	*Wed 9/30/20*
7	*Subtask 10.7 - Hydrate Modeling*	*Tue 10/1/19*	*Wed 9/30/20*
8	**Task 11 - Update Operational Plan for UT-GOM2-2 Scientific Drilling Progr**	**Tue 10/1/19**	**Wed 9/30/20**
9	**Task 12 - UT-GOM2-2 Scientific Drilling Program Vessel Access**	**Tue 10/1/19**	**Wed 9/30/20**
10	**Task 13 - Maintenance & Refinement of Pressure Core Transport, Storage, & Manipulation Capability**	**Tue 10/1/19**	**Wed 9/30/20**
11	*Subtask 13.1 - Hydrate Core Manipulator and Cutter Tool*	*Tue 10/1/19*	*Wed 9/30/20*
12	*Subtask 13.2 - Hydrate Core Effective Stress Chamber*	*Tue 10/1/19*	*Wed 9/30/20*
13	*Subtask 13.3 - Hydrate Core Depressurization Chamber*	*Tue 10/1/19*	*Wed 9/30/20*
14	*Subtask 13.4 - Develop Hydrate Core Transport Capability for UT-GOM2-*	*Tue 10/1/19*	*Wed 9/30/20*
15	*Subtask 13.5 - Expansion of Pressure Core Storage Capability for UT-GOM*	*Tue 10/1/19*	*Wed 9/30/20*
16	*Subtask 13.6 - Continued Storage of Hydrate Cores from UT-GOM2-1*	*Tue 10/1/19*	*Wed 9/30/20*
17	*Subtask 13.7 - X-ray Computed Tomography*	*Tue 10/1/19*	*Wed 9/30/20*
18	*Subtask 13.8 - Pre-Consolidation System*	*Tue 10/1/19*	*Wed 9/30/20*
19	**Task 14 - Performance Assessment, Modifications, & Testing of PCTB**	**Tue 10/1/19**	**Tue 3/31/20**
20	*Subtask 14.1 - PCTB Lab Test*	*Tue 10/1/19*	*Tue 12/31/19*
21	*Subtask 14.2 - PCTB Modifications/Upgrades*	*Tue 10/1/19*	*Tue 12/31/19*
22	*M4B - Demonstration of a Viable Pressure Coring Tool: Lab Test*	*Tue 12/31/19*	*Tue 12/31/19*
23	*Subtask 14.3 - PCTB Land Test*	*Tue 12/31/19*	*Fri 3/27/20*
24	*M4C - Demonstration of a Viable Pressure Coring Tool: Land Test*	*Tue 3/31/20*	*Tue 3/31/20*
25	**Task 15 - UT-GOM2-2 Scientific Drilling Program Preparations**	**Tue 10/1/19**	**Wed 9/30/20**
26	*Subtask 15.3 - Permitting for UT-GOM2-2 Scientific Drilling Program*	*Tue 10/1/19*	*Wed 9/30/20*



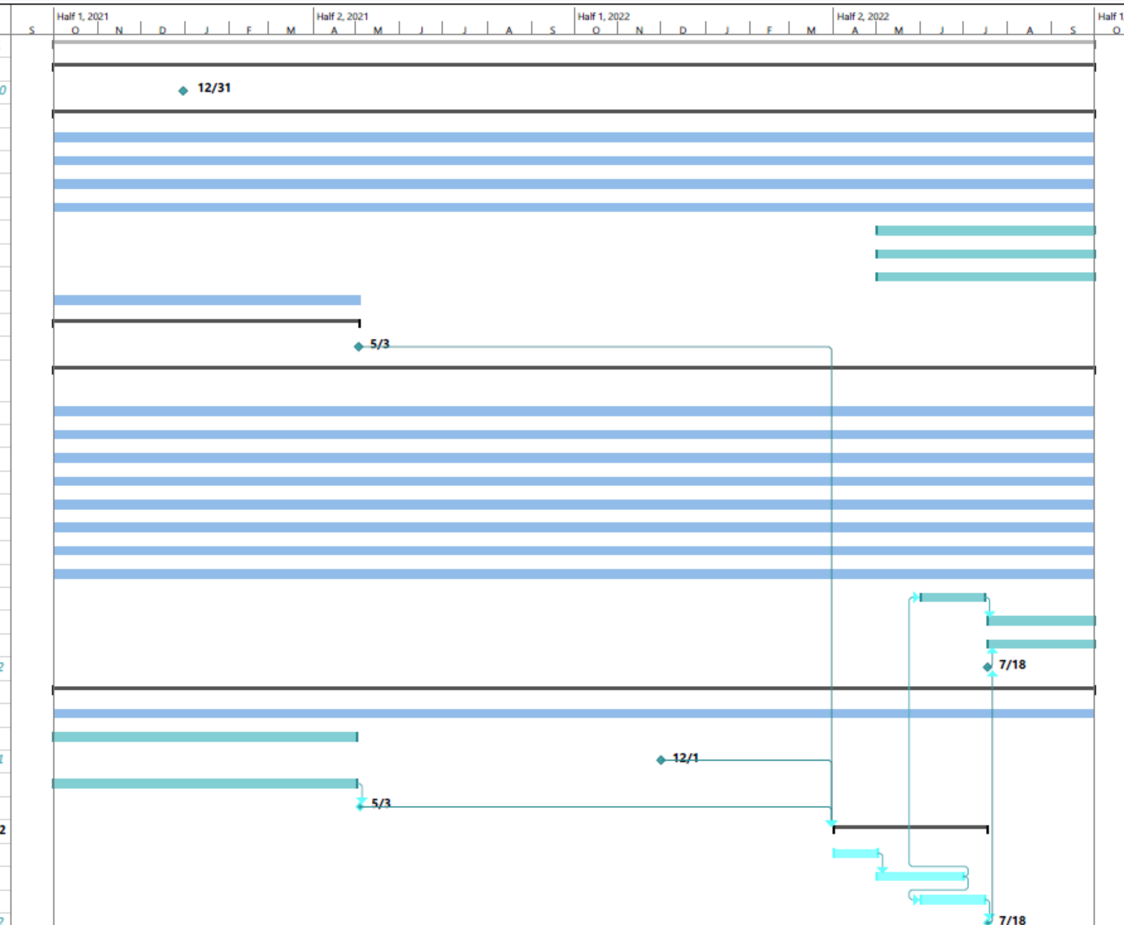
Project: BUDGET PERIOD 4
Date: Thu 8/29/19

