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

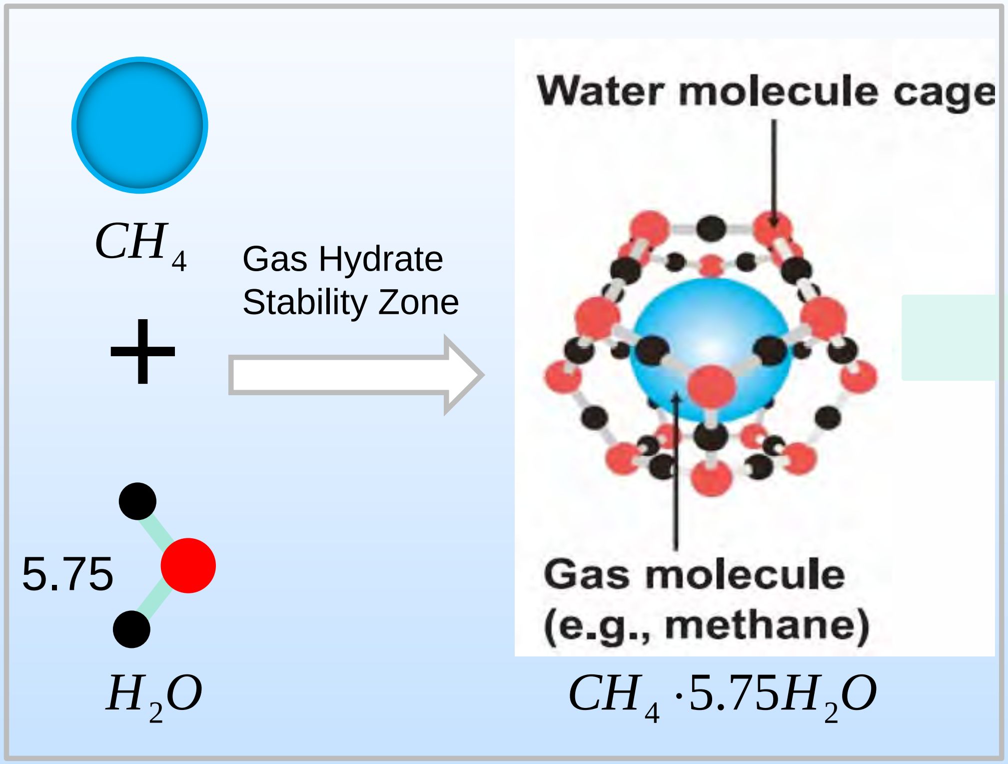
August 13-16, 2018

Presentation Outline

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

Introduction

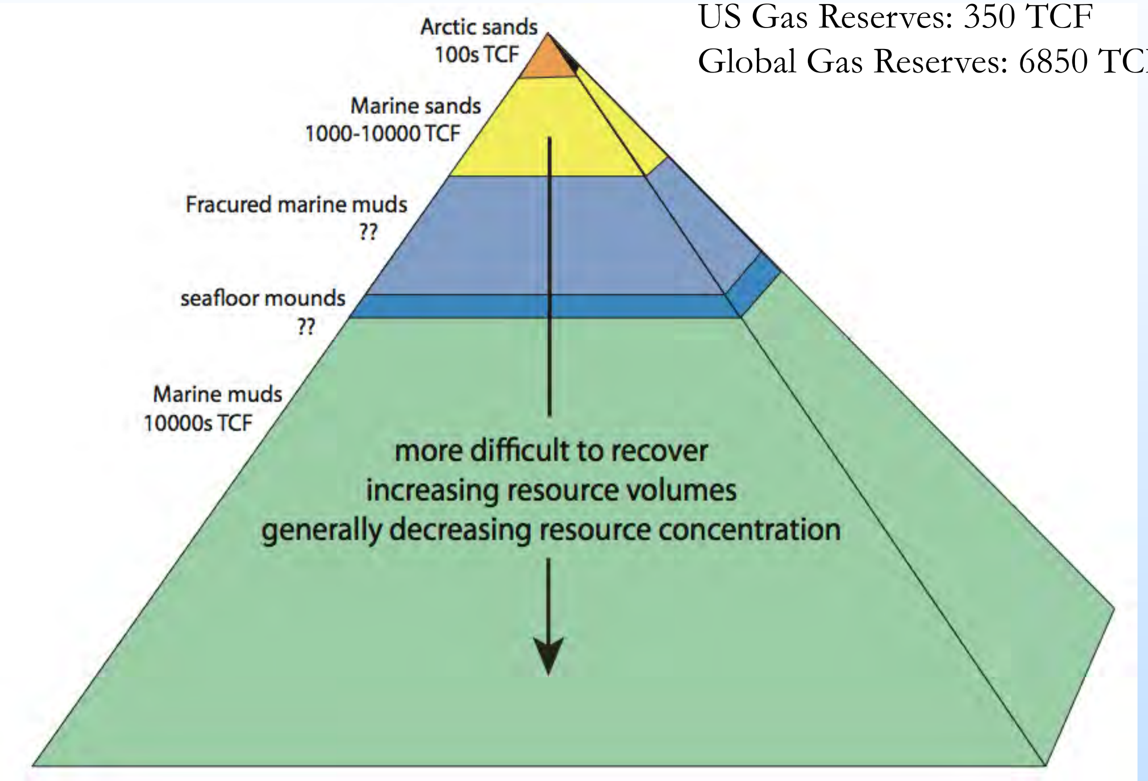
What is methane hydrate?



(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)

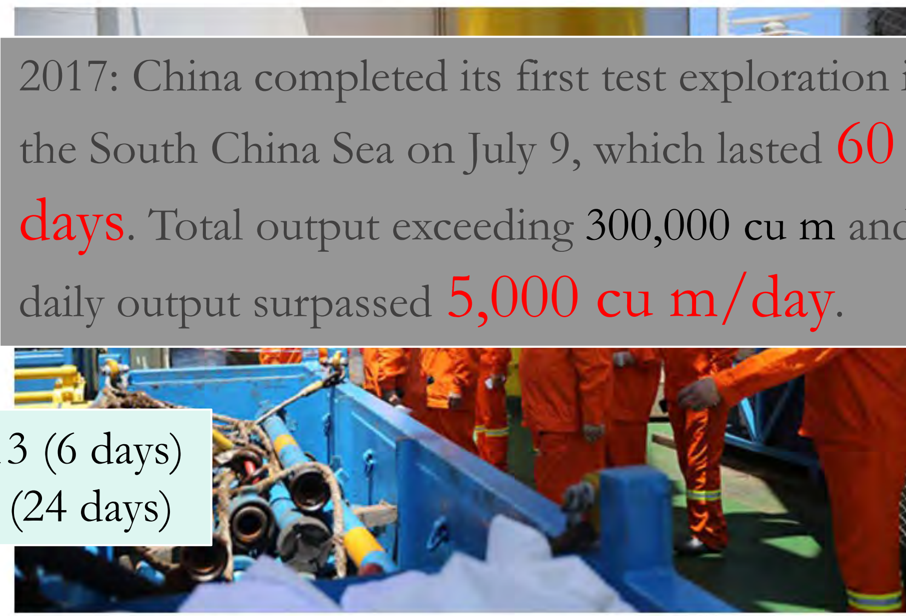
An Energy Coup for Japan: 'Flammable Ice'

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.



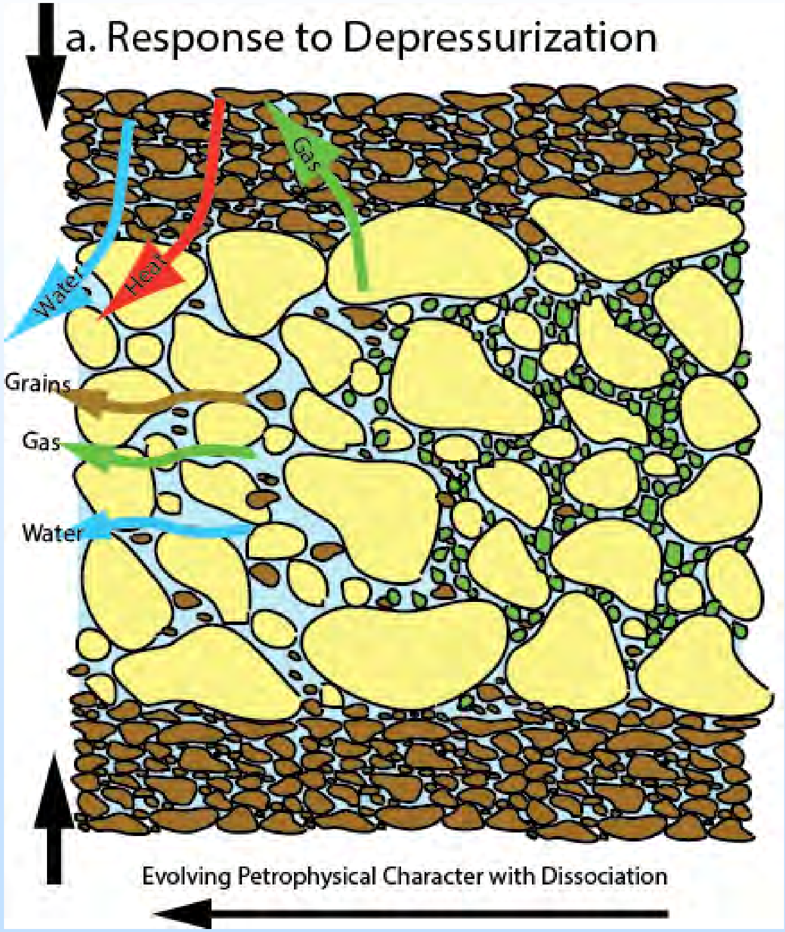
Chinese technicians check their combustible ice mining equipment during an on-the-spot operation in Shenhu Area in the South China Sea, 320 kilometers southeast of Zhuhai city, Guangdong province. [Photo by Guo Junfeng/China Daily]

