Deepwater Methane Hydrate Characterization and Scientific Assessment

DE-FE0023919

Peter Flemings & the GOM2 Team

The University of Texas at Austin

Lamont-Doherty Earth Observatory
Oregon State University
The Ohio State University
USGS

University of New Hampshire
University of Washington
Tufts University
BOEM

U.S. Department of Energy
National Energy Technology Laboratory
2021 Carbon Management and Oil and Gas Research Project Review Meeting
August 2021

Why are we here?

- **5-22% of the world's organic carbon is trapped as gas hydrate**
  - A viable energy source? Response to climate change? Role in Earth's carbon cycle?

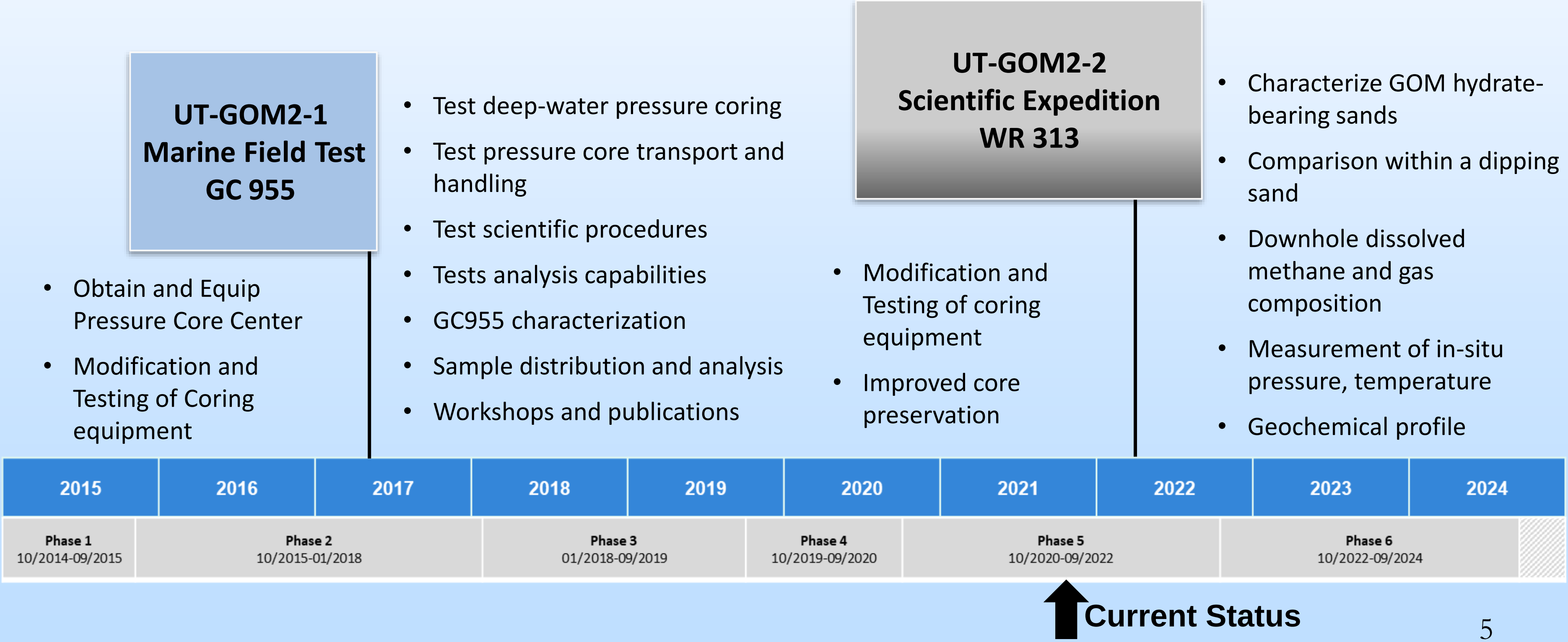
- **Project centerpiece: coring mission to GOM deepwater hydrate reservoir**
  - determine physical, chemical, and biological properties and illuminate origin, dynamic behavior, and response of system to perturbation.
  - First U.S. effort to acquire samples in deepwater hydrate reservoirs.
  - Novel technology to extract rock cores at in situ pressure a mile beneath the ocean, bring them to the surface, and then study those pressurized cores in laboratories around the world.

Presentation Outline

- Introduction
- Technology Development
- Hydrate Science
- UT-GOM2-2 Science Expedition, WR 313

GOM2 Objectives

- To locate, drill, and sample methane hydrate deposits
- To store, manipulate, and analyze pressurized hydrates samples
- To maximize science through sample distribution, analysis, and collaboration



UT-GOM2-1
Marine Field Test
GC 955

- Obtain and Equip Pressure Core Center
- Modification and Testing of Coring equipment

- Test deep-water pressure coring
- Test pressure core transport and handling
- Test scientific procedures
- Tests analysis capabilities
- GC955 characterization
- Sample distribution and analysis
- Workshops and publications

UT-GOM2-2
Scientific Expedition
WR 313

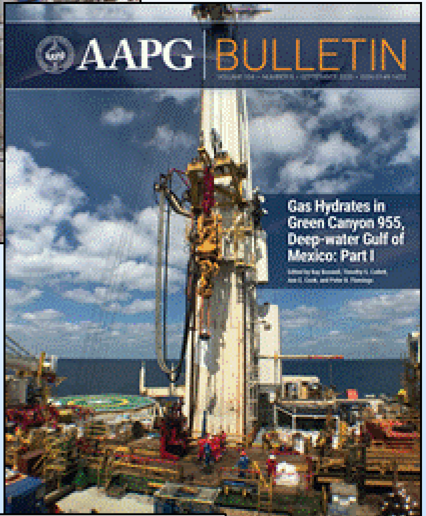
- Modification and Testing of coring equipment
- Improved core preservation

- Characterize GOM hydrate-bearing sands
- Comparison within a dipping sand
- Downhole dissolved methane and gas composition
- Measurement of in-situ pressure, temperature
- Geochemical profile

Current Status

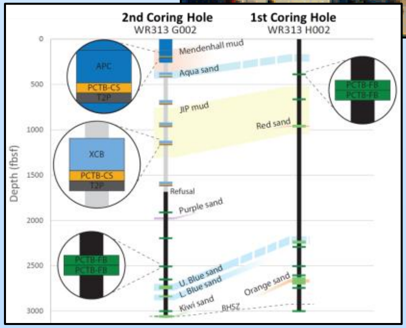
Accomplishments to Date

- Successful Field Execution: GOM2-1
- Successful development of pressure coring and core testing equipment
- Fundamental contributions in characterization, laboratory analysis, and modeling
- Dedicated AAPG Volume 1 and Volume 2 summarize findings
- International research collaboration on analyses of pressure core samples
- Expedition Planning complete: GOM2-2



AAPG BULLETIN

Gas Hydrates in Green Canyon 955, Deep-water Gulf of Mexico: Part I



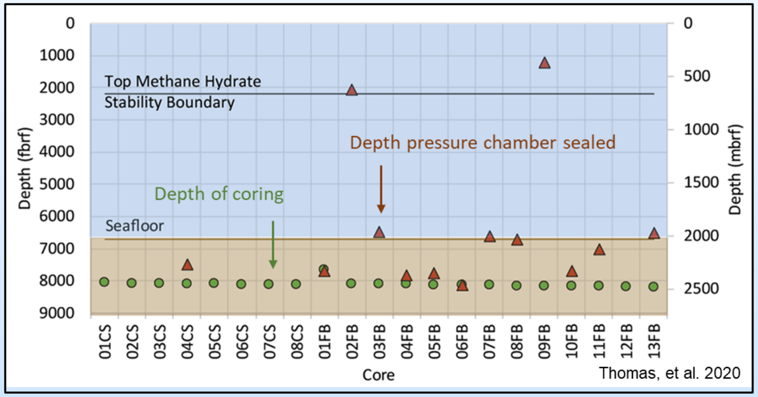
Technology Development
Pressure Coring Tool w/ Ball valve (PCTB)

- Very complex tool
- Tool issues have overlapping consequences
- History of high failure rates
- Initial lack of lab testing equipment and methods made source identification difficult
- We've made continuous improvements

Technology Development
Pressure Coring – results up to Fall 2020

During UT-GOM2-1
- 7 runs failed
- 9 runs sealed late

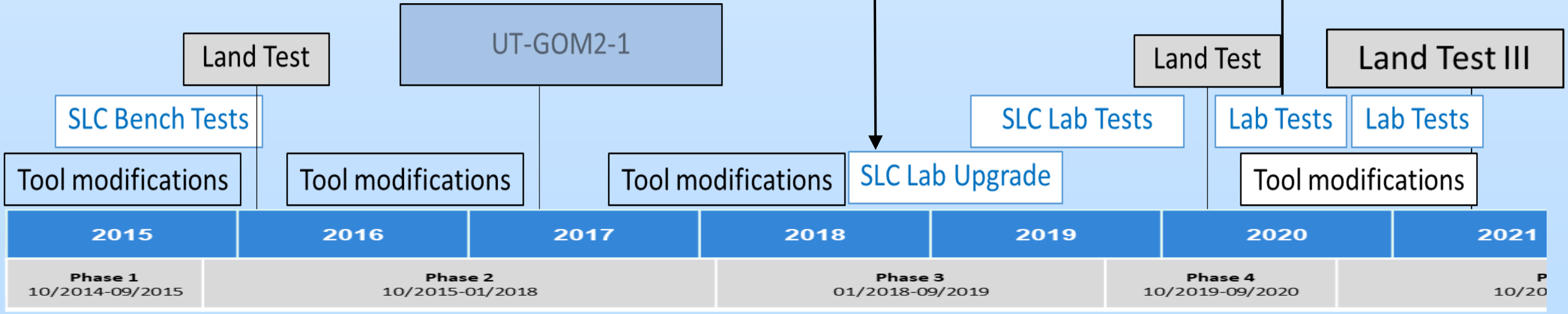
After GOM2-1:
- Improved ability to core at higher flow rates (better tool performance).
- Improved sealing at top of tool.



Thomas, et al. 2020

- Developed ability to replicate failure mechanism at Geotek

Land Test II, Cameron, TX :
- 6 out of 7 coring tests fail
- due to sensitivity of ball valve to presence of grit


Land Test

UT-GOM2-1

Land Test

Land Test III

SLC Bench Tests

SLC Lab Tests

Lab Tests

Lab Tests

Tool modifications

Tool modifications

Tool modifications

SLC Lab Upgrade

Tool modifications

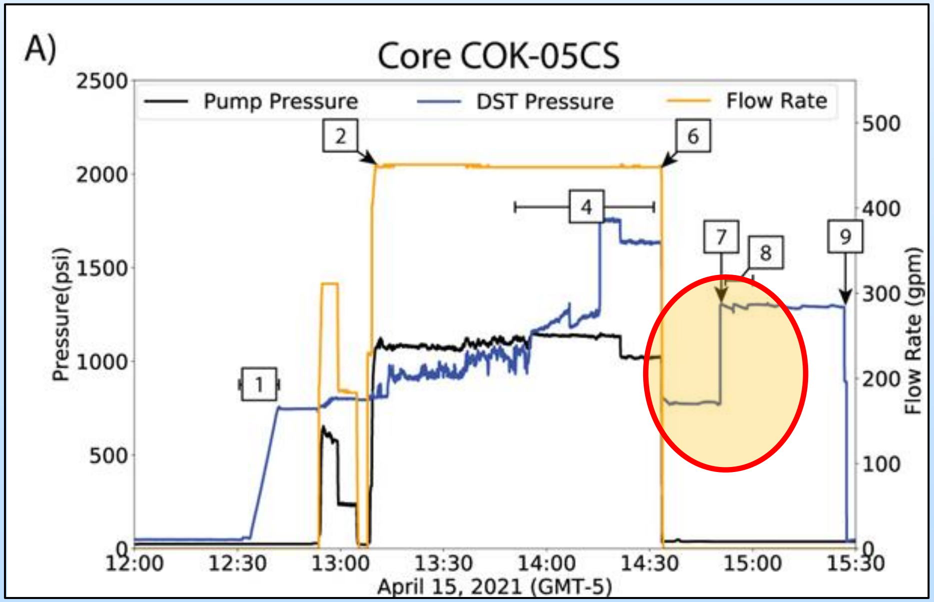
2015	2016	2017	2018	2019	2020	2021

Phase 1 10/2014-09/2015	Phase 2 10/2015-01/2018	Phase 3 01/2018-09/2019	Phase 4 10/2019-09/2020	P 10/20

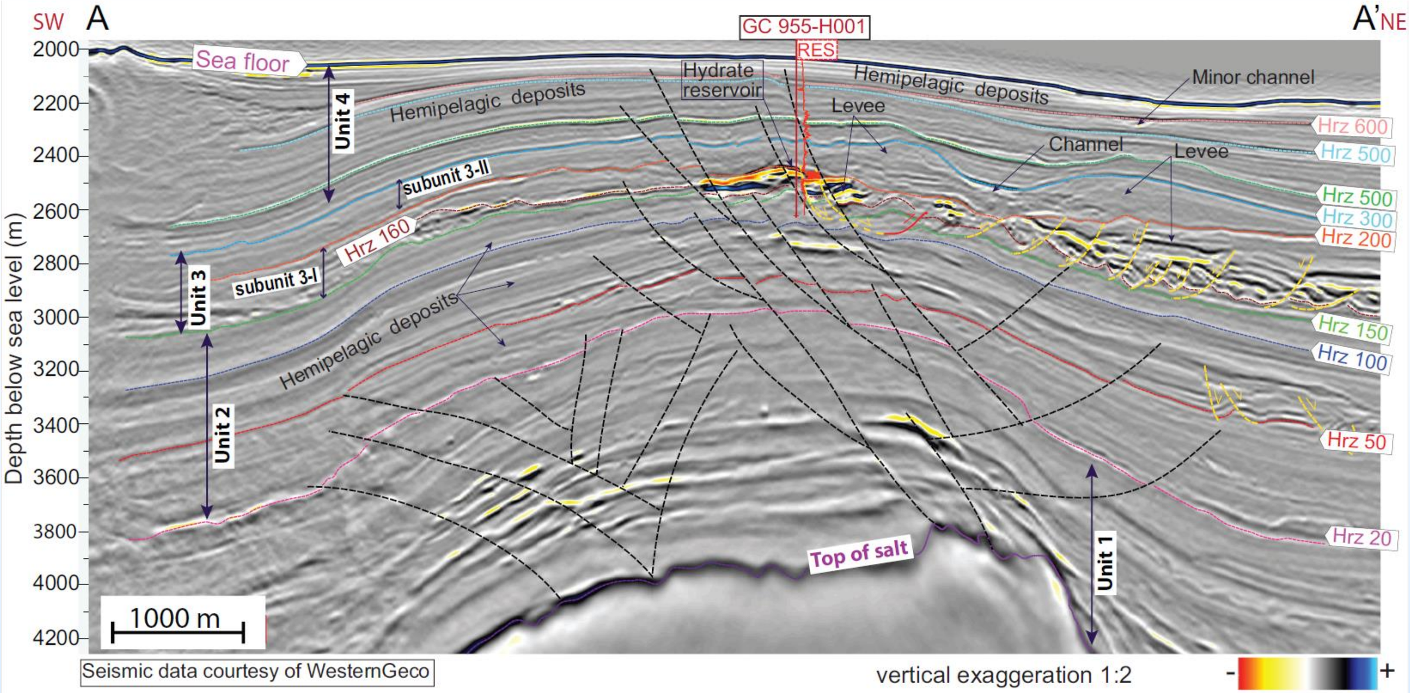
Technology Development
Pressure Coring, Spring 2021

Land Test III Catoosa, OK

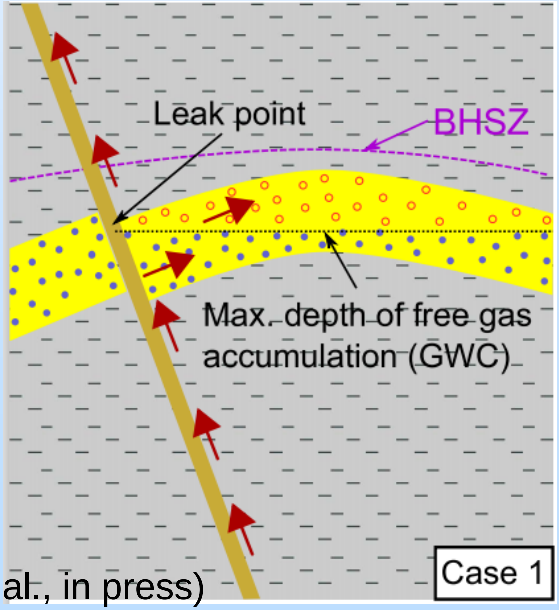
- Successful tool deployments (84%)
- No sealing failures from grit;
- tool modifications solved grit problem without introducing additional failure mechanisms
- Tool is ready to deploy!