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Gantt Chart

PHASE 5: Oct 2020 – Sep 2022

ID	Task Name	Start	Finish
0	**Budget Period 5**	**Thu 10/1/20**	**Fri 9/30/22**
1	**Task 1 - Project Management and Planning**	**Thu 10/1/20**	**Fri 9/30/22**
2	*M5A - Document Results of BP4 Activities*	*Thu 12/31/20*	*Thu 12/31/20*
3	**Task 10 - Core Analysis**	**Thu 10/1/20**	**Fri 9/30/22**
4	*Subtask 10.4 - Continued Pressure Core Analysis (UT-GOM2-1)*	*Thu 10/1/20*	*Fri 9/30/22*
5	*Subtask 10.5 - Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1*	*Thu 10/1/20*	*Fri 9/30/22*
6	*Subtask 10.6 - Additional Core Analysis Capabilities*	*Thu 10/1/20*	*Fri 9/30/22*
7	*Subtask 10.7 - Hydrate Modeling*	*Thu 10/1/20*	*Fri 9/30/22*
8	*Subtask 10.8 - Routine Core Analysis (UT-GOM2-2)*	*Sun 5/1/22*	*Fri 9/30/22*
9	*Subtask 10.9 - Pressure Core Analysis (UT-GOM2-2)*	*Sun 5/1/22*	*Fri 9/30/22*
10	*Subtask 10.10 - Core-log seismic integration (UT-GOM2-2)*	*Sun 5/1/22*	*Fri 9/30/22*
11	**Task 11 - Update Operational Plan for UT-GOM2-2 Scientific Drilling Progra**	**Thu 10/1/20**	**Mon 5/3/21**
12	**Task 12 - UT-GOM2-2 Scientific Drilling Program Vessel Access**	**Thu 10/1/20**	**Mon 5/3/21**
13	*M5B - Complete Contracting/Scheduling of UT-GOM2-2 with Drilling Vesse*	*Mon 5/3/21*	*Mon 5/3/21*
14	**Task 13 - Maintenance & Refinement of Pressure Core Transport, Storage, & Manipulation Capability**	**Thu 10/1/20**	**Fri 9/30/22**
15	*Subtask 13.1 - Hydrate Core Manipulator and Cutter Tool*	*Thu 10/1/20*	*Fri 9/30/22*
16	*Subtask 13.2 - Hydrate Core Effective Stress Chamber*	*Thu 10/1/20*	*Fri 9/30/22*
17	*Subtask 13.3 - Hydrate Core Depressurization Chamber*	*Thu 10/1/20*	*Fri 9/30/22*
18	*Subtask 13.4 - Develop Hydrate Core Transport Capability for UT-GOM2-2*	*Thu 10/1/20*	*Fri 9/30/22*
19	*Subtask 13.5 - Expansion of Pressure Core Storage Capability for UT-GOM2*	*Thu 10/1/20*	*Fri 9/30/22*
20	*Subtask 13.6 - Continued Storage of Hydrate Cores from UT-GOM2-1*	*Thu 10/1/20*	*Fri 9/30/22*
21	*Subtask 13.7 - X-ray Computed Tomography*	*Thu 10/1/20*	*Fri 9/30/22*
22	*Subtask 13.8 - Pre-Consolidation System*	*Thu 10/1/20*	*Fri 9/30/22*
23	*Subtask 13.9 - Transportation of Hydrate Core from UT-GOM2-2*	*Wed 6/1/22*	*Fri 7/15/22*
24	*Subtask 13.10 - Storage of Hydrate Core from UT-GOM2-2*	*Mon 7/18/22*	*Fri 9/30/22*
25	*Subtask 13.11 - Hydrate Core Distribution*	*Mon 7/18/22*	*Fri 9/30/22*
26	*M5C - Complete Project Sample and Data Distribution Plan*	*Mon 7/18/22*	*Mon 7/18/22*
27	**Task - 15 - UT-GOM2-2 Scientific Drilling Program Preparations**	**Thu 10/1/20**	**Fri 9/30/22**
28	*Subtask 15.3 - Permitting for UT-GOM2-2*	*Thu 10/1/20*	*Fri 9/30/22*
29	*Subtask 15.4 - Review and Complete NEPA Requirements*	*Thu 10/1/20*	*Sat 5/1/21*
30	*M5D - Complete Pre-Expedition Permitting Requierements for UT-GOM2-2*	*Wed 12/1/21*	*Wed 12/1/21*
31	*Subtask 15.5 - Finalize Operational Plan for UT-GOM2-2*	*Thu 10/1/20*	*Sat 5/1/21*
32	*M5E - Complete UT-GOM2-2 Operational Plan Report*	*Mon 5/3/21*	*Mon 5/3/21*
33	**Task 16 - UT-GOM2-2 Scientific Drilling Program Field Operations**	**Fri 4/1/22**	**Mon 7/18/22**
34	*Subtask 16.1 - Mob. of Ocean Drilling and Pressure Coring Capability*	*Fri 4/1/22*	*Sun 5/1/22*
35	*Subtask 16.2 - Field Project Management, Operations, and Research*	*Sun 5/1/22*	*Thu 6/30/22*
36	*Subtask 16.3 - Demobilization of Staff, Labs, and Equipment*	*Wed 6/1/22*	*Fri 7/15/22*
37	*M5F - Complete UT-GOM2-2 Field Operations*	*Mon 7/18/22*	*Mon 7/18/22*



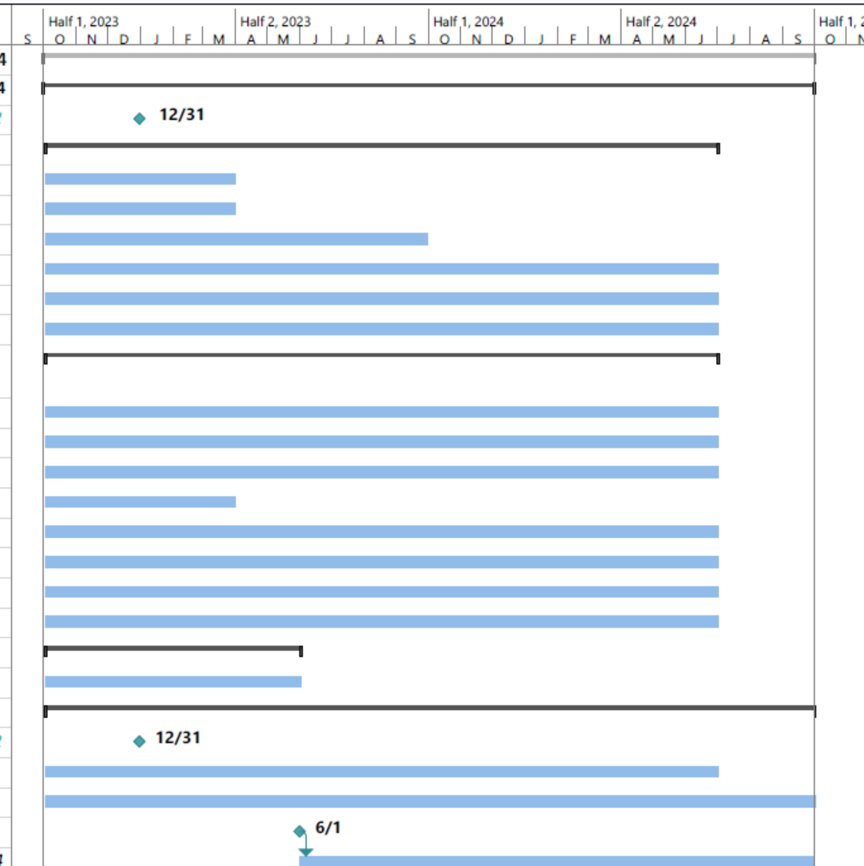
Project: Budget Period 5
Date: Thu 8/29/19

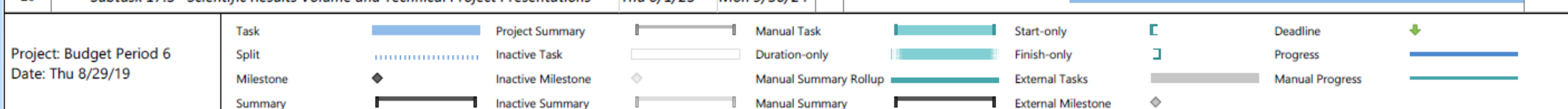
Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	

Gantt Chart

PHASE 6: Oct 2022 – Sep 2024

ID	Task Name	Start	Finish
0	**Budget Period 6**	**Sat 10/1/22**	**Tue 10/1/24**
1	**Task 1 - Project Management and Planning**	**Sat 10/1/22**	**Mon 9/30/24**
2	*M6A - Document Results of BP5 Activities*	*Sat 12/31/22*	*Sat 12/31/22*
3	**Task 10 - Core Analysis**	**Mon 10/3/22**	**Mon 7/1/24**
4	*Subtask 10.4 - Continued Pressure Core Analysis (UT-GOM2-1)*	*Mon 10/3/22*	*Fri 3/31/23*
5	*Subtask 10.5 - Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)*	*Mon 10/3/22*	*Fri 3/31/23*
6	*Subtask 10.6 - Additional Core Analysis Capabilities*	*Mon 10/3/22*	*Fri 9/29/23*
7	*Subtask 10.7 - Hydrate Modeling*	*Mon 10/3/22*	*Mon 7/1/24*
8	*Subtask 10.11 - Continued Pressure Core Analysis (UT-GOM2-2)*	*Mon 10/3/22*	*Mon 7/1/24*
9	*Subtask 10.12 - Continued Core-Log Seismic Synthesis (UT-GOM2-2)*	*Mon 10/3/22*	*Mon 7/1/24*
10	**Task 13 - Maintenance & Refinement of Pressure Core Transport, Storage, & Manipulation Capability**	**Mon 10/3/22**	**Mon 7/1/24**
11	*Subtask 13.1 - Hydrate Core Manipulator and Cutter Tool*	*Mon 10/3/22*	*Mon 7/1/24*
12	*Subtask 13.2 - Hydrate Core Effective Stress Chamber*	*Mon 10/3/22*	*Mon 7/1/24*
13	*Subtask 13.3 - Hydrate Core Depressurization Chamber*	*Mon 10/3/22*	*Mon 7/1/24*
14	*Subtask 13.6 - Continued Storage of Hydrate Cores from UT-GOM2-1*	*Mon 10/3/22*	*Fri 3/31/23*
15	*Subtask 13.7 - X-ray Computed Tomography*	*Mon 10/3/22*	*Mon 7/1/24*
16	*Subtask 13.8 - Pre-Consolidation System*	*Mon 10/3/22*	*Mon 7/1/24*
17	*Subtask 13.10 - Storage of Hydrate Core from UT-GOM2-2*	*Mon 10/3/22*	*Mon 7/1/24*
18	*Subtask 13.11 - Hydrate Core Distribution*	*Mon 10/3/22*	*Mon 7/1/24*
19	**Task 16 - UT-GOM2-2 Scientific Drilling Program Field Operations**	**Mon 10/3/22**	**Thu 6/1/23**
20	*Subtask 16.4 - Post-Expedition Permitting*	*Mon 10/3/22*	*Thu 6/1/23*
21	**Task 17 - Project Data Analysis and Reporting**	**Mon 10/3/22**	**Tue 10/1/24**
22	*M6B - Complete Preliminary UT-GOM2-2 Expedition Summary*	*Sat 12/31/22*	*Sat 12/31/22*
23	*Subtask 17.1 - Sample and Data Distribution and Archiving*	*Mon 10/3/22*	*Mon 7/1/24*
24	*Subtask 17.2 - Collaborative Post-Field Project Analysis of Geologic Data and Sa*	*Mon 10/3/22*	*Tue 10/1/24*
25	*M6C - Initiate Comprehensive Scientific Results Volume*	*Thu 6/1/23*	*Thu 6/1/23*
26	*Subtask 17.3 - Scientific Results Volume and Technical Project Presentations*	*Thu 6/1/23*	*Mon 9/30/24*