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)**

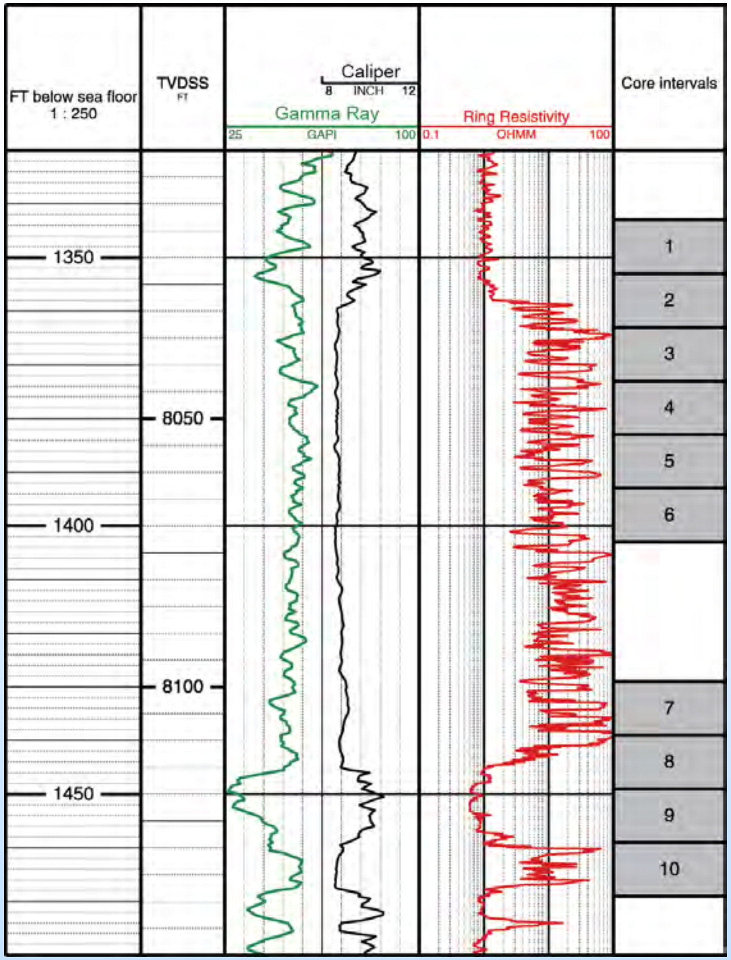
9

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

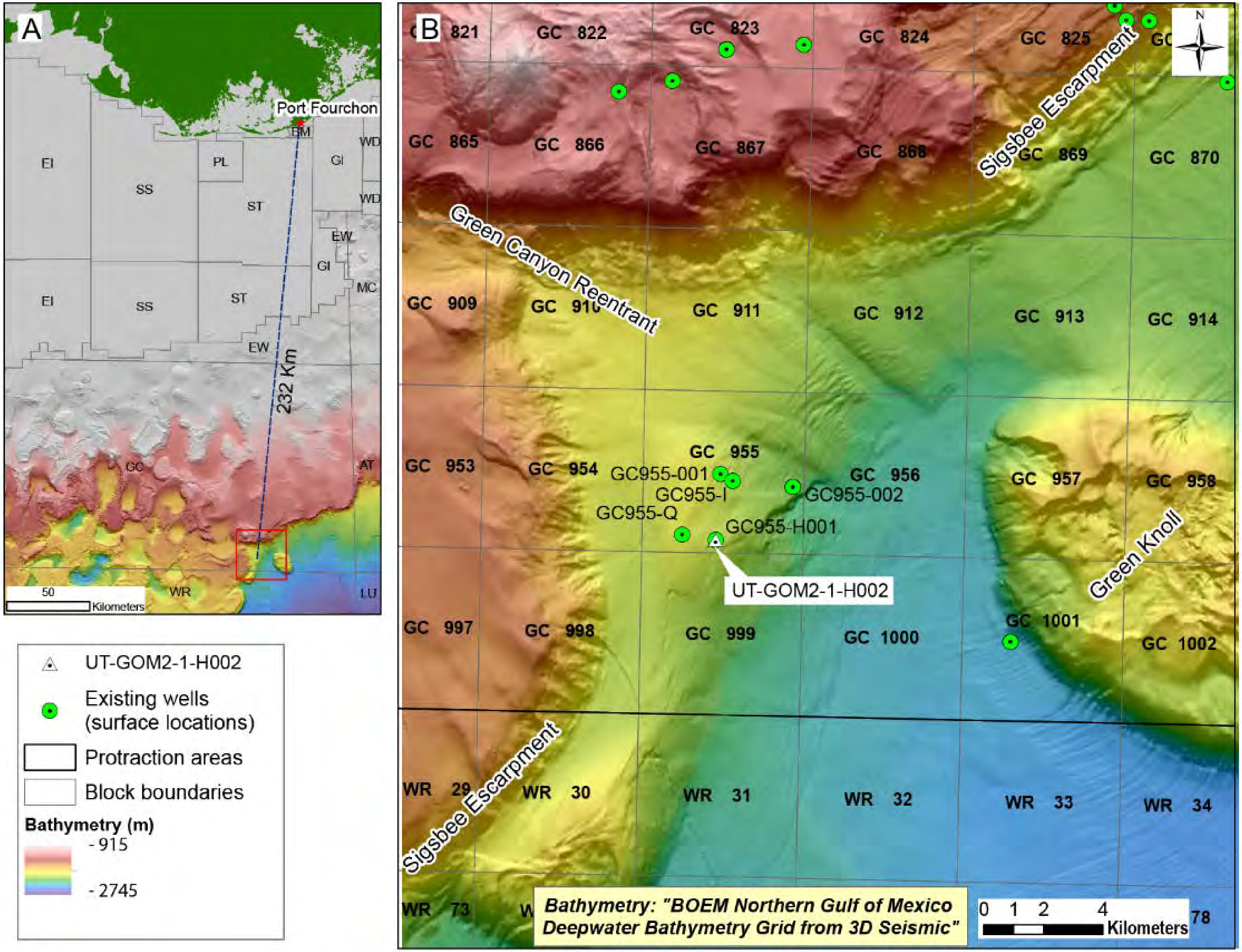
Onboard scientists
Tim Collett, USGS
Ann Cook, Ohio State University
Skyler Dong, University of Texas
Peter Flemings, University of Texas
Gilles Guerin, Columbia University
Melanie Holland, Geotek
Kevin Meazell, University of Texas
Joshua O'Connell, University of Texas
Ethan Petrou, University of Texas
Stephen Phillips, 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

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

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
Jesse Houghton, University of Texas
Colleen Morgan, University of Texas
Jamie Morrison, University of Texas
Katherine Perry, University of Texas
Rikk Rodriguez, University of Texas
Steve Rosen, University of Texas
Judy Sansom, University of Texas
Carla Thomas, University of Texas

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



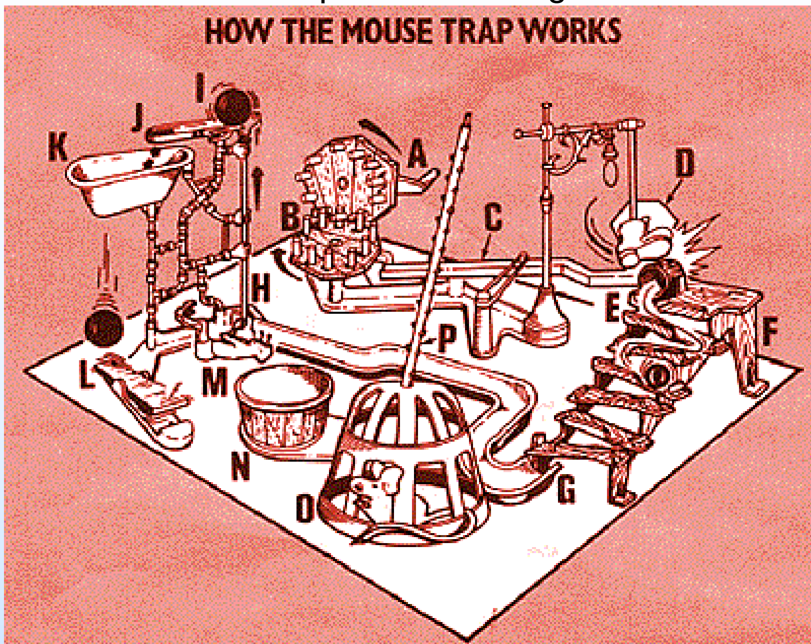
A
Port Fourchon
232 Km
50
Kilometers
B
UT-GOM2-1-H002
Existing wells
(surface locations)
Protraction areas
Block boundaries
Bathymetry (m)
- 915
- 2745
Green Canyon Reentrant
Sigsbee Escarpment
Green Knoll
GC 955
GC955-001
GC955-I
GC955-002
GC955-Q
GC955-H001
UT-GOM2-1-H002
Bathymetry: "BOEM Northern Gulf of Mexico Deepwater Bathymetry Grid from 3D Seismic"
0 1 2 4
Kilometers

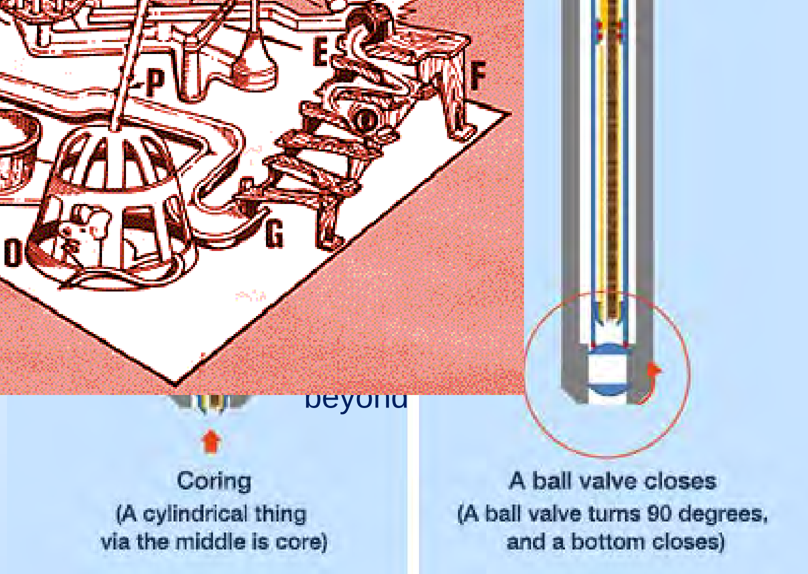
Making up BHA

Spud-in for H002 Well

Recovering pressure core

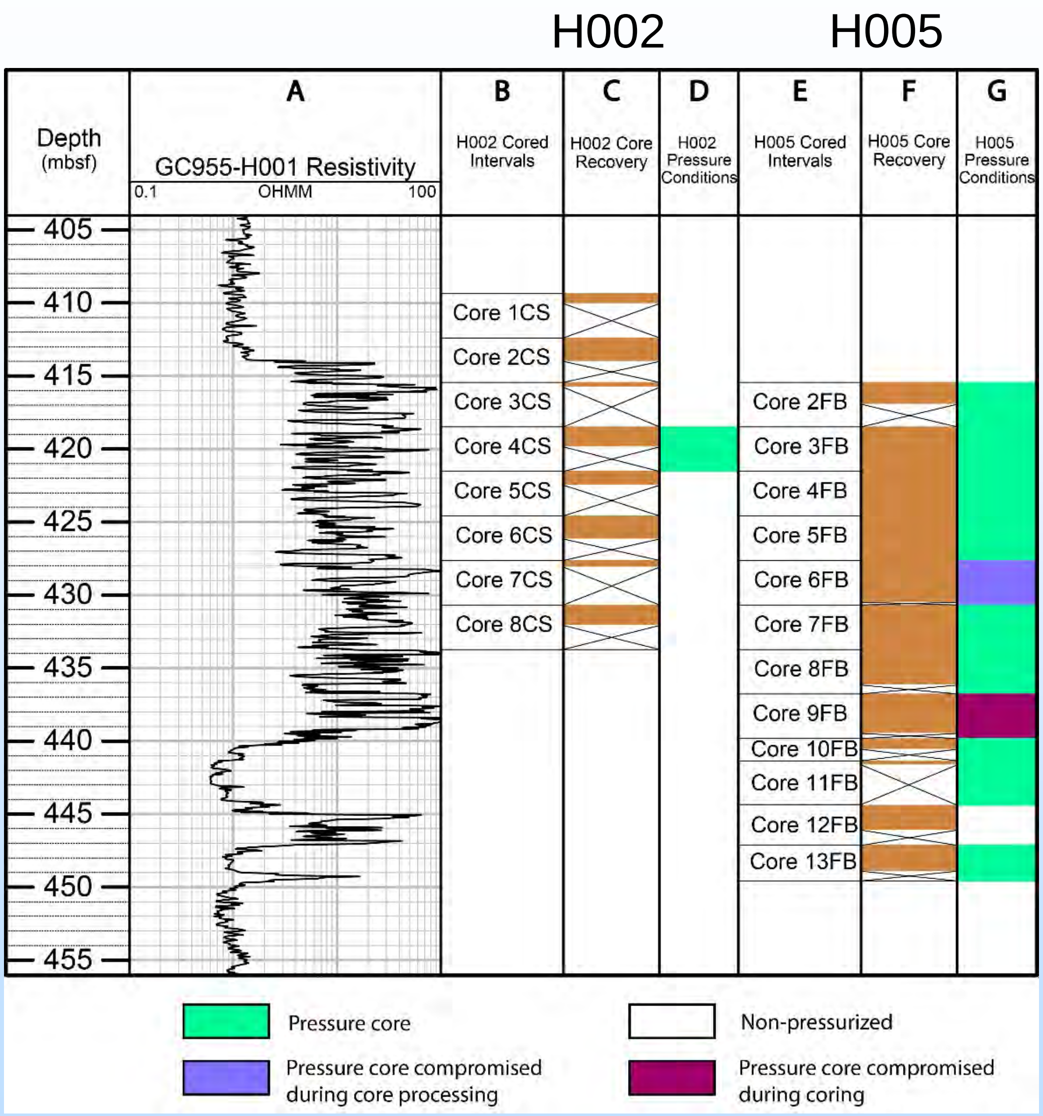
What are pressure coring tools?