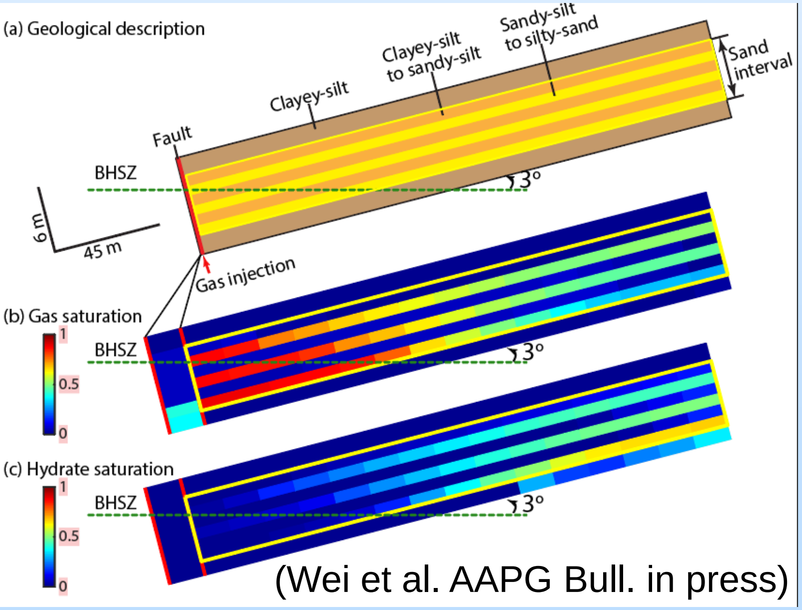
Science Theme 1: Methane from below and dominantly biogenic



- Some gas is sourced from deep reservoirs, but the primary source is biogenic methane
- Biogenic methane may be made within the HSZ or below the HSZ



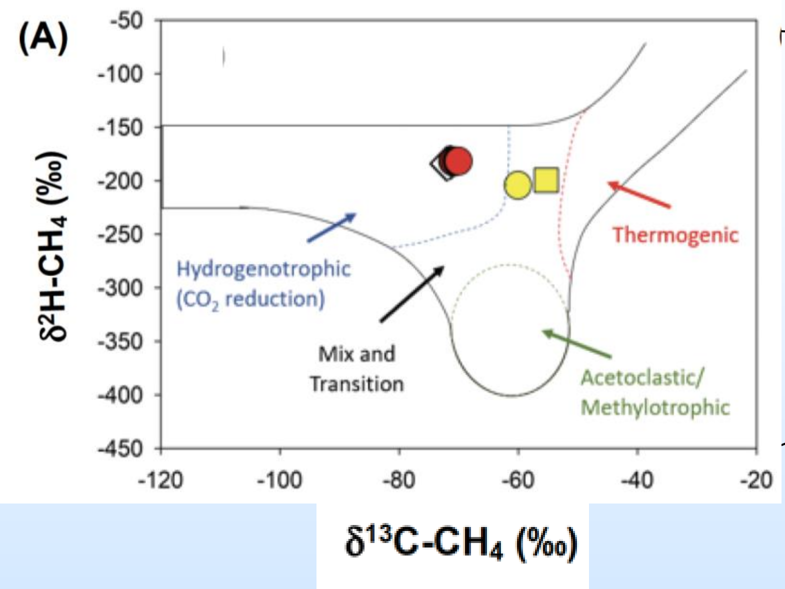
(Santra et al., in press)

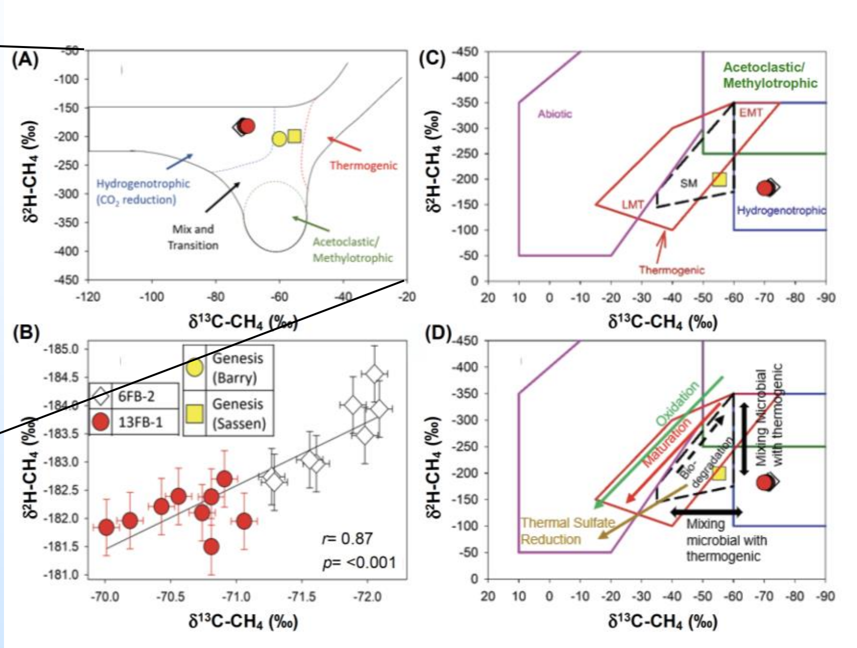


(Wei et al. AAPG Bull. in press)

Science Theme 1: Methane from below and dominantly biogenic

By assessing gas and gas isotope ratios we can interpret the source of methane in the hydrates



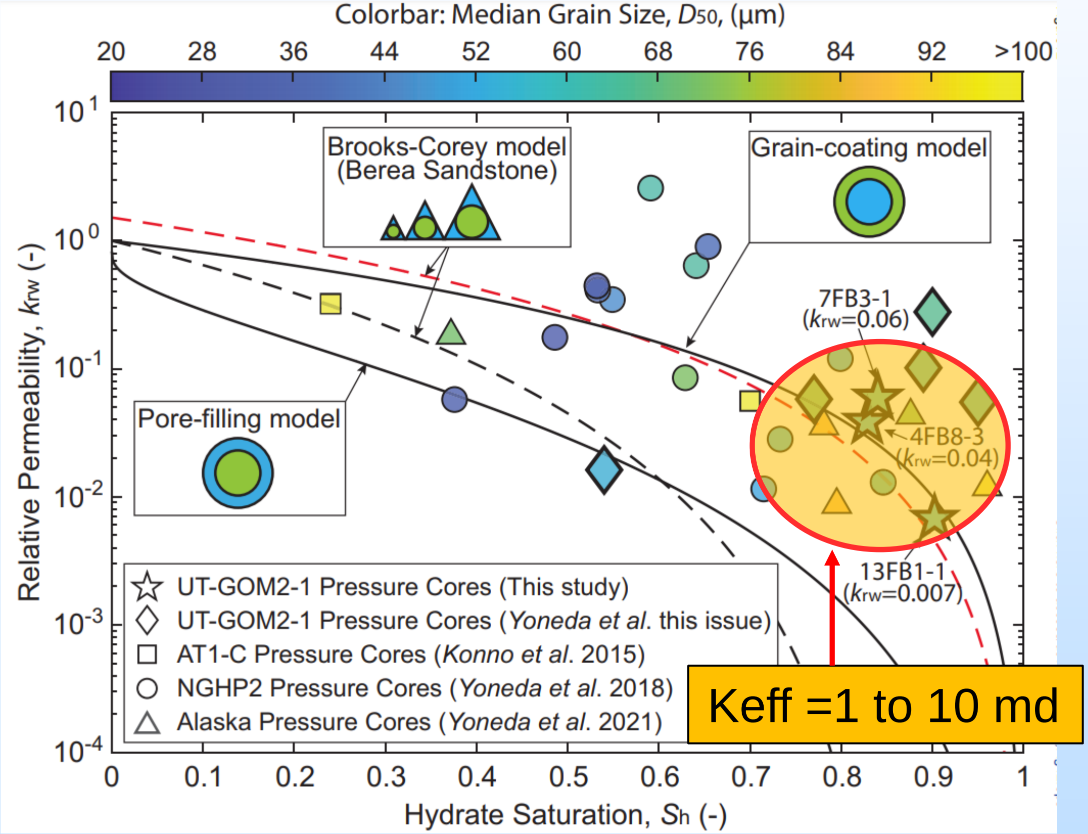


(Moore et al., Ahead of Print)

GC 955 Hydrate-bearing sediment :

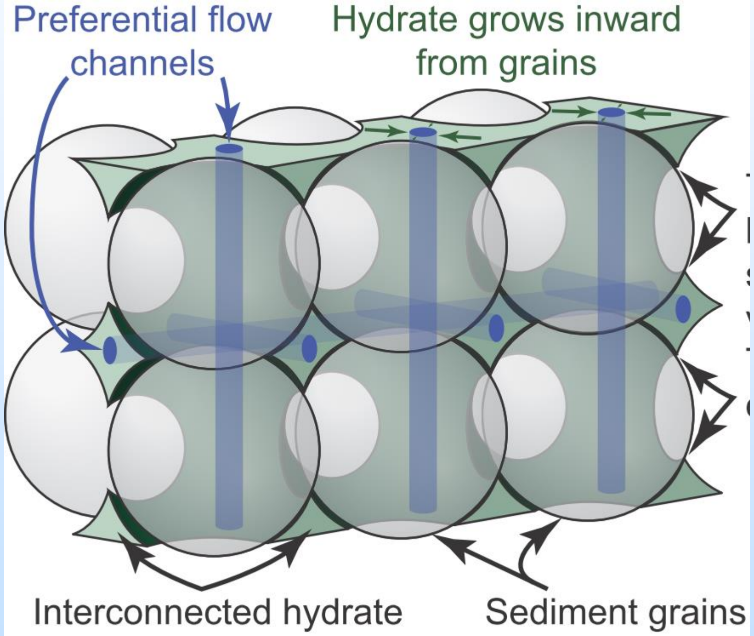
- ≥76% microbial methane by hydrogenotrophic (CO2 reduction) methanogenesis
- Increased thermogenic proportions (~6%) in a hydrate-bearing layer below the main hydrate-bearing interval
- Microbial methane may be abundant below the base of gas hydrate stability

Science Theme 2: High Effective Permeability



Keff =1 to 10 md

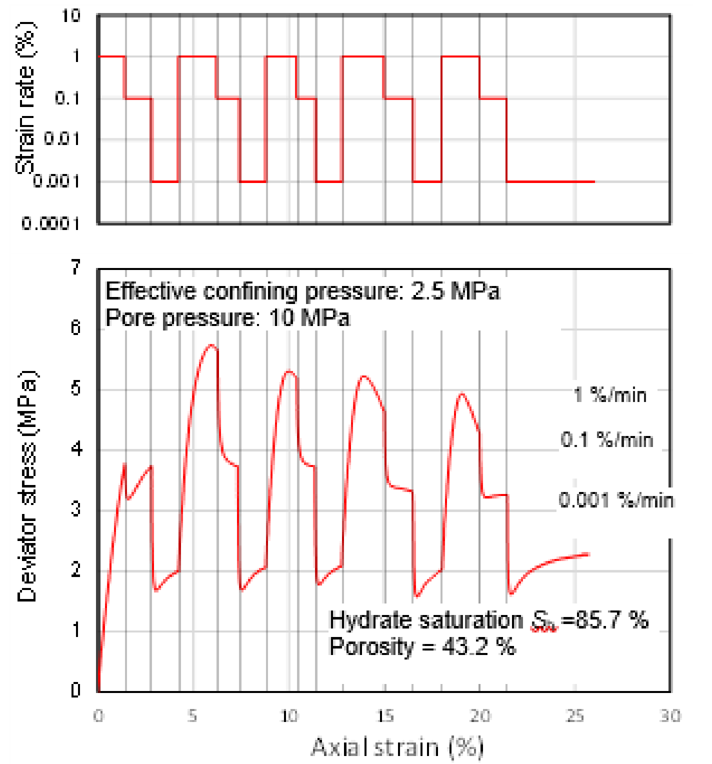
(Fang et al., in press)



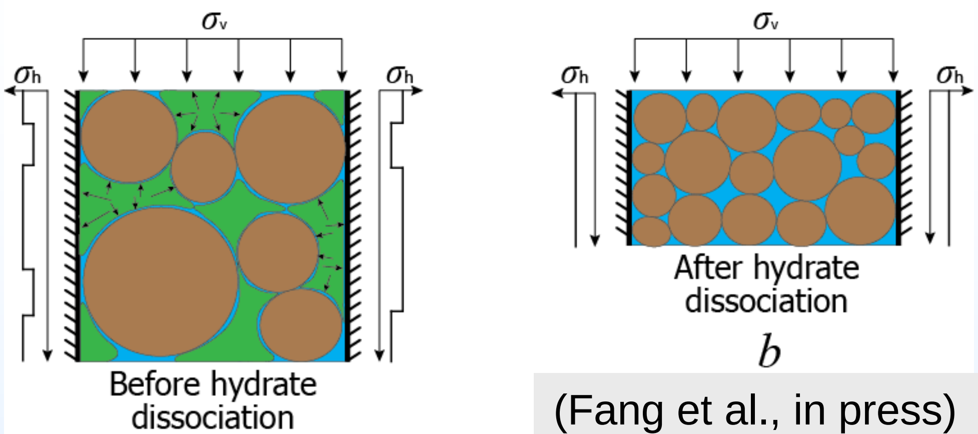
(Yoneda et al., in press)