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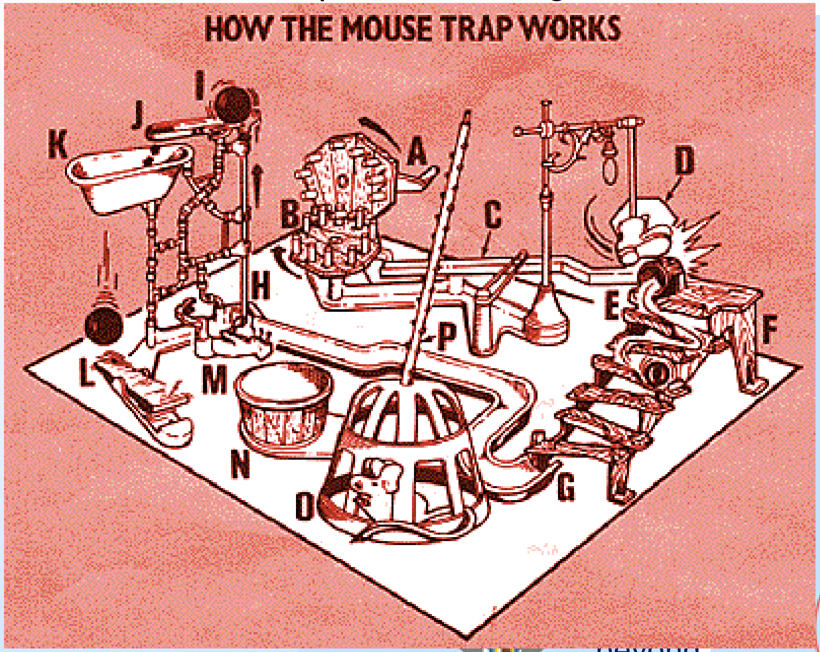
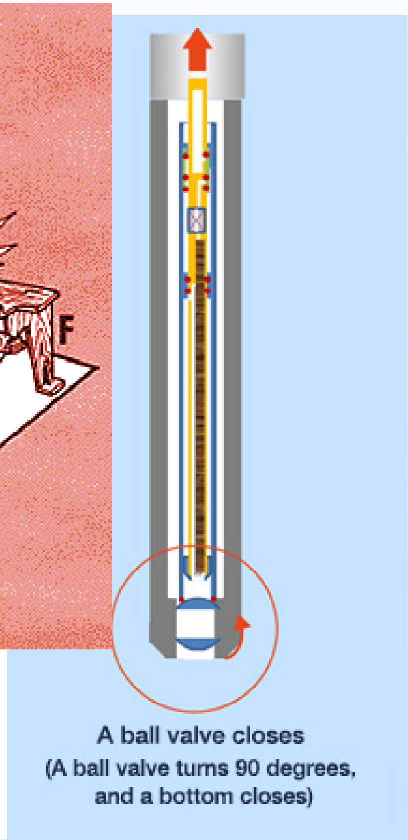
End of presentation

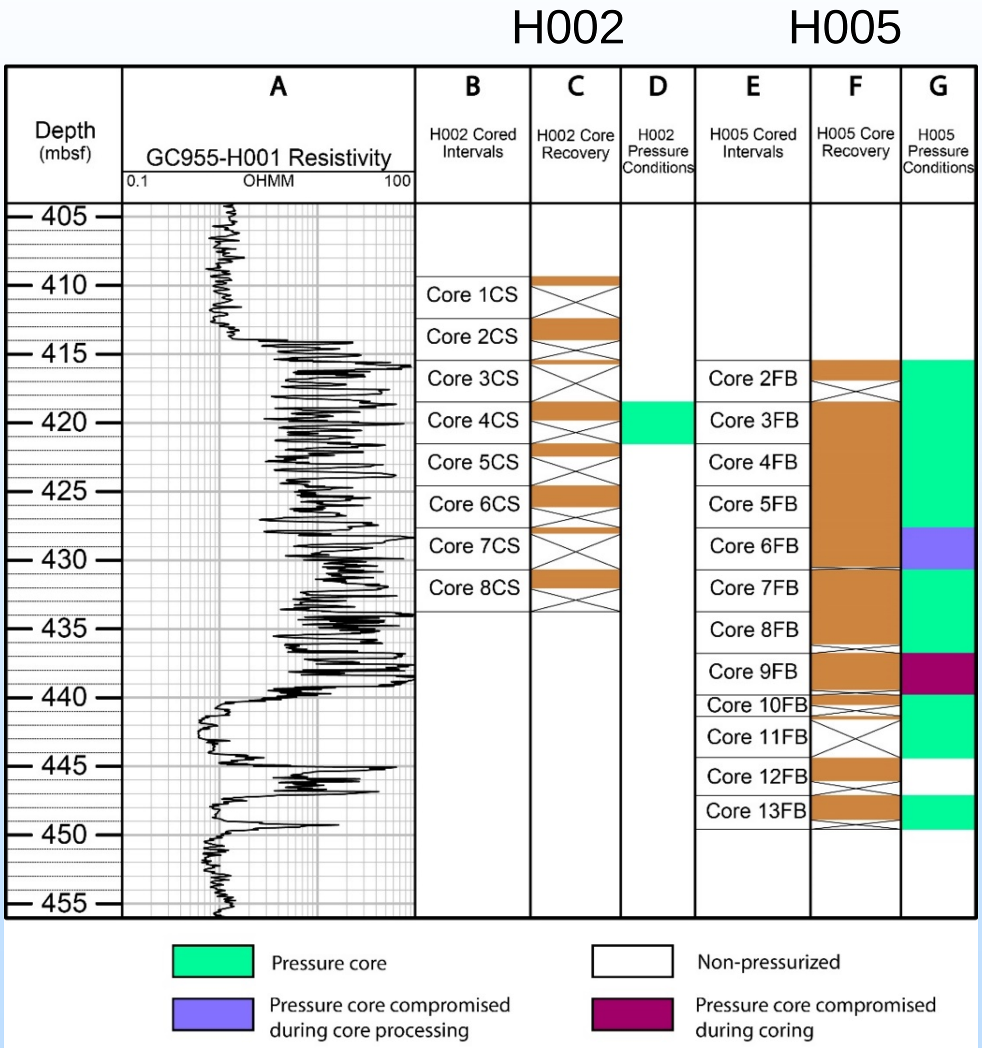
What are pressure coring tools?





