Behavior of Sediments Containing Methane Hydrate, Water, and Gas Subjected to Gradients and Changing Conditions

FP00008137

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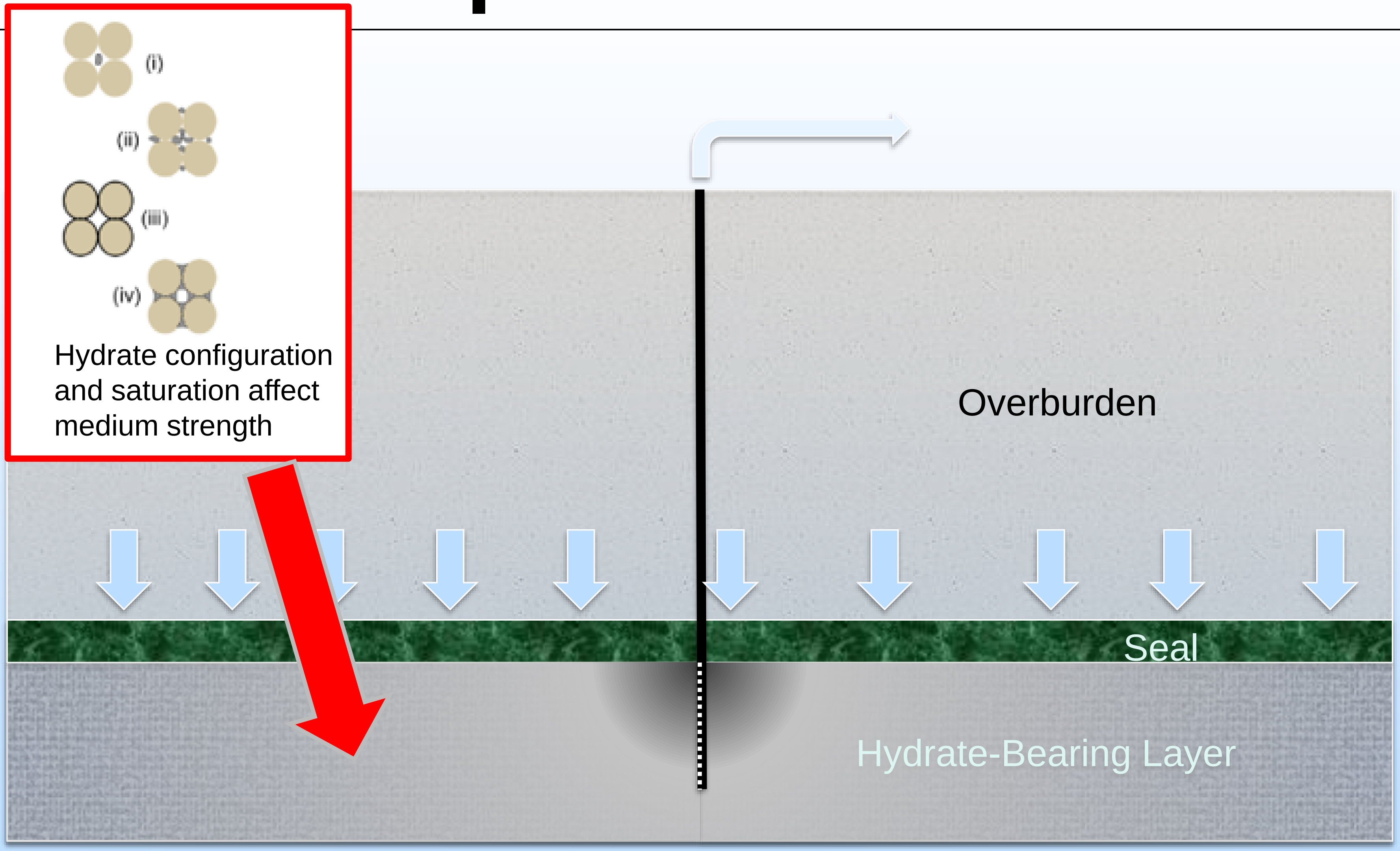
Presentation Outline

Alaska Field Test (AFT) Geomechanics

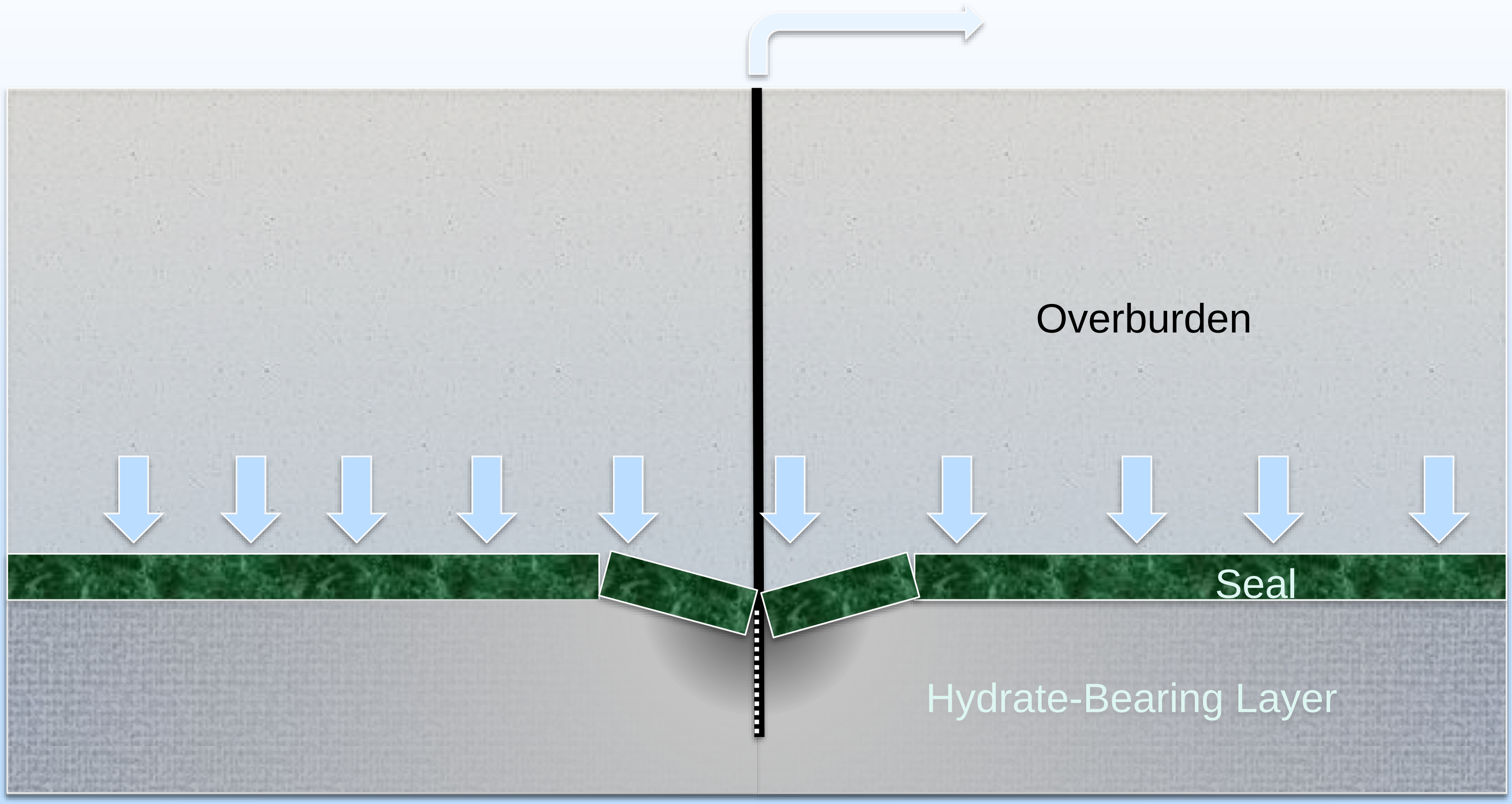
- Description of Problem
- Develop Analog Materials
- Develop Skeletal Hydrate Formation Method
- Develop Measurement Technique for Subvoxel Length Quantification
- Develop Data Analysis Tools
- Perform Tests and Analyze Measurements on Relevant Samples