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

UT-GOM2-1 Expedition - May 2017



- 12 successful pressure cores in main hydrate reservoir

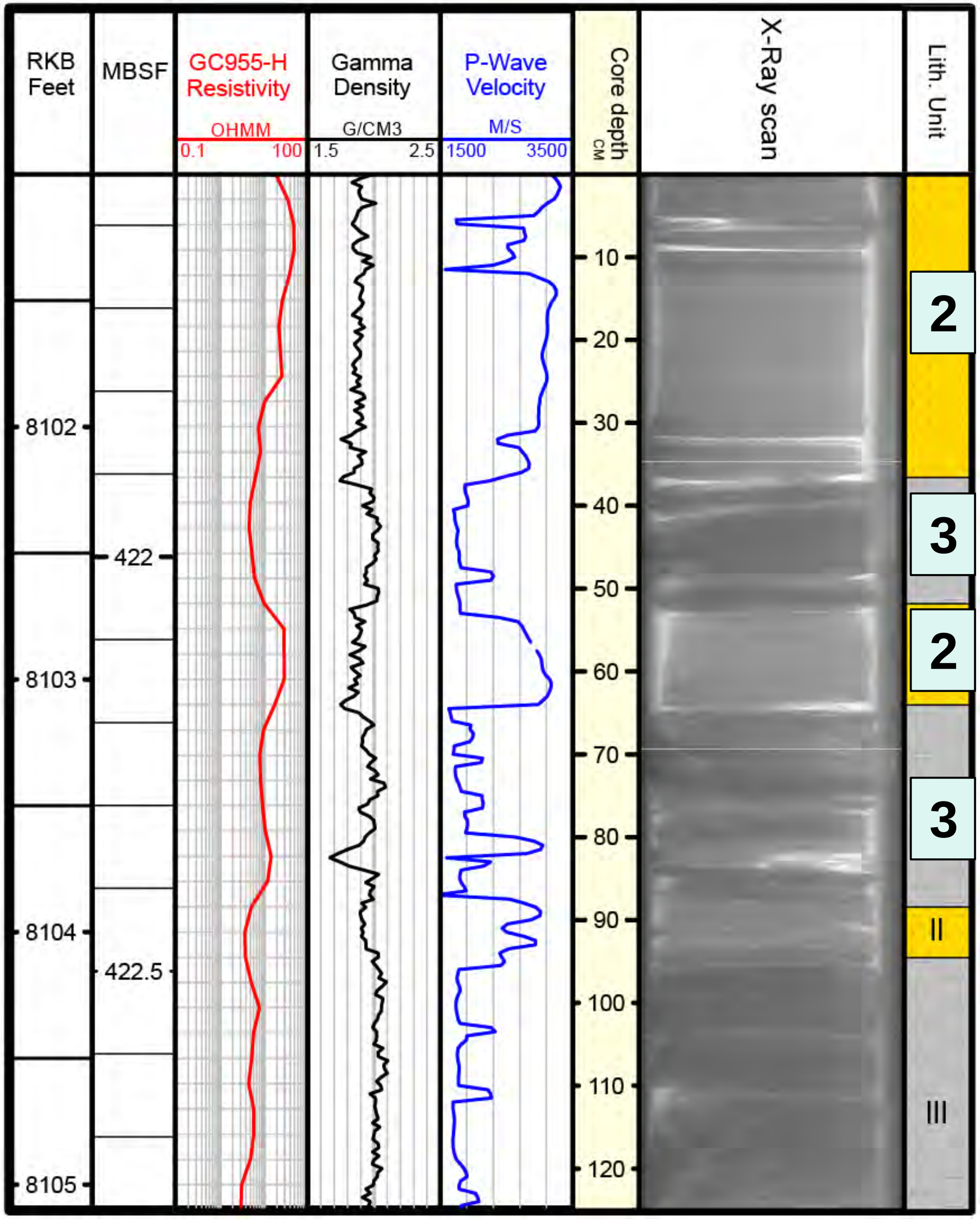
Lithofacies

<u>Lithofacies 2</u>

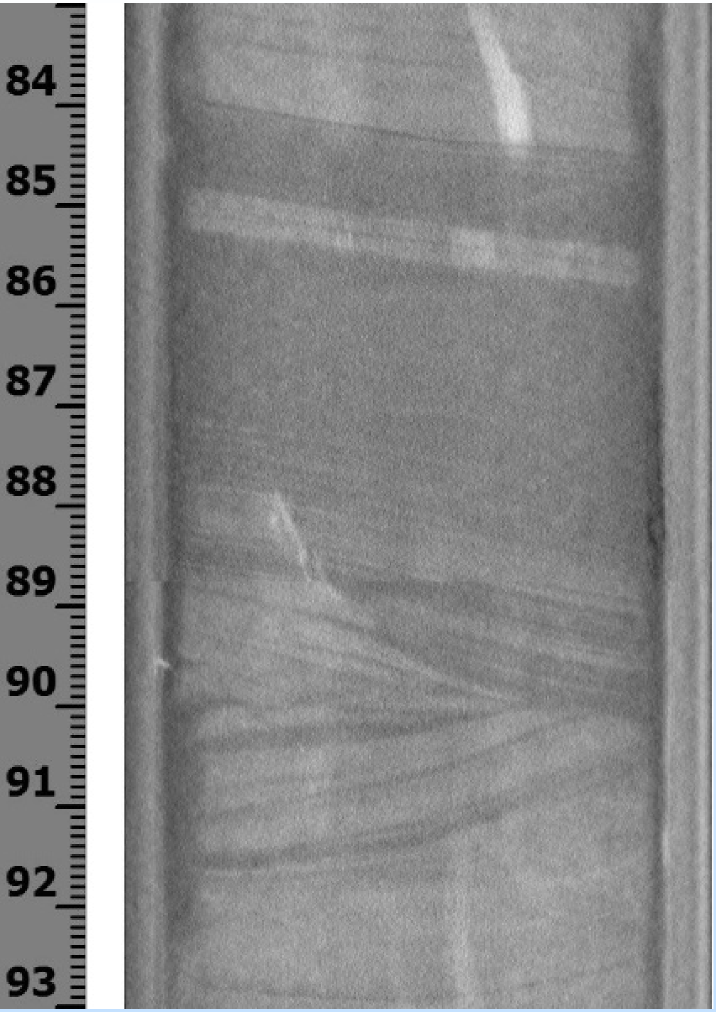
- **Interbedded with lithofacies 3.**
- **low density (2.05-2.1 g/cc) and high velocity (3000-3250 m/s)**
- **Ripples and/or cross-bedding.**
- **Most continuous underformed samples.**

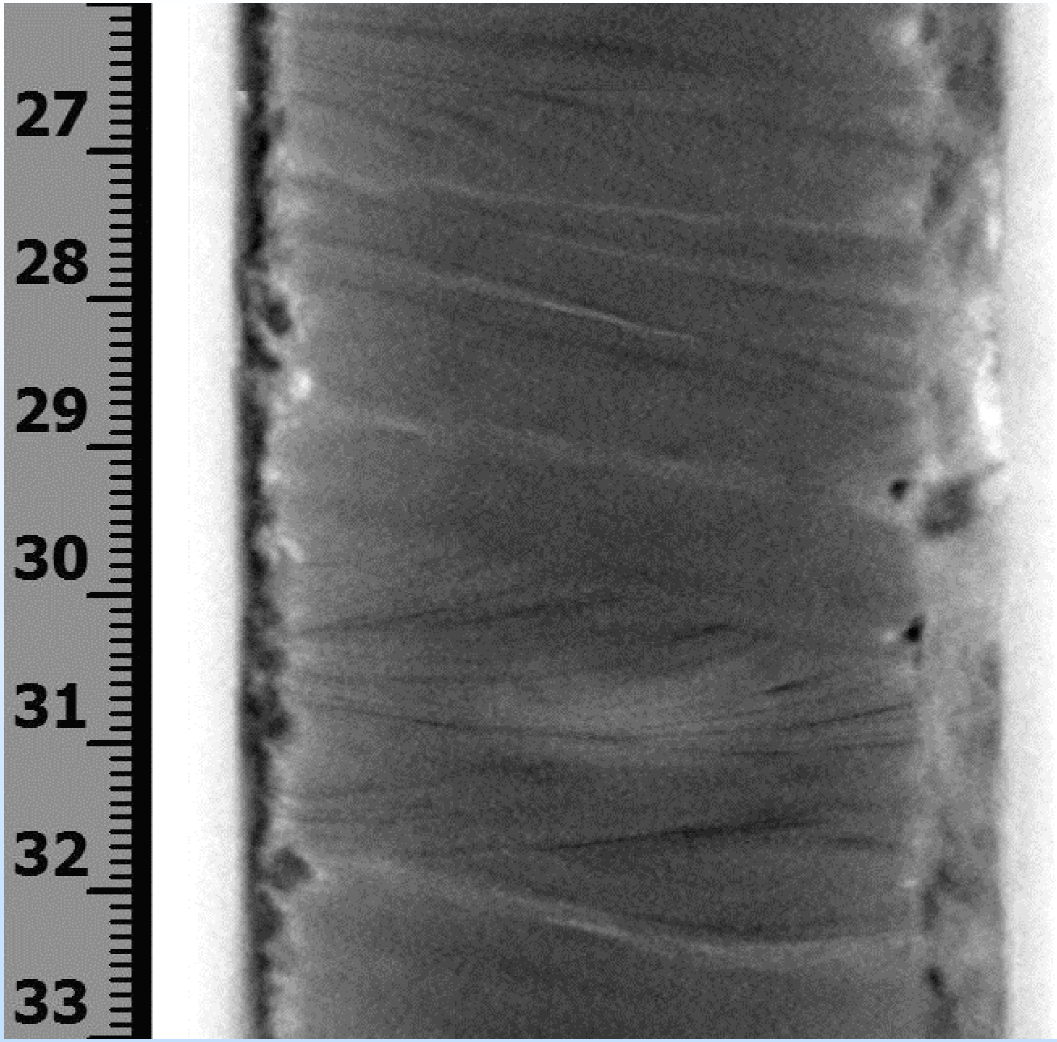
<u>Lithofacies 3</u>

- **Interbedded with lithofacies 2**
- **High density (~1.9g/cc) and low velocity (~1700 m/s)**
- **Generally massive and more deformed**