Science Theme 3: Visco-elastic behavior

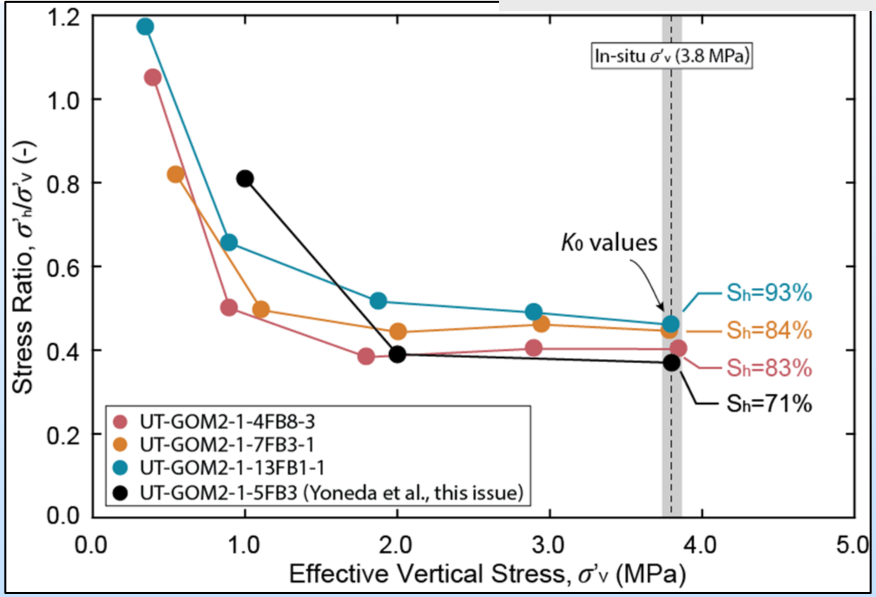
Hydrate strength strain rate dependent



(Yoneda et al., in press)



(Fang et al., in press)



Commonly described by flow law:

$$\dot{\varepsilon} = A_0 exp\left[-\frac{Q}{K_c T}\right] q^b.$$

Higher lateral stress in hydrate reservoirs

- Impacts stress state

Hydrate can be load-bearing

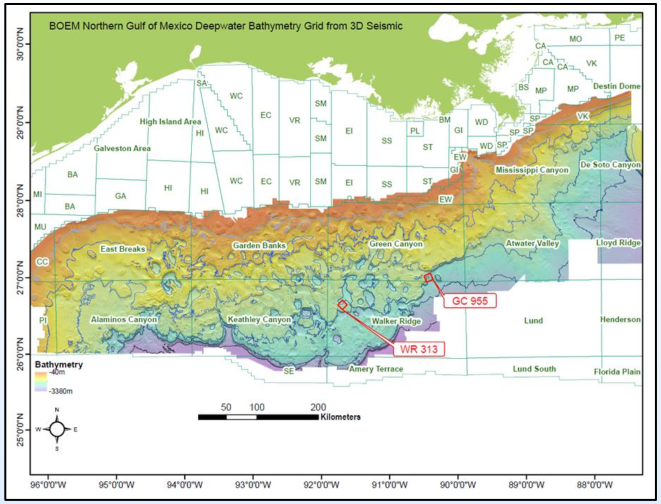
- compaction during production

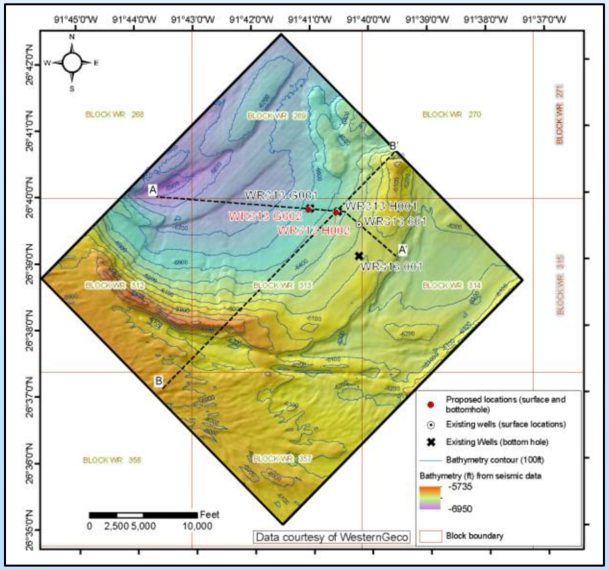
AAPG Bulletin GC 955 Dedicated Vol 2

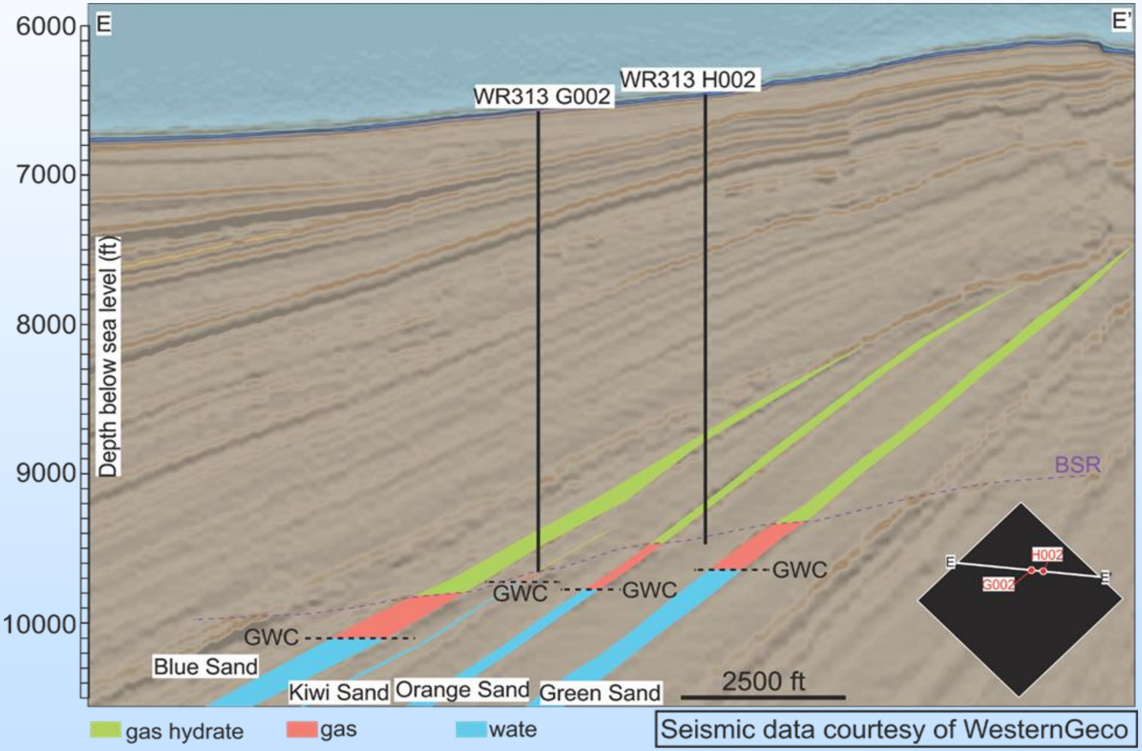
Lead Editor co-PI Ann Cook, 9 papers, Anticipated publication late 2021

Primary Author	Working Title	Status
Oti	Using X-ray Computed Tomography (XCT) to Estimate Hydrate Saturation in Sediment Cores from Green Canyon 955, northern Gulf of Mexico	Ahead of Print
Moore	Integrated geochemical approach to determine the source of methane in gas hydrate from Green Canyon Block 955 in the Gulf of Mexico	Ahead of Print
Daigle	Pore structure of sediments from Green Canyon 955 determined by mercury intrusion	Accepted
Wei	Methane migration mechanisms for the Green Canyon Block 955 gas hydrate reservoir, northern Gulf of Mexico	Ahead of Print
Santra	Occurrence of High-Saturation Gas Hydrate in a Fault-Compartmentalized Anticline and the Role of Seal- Green Canyon, Abyssal Gulf of Mexico	Accepted
Yoneda	Comprehensive pressure core analysis for hydrate-bearing sediments from Gulf of Mexico Green Canyon Block 955, including assessments of geomechanical viscous behavior and NMR permeability	Ahead of Print
Fang	Permeability of methane hydrate-bearing sandy silts in the deepwater Gulf of Mexico (Green Canyon block 955)	Accepted
Fang	Compression behavior of hydrate-bearing sediments	Accepted
Phillips	Thermodynamic insights into the production of methane hydrate reservoirs from depressurization of pressure cores	Accepted

UT-GOM2-2 Planning
Second hydrate pressure coring exp at WR 313



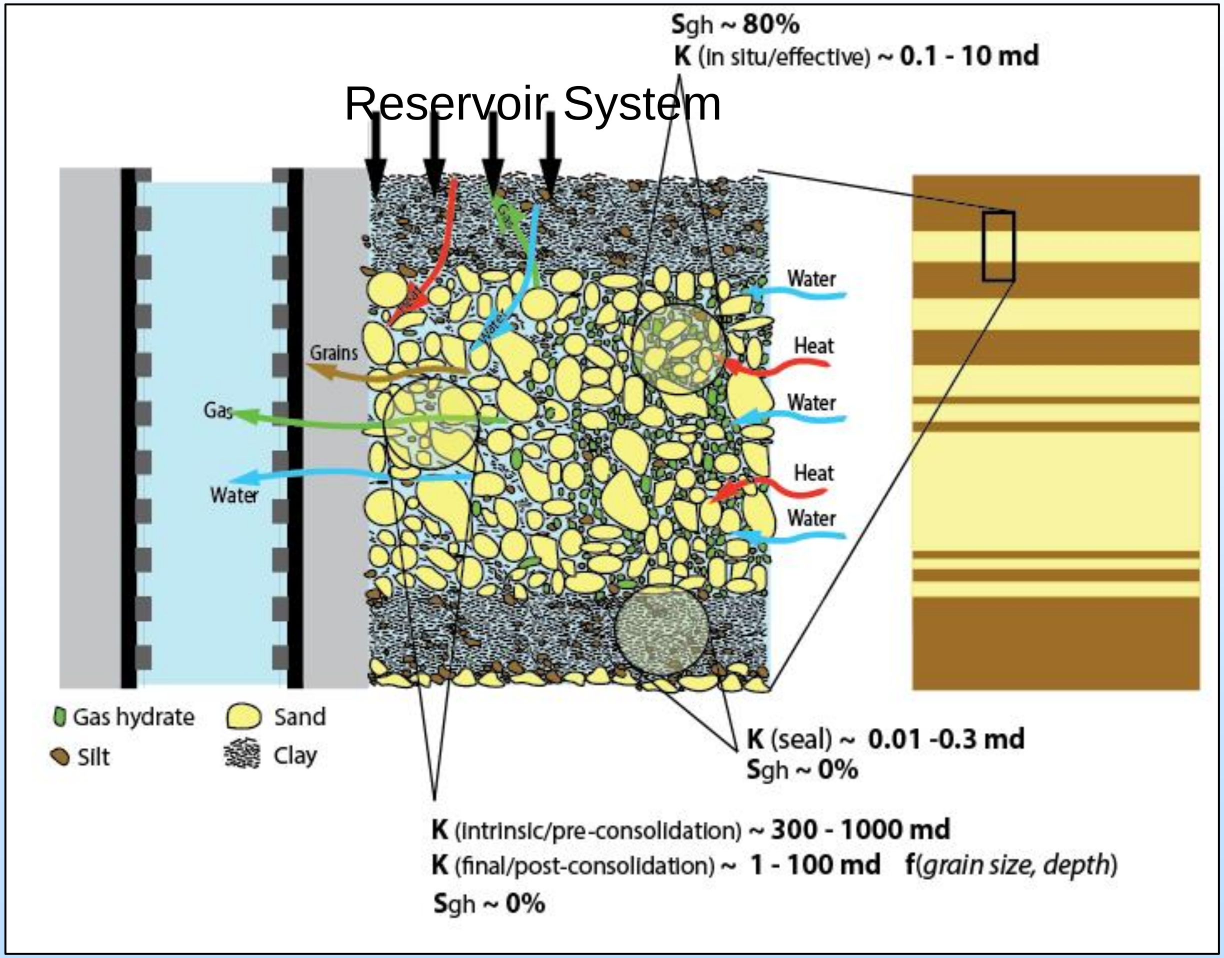




Modified from Boswell & Collet, 2016

UT-GOM2-2 Planning
WR 313 Science Objectives

6 specific objectives all contribute to reservoir and basin systems understanding of WR313

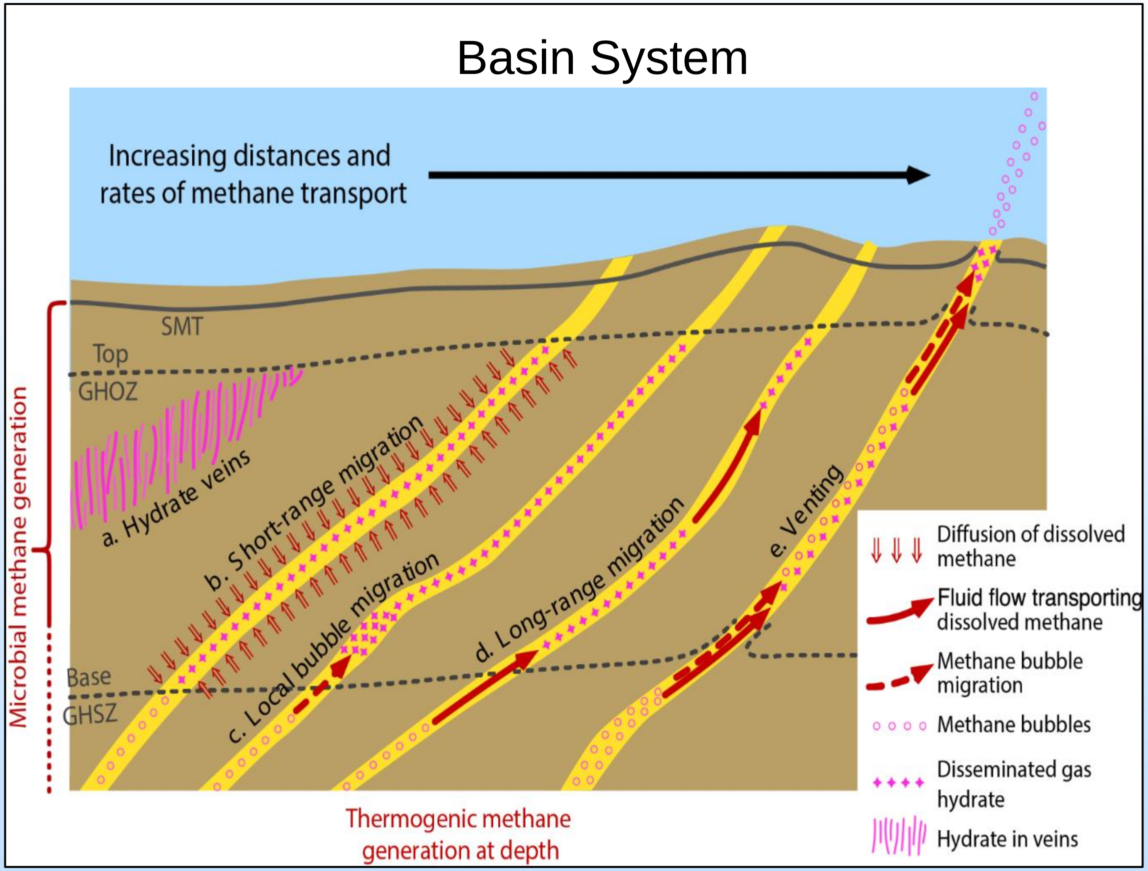


Modified from Boswell & Collet, 2016

Steps:

- Obtain pressure core
- Determine hydrate concentration, gas composition, age, sediment texture, pore water chemistry
- Determine permeability, compression, capillary behavior, strength
- Elucidate reservoir production behavior to inform reservoir simulation