Description of Problem

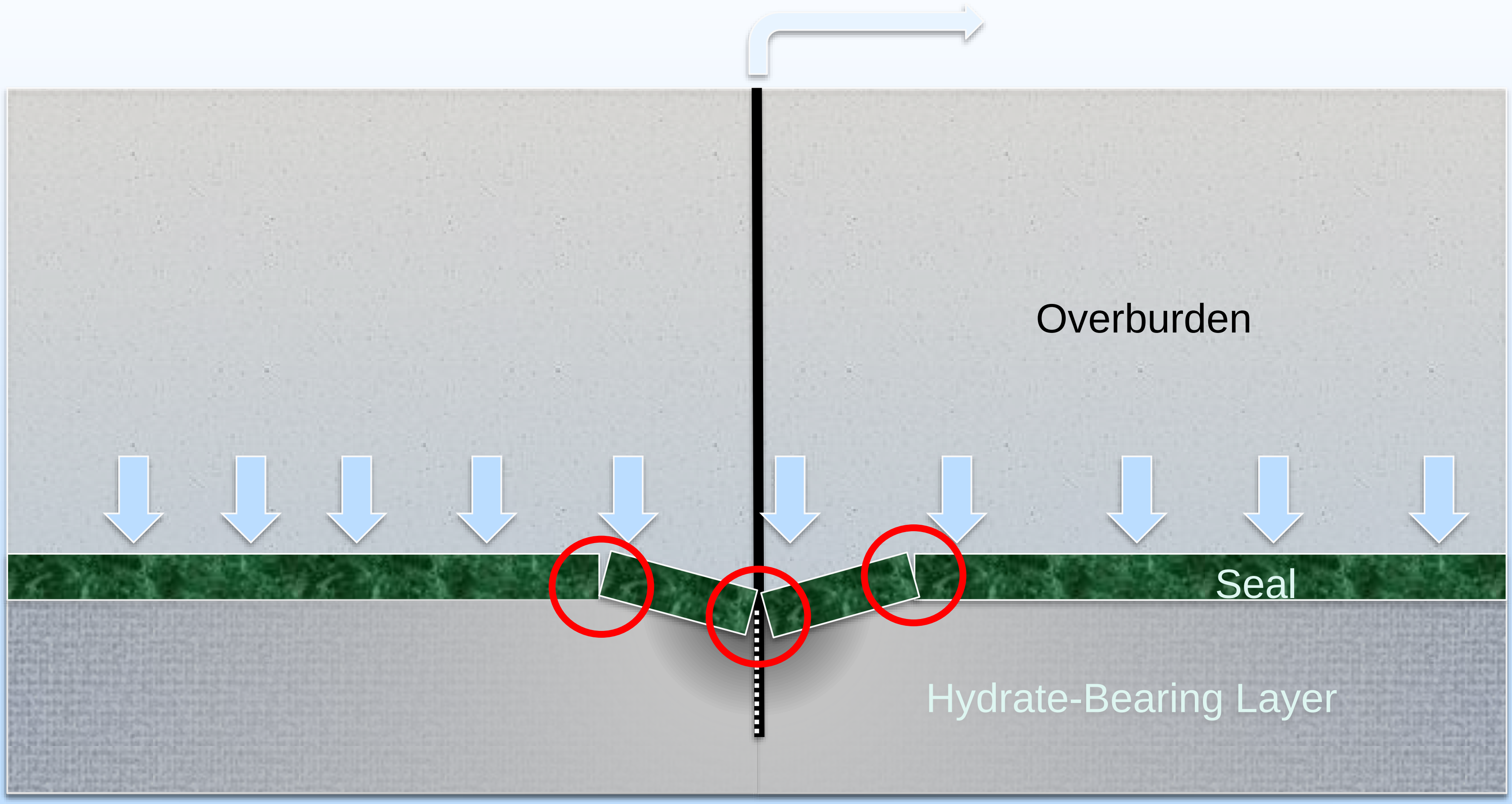


From Madhusudhan et al, 2018

Description of Problem

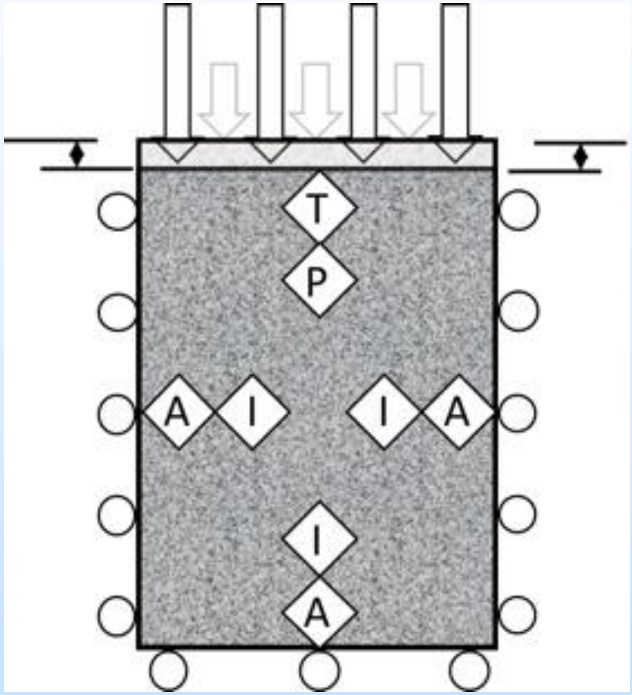


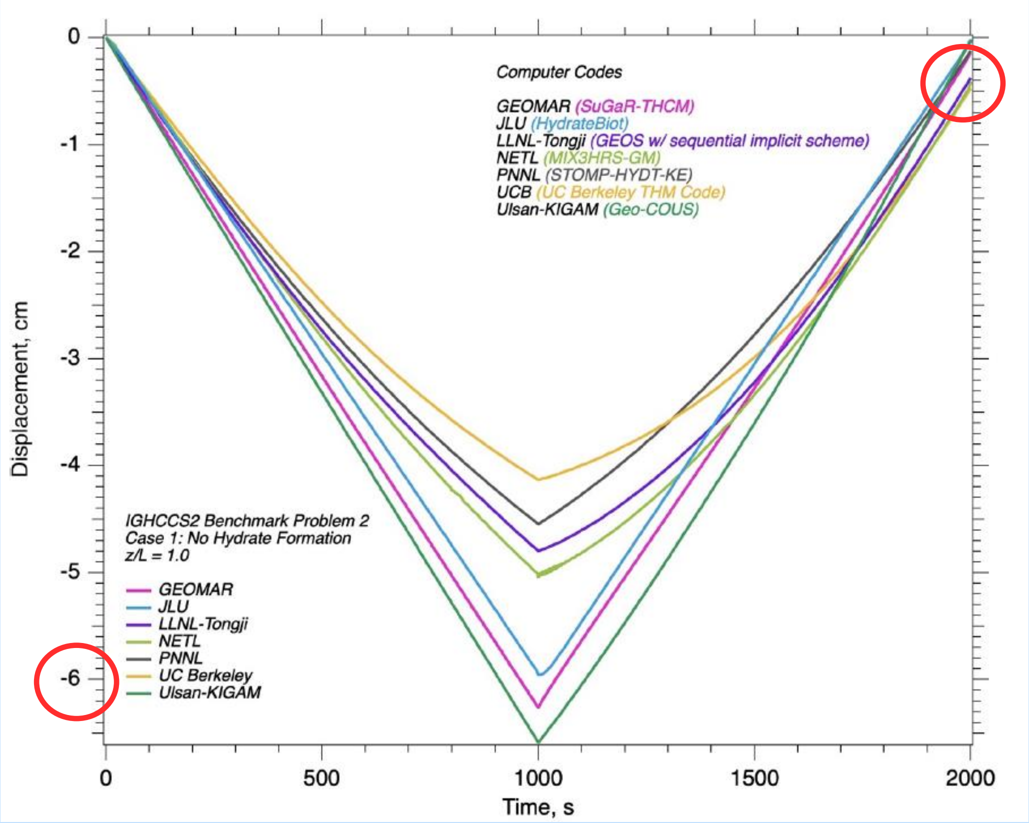
Description of Problem



Extended Terzaghi Problem (IGHCC2)

- How does the consolidation occur?
- Can we track it spatially?