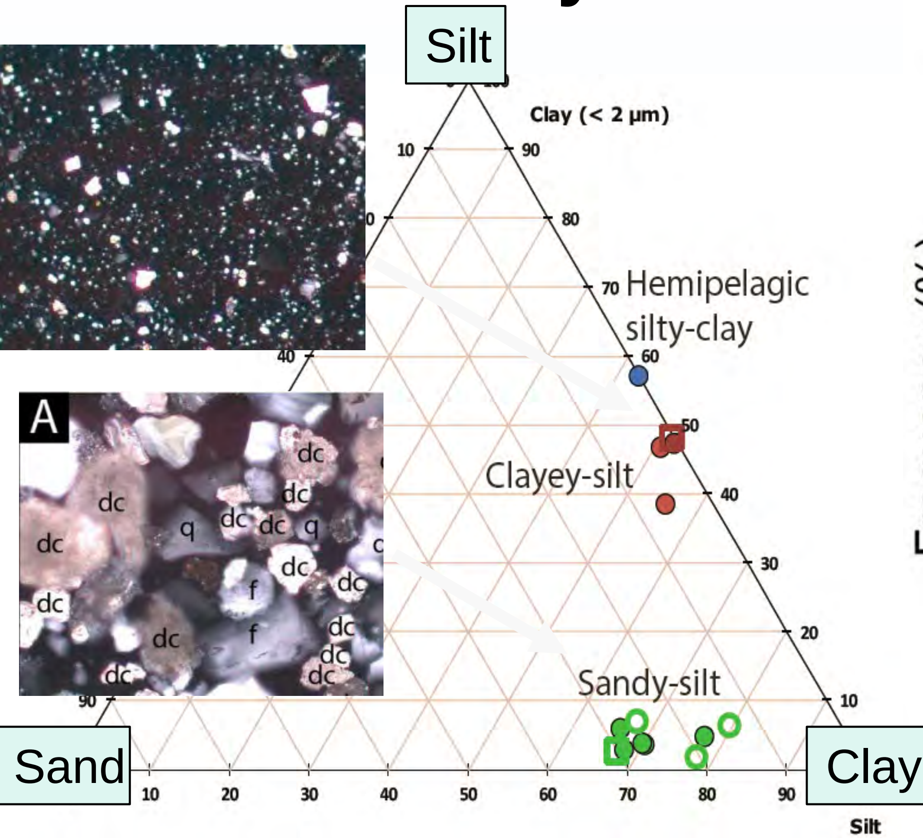


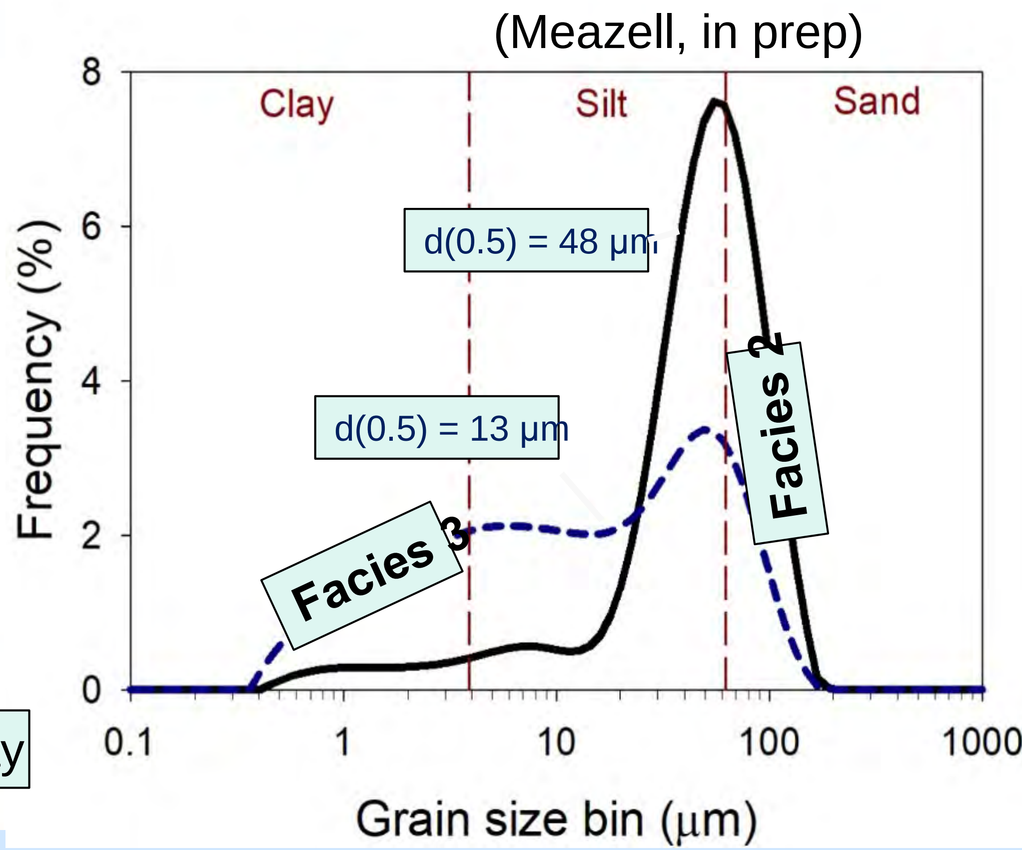
Lithofacies 2

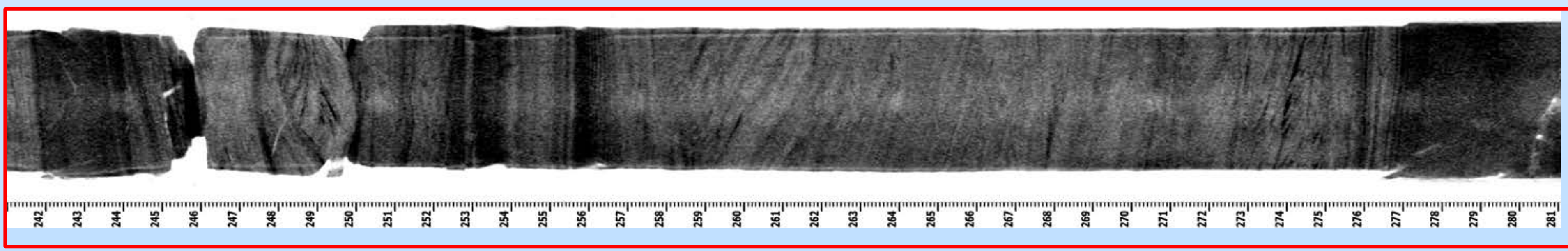




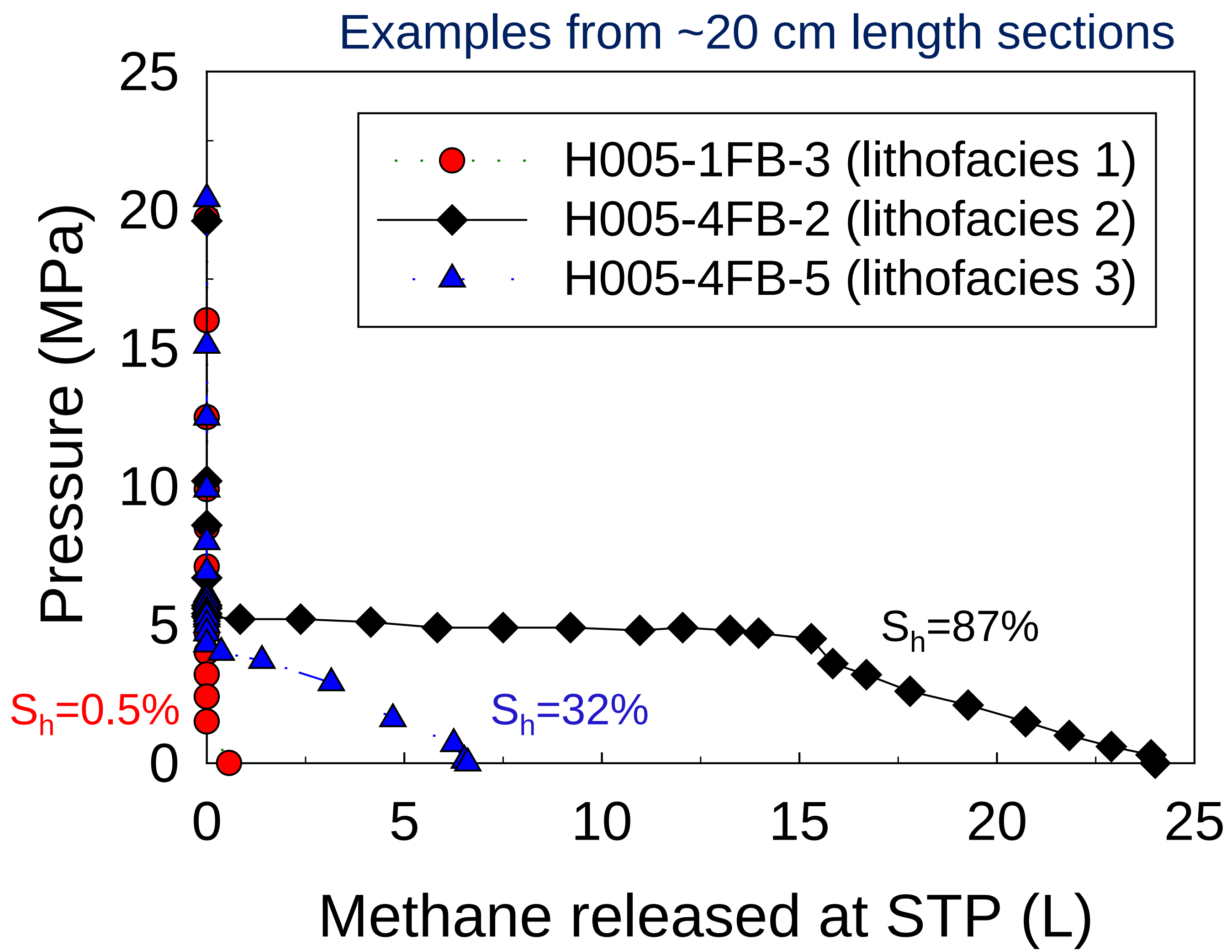
‘Sand’ is ‘sandy silt’





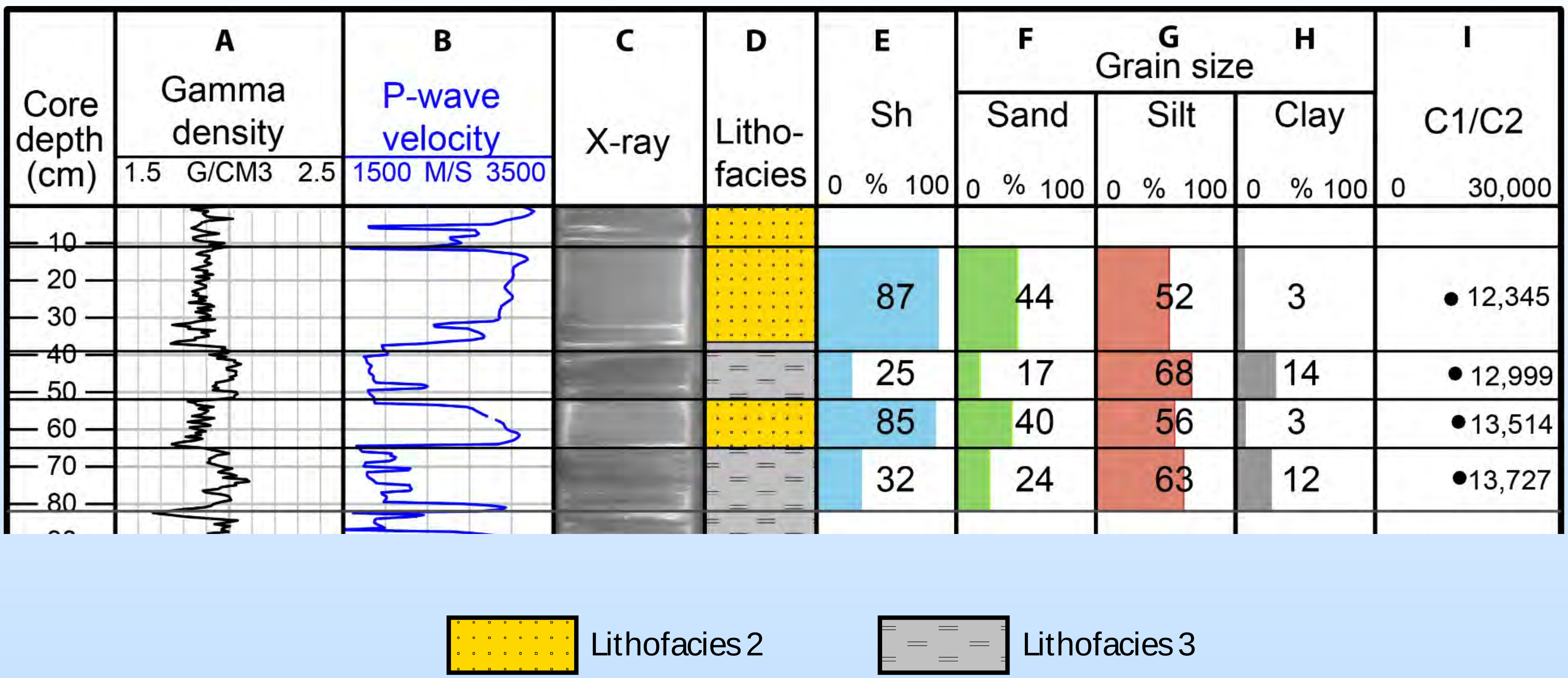


Hydrate Concentration (S_h)

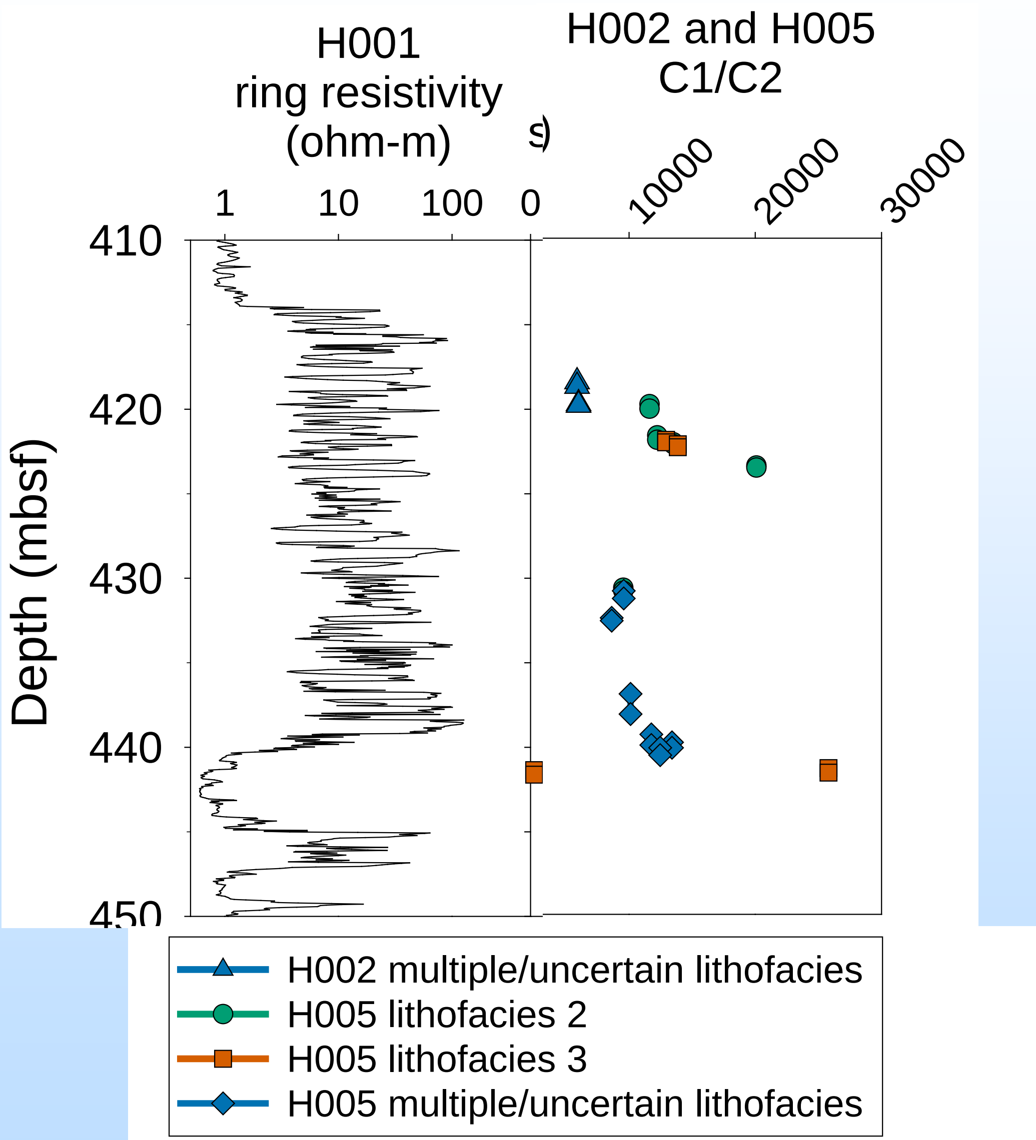


Hydrate Concentration (S_h)