UT-GOM2-2 Planning
WR 313 Science Objectives



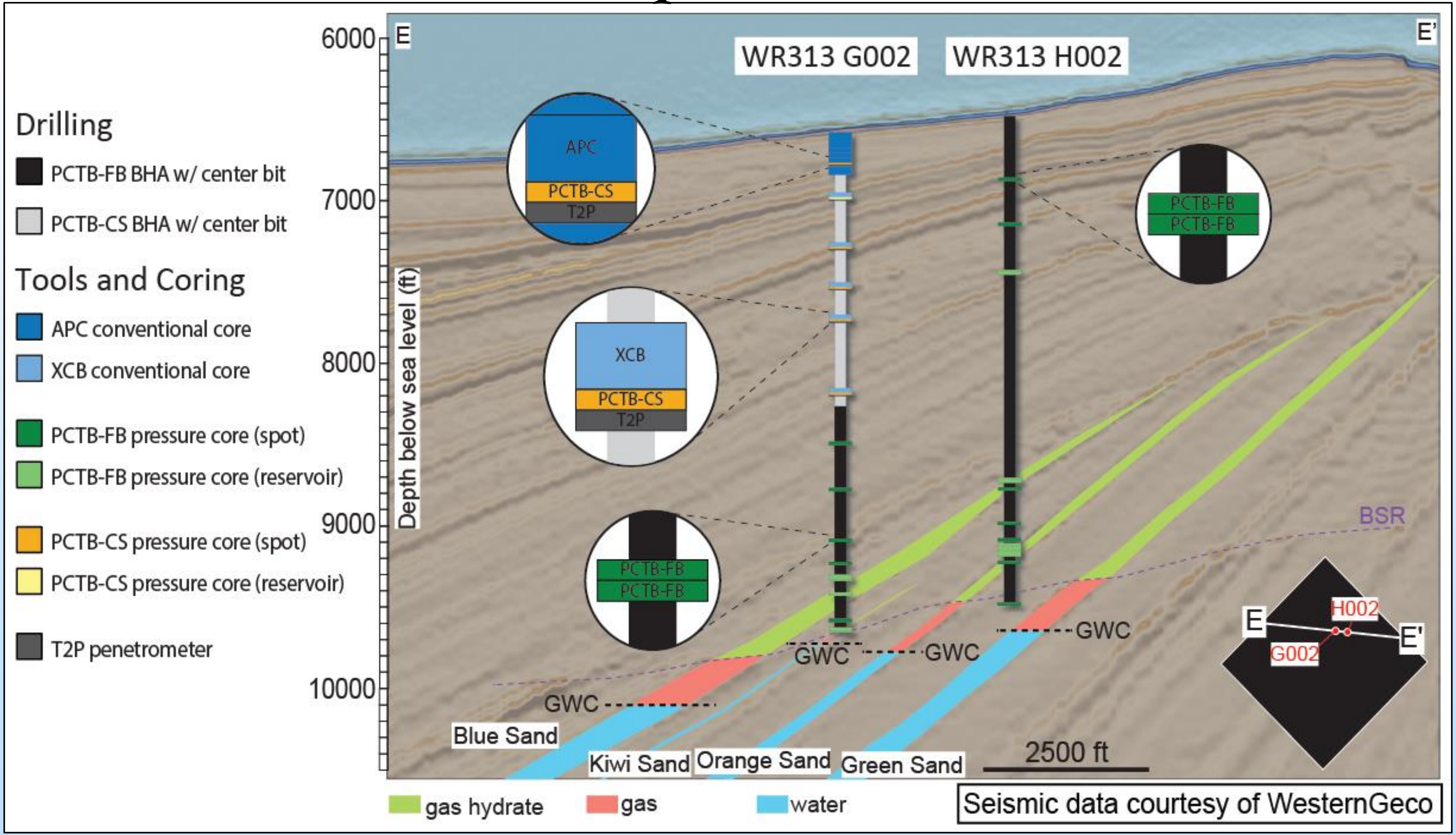
Basin System

Malinverno & Goldberg, 2015

Steps:

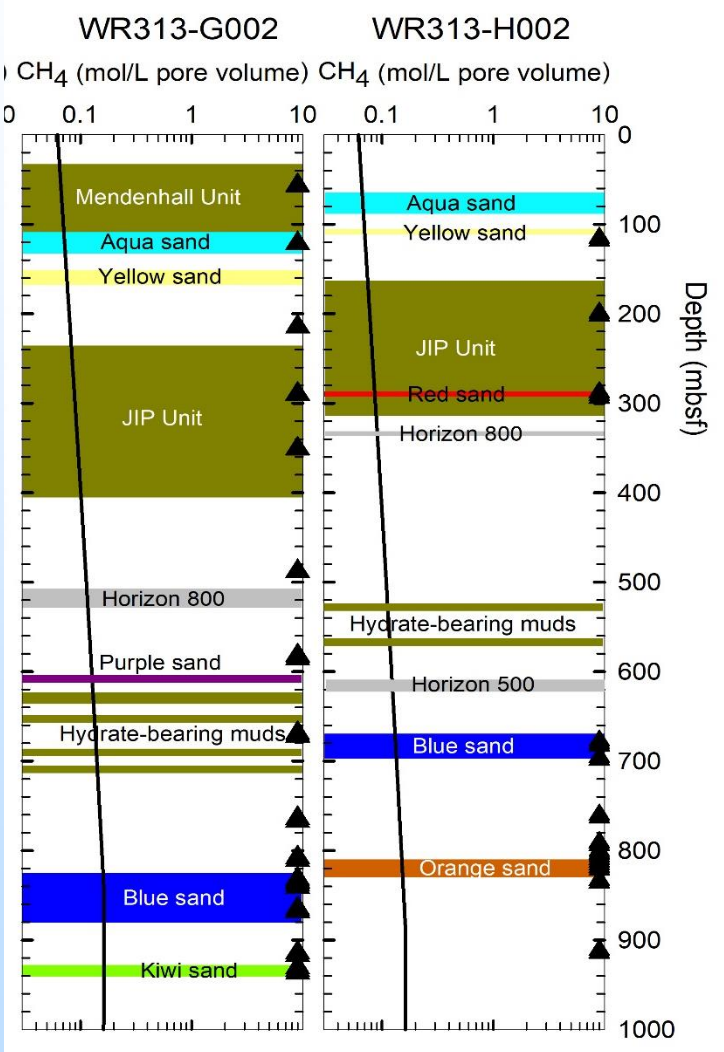
- Collect sediment (some at in situ conditions), gas, and pore water samples, pressure and temperature with depth
- Characterize dissolved methane/hydrate concentration, gas molecular composition (microbial source), pore water geochemistry and sedimentology, variation in organic carbon with depth, age of sediments.
- Interpret:
  - how the microbial factory works (shallow vs deep methane generation)
  - How are the products transported to the deposit
- Elucidate entire carbon cycle

UT-GOM2-2 Planning
WR 313 Operational Plan

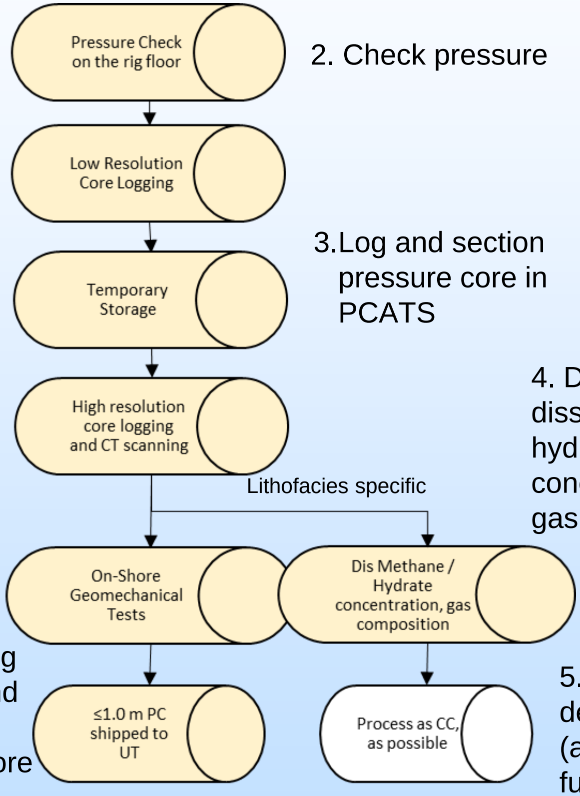


Seismic data courtesy of WesternGeco

UT-GOM2-2 Planning
Core Acquisition, Analysis and Distribution



1. Obtain pressure cores of target sands and background muds



2. Check pressure

3. Log and section pressure core in PCATS

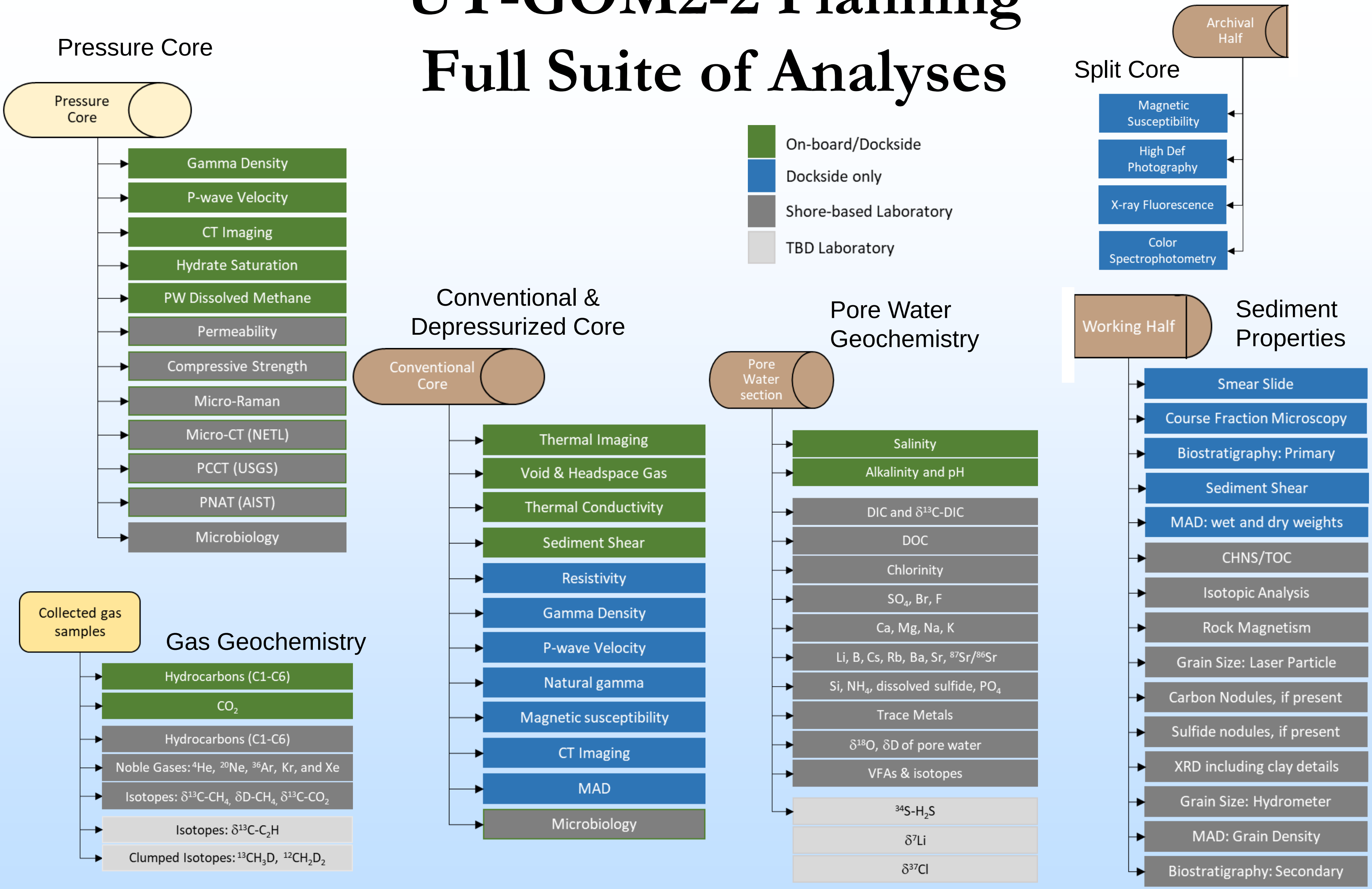
4. Determine dissolved methane / hydrate concentration, collect gas samples

5. Process slow depressurized core (as possible) through full suite of conventional core analysis methods

6. Save long sections and distribute pressure core from UT

7. Compare results within the sand, along a dipping sand, and between different sands.

UT-GOM2-2 Planning
Full Suite of Analyses



🟩 On-board/Dockside
🟦 Dockside only
⬛ Shore-based Laboratory
⬜ TBD Laboratory

Pressure Core

Pressure Core
- Gamma Density
- P-wave Velocity
- CT Imaging
- Hydrate Saturation
- PW Dissolved Methane
- Permeability
- Compressive Strength
- Micro-Raman
- Micro-CT (NETL)
- PCCT (USGS)
- PNAT (AIST)
- Microbiology

Gas Geochemistry

Collected gas samples
- Hydrocarbons (C1-C6)
- CO_2
- Hydrocarbons (C1-C6)
- Noble Gases: ^{4}He, ^{20}Ne, ^{36}Ar, Kr, and Xe
- Isotopes: δ^{13}C-CH_4, δD-CH_4, δ^{13}C-CO_2
- Isotopes: δ^{13}C-C_2H
- Clumped Isotopes: $^{13}CH_3D$, $^{12}CH_2D_2$

Conventional & Depressurized Core

Conventional Core
- Thermal Imaging
- Void & Headspace Gas
- Thermal Conductivity
- Sediment Shear
- Resistivity
- Gamma Density
- P-wave Velocity
- Natural gamma
- Magnetic susceptibility
- CT Imaging
- MAD
- Microbiology

Pore Water Geochemistry

Pore Water section
- Salinity
- Alkalinity and pH
- DIC and δ^{13}C-DIC
- DOC
- Chlorinity
- SO_4, Br, F
- Ca, Mg, Na, K
- Li, B, Cs, Rb, Ba, Sr, ^{87}Sr/^{86}Sr
- Si, NH_4, dissolved sulfide, PO_4
- Trace Metals
- δ^{18}O, δD of pore water
- VFAs & isotopes
- ^{34}S-H_2S
- δ^7Li
- δ^{37}Cl

Split Core

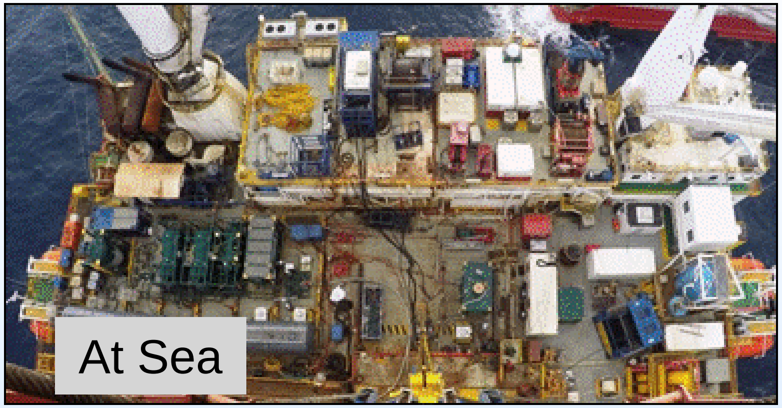
Archival Half
- Magnetic Susceptibility
- High Def Photography
- X-ray Fluorescence
- Color Spectrophotometry