White, M.D., T.J. Kneafsey, Y. Seol, W.F. Waite, S. Uchida, J.S. Lin, E.M. Myshakin, *et al.* "An International Code Comparison Study on Coupled Thermal, Hydrologic and Geomechanical Processes of Natural Gas Hydrate-Bearing Sediments." *Marine and Petroleum Geology* 120 (2020/10/01/ 2020): 104566.

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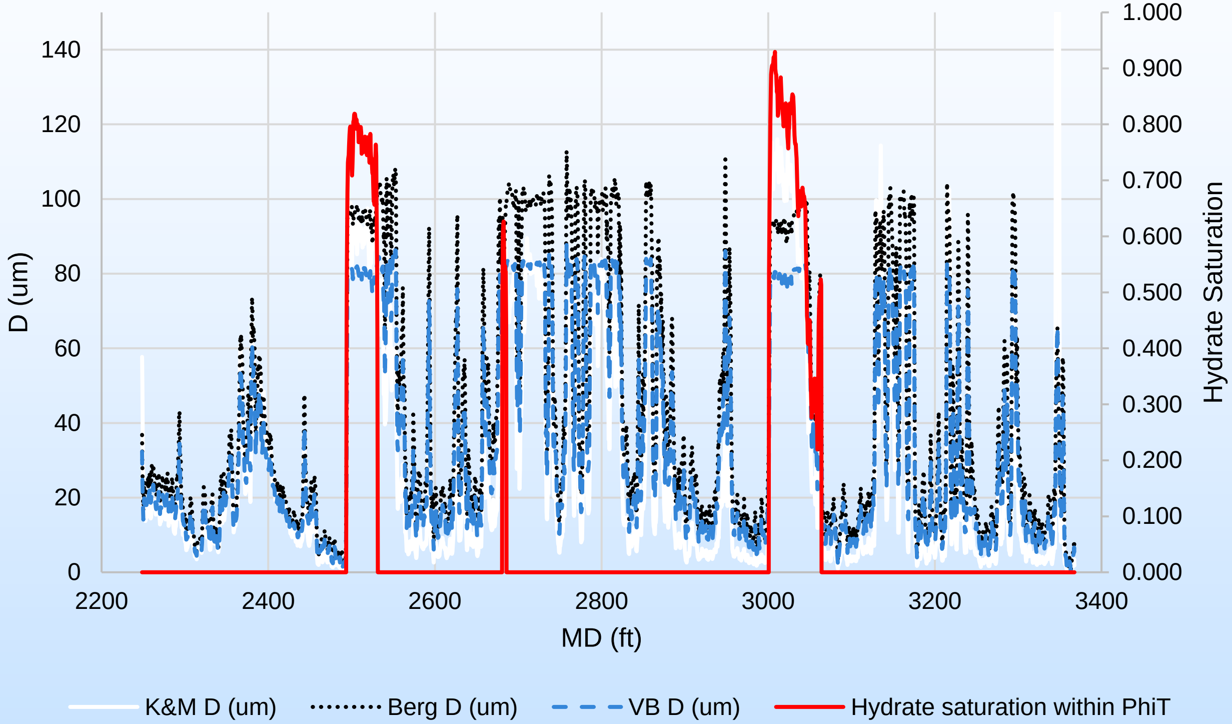
Analog Materials - AFT Media Summary