Core H005-04FB



Really Dry Gas



- Nearly pure methane
- Ethane < 200 ppm

<u>Ongoing gas analyses</u>

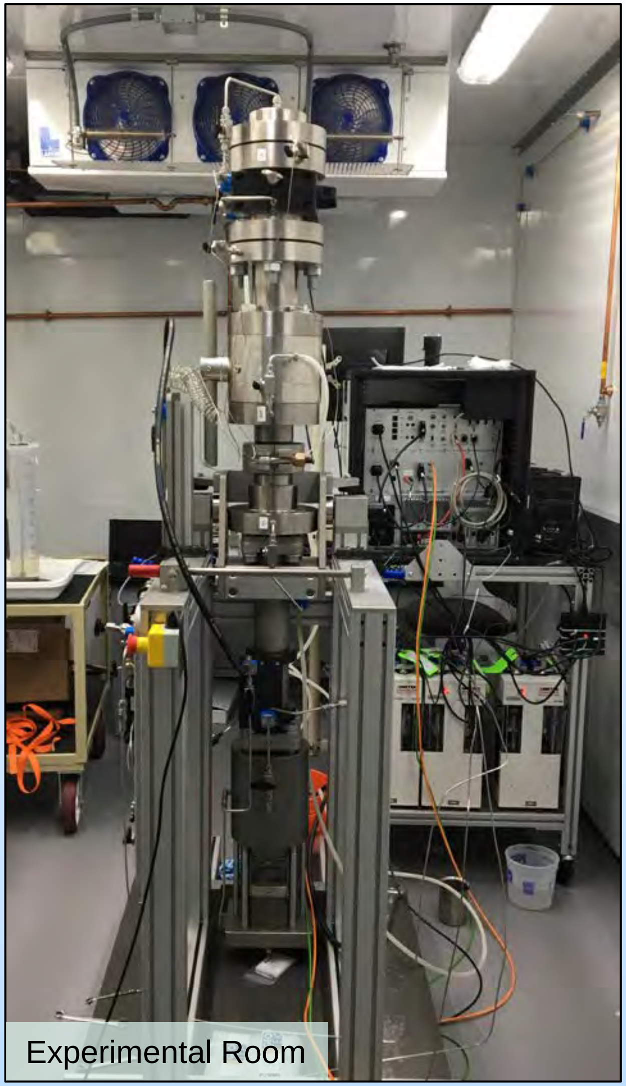
- Methane $\delta^{13}C$ and δD
- Noble gases
- Clumped methane isotopes $\Delta 18$

Ongoing Experimental Analysis: UT Pressure Core Center

(a) Pressure Core Chamber and Mini-PCATS

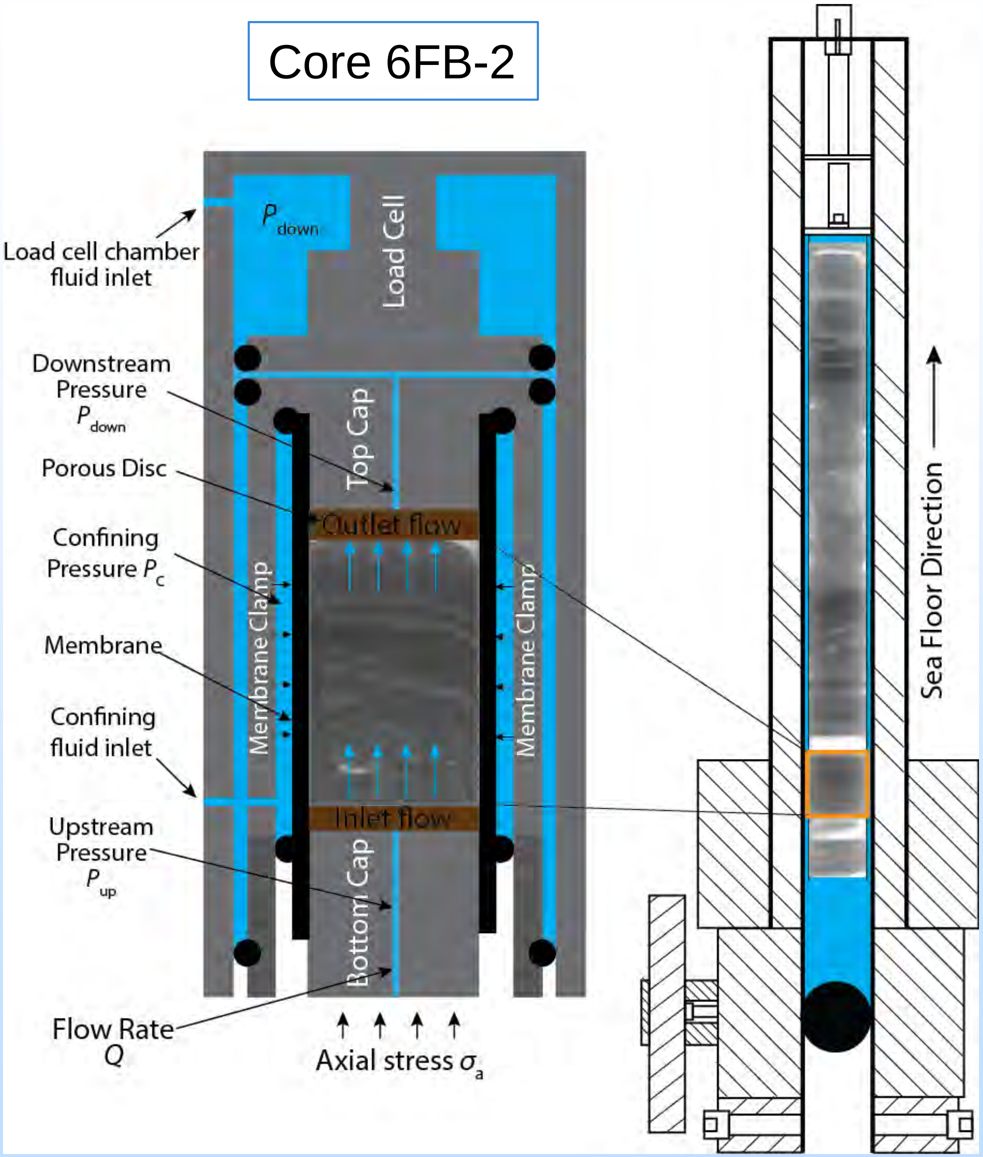
Cold Storage Room

(b) K0 Permeameter

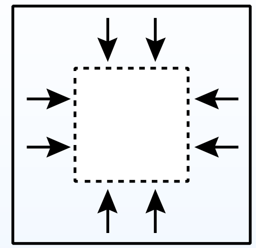


Experimental Room

K0 Permeability Measurement



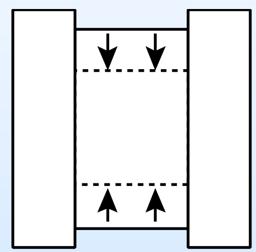
Hydrostatic



Drained Hydrostatic Consolidation

Permeability Measurement

K0 Condition



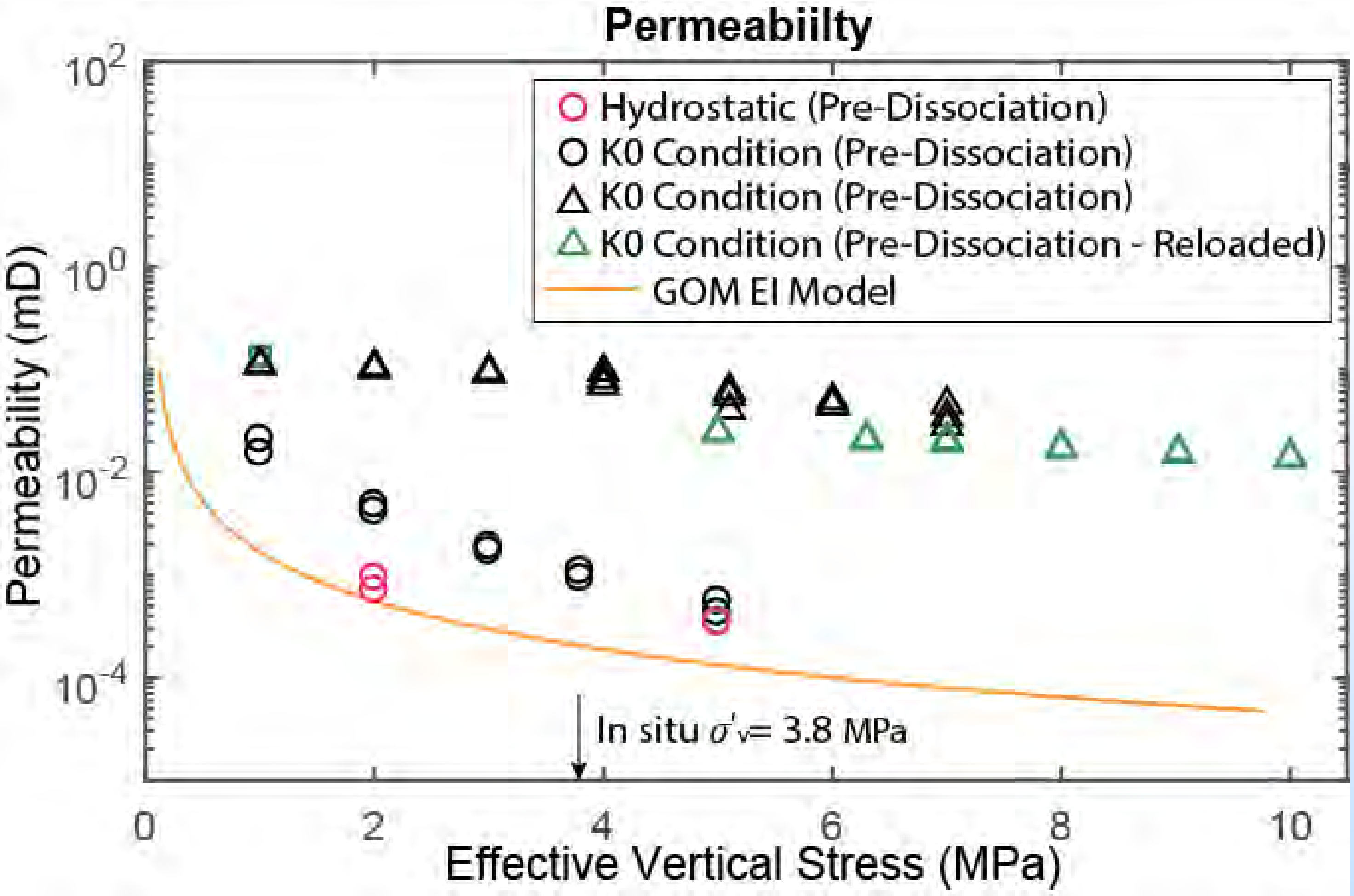
Drained K0 Consolidation

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)