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

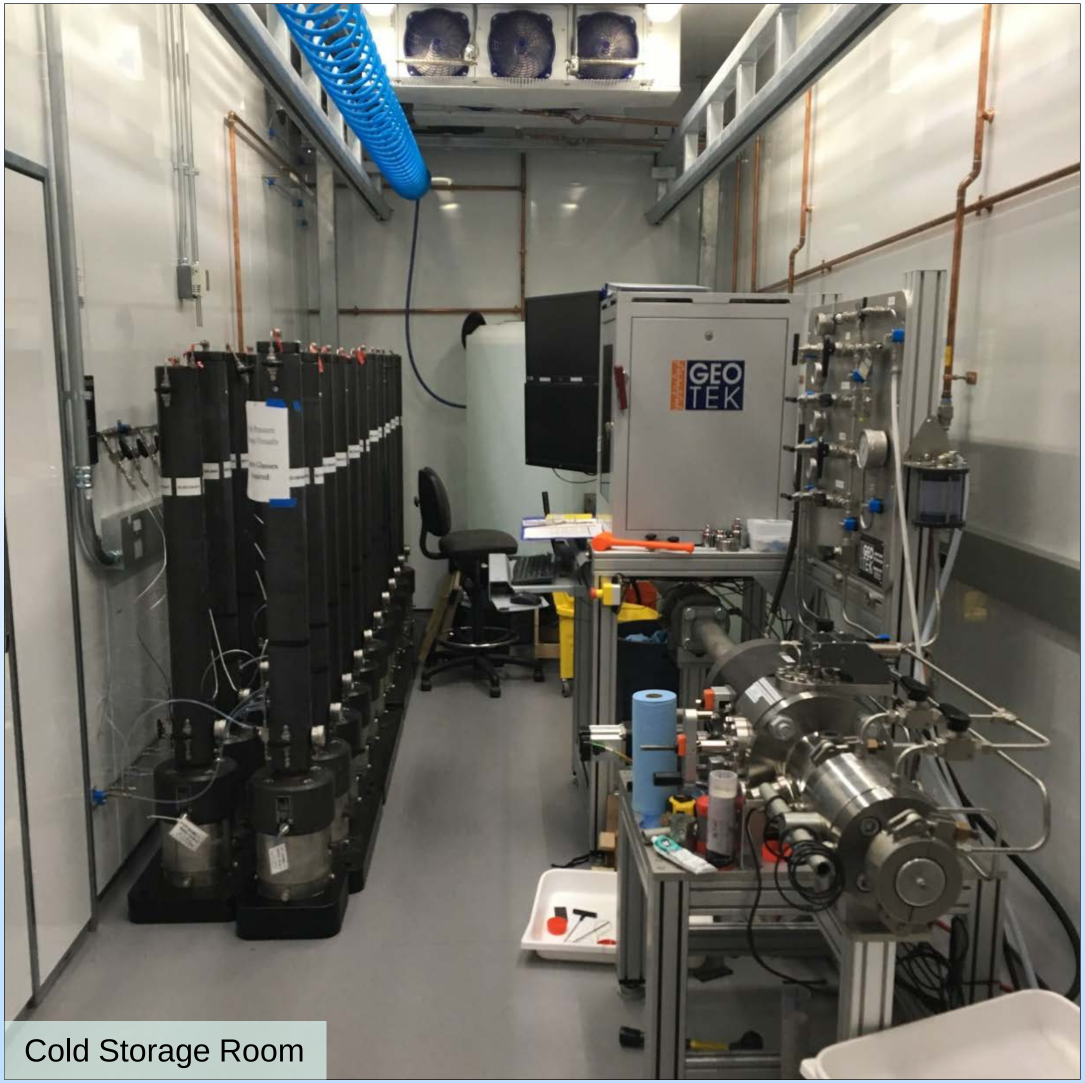
UT-GOM2-1 Expedition - May 2017



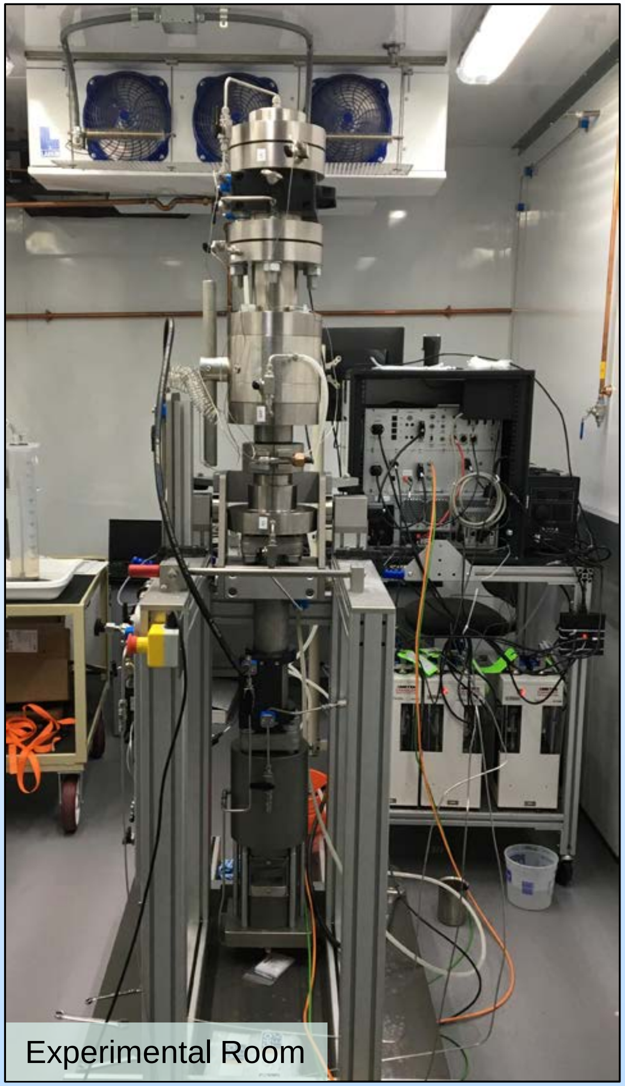
- 12 successful pressure cores in main hydrate reservoir

Ongoing Experimental Analysis: UT Pressure Core Center

(a) Pressure Core Chamber and Mini-PCATS



(b) K0 Permeameter



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)

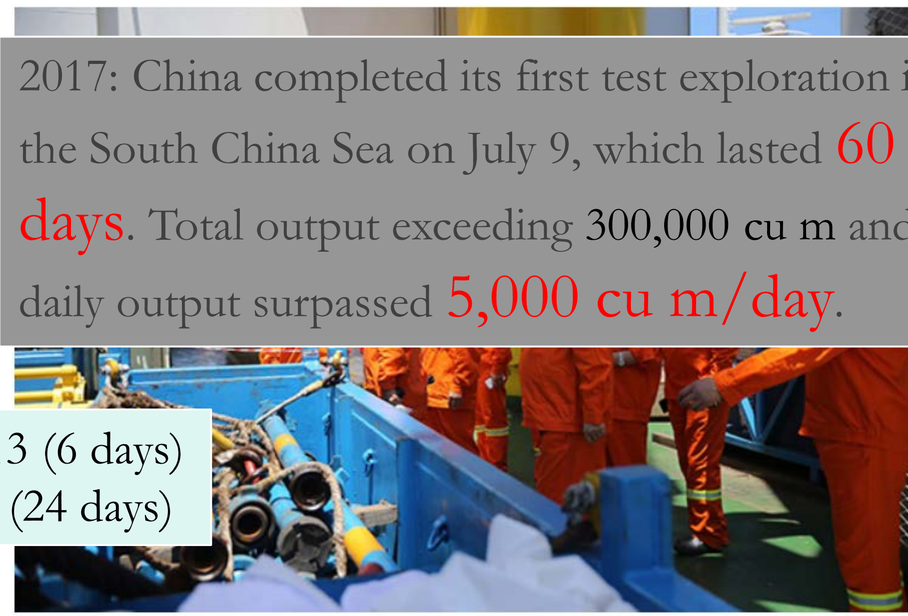
An Energy Coup for Japan: 'Flammable Ice'

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

Combustible ice heralds clean energy

By Zheng Xin and Zou Shuo | China Daily | Updated: 2017-09-04 07:10

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.



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]