- Develop 2 analog materials representative of AFT
  - AFT1 - F110/5% kaolinite (D ~ 110 microns)
  - AFT2 - Sand mix (1:1) 125 um F110:76-101 um F110 sand
  - AFT3 - Layered sand (>125 um F110 sand;<125 um F110 sand)

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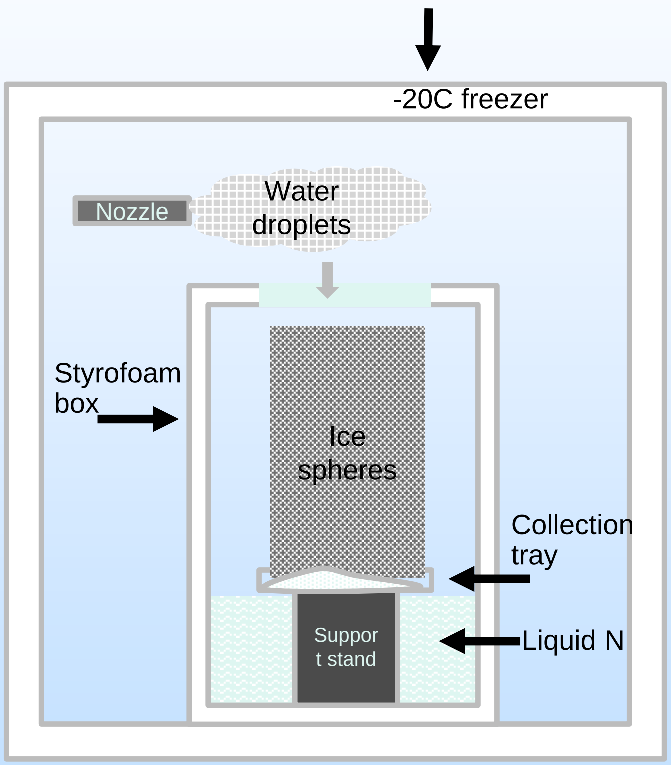
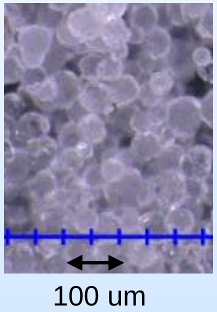
Skeletal Hydrate Formation Method

Ice making

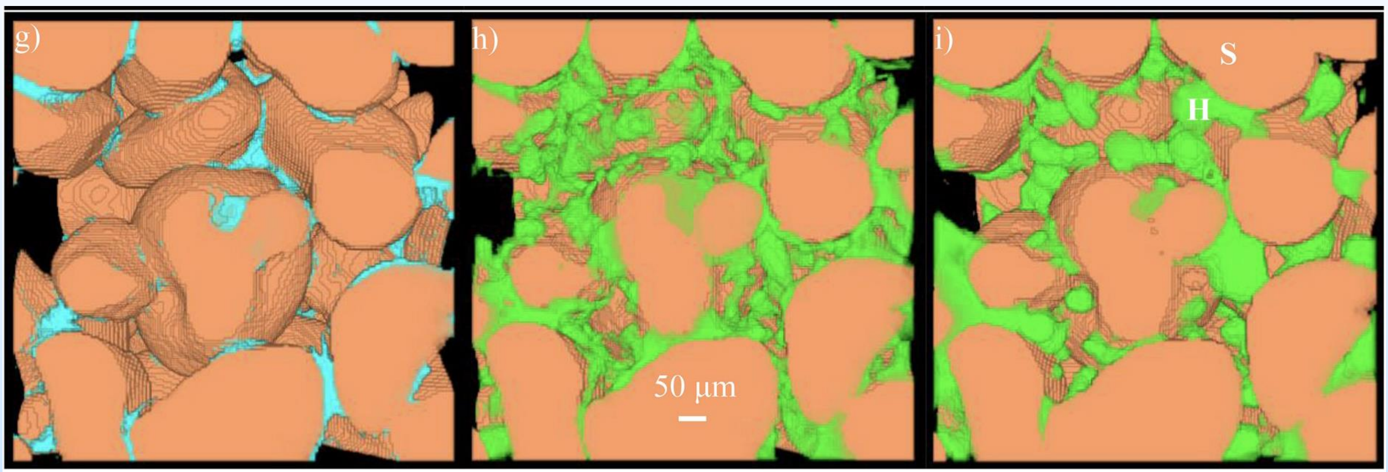


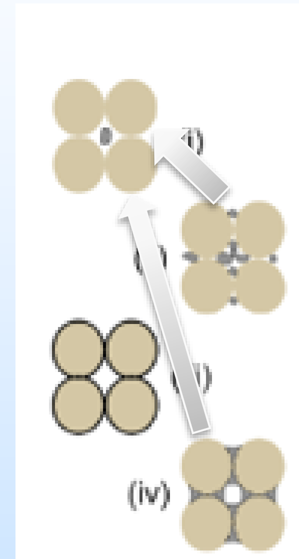


Mix ice with frozen sand and pack in sleeve

Learnings

- Powdered ice and sand do not pack well (yields unnatural initial porosity)
- Hydrate evolves from wall-attaching to pore-filling as an effect of Ostwald ripening





Lei, L., Y. Seol, J.-H. Choi, and T.J. Kneafsey. "Pore Habit of Methane Hydrate and Its Evolution in Sediment Matrix – Laboratory Visualization with Phase-Contrast Micro-Ct." *Marine and Petroleum Geology* 104 (2019/06/01/ 2019): 451-67.

Chen, X., and D.N. Espinoza. "Ostwald Ripening Changes the Pore Habit and Spatial Variability of Clathrate Hydrate." *Fuel* 214 (2018/02/15/ 2018): 614-22.