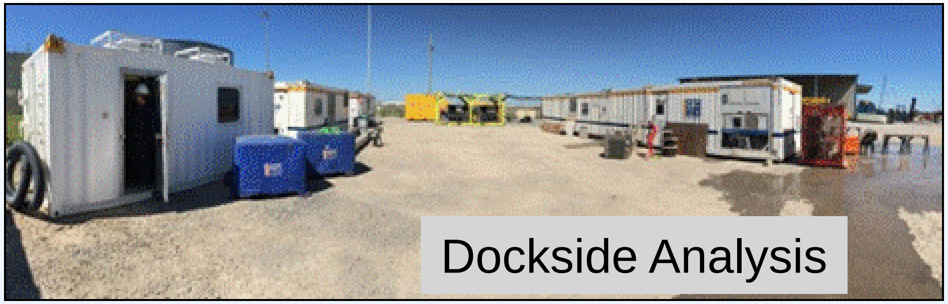
Sediment Properties

Working Half
- Smear Slide
- Course Fraction Microscopy
- Biostratigraphy: Primary
- Sediment Shear
- MAD: wet and dry weights
- CHNS/TOC
- Isotopic Analysis
- Rock Magnetism
- Grain Size: Laser Particle
- Carbon Nodules, if present
- Sulfide nodules, if present
- XRD including clay details
- Grain Size: Hydrometer
- MAD: Grain Density
- Biostratigraphy: Secondary

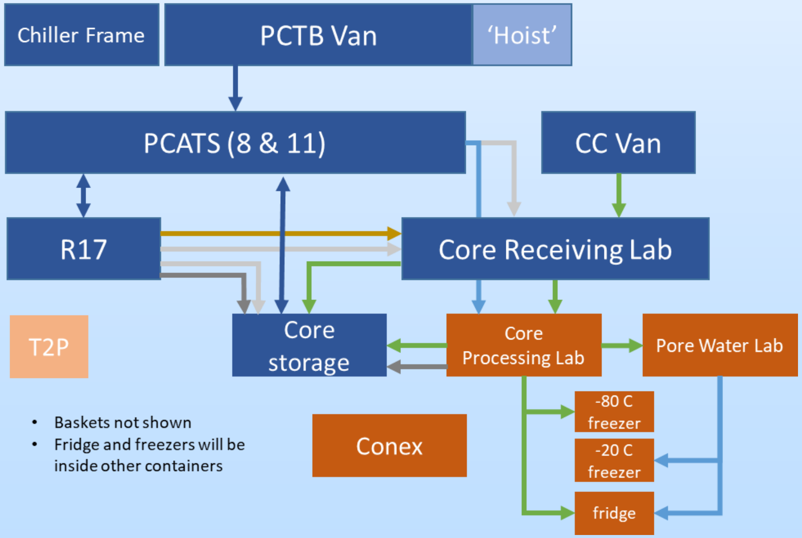
60+ Planned Analyses

UT-GOM2-2 Mobilization
Containers, Equipment, Science Team



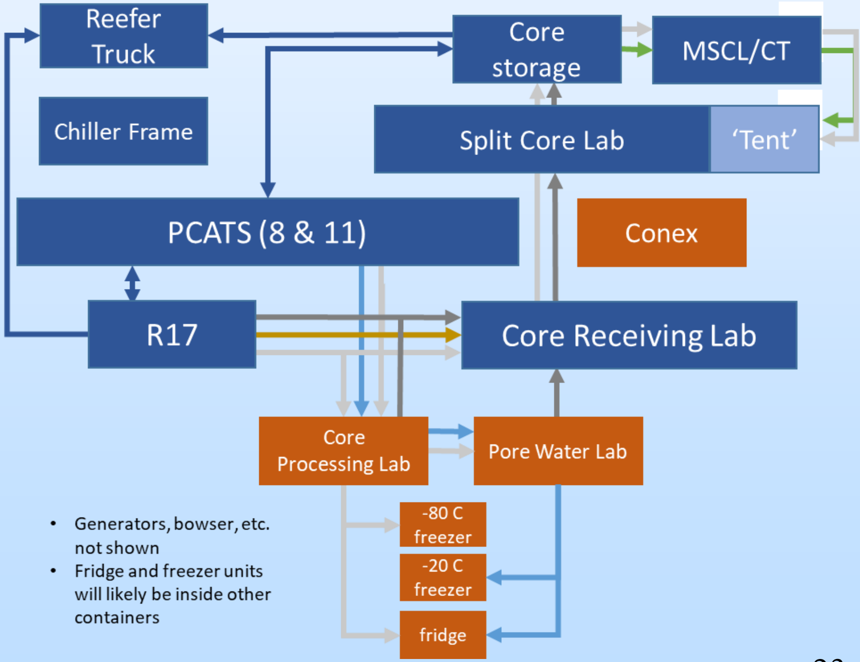


On-board containers and sample movement



- Baskets not shown
- Fridge and freezers will be inside other containers

Dockside containers and sample movement



- Generators, bowser, etc. not shown
- Fridge and freezer units will likely be inside other containers

Detailed plans for Equipment, People, Samples, and Data near completion

UT-GOM2-2 Planning
Permitting, Bonding, and Vessel Procurement

Permitting

- BOEM Exploration Plan is officially submitted

    RUE Request

    - Submitted April 15

    Exploration Plan & Shallow Hazard Assessments

    - Submitted April 16
    - Preliminary review complete , no major revisions or additions anticipated

General Lease Bond

- Submitted July 8, Accept July 9

Vessel Procurement

- First Vessel estimate received Aug 9

Project Summary

- Improved pressure coring technology. Tool now ready for science expedition.
- New insights into petrophysical/geomechanical properties of hydrate-bearing core.
- Advances in our understanding of how hydrate reservoirs form and the origin of the methane source.
- Detailed planning and permitting steps next expedition UT-GOM2-2, WR 313, is complete
- We are poised and ready for ‘22 expedition

Thank you!

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

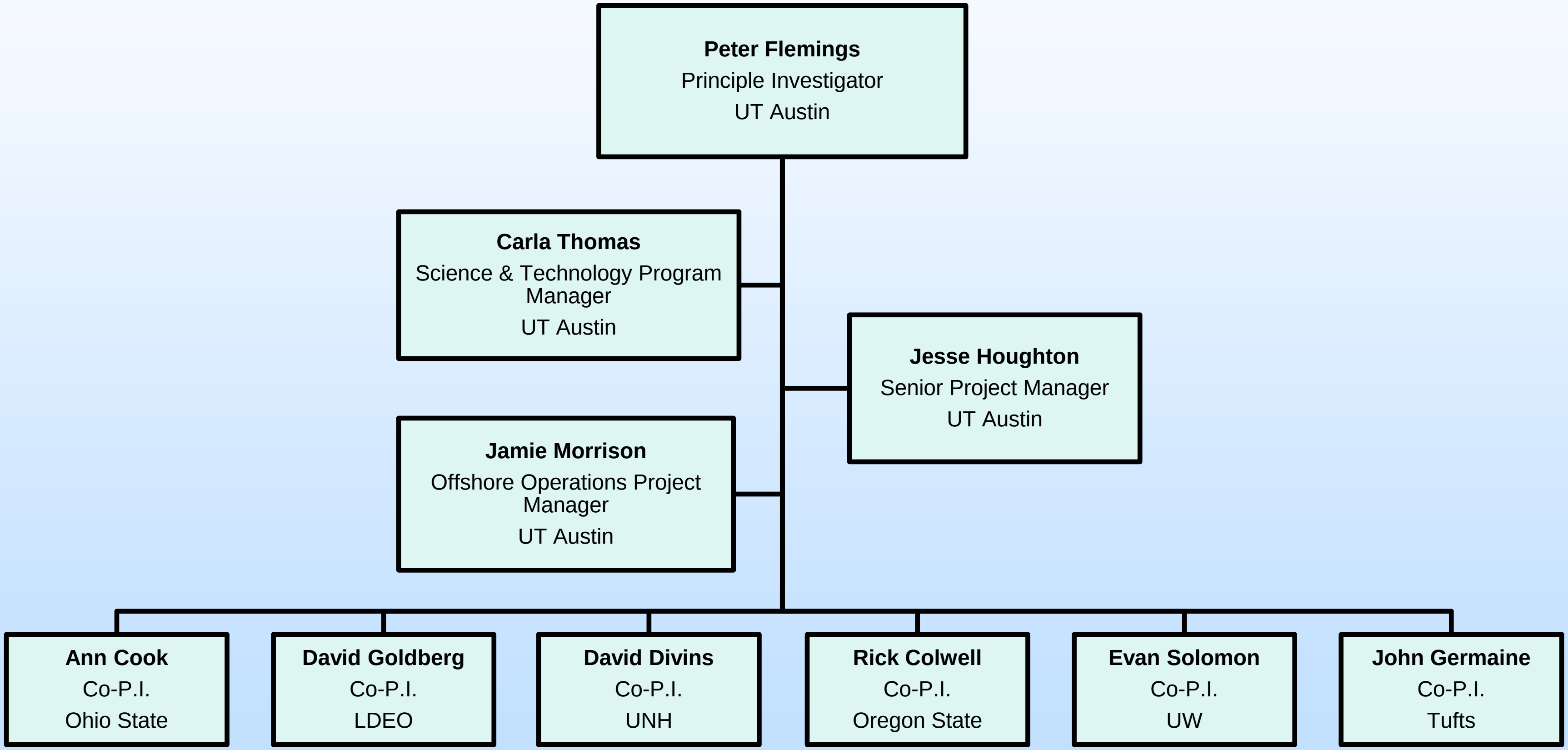
Goals and Objectives

- 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.
  - **Sub-recipients:**
    - **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 LWD lead
    - **Tufts University**: Physical / petrophysical properties lead

Organization Chart
Project Team



Peter Flemings
Principle Investigator
UT Austin

Carla Thomas
Science & Technology Program Manager
UT Austin

Jesse Houghton
Senior Project Manager
UT Austin

Jamie Morrison
Offshore Operations Project Manager
UT Austin

Ann Cook
Co-P.I.
Ohio State

David Goldberg
Co-P.I.
LDEO

David Divins
Co-P.I.
UNH

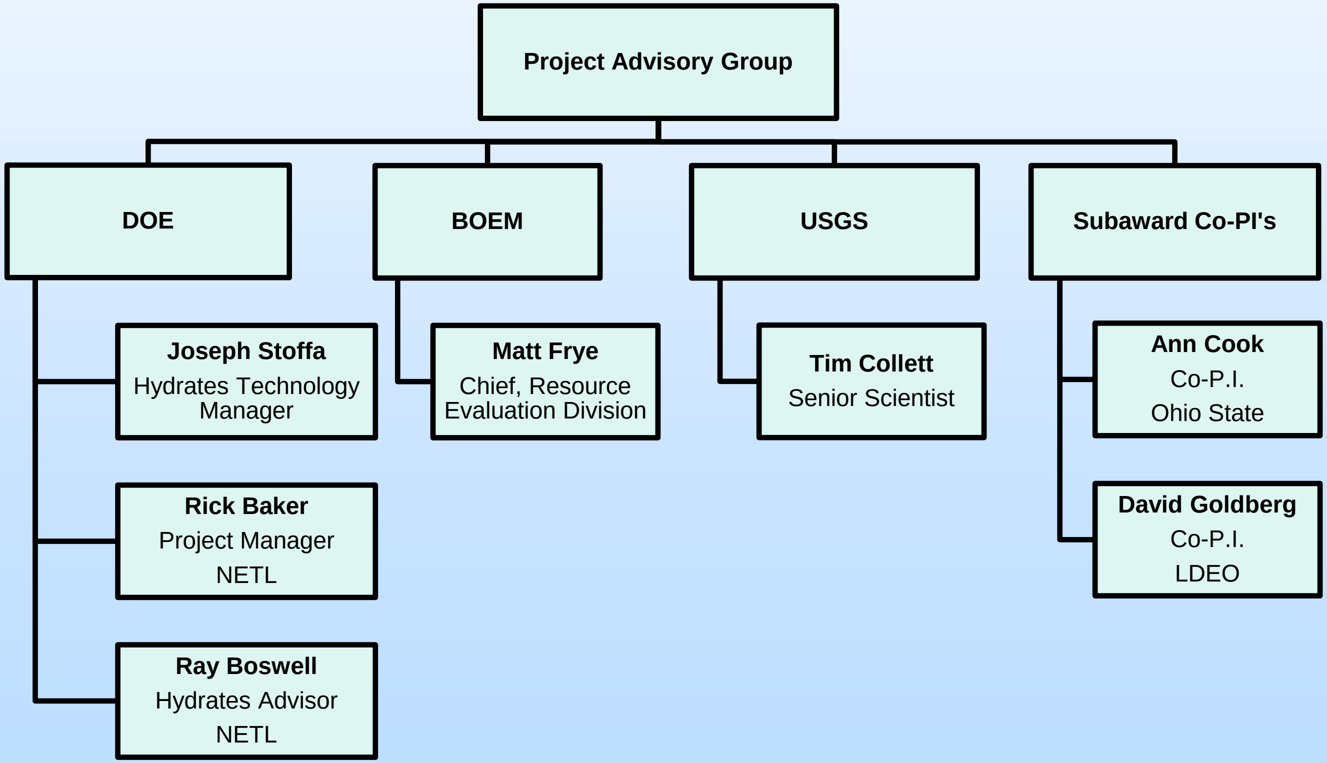
Rick Colwell
Co-P.I.
Oregon State

Evan Solomon
Co-P.I.
UW

John Germaine
Co-P.I.
Tufts

Organization Chart
Project Advisory Group

- The Project Advisory Group will provide guidance to the Project Team in technical and/or logistical decisions that have significant impact to the project or project objectives.