UT GOM2-1 Executed Spring 2017

May 2 Mobilize

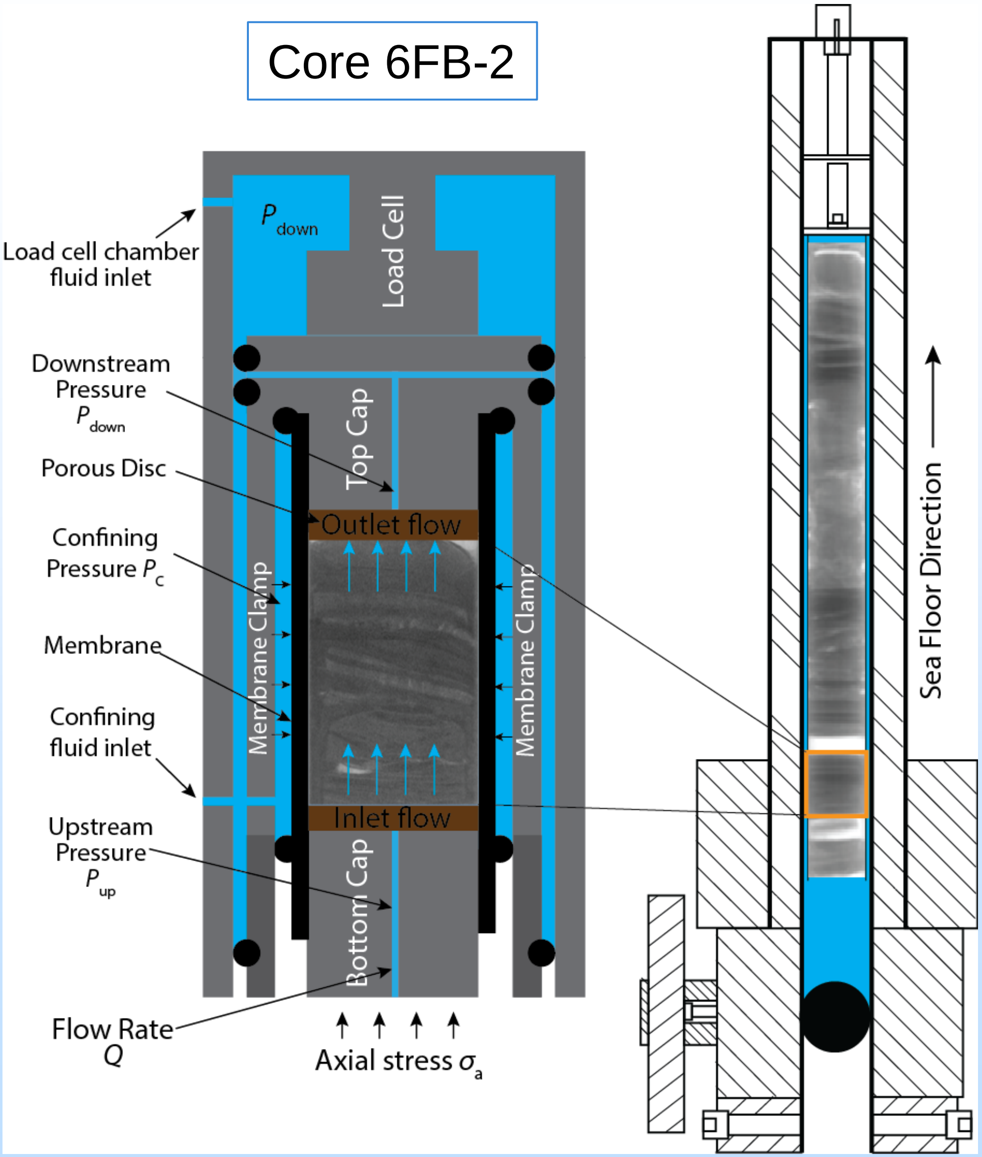
May 11 Execute

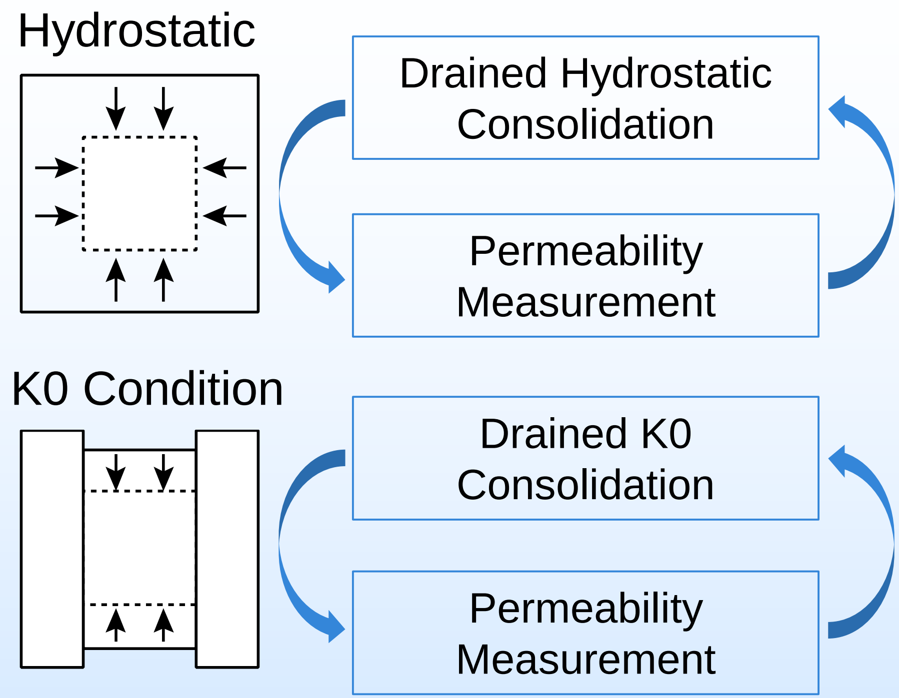
May 23 Demobilize

May 26 Establish shore-based lab

June 3 Complete Operations

K0 Permeability Measurement

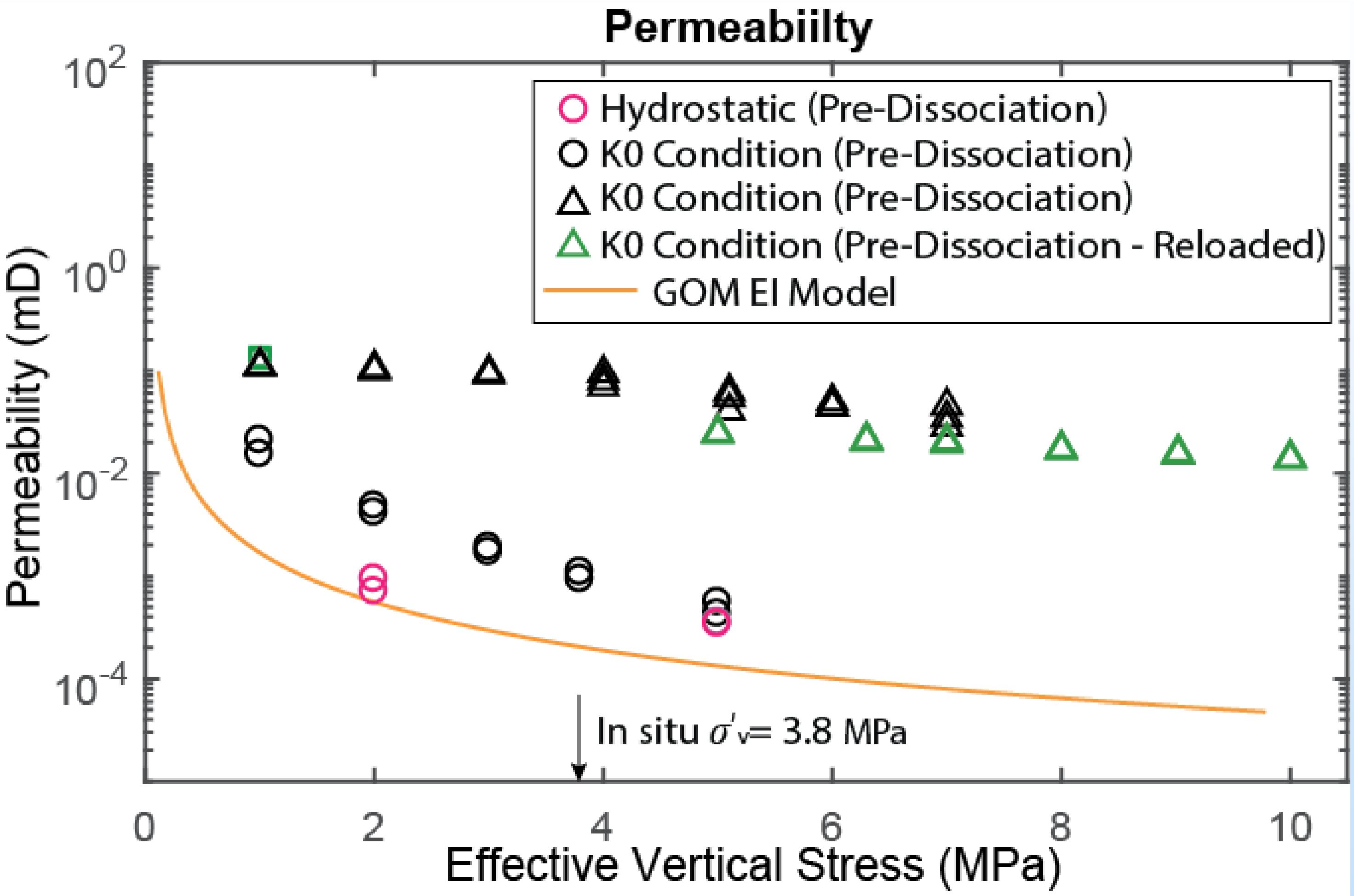




- ✓ Tests pre- and post-dissociation
- ✓ Consolidation at Hydrostatic stress
- ✓ Consolidation K0 condition
- ✓ 3 permeability tests per stress state

(22 consolidation tests & 61 perm tests)