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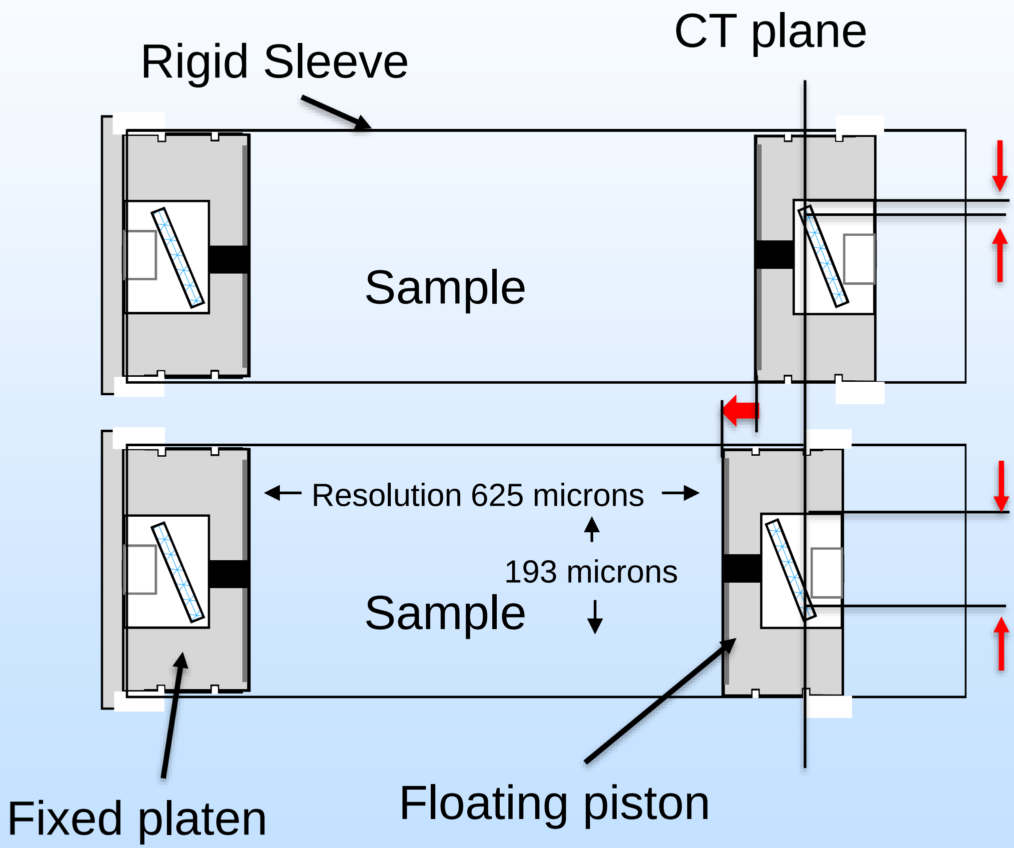
Total Sample Length Measurement



Slanted X-ray visible coupon in platen and piston shows axial displacement as lateral displacement and sensitivity is controlled by angle of coupon
Can achieve reasonable quantification down to ~ 5% of voxel length.

Small axial translation yields large signal on CT plane

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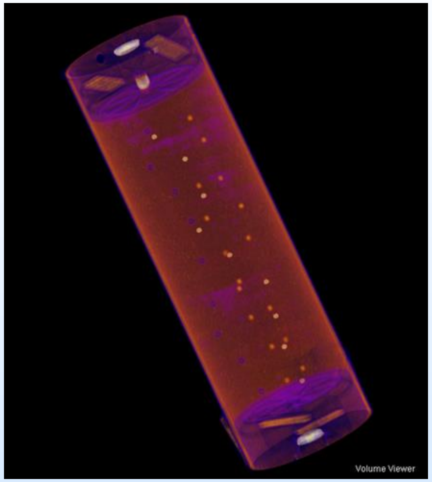
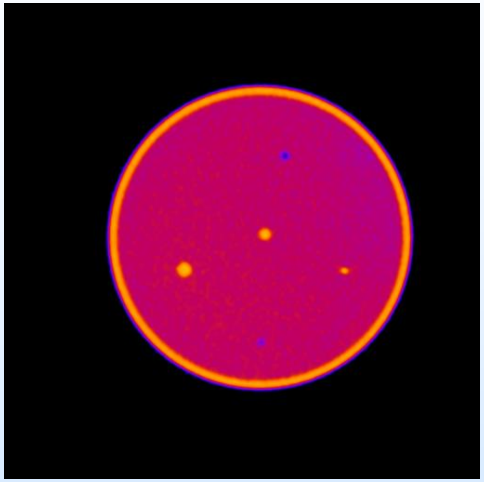
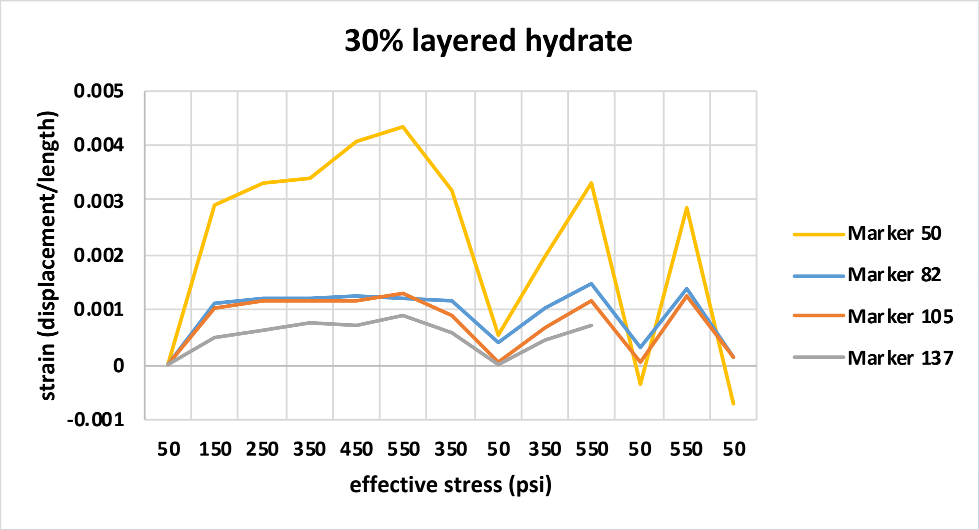
What About the Middle