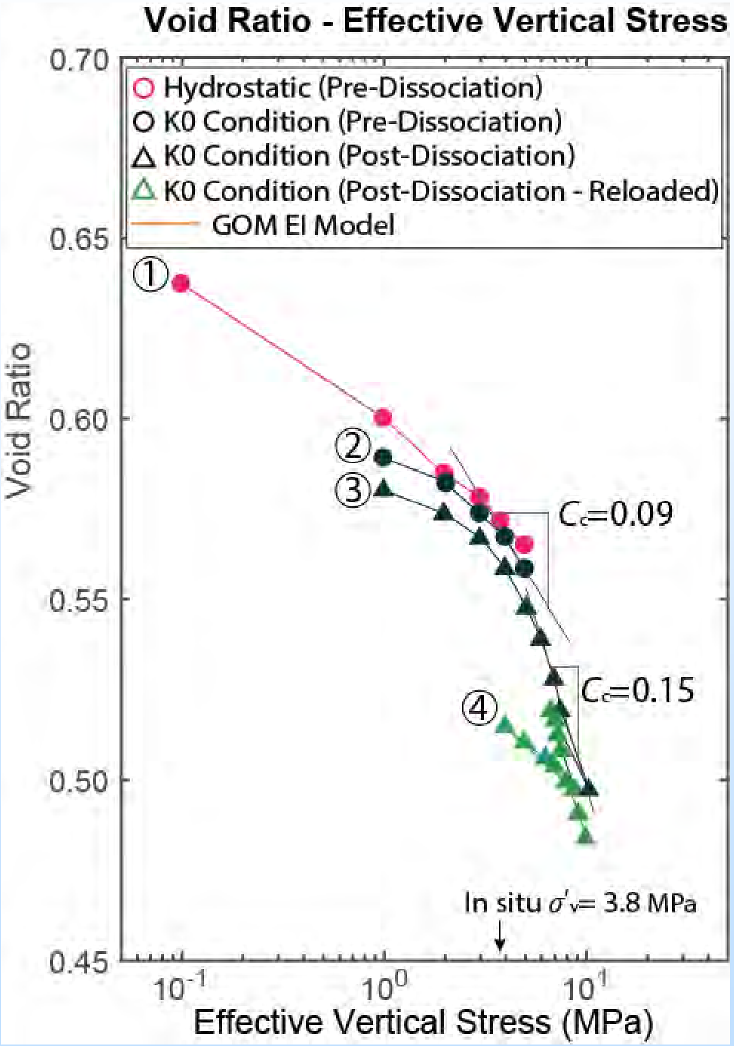
Initial Permeability Measurements



- ✓ 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

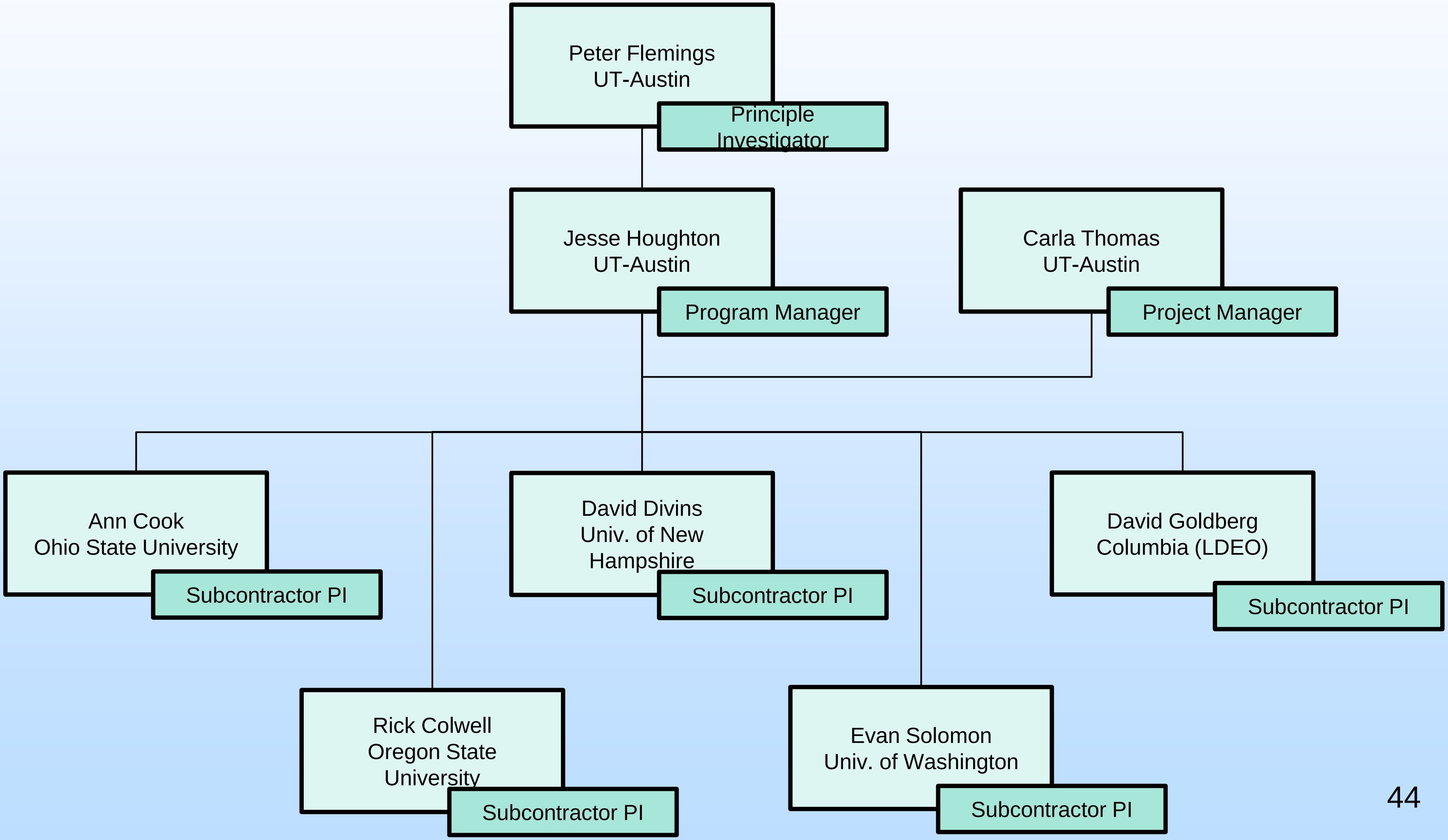
Goals and Objectives

- 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.

Organization Chart

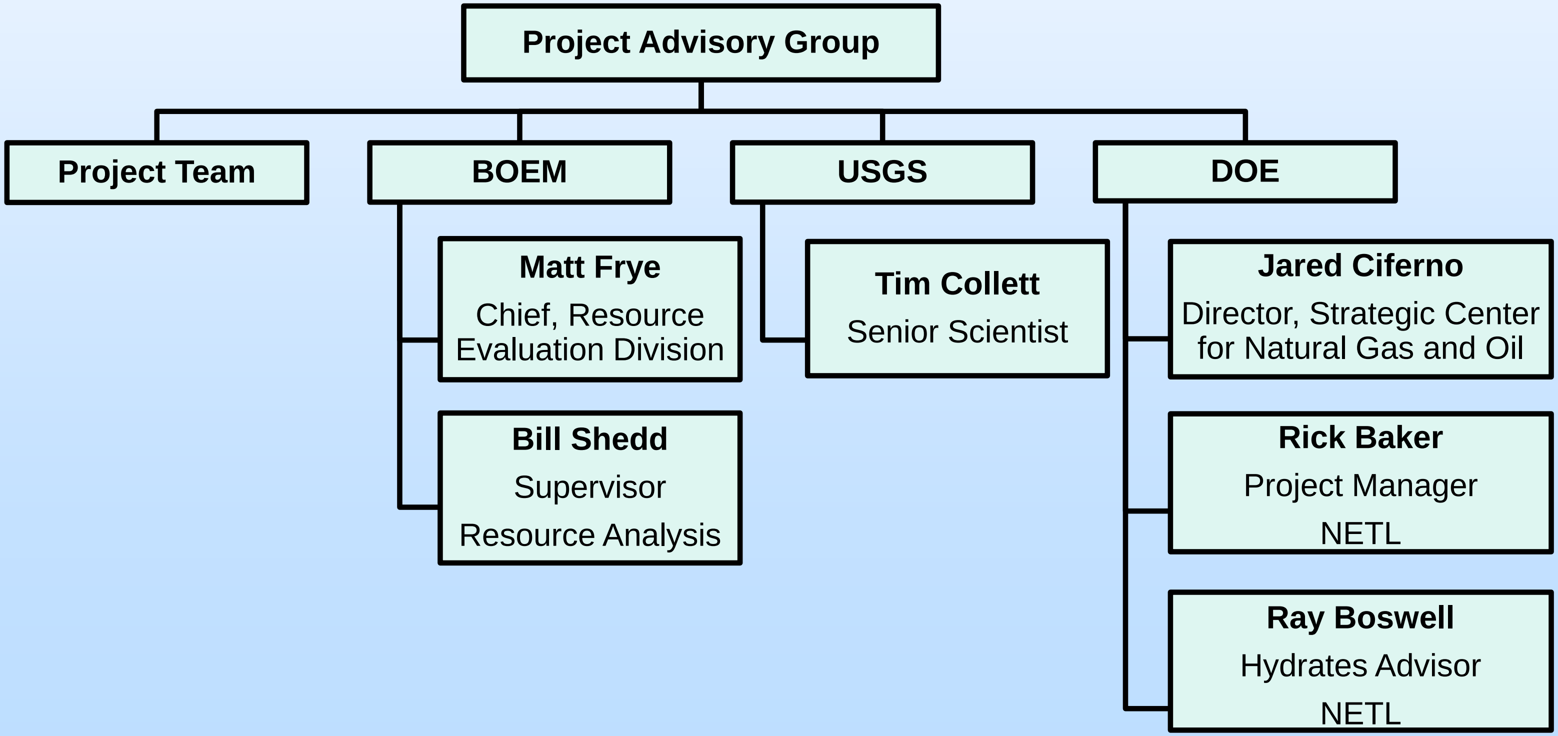
- Project Team
  - **The University of Texas Institute for Geophysics** is the prime contractor, responsible for leading development and execution of all scientific, technical, and logistical aspects of the project.
  - There are five sub-recipients on this project:
    - **Ohio State University**: Site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



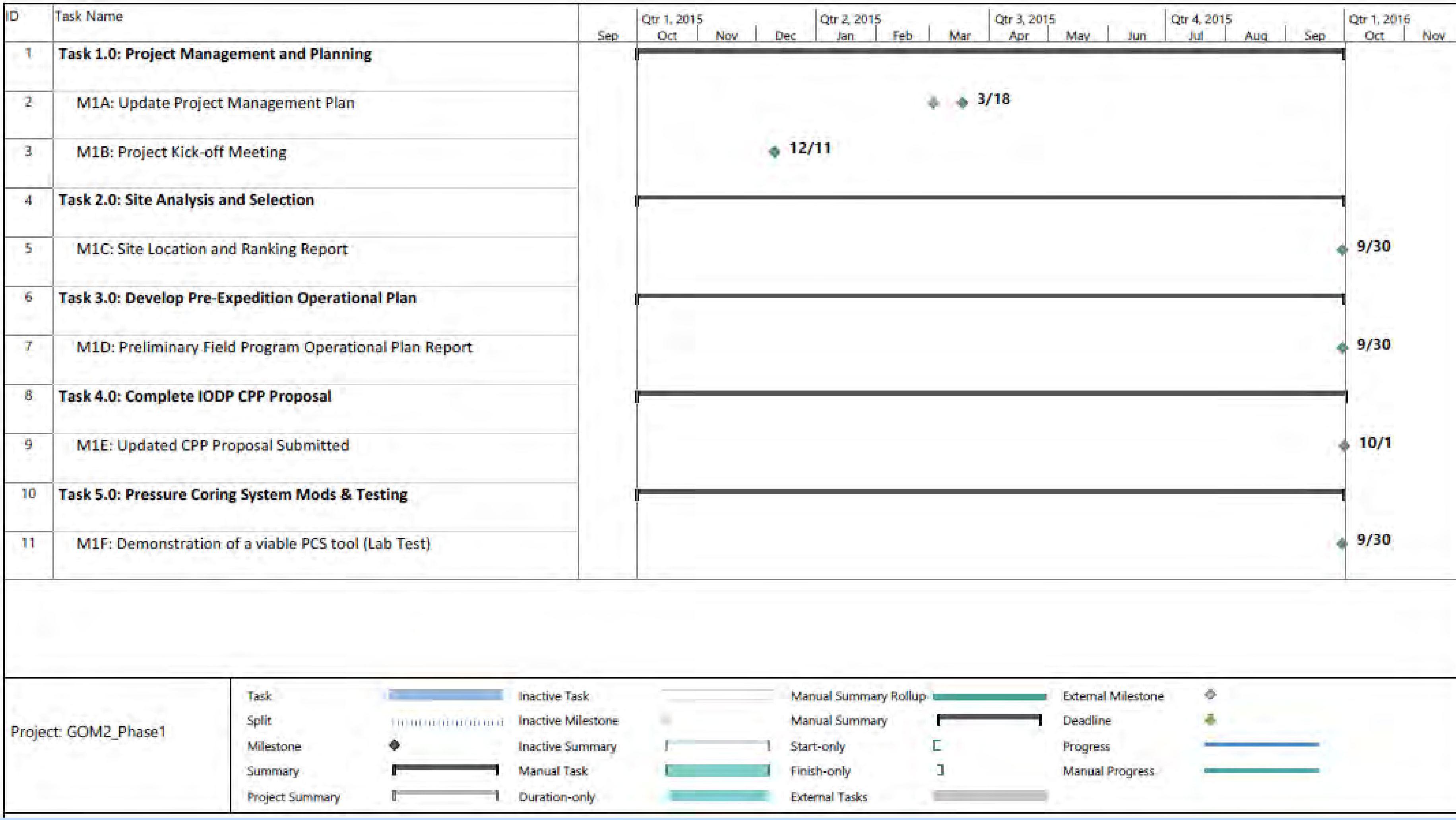
Organization Chart

- 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.