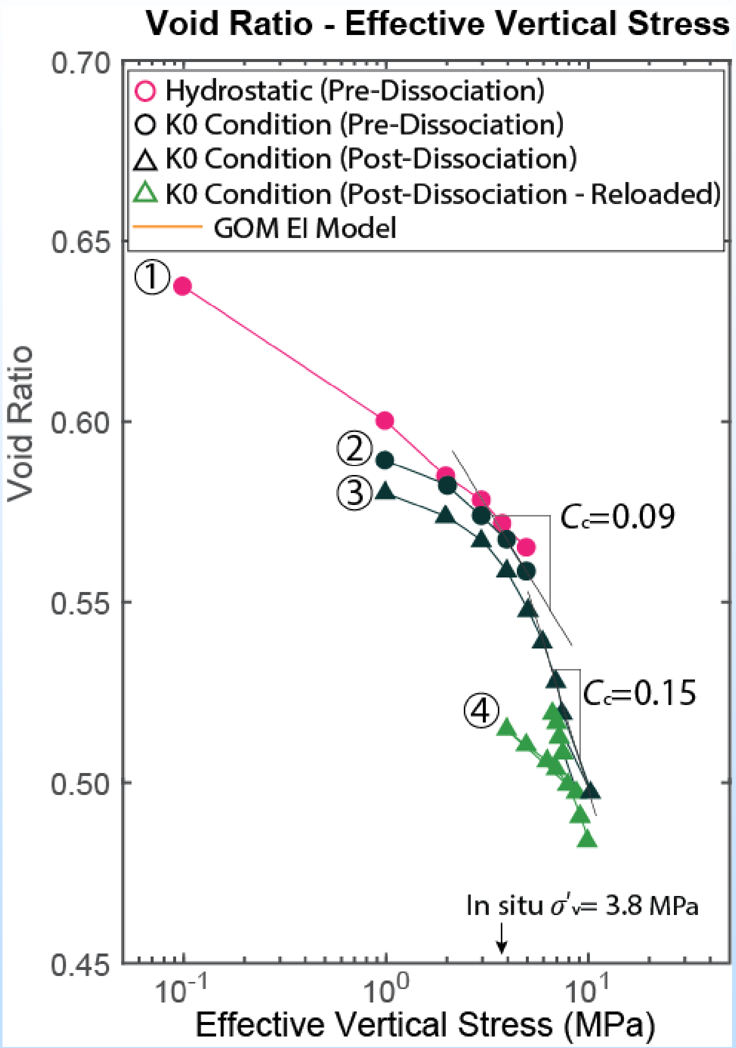
Initial Permeability Measurements



- ✓ 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

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 $C_c = 0.15$

UT-GOM2-2 Scientific Drilling Program

Plan Overview

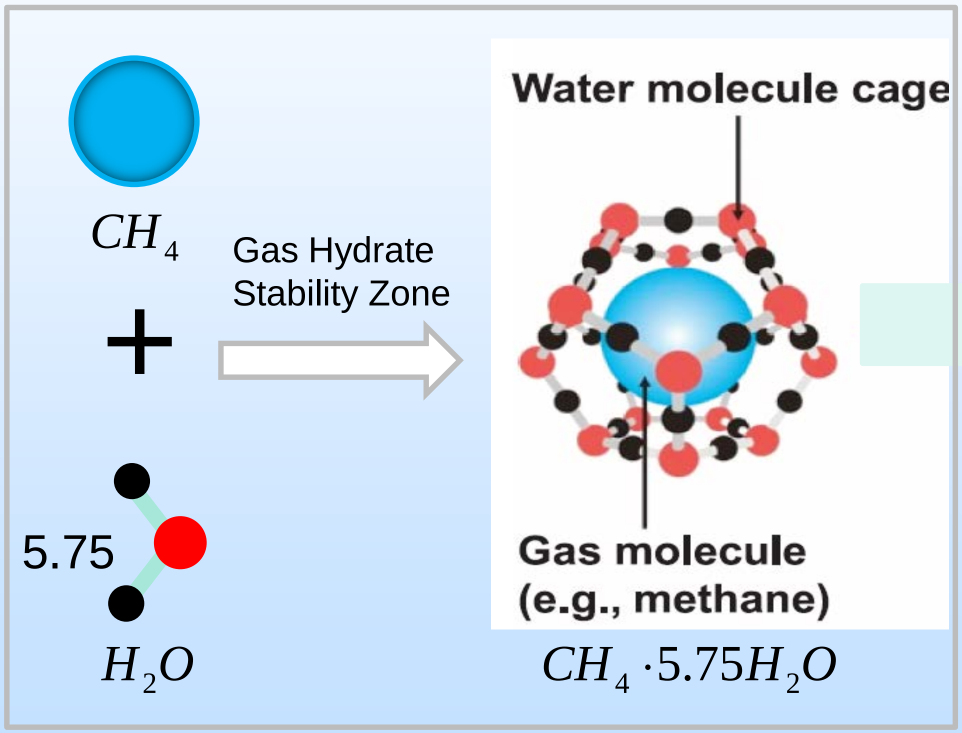
- Will occur in 2022
- UT contracts industry vessel similar to Helix Q4000
- Conventional and pressure core two holes in Terrebonne Basin at JIP LWD locations:
  - <u>**WR313-H002**</u>

    ~28 pressure coring deployments, including 7 continuous pressure cores through and around the Orange Sand
  - <u>**WR313-G002**</u>

    ~19 pressure coring deployments, continuous conventional coring to 250 fbsf, conventional spot coring below 250 fbsf

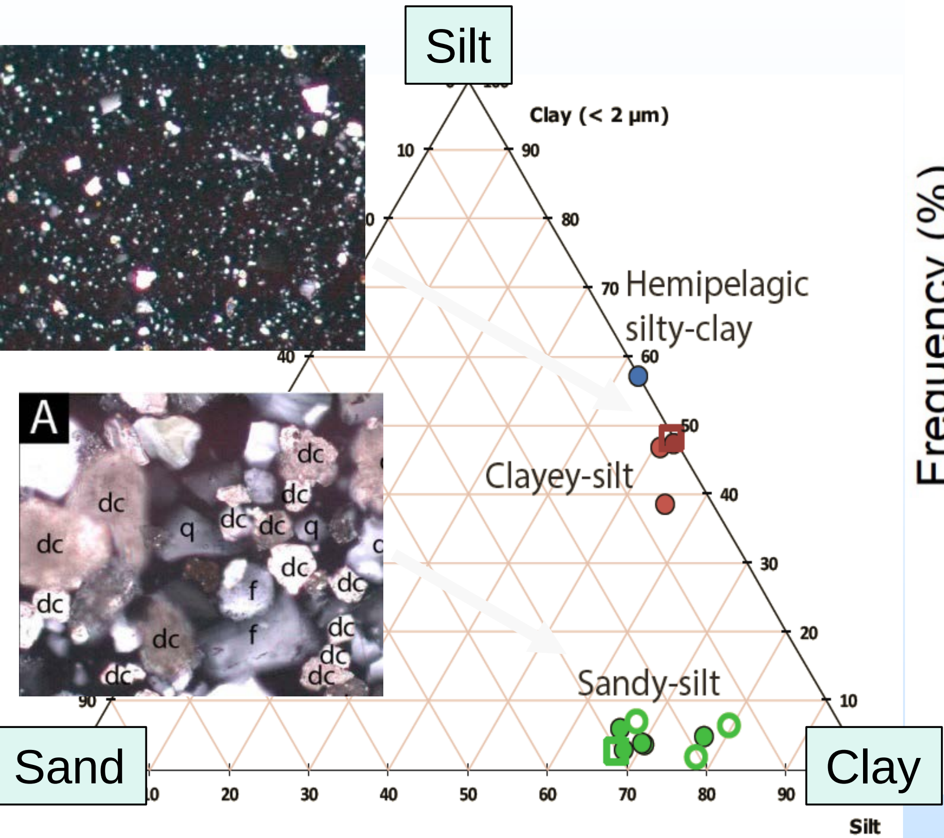
Introduction

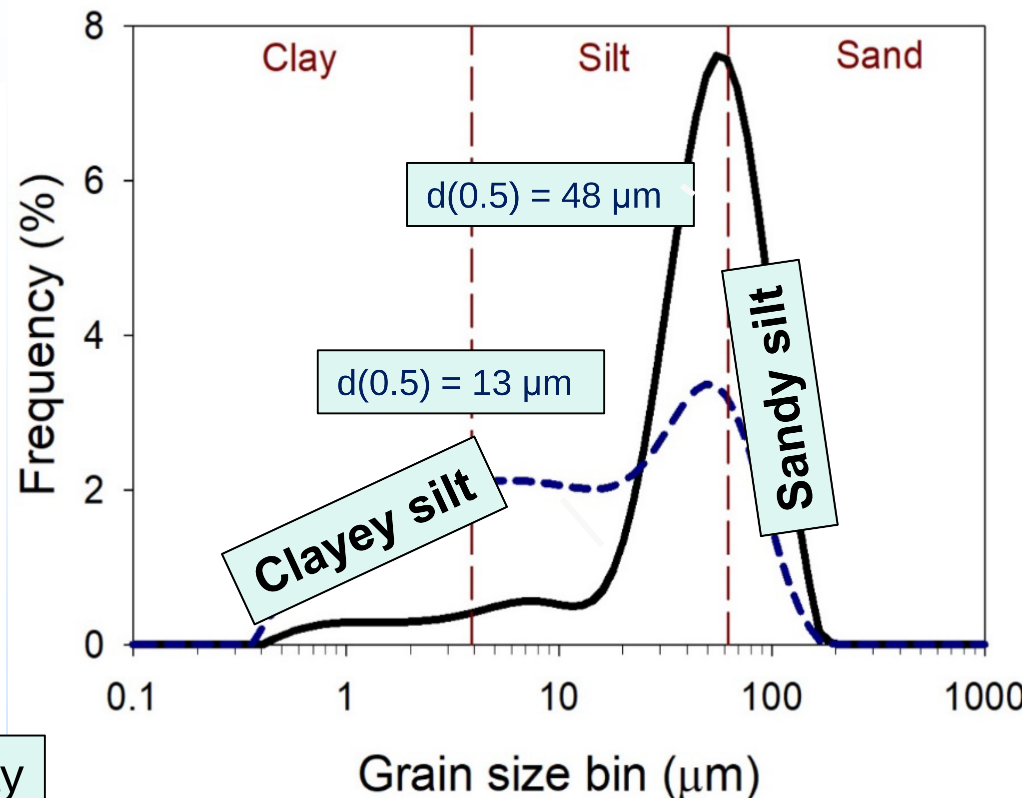
What is methane hydrate?