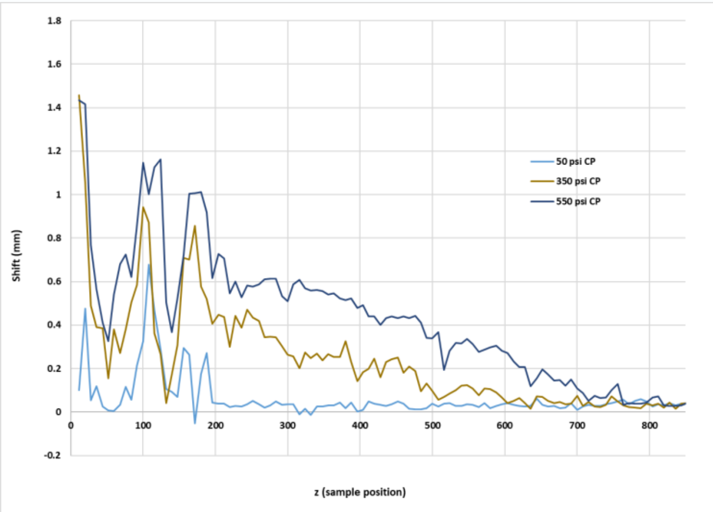




Embedded spheres to look at intermediate positions

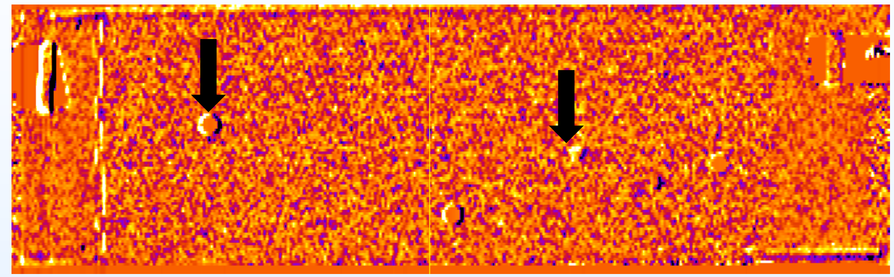
a) PIV (imageJ) – some reasonable results, but also some inconsistancies
b) DIC (imageJ) – results unclear, shows shifts but no quantification
c) Using similar method used for endcap shifts is too time intensive, each sphere would be done separately for each depth and every image
d) Pursuing PIV collaboration with Stuart Walsh (Monash U, Aus)
e) Particle Tracking – some success

Quantification

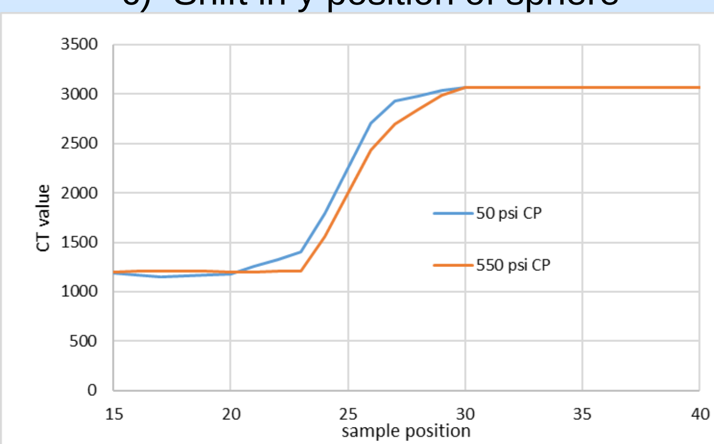


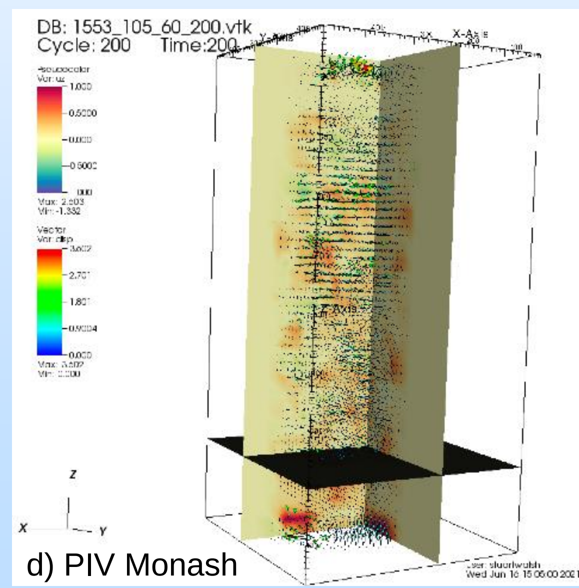
a) PIV showing decrease in compaction with length

b) Correlation array



c) Shift in y position of sphere





d) PIV Monash

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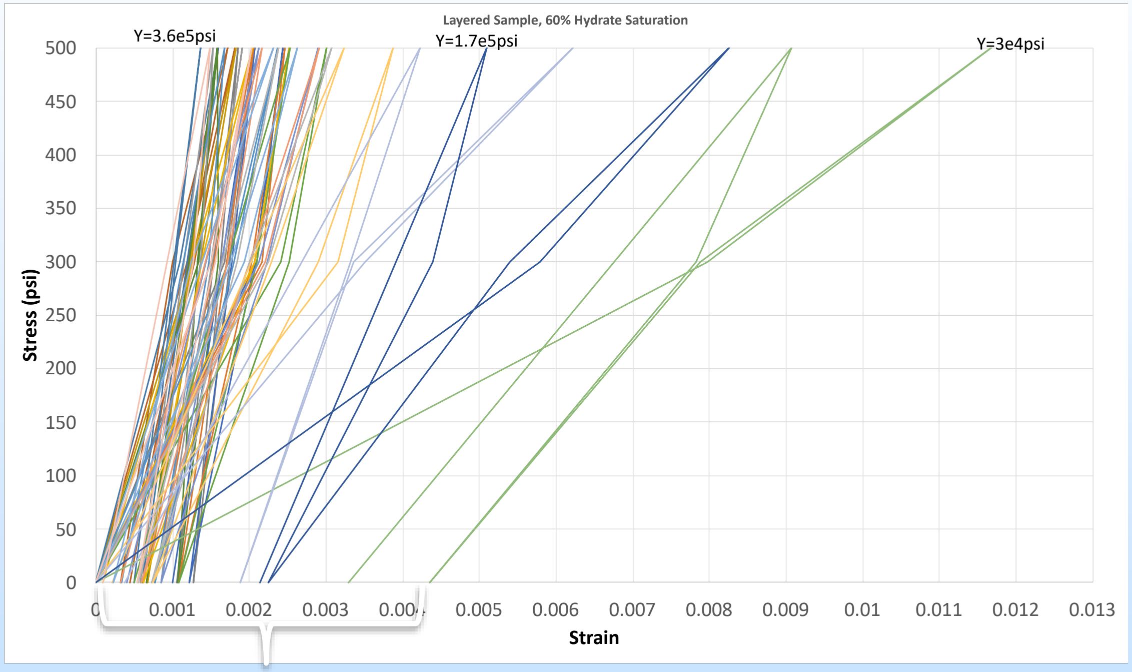
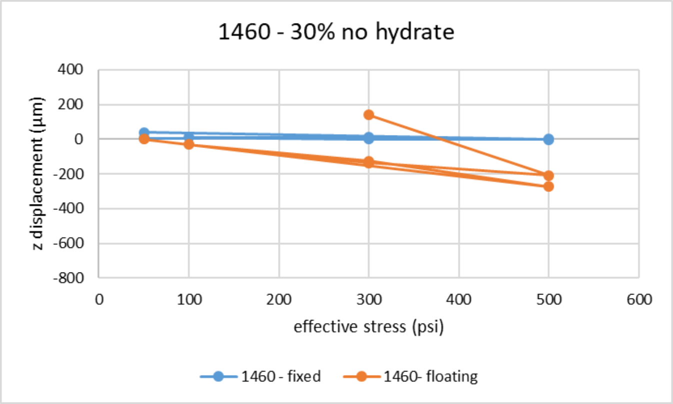
Layered 60% Hydrate, Intermediate Locations