Project Advisory Group

DOE

Joseph Stoffa
Hydrates Technology Manager

Rick Baker
Project Manager
NETL

Ray Boswell
Hydrates Advisor
NETL

BOEM

Matt Frye
Chief, Resource Evaluation Division

USGS

Tim Collett
Senior Scientist

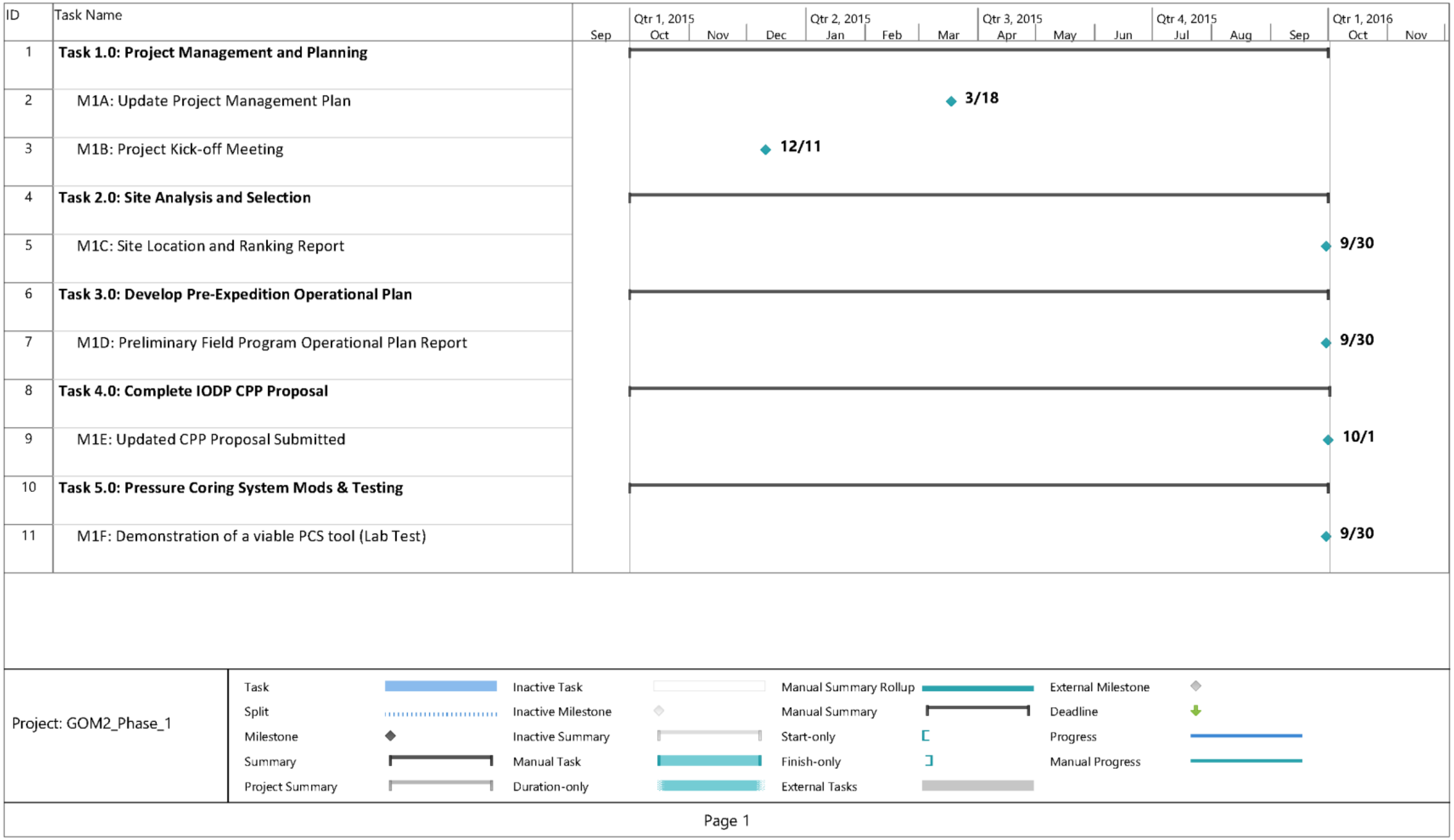
Subaward Co-PI's

Ann Cook
Co-P.I.
Ohio State

David Goldberg
Co-P.I.
LDEO

Gantt Chart (1 of 6)

PHASE 1: Oct 2014 – Sep 2015



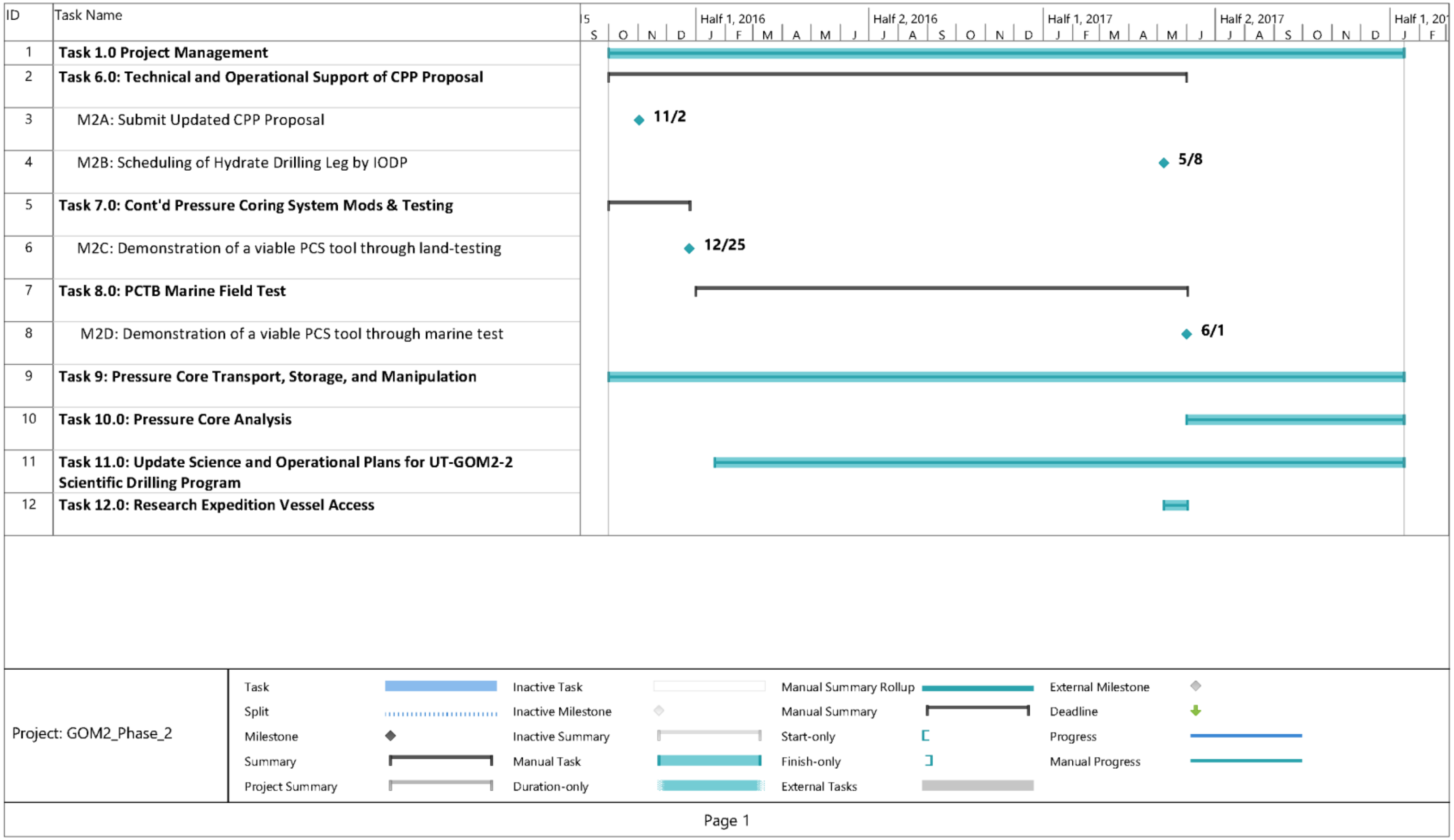
ID	Task Name
1	**Task 1.0: Project Management and Planning**
2	M1A: Update Project Management Plan
3	M1B: Project Kick-off Meeting
4	**Task 2.0: Site Analysis and Selection**
5	M1C: Site Location and Ranking Report
6	**Task 3.0: Develop Pre-Expedition Operational Plan**
7	M1D: Preliminary Field Program Operational Plan Report
8	**Task 4.0: Complete IODP CPP Proposal**
9	M1E: Updated CPP Proposal Submitted
10	**Task 5.0: Pressure Coring System Mods & Testing**
11	M1F: Demonstration of a viable PCS tool (Lab Test)

Project: GOM2_Phase_1

Page 1

Gantt Chart (2 of 6)

PHASE 2: Oct 2015 – Jan 2018

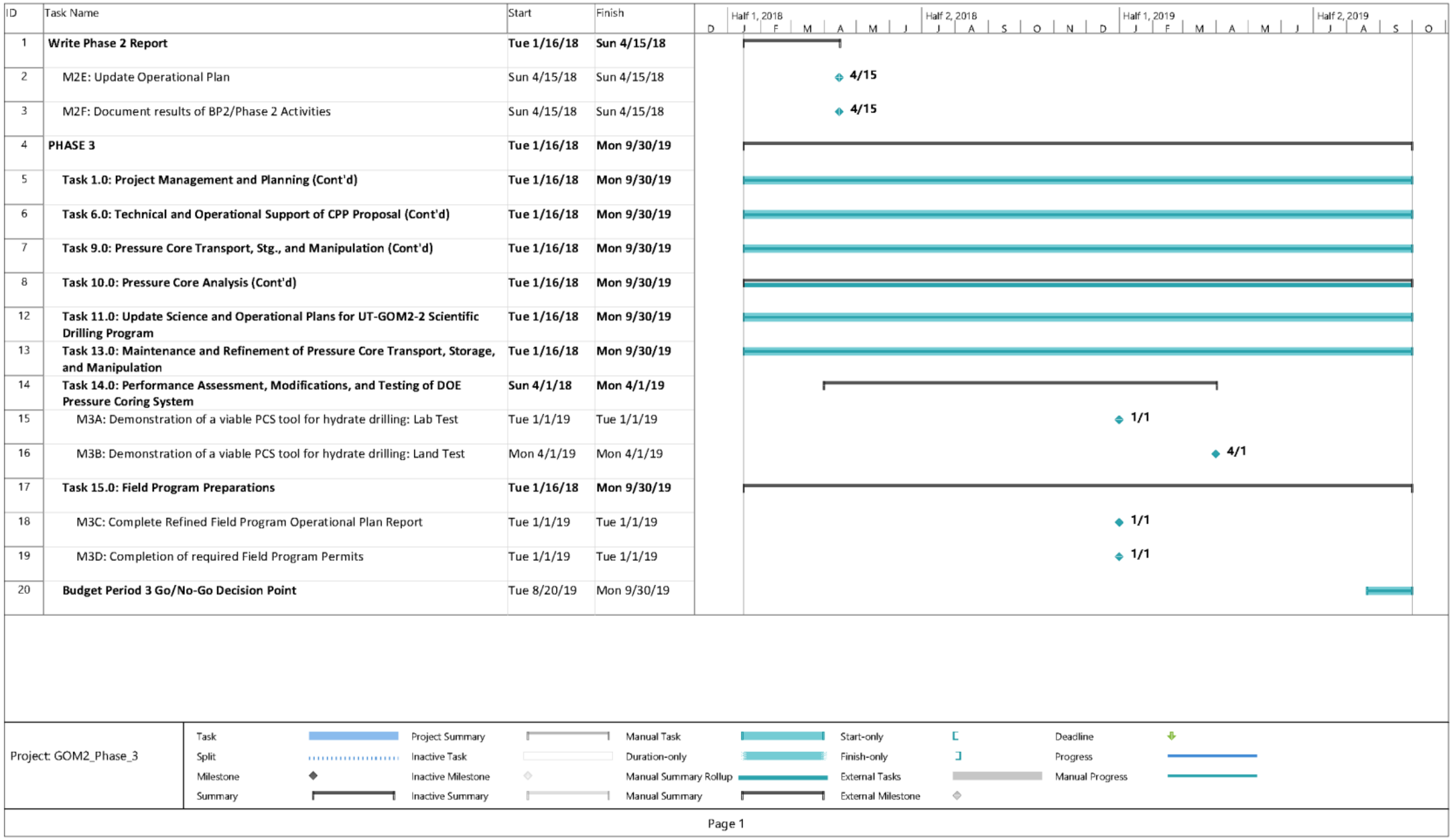


ID	Task Name
1	**Task 1.0 Project Management**
2	**Task 6.0: Technical and Operational Support of CPP Proposal**
3	M2A: Submit Updated CPP Proposal
4	M2B: Scheduling of Hydrate Drilling Leg by IODP
5	**Task 7.0: Cont'd Pressure Coring System Mods & Testing**
6	M2C: Demonstration of a viable PCS tool through land-testing
7	**Task 8.0: PCTB Marine Field Test**
8	M2D: Demonstration of a viable PCS tool through marine test
9	**Task 9: Pressure Core Transport, Storage, and Manipulation**
10	**Task 10.0: Pressure Core Analysis**
11	**Task 11.0: Update Science and Operational Plans for UT-GOM2-2 Scientific Drilling Program**
12	**Task 12.0: Research Expedition Vessel Access**

Project: GOM2_Phase_2

Gantt Chart (3 of 6)