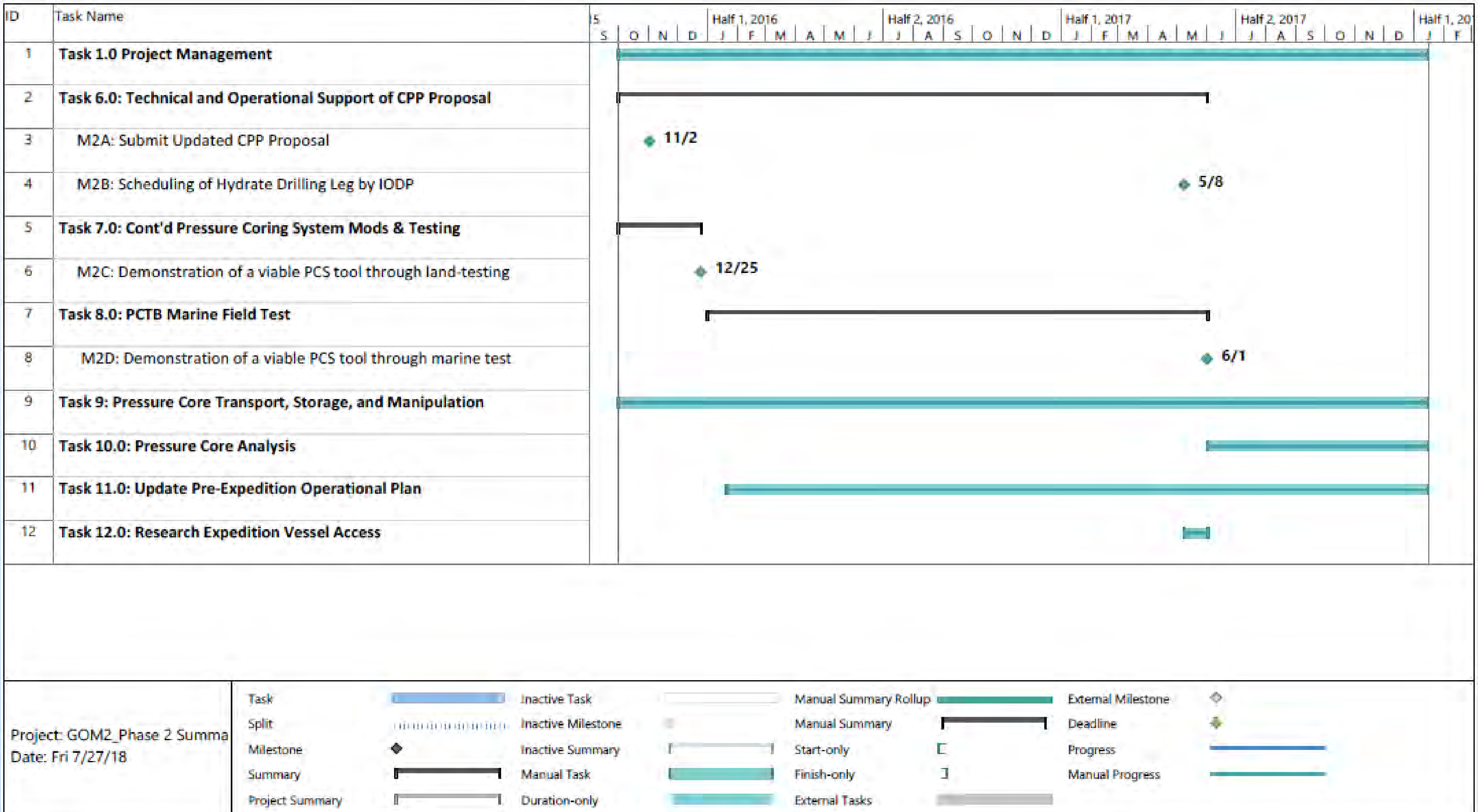
Gantt Chart

PHASE 1: Oct 2014 – Sep 2015



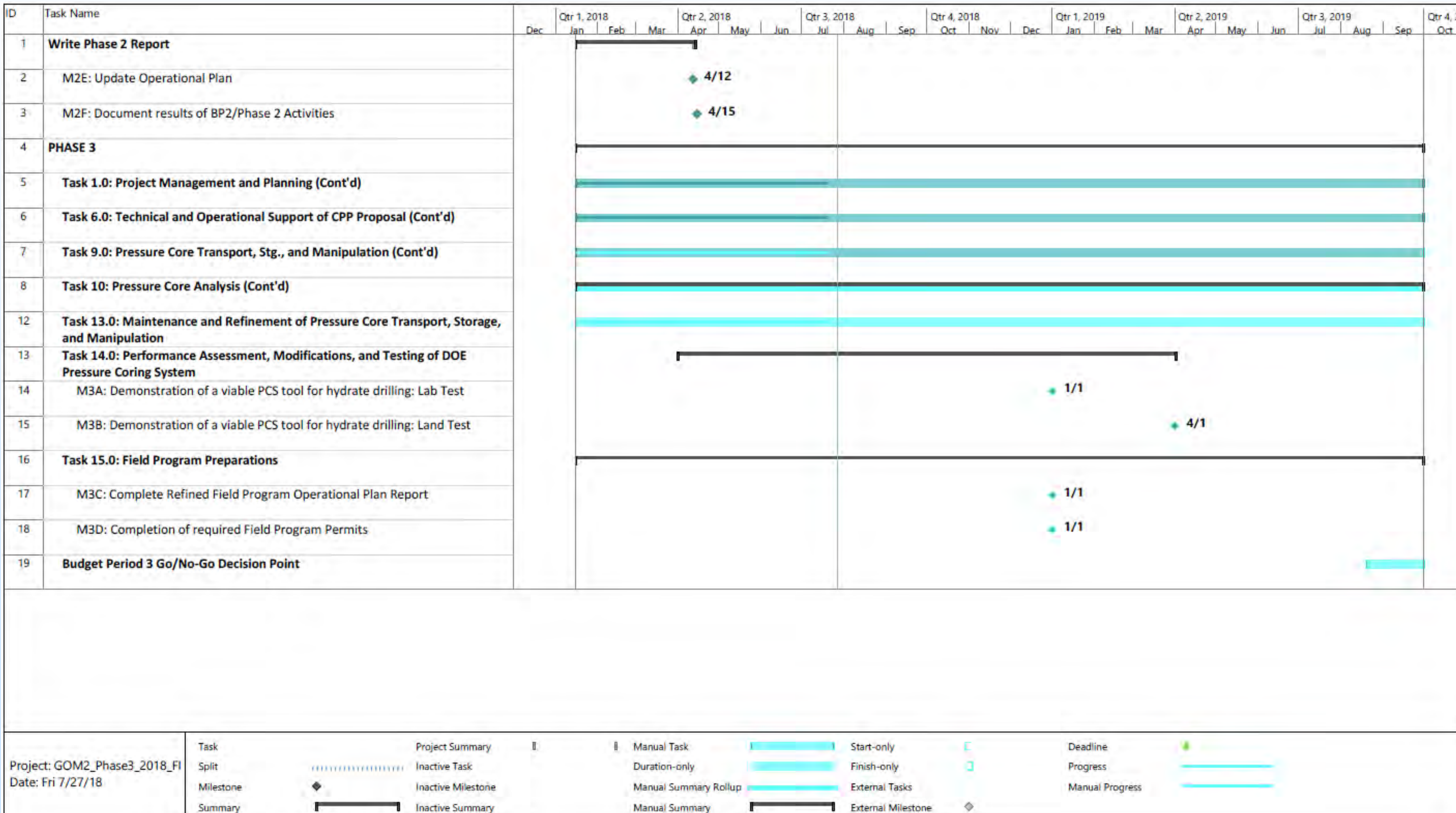
Gantt Chart

PHASE 2: Oct 2015 – Jan 2018



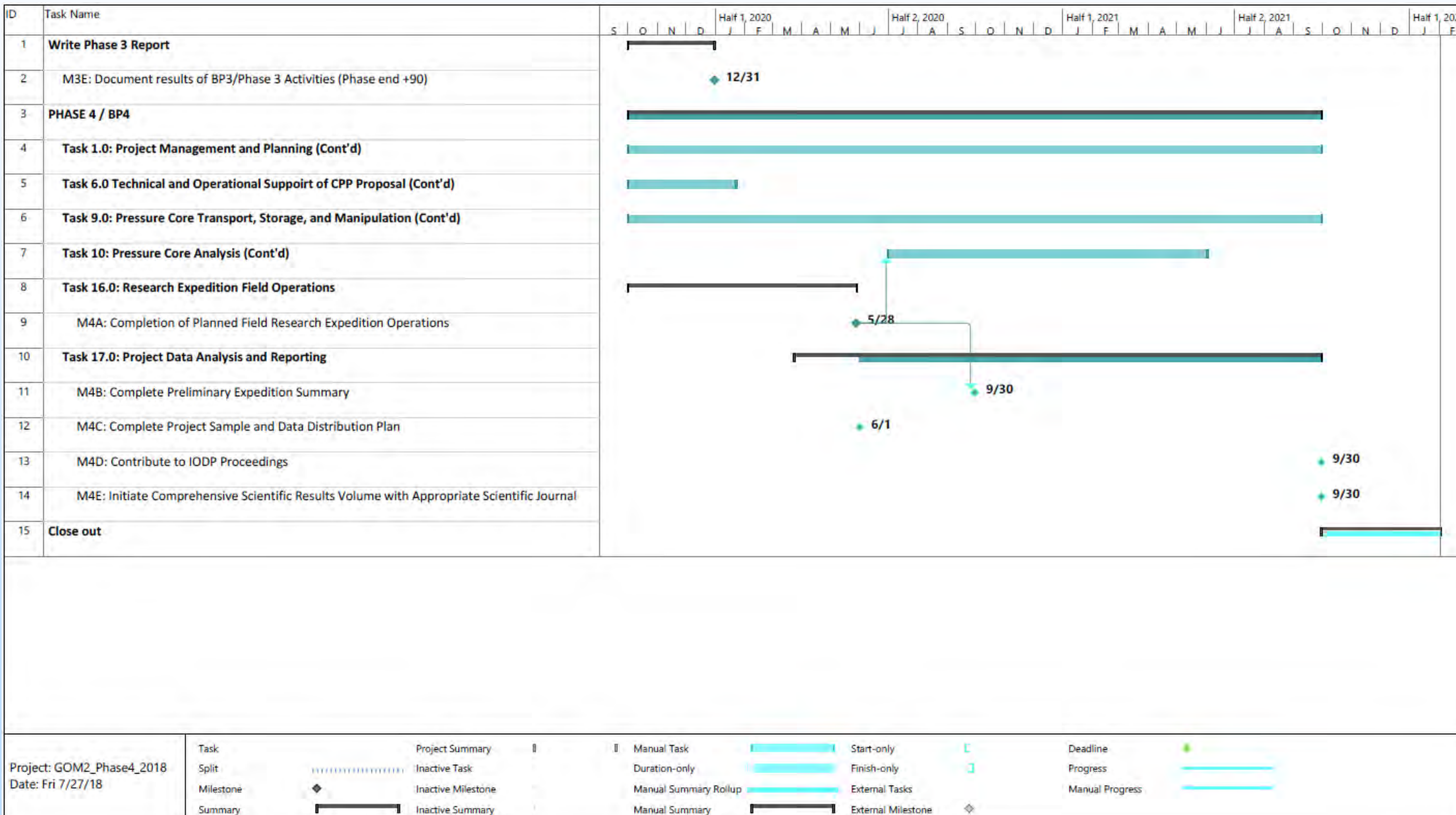
Gantt Chart

PHASE 3: Jan 2018 – Sep 2019



Gantt Chart

PHASE 4: Oct 2019 – Sep 2021



Bibliography

- Cook. A. E., and Waite, W. F., (2018). Archie's saturation exponent for natural gas hydrate in coarse-grained reservoirs. Journal of Geophysical Research. DOI: 10.1002/2017JB015138
- Cook, A. E., & Sawyer, D. (2015). Methane migration in the Terrebonne Basin gas hydrate system, Gulf of Mexico. Presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Cook, A.E., & Sawyer, D. (2015). The mud-sand crossover on marine seismic data. Geophysics, v. 80, no. 6, A109-A114. 10.1190/geo2015-0291.1.
- Cook, A.E., and Waite, B. (2016). Archie's saturation exponent for natural gas hydrate in coarse-grained reservoir. Presented at Gordon Research Conference, Galveston, TX.
- Cook, A.E., Hillman, J., & Sawyer, D. (2015). Gas migration in the Terrebonne Basin gas hydrate system. Abstract OS23D-05 presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Cook, A.E., Hillman, J., Sawyer, D., Treiber, K., Yang, C., Frye, M., Shedd, W., Palmes, S. (2016). Prospecting for Natural Gas Hydrate in the Orca & Choctaw Basins in the Northern Gulf of Mexico. Poster presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Fang, Y., Flemings, P.B., Daigle, H., O'Connell, J., Polito, P., (2018). Measure permeability of natural hydrate-bearing sediments using K0 permeameter. Presented at Gordon Research Conference on Gas Hydrate, Galveston, TX. Feb 24- Mar 02, 2018.
- Flemings, P., Phillips, S., and the UT-GOM2-1 Expedition Scientists, (2018). Recent results of pressure coring hydrate-bearing sands in the deepwater Gulf of Mexico: Implications for formation and production. Talk presented at the 2018 Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX, February 24-March 2, 2018.

Bibliography

- Darnell, K., Flemings, P.B., DiCarlo, D.A. (2016). Nitrogen-assisted Three-phase Equilibrium in Hydrate Systems Composed of Water, Methane, Carbon Dioxide, and Nitrogen. Presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Goldberg, D., Küçük, H.M., Haines, S., Guerin, G. (2016). Reprocessing of high resolution multichannel seismic data in the Gulf of Mexico: implications for BSR character in the Walker Ridge and Green Canyon areas. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.
- Hammon, H., Phillips, S., Flemings, P., and the UT-GOM2-1 Expedition Scientists, (2018). Drilling-induced disturbance within methane hydrate pressure cores in the northern Gulf of Mexico. Poster presented at the 2018 Gordon Research Conference and Seminar on Natural Gas Hydrate Systems, Galveston, TX, February 24-March 2, 2018.
- Heber, R., Kinash, N., Cook, A., Sawyer, D., Sheets, J., and Johnson, J.E. (2017). Mineralogy of Gas Hydrate Bearing Sediment in Green Canyon Block 955 Northern Gulf of Mexico. Abstract OS53B-1206 presented at American Geophysical Union, Fall Meeting, New Orleans, LA.
- Hillman, J., Cook, A. & Sawyer, D. (2016). Mapping and characterizing bottom-simulating reflectors in 2D and 3D seismic data to investigate connections to lithology and frequency dependence. Presented at Gordon Research Conference, Galveston, TX.
- Hillman, J, Cook, A.E., Sawyer, D., Küçük, H.M., and Goldberg, D.S. (2017). The character and amplitude of bottom-simulating reflectors in marine seismic data. Earth & Planetary Science Letters, doi:http://dx.doi.org/10.1016/j.epsl.2016.10.058

Bibliography

– Hillman, J.I.T., Cook, A.E., Daigle, H., Nole, M., Malinverno, A., Meazell, K. and Flemings, P.B. (2017). Gas hydrate reservoirs and gas migration mechanisms in the Terrebonne Basin, Gulf of Mexico. Marine and Petroleum Geology, doi:10.1016/j.marpetgeo.2017.07.029

– Johnson, J. (2018). High Porosity and Permeability Gas Hydrate Reservoirs: A Sedimentary Perspective. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.

– Kinash, N. Cook, A., Sawyer, D. and Heber, R. (2017). Recovery and Lithologic Analysis of Sediment from Hole UT-GOM2-1-H002, Green Canyon 955, Northern Gulf of Mexico. Abstract OS53B-1207 presented at American Geophysical Union, Fall Meeting, New Orleans, LA.

– Küçük, H.M., Goldberg, D.S, Haines, S., Dondurur, D., Guerin, G., and Çifçi, G. (2016). Acoustic investigation of shallow gas and gas hydrates: comparison between the Black Sea and Gulf of Mexico. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.

– Majumdar, U., Cook, A. E., Shedd, W., and Frye, M. (2016). The connection between natural gas hydrate and bottom-simulating reflectors. Geophysical Research Letters, DOI: 10.1002/2016GL069443

– Malinverno, A. (2015). Monte Carlo inversion applied to reaction-transport modeling of methane hydrate in continental margin sediments. Abstract OS23B-2003 presented at American Geophysical Union, Fall Meeting, San Francisco, CA.

– Malinverno, A. (2016). Modeling gas hydrate formation from microbial methane in the Terrebonne basin, Walker Ridge, Gulf of Mexico. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.

Bibliography

- Malinverno, A., Cook, A. E., Daigle, H., Oryan, B. (2017). Methane Hydrate Formation from Enhanced Organic Carbon Burial During Glacial Lowstands: Examples from the Gulf of Mexico. EOS Trans. American Geophysical Union, Fall Meeting, New Orleans, LA.
- Meazell, K., Flemings, P. B., Santra, M., and the UT-GOM2-01 Scientists (2018). Sedimentology of the clastic hydrate reservoir at GC 955, Gulf of Mexico. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.