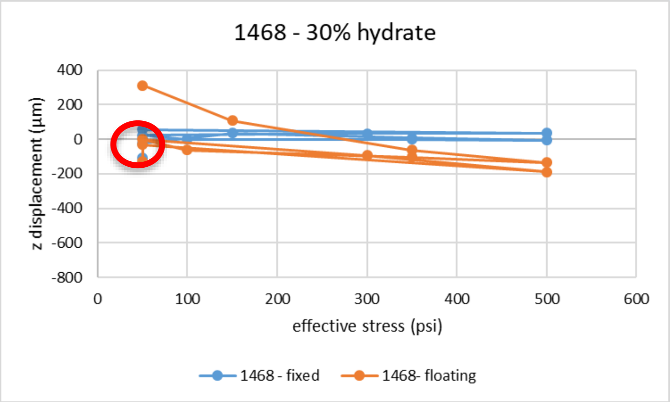
- Strains normalized to compute Young's Modulus
- Residual strain in every cycle at every location

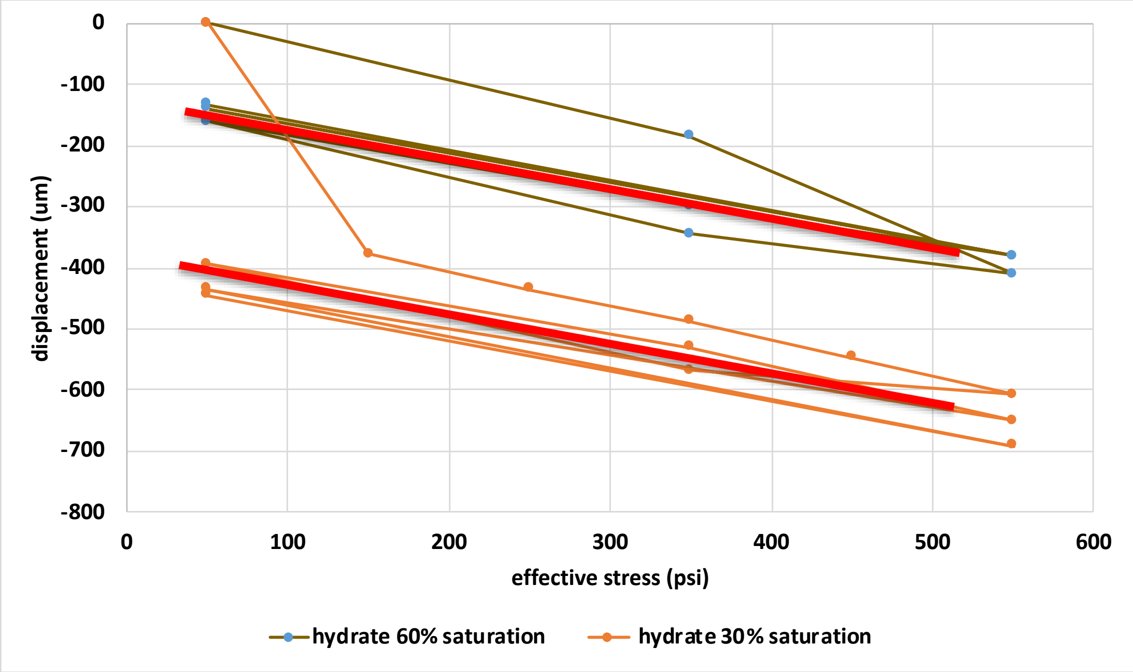


Residual Strain

Uniform/Layered







Slopes are very similar meaning Young's Moduli will be similar

Project Successes

- Continued Method Development and Evaluation
  - Layered Sample
  - Skeletal hydrate
- Successful Tests
  - 12 Experiments
  - Total Number of CT scans – 317
  - Total Number of Images Collected – 106,195 (~54Gb, $27x10^9$ data points)
- Data Analysis Methods
- Operating CT Scanner
- (Some COVID Limitations)

Synergy Opportunities

– Project results from synergy with IGHCC2 and ongoing collaboration with NETL

Project Summary

– Predicted displacements exceed measurements.
– Dissociation of hydrate causes significant strain.
– Excess-gas hydrate formation method allows for establishing initial conditions.
– Realistic timely formation of hydrate as part of medium skeleton still elusive.

Next Steps

– Evaluation/comparison of all data collected.
– Completion of experiment matrix.
– Publish results.

Appendix

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

Benefit to the Program

This work helps meet the program goals for hydrates by improving the understanding of the processes associated with:

1. Quantifying relevant processes and influences
2. Aiding in understanding gas production from sediments having a variety of properties (e.g. layers, varying materials),
3. Providing a better understanding of hydrate behavior in systems having a natural or imposed gradient,
4. Aiding in understanding mechanical property changes.

This project provides important information for interpreting other laboratory and field tests quantifying the importance of natural and imposed thermal, chemical, or capillary pressure gradients, and impacts on hydrological and mechanical behavior of hydrate-bearing sediments. Questions asked and answered on this project are from a reservoir perspective understanding that many nonideal conditions can exist.