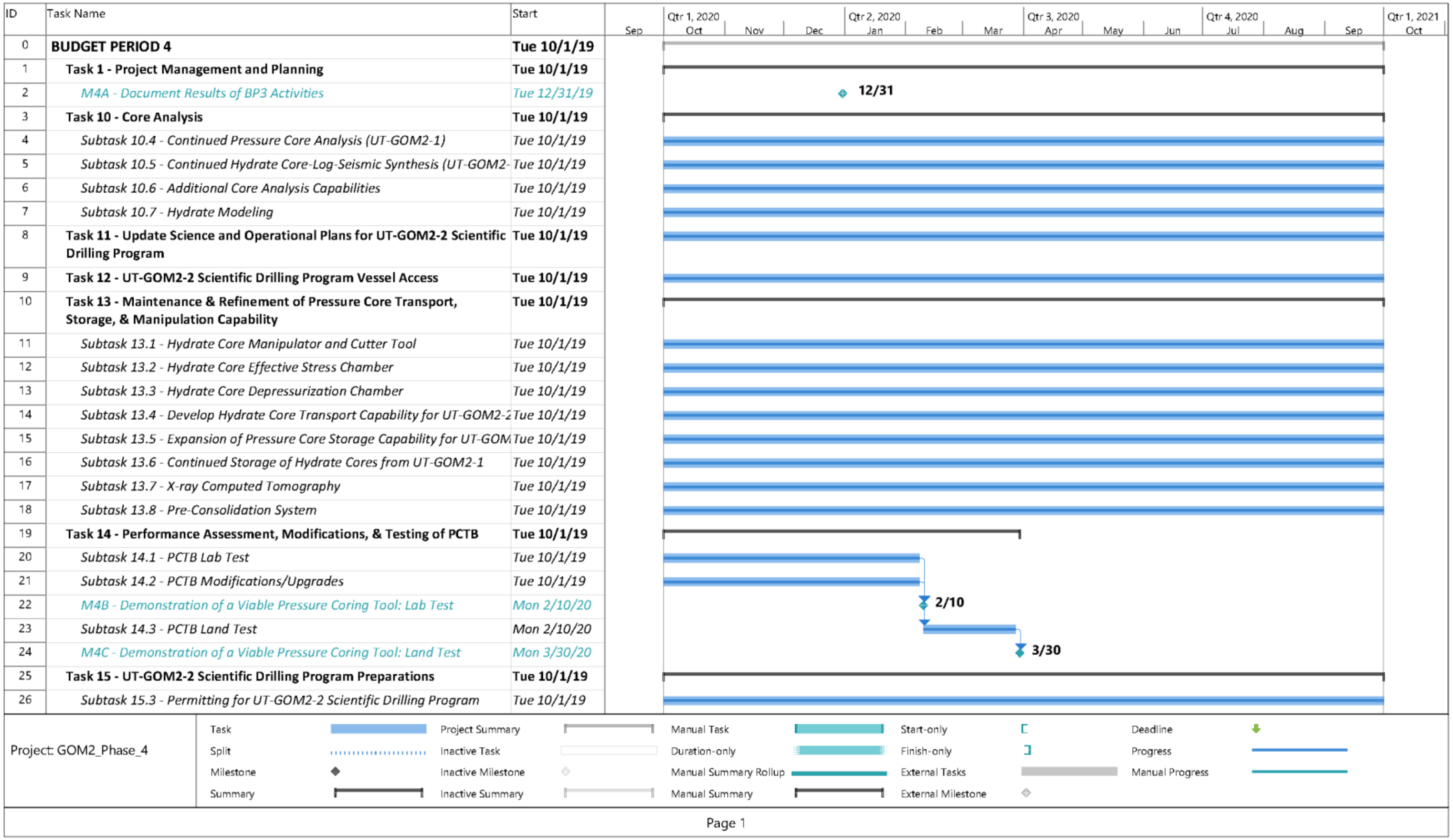
PHASE 3: Jan 2018 – Sep 2019



ID	Task Name	Start	Finish
1	**Write Phase 2 Report**	**Tue 1/16/18**	**Sun 4/15/18**
2	M2E: Update Operational Plan	Sun 4/15/18	Sun 4/15/18
3	M2F: Document results of BP2/Phase 2 Activities	Sun 4/15/18	Sun 4/15/18
4	**PHASE 3**	**Tue 1/16/18**	**Mon 9/30/19**
5	**Task 1.0: Project Management and Planning (Cont'd)**	**Tue 1/16/18**	**Mon 9/30/19**
6	**Task 6.0: Technical and Operational Support of CPP Proposal (Cont'd)**	**Tue 1/16/18**	**Mon 9/30/19**
7	**Task 9.0: Pressure Core Transport, Stg., and Manipulation (Cont'd)**	**Tue 1/16/18**	**Mon 9/30/19**
8	**Task 10.0: Pressure Core Analysis (Cont'd)**	**Tue 1/16/18**	**Mon 9/30/19**
12	**Task 11.0: Update Science and Operational Plans for UT-GOM2-2 Scientific Drilling Program**	**Tue 1/16/18**	**Mon 9/30/19**
13	**Task 13.0: Maintenance and Refinement of Pressure Core Transport, Storage, and Manipulation**	**Tue 1/16/18**	**Mon 9/30/19**
14	**Task 14.0: Performance Assessment, Modifications, and Testing of DOE Pressure Coring System**	**Sun 4/1/18**	**Mon 4/1/19**
15	M3A: Demonstration of a viable PCS tool for hydrate drilling: Lab Test	Tue 1/1/19	Tue 1/1/19
16	M3B: Demonstration of a viable PCS tool for hydrate drilling: Land Test	Mon 4/1/19	Mon 4/1/19
17	**Task 15.0: Field Program Preparations**	**Tue 1/16/18**	**Mon 9/30/19**
18	M3C: Complete Refined Field Program Operational Plan Report	Tue 1/1/19	Tue 1/1/19
19	M3D: Completion of required Field Program Permits	Tue 1/1/19	Tue 1/1/19
20	**Budget Period 3 Go/No-Go Decision Point**	Tue 8/20/19	Mon 9/30/19

Gantt Chart (4 of 6)

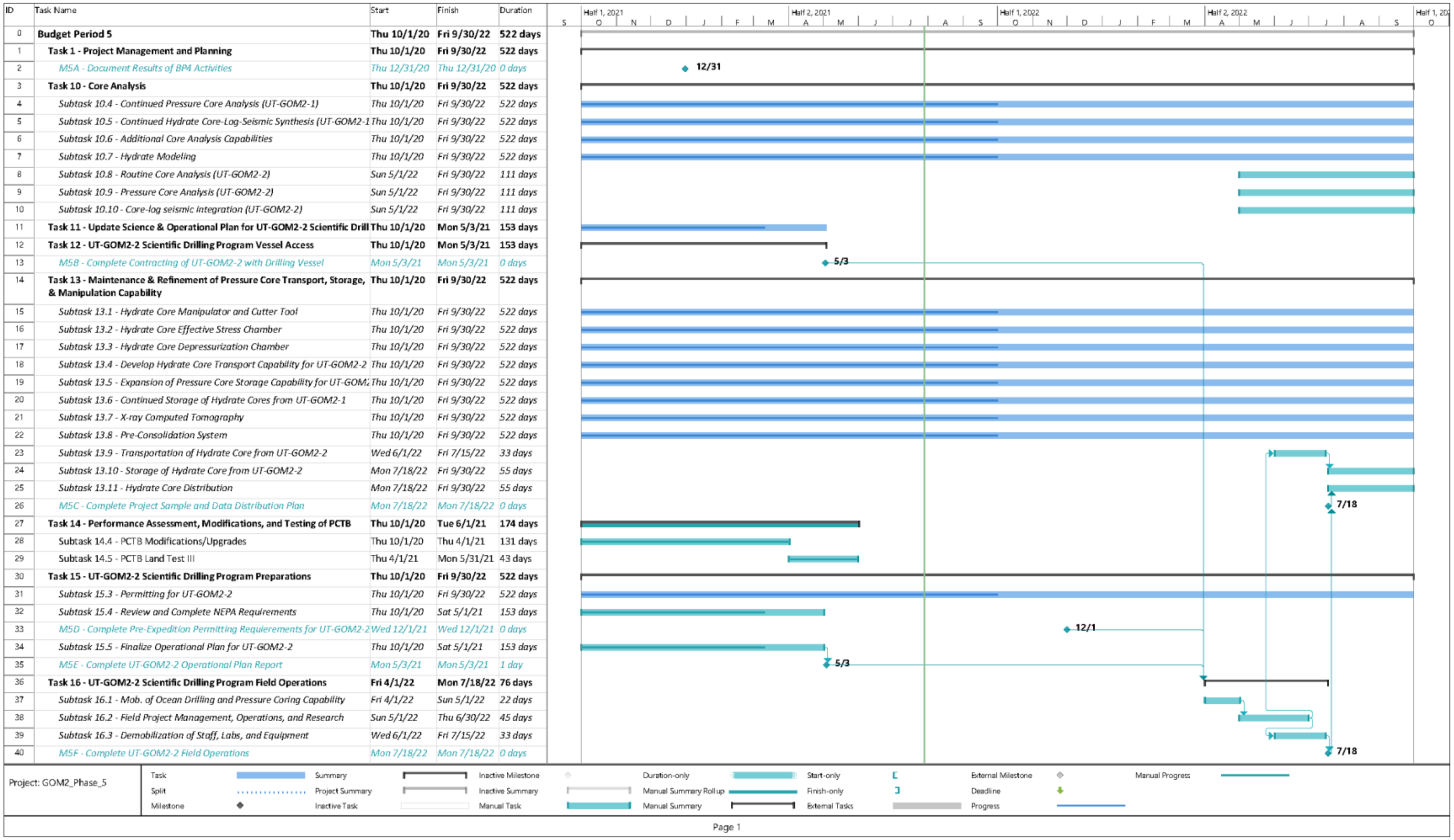
PHASE 4: Oct 2019 – Sep 2020



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

Gantt Chart (5 of 6)

PHASE 5: Oct 2020 – Sep 2022

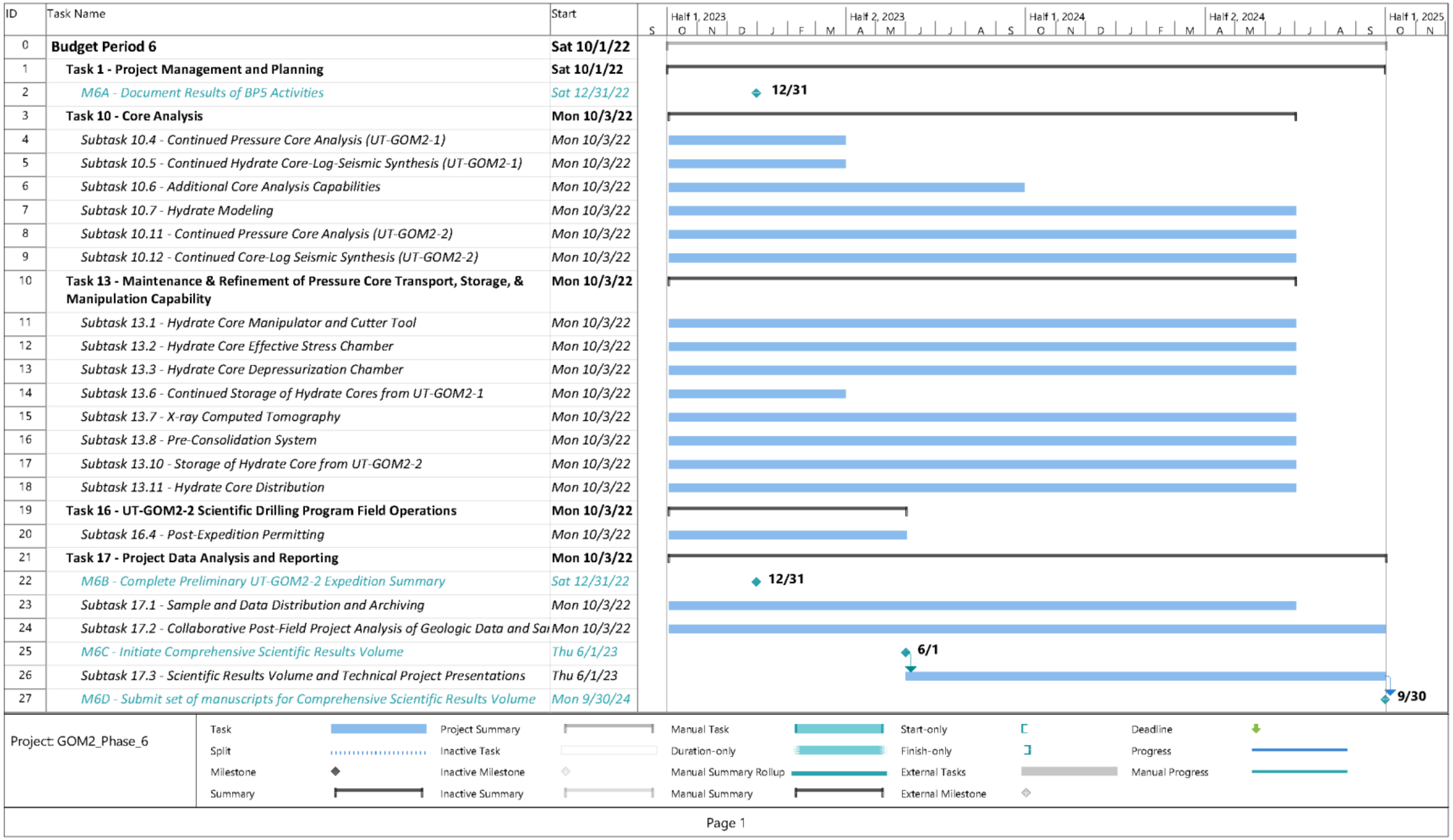


ID	Task Name	Start	Finish	Duration
0	**Budget Period 5**	**Thu 10/1/20**	**Fri 9/30/22**	**522 days**
1	**Task 1 - Project Management and Planning**	**Thu 10/1/20**	**Fri 9/30/22**	**522 days**
2	*M5A - Document Results of BP4 Activities*	*Thu 12/31/20*	*Thu 12/31/20*	*0 days*
3	**Task 10 - Core Analysis**	**Thu 10/1/20**	**Fri 9/30/22**	**522 days**
4	*Subtask 10.4 - Continued Pressure Core Analysis (UT-GOM2-1)*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
5	*Subtask 10.5 - Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
6	*Subtask 10.6 - Additional Core Analysis Capabilities*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
7	*Subtask 10.7 - Hydrate Modeling*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
8	*Subtask 10.8 - Routine Core Analysis (UT-GOM2-2)*	*Sun 5/1/22*	*Fri 9/30/22*	*111 days*
9	*Subtask 10.9 - Pressure Core Analysis (UT-GOM2-2)*	*Sun 5/1/22*	*Fri 9/30/22*	*111 days*
10	*Subtask 10.10 - Core-log seismic integration (UT-GOM2-2)*	*Sun 5/1/22*	*Fri 9/30/22*	*111 days*
11	**Task 11 - Update Science & Operational Plan for UT-GOM2-2 Scientific Drill**	**Thu 10/1/20**	**Mon 5/3/21**	**153 days**
12	**Task 12 - UT-GOM2-2 Scientific Drilling Program Vessel Access**	**Thu 10/1/20**	**Mon 5/3/21**	**153 days**
13	*M5B - Complete Contracting of UT-GOM2-2 with Drilling Vessel*	*Mon 5/3/21*	*Mon 5/3/21*	*0 days*
14	**Task 13 - Maintenance & Refinement of Pressure Core Transport, Storage, & Manipulation Capability**	**Thu 10/1/20**	**Fri 9/30/22**	**522 days**
15	*Subtask 13.1 - Hydrate Core Manipulator and Cutter Tool*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
16	*Subtask 13.2 - Hydrate Core Effective Stress Chamber*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
17	*Subtask 13.3 - Hydrate Core Depressurization Chamber*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
18	*Subtask 13.4 - Develop Hydrate Core Transport Capability for UT-GOM2-2*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
19	*Subtask 13.5 - Expansion of Pressure Core Storage Capability for UT-GOM2*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
20	*Subtask 13.6 - Continued Storage of Hydrate Cores from UT-GOM2-1*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
21	*Subtask 13.7 - X-ray Computed Tomography*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
22	*Subtask 13.8 - Pre-Consolidation System*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
23	*Subtask 13.9 - Transportation of Hydrate Core from UT-GOM2-2*	*Wed 6/1/22*	*Fri 7/15/22*	*33 days*
24	*Subtask 13.10 - Storage of Hydrate Core from UT-GOM2-2*	*Mon 7/18/22*	*Fri 9/30/22*	*55 days*
25	*Subtask 13.11 - Hydrate Core Distribution*	*Mon 7/18/22*	*Fri 9/30/22*	*55 days*
26	*M5C - Complete Project Sample and Data Distribution Plan*	*Mon 7/18/22*	*Mon 7/18/22*	*0 days*
27	**Task 14 - Performance Assessment, Modifications, and Testing of PCTB**	**Thu 10/1/20**	**Tue 6/1/21**	**174 days**
28	Subtask 14.4 - PCTB Modifications/Upgrades	Thu 10/1/20	Thu 4/1/21	131 days
29	Subtask 14.5 - PCTB Land Test III	Thu 4/1/21	Mon 5/31/21	43 days
30	**Task 15 - UT-GOM2-2 Scientific Drilling Program Preparations**	**Thu 10/1/20**	**Fri 9/30/22**	**522 days**
31	*Subtask 15.3 - Permitting for UT-GOM2-2*	*Thu 10/1/20*	*Fri 9/30/22*	*522 days*
32	*Subtask 15.4 - Review and Complete NEPA Requirements*	*Thu 10/1/20*	*Sat 5/1/21*	*153 days*
33	*M5D - Complete Pre-Expedition Permitting Requierements for UT-GOM2-2*	*Wed 12/1/21*	*Wed 12/1/21*	*0 days*
34	*Subtask 15.5 - Finalize Operational Plan for UT-GOM2-2*	*Thu 10/1/20*	*Sat 5/1/21*	*153 days*
35	*M5E - Complete UT-GOM2-2 Operational Plan Report*	*Mon 5/3/21*	*Mon 5/3/21*	*1 day*
36	**Task 16 - UT-GOM2-2 Scientific Drilling Program Field Operations**	**Fri 4/1/22**	**Mon 7/18/22**	**76 days**
37	*Subtask 16.1 - Mob. of Ocean Drilling and Pressure Coring Capability*	*Fri 4/1/22*	*Sun 5/1/22*	*22 days*
38	*Subtask 16.2 - Field Project Management, Operations, and Research*	*Sun 5/1/22*	*Thu 6/30/22*	*45 days*
39	*Subtask 16.3 - Demobilization of Staff, Labs, and Equipment*	*Wed 6/1/22*	*Fri 7/15/22*	*33 days*
40	*M5F - Complete UT-GOM2-2 Field Operations*	*Mon 7/18/22*	*Mon 7/18/22*	*0 days*