- Meazell, K., & Flemings, P.B. (2016). Heat Flux and Fluid Flow in the Terrebonne Basin, Northern Gulf of Mexico. Presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Meazell, K., & Flemings, P.B. (2016). New insights into hydrate-bearing clastic sediments in the Terrebonne basin, northern Gulf of Mexico. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.
- 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.
- Meazell, K. (2015), Methane hydrate-bearing sediments in the Terrebonne basin, northern Gulf of Mexico. Abstract OS23B-2012 presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Moore, M., Darrah, T., Cook, A., Sawyer, D., Phillips, S., Whyte, C., Lary, B., and UT-GOM2-01 Scientists (2017). The genetic source and timing of hydrocarbon formation in gas hydrate reservoirs in Green Canyon, Block GC955. Abstract OS44A-03 presented at American Geophysical Union, Fall Meeting, New Orleans, LA.

Bibliography

– Morrison, J., Flemings, P., and the UT-GOM2-1 Expedition Scientists (2018). Hydrate Coring in Deepwater Gulf of Mexico, USA. Poster presented at the 2018 Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.

– Oryan, B., Malinverno, A., Goldberg, D., Fortin, W. (2017). Do Pleistocene glacial-interglacial cycles control methane hydrate formation? An example from Green Canyon, Gulf of Mexico. EOS Trans. American Geophysical Union, Fall Meeting, New Orleans, LA.

– Oti, E., Cook, A. (2018). Non-Destructive X-ray Computed Tomography (XCT) of Previous Gas Hydrate Bearing Fractures in Marine Sediment. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.

– Oti, E., Cook, A., Buchwalter, E., and Crandall, D. (2017). Non-Destructive X-ray Computed Tomography (XCT) of Gas Hydrate Bearing Fractures in Marine Sediment. Abstract OS44A-05 presented at American Geophysical Union, Fall Meeting, New Orleans, LA.

– Phillips, S.C., Flemings, P.B., Holland, M.E., Schultheiss, P.J., Waite, W.F., Petrou, E.G., Jang, J., Polito, P.J., O'Connell, J., Dong, T., Meazell, K., and Expedition UT-GOM2-1 Scientists, (2017). Quantitative degassing of gas hydrate-bearing pressure cores from Green Canyon 955. Gulf of Mexico. Talk and poster presented at the 2018 Gordon Research Conference and Seminar on Natural Gas Hydrate Systems, Galveston, TX, February 24-March 2, 2018.

– Phillips, S.C., Borgfedlt, T., You, K., Meyer, D., and Flemings, P. (2016). Dissociation of laboratory-synthesized methane hydrate by depressurization. Poster presented at Gordon Research Conference and Gordon Research Seminar on Natural Gas Hydrates, Galveston, TX.

Bibliography

- Phillips, S.C., *You, K., Borgfeldt, T., *Meyer, D.W., *Dong, T., Flemings, P.B. (2016). Dissociation of Laboratory-Synthesized Methane Hydrate in Coarse-Grained Sediments by Slow Depressurization. Presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- Phillips, S.C., You, K., Flemings, P.B., Meyer, D.W., and Dong, T. (under review). Dissociation of Laboratory-Synthesized Methane Hydrate in Coarse-Grained Sediments By Slow Depressurization. Marine and Petroleum Geology.
- Portnov, A., Cook, A., Heidari, M., Sawyer, D., Santra, M., Nikolinakou, M. (2018). Salt-driven Evolution of Gas Hydrate Reservoirs in the Deep-sea Gulf of Mexico. Presented at Gordon Research Conference on Natural Gas Hydrate Systems, Galveston, TX.
- Santra, M., Flemings, P., Scott, E., Meazell, K. (2018). Evolution of Gas Hydrate Bearing Deepwater Channel-Levee System in Green Canyon Area in Northern Gulf of Mexico. Presented at Gordon Research Conference and Gordon Research Seminar on Natural Gas Hydrates, Galveston, TX.
- Sheik, C., Reese, B., Twing, K., Sylvan, J., Grim, S., Schrenk, M., Sogin, M., and Colwell, F. (2018). Identification and removal of contaminant sequences from ribosomal gene databases: lessons from the census of deep life. Frontiers in Microbiology. doi: 10.3389/fmicb.2018.00840
- Treiber, K, Sawyer, D., & Cook, A. (2016). Geophysical interpretation of gas hydrates in Green Canyon Block 955, northern Gulf of Mexico, USA. Poster presented at Gordon Research Conference, Galveston, TX.

Bibliography

- Worman, S. and, Flemings, P.B. (2016). Genesis of Methane Hydrate in Coarse-Grained Systems: Northern Gulf of Mexico Slope (GOM^2). Poster presented at The University of Texas at Austin, GeoFluids Consortia Meeting, Austin, TX.
- Yang, C., Cook, A., & Sawyer, D. (2016). Geophysical interpretation of the gas hydrate reservoir system at the Perdido Site, northern Gulf of Mexico. Presented at Gordon Research Conference, Galveston, TX, United States.
- You, K.Y., DiCarlo, D. & Flemings, P.B. (2015), Quantifying methane hydrate formation in gas-rich environments using the method of characteristics. Abstract OS23B-2005 presented at 2015, Fall Meeting, AGU, San Francisco, CA, 14-18 Dec.
- You, K., Flemings, P.B. (2016). Methane Hydrate Formation in Thick Sand Reservoirs: Long-range Gas Transport or Short-range Methane Diffusion?. Presented at American Geophysical Union, Fall Meeting, San Francisco, CA.
- You, K., and Flemings, P. B. (2017). Methane Hydrate Formation In Thick Sand Reservoirs: 1. Short-Range Methane Diffusion, Marine and Petroleum Geology.
- You, K.Y., Flemings, P.B., & DiCarlo, D. (2015). Quantifying methane hydrate formation in gas-rich environments using the method of characteristics. Poster presented at 2016 Gordon Research Conference and Gordon Research Seminar on Natural Gas Hydrates, Galveston, TX.
- You, K., and Flemings, P. B. (2018). Methane Hydrate Formation in Thick Marine Sands by Free Gas Flow. Presented at Gordon Research Conference on Gas Hydrate, Galveston, TX. Feb 24- Mar 02, 2018.

End of presentation