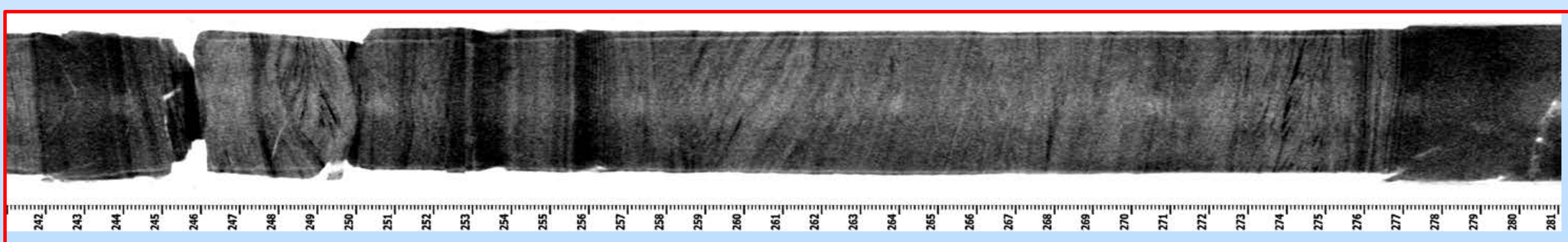
(Collett et al., 2009)

Sandy Silt





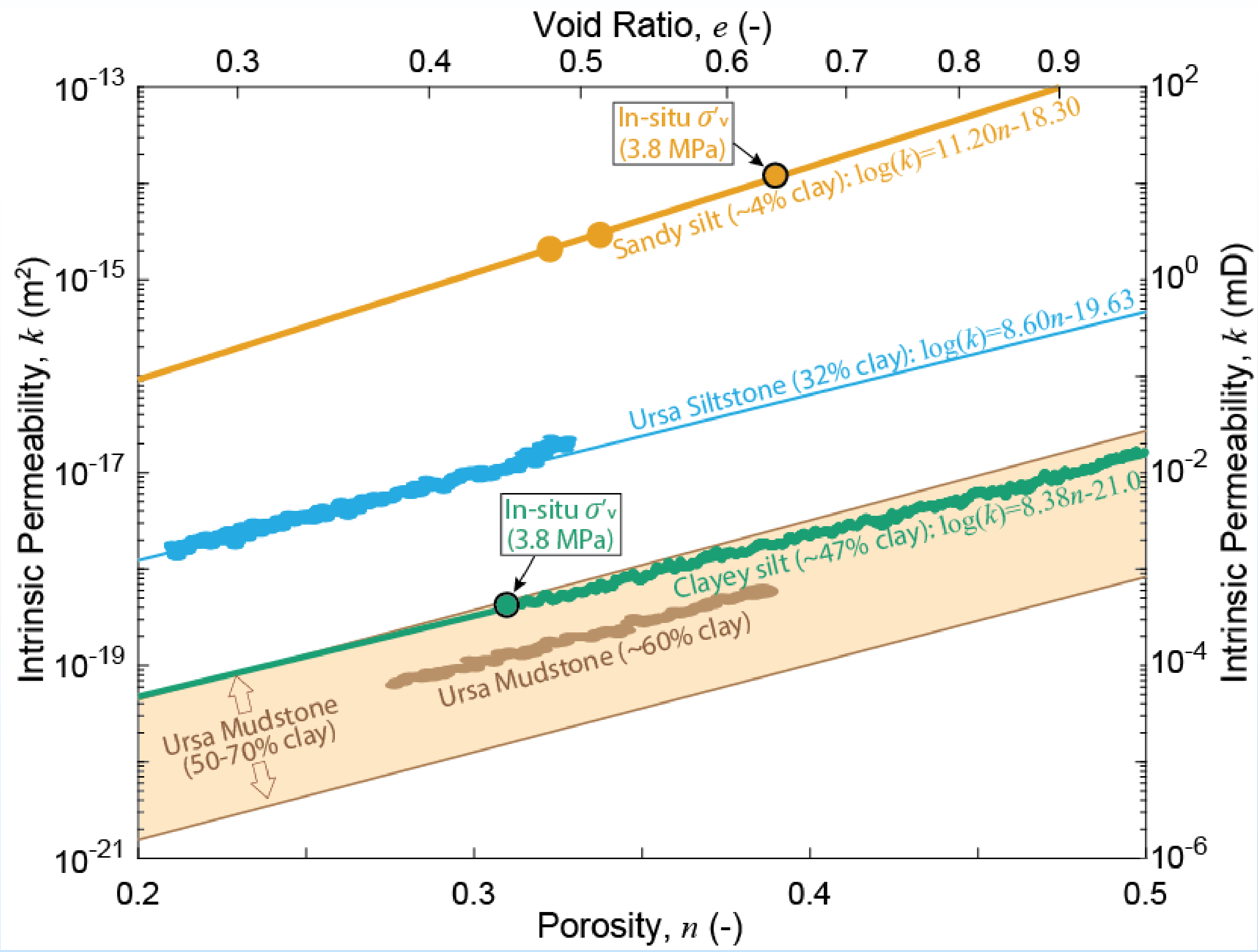
(Meazell, in prep)



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?

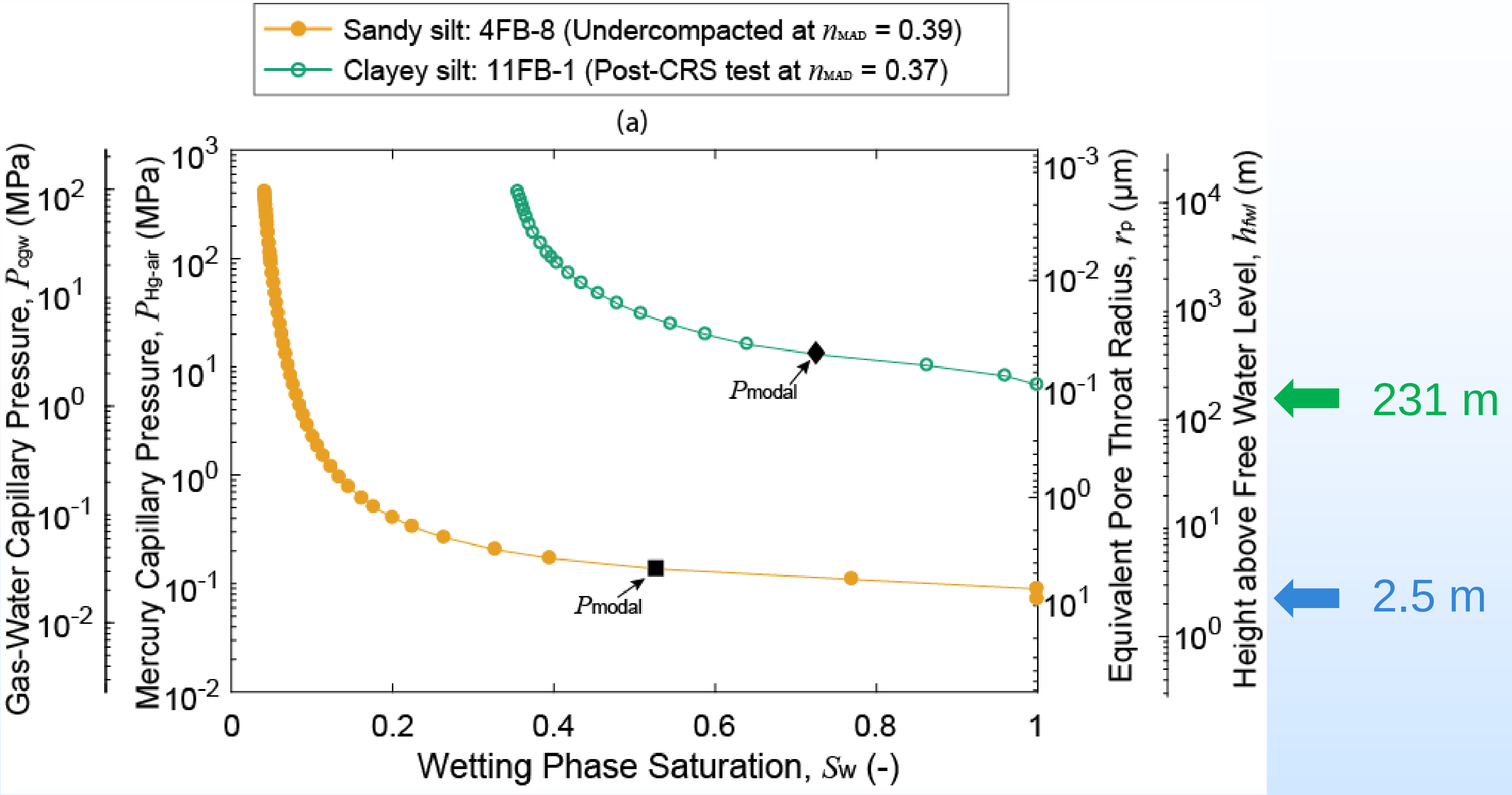
Results of Intrinsic permeability



(Fang et al., AAPG Bulletin, accept pending revisions)

- Sandy silt: 11.8 mD (1.18×10^{-14} m^2) at in-situ effective stress (3.8 MPa)
- Clayey silt: 3.84×10^{-4} mD (3.84×10^{-19} m^2) at in-situ effective stress (3.8 MPa)
- Intrinsic permeability is lithology-dependent.