Project Overview
Goals and Objectives

The objective of this work is to measure physical, chemical, mechanical, and hydrologic property changes in sediments containing methane hydrate, water, and gas subjected to varying stimuli and conditions such as injection of non-methane gases, effects of sediment layering, and the effects of relevant gradients (thermal, chemical (salinity or gas chemistry), and capillary pressure) on hydrate behavior. In this set of tests, we plan to evaluate the mechanical properties of hydrate-bearing sediments under controlled conditions to provide data sets for comparisons to numerical models. Measurements performed in this project are designed to supplement and support field and numerical simulation investigations to provide benchmark measurements and reality checks. We will share our results with those analyzing the test data, and the scientific community, and communicate with those analyzing the field test to ensure our tests are on target to answer their questions. The investigated hydrate-bearing sediments that are intended to model potential energy targets.

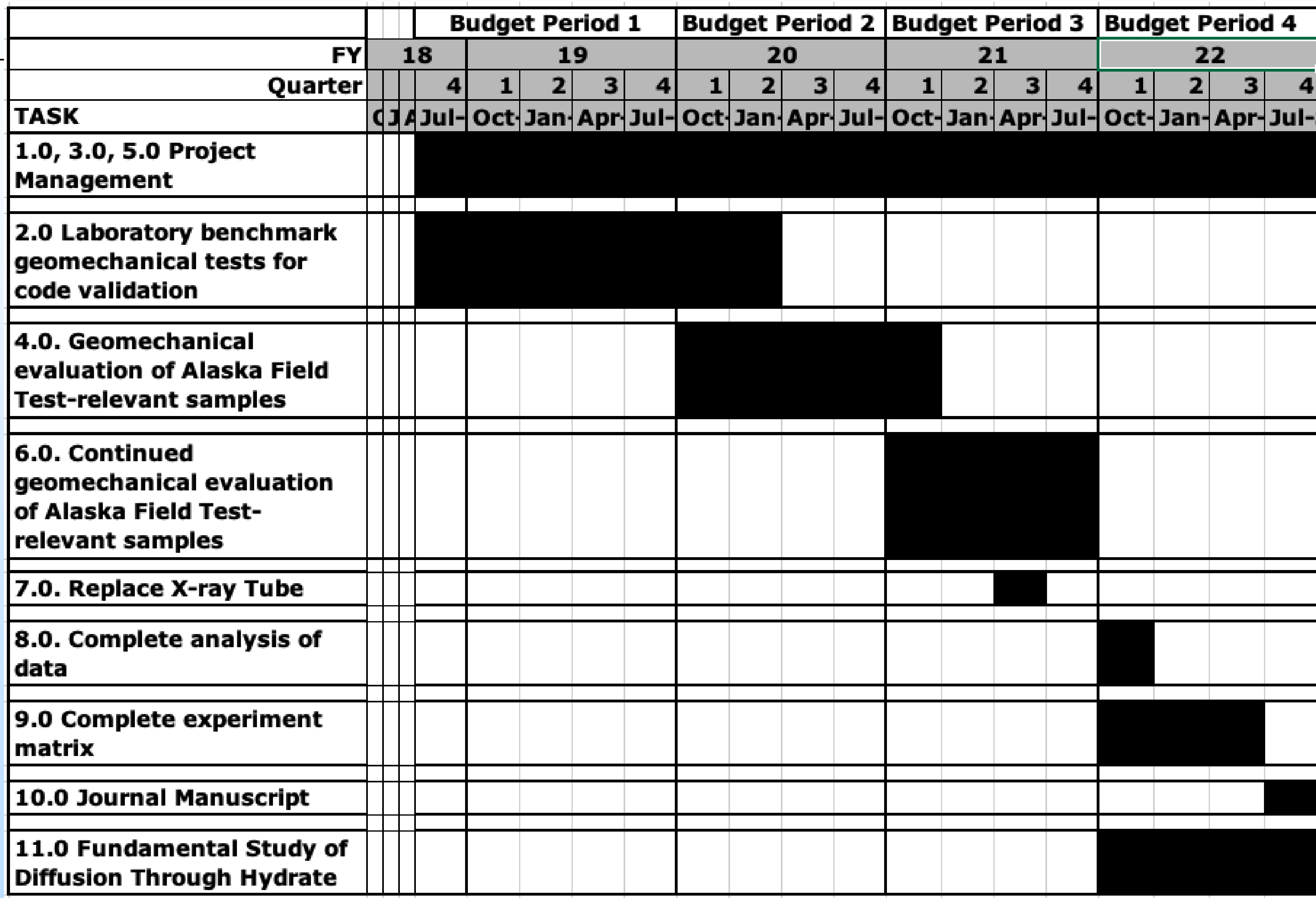
Tasks are intended to address unknowns in the behavior of hydrate-bearing sediments subjected to dissociation relevant to a planned DOE gas hydrate production test to be conducted on the Alaska North Slope. Geomechanical processes such as compaction are the primary subject of laboratory-based investigations.

Organization Chart

LBNL

- Tim Kneafsey – PI
- Sharon Borglin – Chief Experimentalist

Gantt Chart


Budget Period 1
Budget Period 2
Budget Period 3
Budget Period 4
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1.0, 3.0, 5.0 Project Management
2.0 Laboratory benchmark geomechanical tests for code validation
4.0. Geomechanical evaluation of Alaska Field Test-relevant samples
6.0. Continued geomechanical evaluation of Alaska Field Test-relevant samples
7.0. Replace X-ray Tube
8.0. Complete analysis of data
9.0 Complete experiment matrix
10.0 Journal Manuscript
11.0 Fundamental Study of Diffusion Through Hydrate

Bibliography

– List peer reviewed publications generated from the project per the format of the examples below.

- Journal, one author:
  – Gaus, I., 2010, Role and impact of CO_2-rock interactions during CO_2 storage in sedimentary rocks: International Journal of Greenhouse Gas Control, v. 4, p. 73-89
- Journal, multiple authors:
  – MacQuarrie, K., and Mayer, K.U., 2005, Reactive transport modeling in fractured rock: A state-of-the-science review. Earth Science Reviews, v. 72, p. 189-227.
- Publication:
  – Bethke, C.M., 1996, Geochemical reaction modeling, concepts and applications: New York, Oxford University Press, 397 p.