Project: GOM2_Phase_5

Gantt Chart (6 of 6)

PHASE 6: Oct 2022 – Sep 2024



ID	Task Name	Start
0	**Budget Period 6**	**Sat 10/1/22**
1	**Task 1 - Project Management and Planning**	**Sat 10/1/22**
2	*M6A - Document Results of BP5 Activities*	*Sat 12/31/22*
3	**Task 10 - Core Analysis**	**Mon 10/3/22**
4	*Subtask 10.4 - Continued Pressure Core Analysis (UT-GOM2-1)*	*Mon 10/3/22*
5	*Subtask 10.5 - Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)*	*Mon 10/3/22*
6	*Subtask 10.6 - Additional Core Analysis Capabilities*	*Mon 10/3/22*
7	*Subtask 10.7 - Hydrate Modeling*	*Mon 10/3/22*
8	*Subtask 10.11 - Continued Pressure Core Analysis (UT-GOM2-2)*	*Mon 10/3/22*
9	*Subtask 10.12 - Continued Core-Log Seismic Synthesis (UT-GOM2-2)*	*Mon 10/3/22*
10	**Task 13 - Maintenance & Refinement of Pressure Core Transport, Storage, & Manipulation Capability**	**Mon 10/3/22**
11	*Subtask 13.1 - Hydrate Core Manipulator and Cutter Tool*	*Mon 10/3/22*
12	*Subtask 13.2 - Hydrate Core Effective Stress Chamber*	*Mon 10/3/22*
13	*Subtask 13.3 - Hydrate Core Depressurization Chamber*	*Mon 10/3/22*
14	*Subtask 13.6 - Continued Storage of Hydrate Cores from UT-GOM2-1*	*Mon 10/3/22*
15	*Subtask 13.7 - X-ray Computed Tomography*	*Mon 10/3/22*
16	*Subtask 13.8 - Pre-Consolidation System*	*Mon 10/3/22*
17	*Subtask 13.10 - Storage of Hydrate Core from UT-GOM2-2*	*Mon 10/3/22*
18	*Subtask 13.11 - Hydrate Core Distribution*	*Mon 10/3/22*
19	**Task 16 - UT-GOM2-2 Scientific Drilling Program Field Operations**	**Mon 10/3/22**
20	*Subtask 16.4 - Post-Expedition Permitting*	*Mon 10/3/22*
21	**Task 17 - Project Data Analysis and Reporting**	**Mon 10/3/22**
22	*M6B - Complete Preliminary UT-GOM2-2 Expedition Summary*	*Sat 12/31/22*
23	*Subtask 17.1 - Sample and Data Distribution and Archiving*	*Mon 10/3/22*
24	*Subtask 17.2 - Collaborative Post-Field Project Analysis of Geologic Data and Sa*	*Mon 10/3/22*
25	*M6C - Initiate Comprehensive Scientific Results Volume*	*Thu 6/1/23*
26	*Subtask 17.3 - Scientific Results Volume and Technical Project Presentations*	*Thu 6/1/23*
27	*M6D - Submit set of manuscripts for Comprehensive Scientific Results Volume*	*Mon 9/30/24*

Project: GOM2_Phase_6

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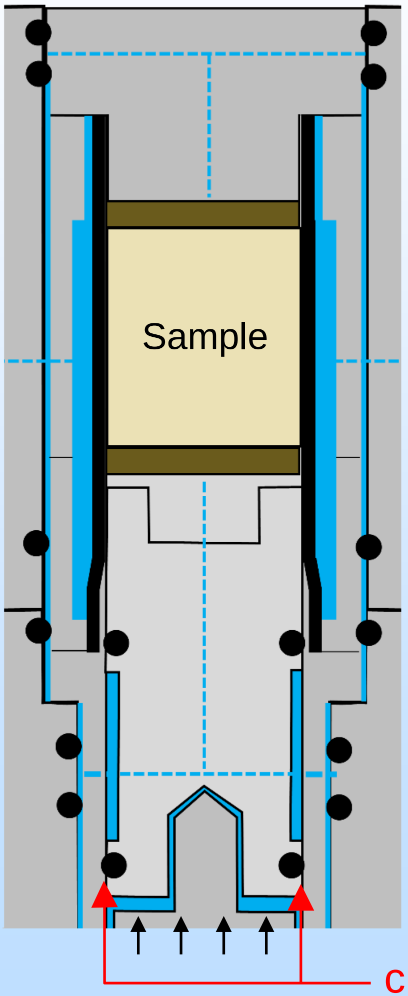
All GOM2 Collaborations

Technology Development
Pressure Core Geomechanical Testing

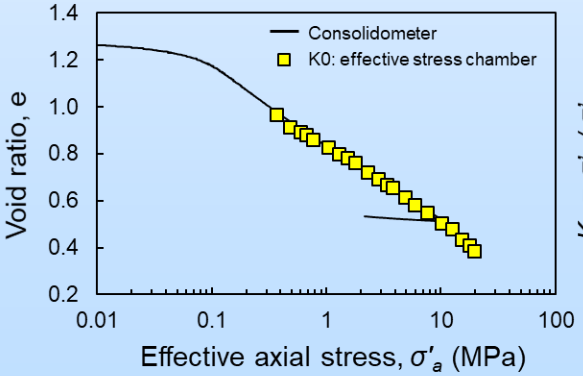


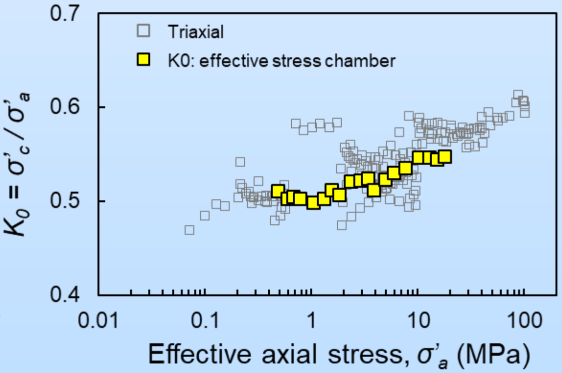
critical seal

K_0: effective stress chamber
Procedures and seal rings were modified to increase the max applied effective stress from 4 to 20 MPa.

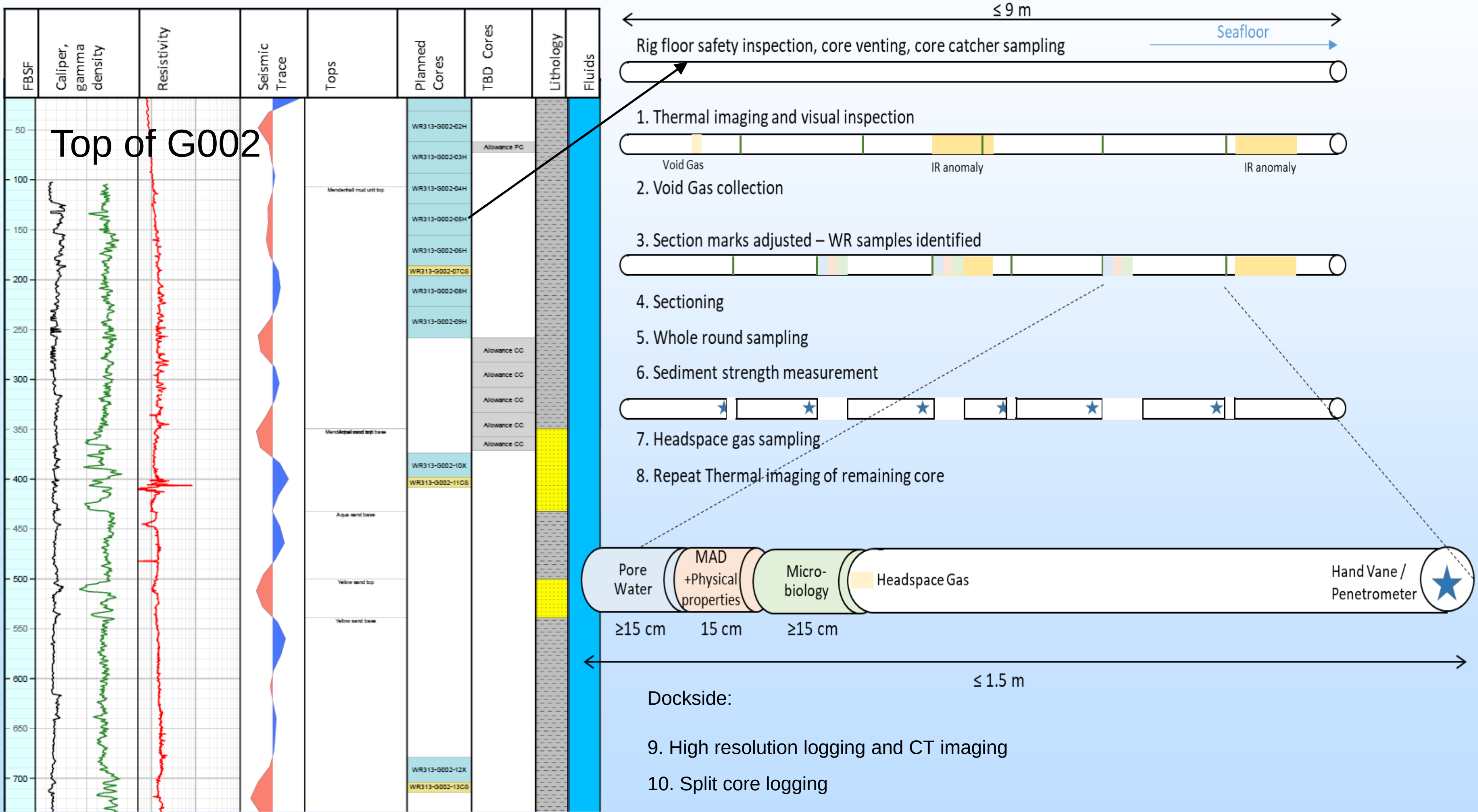
Measurements were validated by comparing results from K_0 to classical devices.

K_0 is now able to characterize UT-GOM2-2 pressure cores (in-situ stress levels ~10 MPa)





UT-GOM2-2 Planning
Core Acquisition, Analysis and Distribution



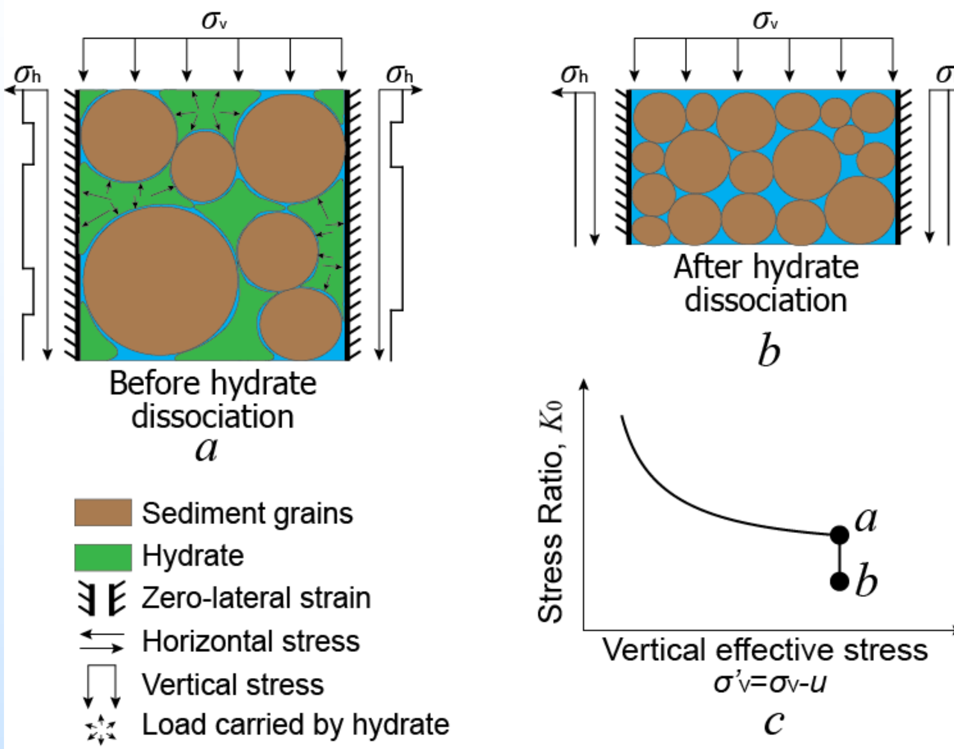
Rig floor safety inspection, core venting, core catcher sampling

1. Thermal imaging and visual inspection
2. Void Gas collection
3. Section marks adjusted – WR samples identified
4. Sectioning
5. Whole round sampling
6. Sediment strength measurement
7. Headspace gas sampling
8. Repeat Thermal imaging of remaining core

Dockside:

9. High resolution logging and CT imaging
10. Split core logging
11. Split core description and sampling

Theme 3: Visco-elastic behavior

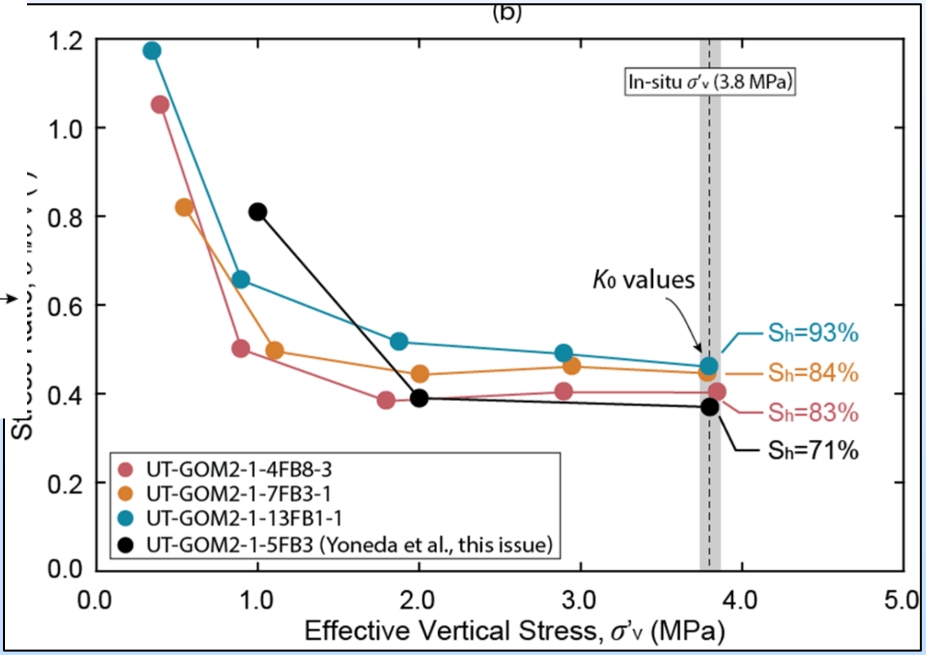


Hydrate is viscous fluid phase that cannot escape the pore space during the compression.

It bears the load during compression.

(Yoneda et al. in press)

Stress Ratio (K_0) proportional to hydrate saturation



(Fang et al., in press)