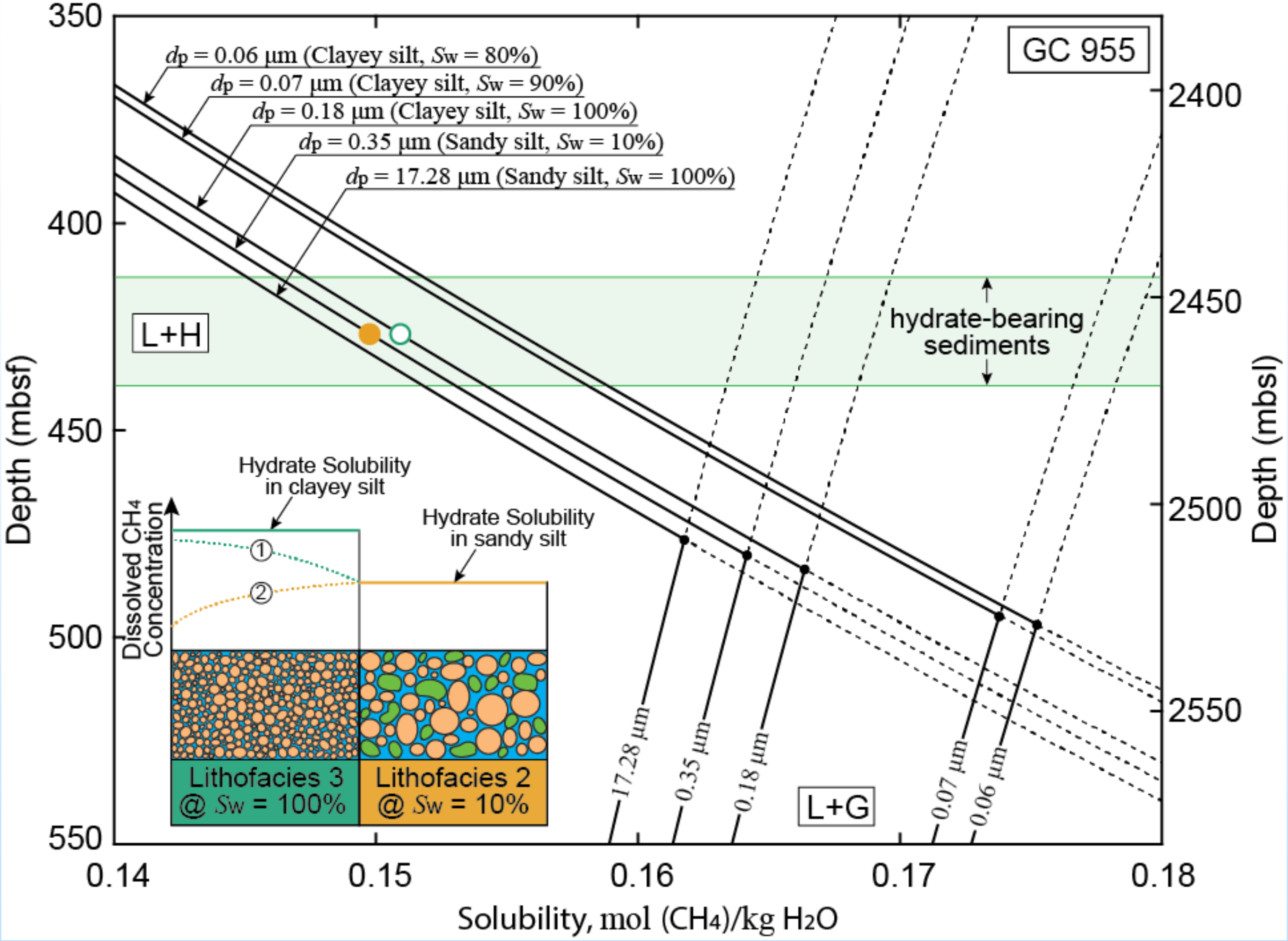
Capillary behavior of Sandy Silt & Clayey Silt



(Fang et al., AAPG Bulletin, accept pending revisions)

Facies	Hydrate Saturation	Equivalent Pore Diameter (micron)
Sandy silt	0%	17.28
Sandy silt	90%	0.35
Clayey silt	0%	0.18
Clayey silt	10%	0.07
Clayey silt	20%	0.06

Why hydrate does not form in lithofacies 3?



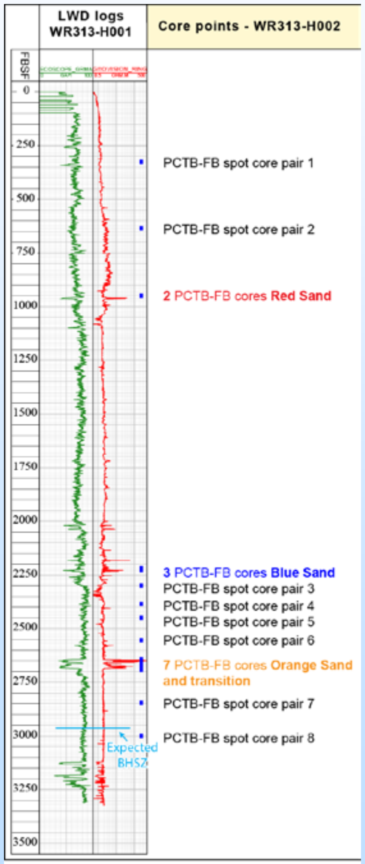
(Fang et al., AAPG Bulletin, accept pending revisions)

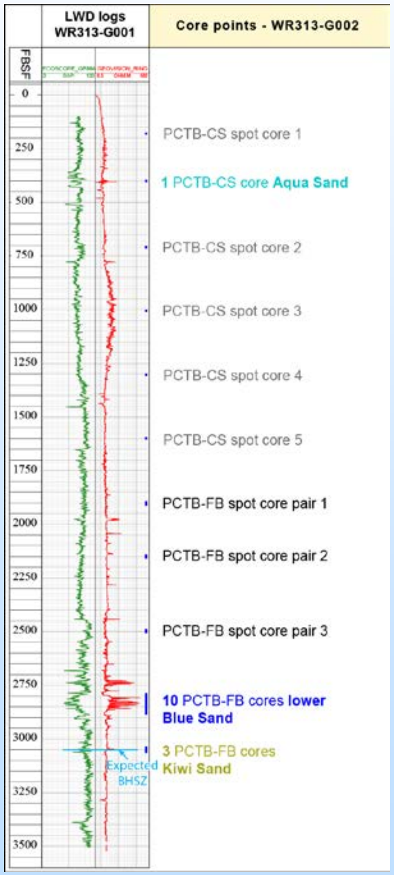
Path (1): Methane source in clayey silt (biogenic degradation of organic matter)

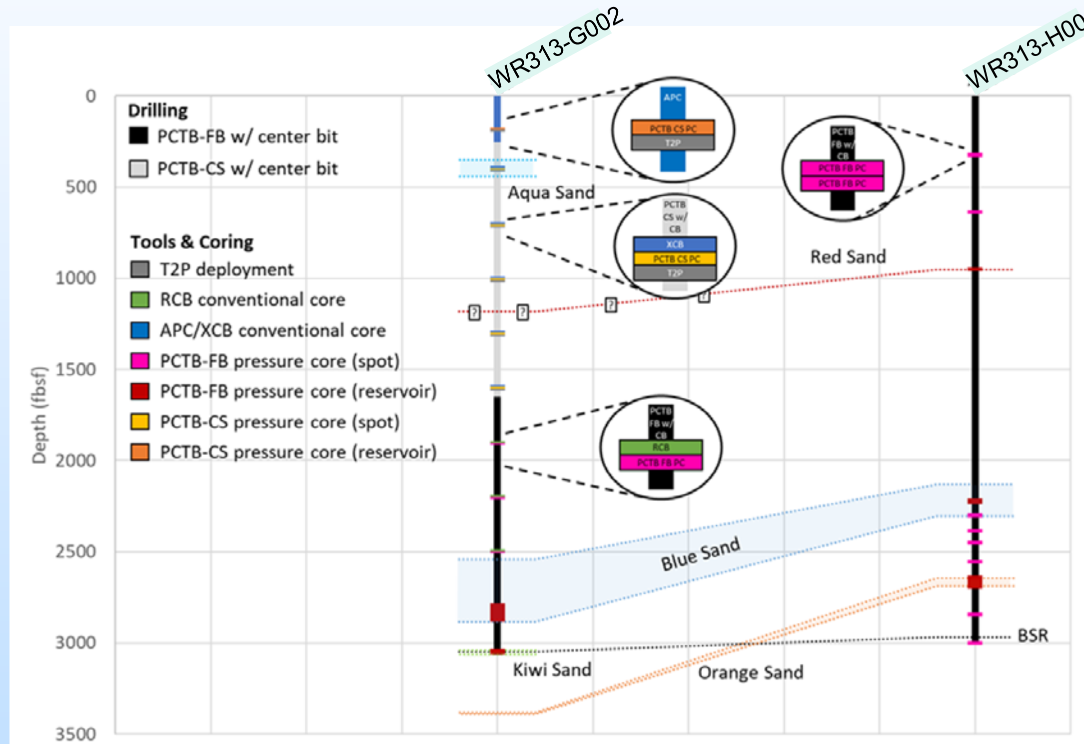
Path (2): Methane invades in sandy silt (free gas invasion)

UT-GOM2-2 Scientific Drilling Program

Coring Plan – Graphical Representation







UT-GOM2-2 Expedition - 2022