

DOE Award No.: FP00008138

Quarterly Research Performance Progress Report

(Period Ending 3/31/2020)

**NUMERICAL STUDIES FOR THE CHARACTERIZATION OF
RECOVERABLE RESOURCES FROM METHANE HYDRATE DEPOSITS**
Project Period (August 1, 2018 to Open)

Submitted by:
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Prepared for:
United States Department of Energy
National Energy Technology Laboratory

April 30, 2020



U.S. DEPARTMENT OF
ENERGY

**NATIONAL ENERGY
TECHNOLOGY LABORATORY**

Office of Fossil Energy

RESEARCH PERFORMANCE PROGRESS REPORT

DISCLAIMER

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ACCOMPLISHMENTS:

Budget Period 2:

Task 6. Project Management Plan

Status: Ongoing

A Draft PMP was submitted for Budget Period #2 in March 2020, with a revised FWP and SOPO.

In August, 2019, postdoc Zhi Li began working in our group at LBNL, with a focus on TOUGH+ simulations of unconventional reservoirs. At the end of Q1, Alejandro Queiruga left LBNL on short notice.

As of March 17, 2020, LBNL is closed under the county-wide shelter-in-place order in response to CoVID-19. Staff are working remotely on computational projects through the end of May.

Task 7. Code Maintenance, Updates, and Support

Status: Ongoing

Use of TOUGH+HYDRATE on other non-DOE projects revealed complications in the thermodynamic relationships used to manage hydrate formation in situations where the system is water-limited. While this situation is rare for the systems studied through this FWP, the HYDRATE EOS has been modified to fix issues with small timesteps during water-limited hydrate formation. These improvements will be included in the next release of the T+M simulator

Task 8. Study of the Baseline (Reference) Case in the Alaska Field Test
Task 9. Analysis of Sensitivity to Reservoir Flow and Thermal Properties
Task 10. Analysis of Sensitivity to Production Operational Parameters
Task 11. Analysis of Sensitivity to Reservoir Geomechanical Properties
Task 12. System Sensitivity to 3D Heterogeneity

Status: Ongoing

We began discussions about the upcoming field test in Q4, received data in August 2019, and received revised data in December 2019.

Preliminary results for the reference case and several sensitivity cases were presented to the DOE team in October, 2019. As a general conclusion: water production is a pervasive issue for this system, and production operation management or well construction can have only minor effects on H₂O production. The preliminary analysis, plus the results of simulations performed in January 2020, were presented at the 2020 Gordon Conference on Natural Gas Hydrate Systems in Galveston TX on February 23-28, 2020.

In Q3, simulations of the planned Alaska long term production test will continue, using updated data and parameters in collaboration with NETL and USGS. The focus will be on the determination of water production under different scenarios, parametric sensitivity analysis, and the effect of well configurations.

These results will be included in a paper being prepared for the 10th International Conference on Gas Hydrates in Singapore, currently postponed until December.

Task 13. Activities in Support of the DOE International Gas Hydrate Collaborations

Status: Ongoing

Our group finished in Q3 FY19 the paper for the JMPG Special Edition on the India Gas Hydrates program, and the special issue was released in Q1 FY20.

Task 14. Participation in the Code Comparison Study of Coupled Flow, Thermal and Geomechanical Processes

Status: Ongoing

LBNL contributed solutions to Problems #1, #2, and #4, and designed Problem #3. We participated in regular teleconferences with study leaders and other simulation teams.

In Q2, the LBNL team members contributed to the final draft, editing, and submission of the journal article describing the IGHCCS2 results and analysis:

White, M.D., Kneafsey, T.J., Seol, Y., Waite, W.F., Uchida, S., Lin, J.-S., Myshakin, E.M., Gai, X., Gupta, S., Reagan, M.T., Queiruga, A.F., Kimoto, S., IGHCCS2 Participants, "An International Code Comparison Study on Coupled Thermal, Hydrologic and Geomechanical Processes of Natural Gas Hydrate-Bearing Sediments," *Marine and Petroleum Geology*, in review.

The insights gained from the CCS have led to the development of a new code testing and validation system for TOUGH+HYDRATE, as well as motivating us to perform additional evaluations of the TOUGH+ code architecture, numerical methods, and other issues.

We have performed a formal simulation analysis of mesh convergence for hydrate dissociation simulations for 1D and 2D systems. Use of 2D cartesian and 1D axisymmetric representations of the same vertical well problem gives very similar results, with discrepancies attributable to different hydrate lensing behaviors seeded by the structure and discretization of the meshes. The investigation will next assess the effect of kinetics in hydrate formation (particularly hydrate lens formation) and the interaction between localized fine discretization and the importance of kinetic modeling. The initial results of this study were presented at the AGU Fall Meeting in Q1, and the analysis will continue in FY20 and the results will be presented at the 10th International Conference on Gas Hydrates in Singapore, in December 2020.

Task 15. Publications, Tech Transfer, and Travel

Status: Ongoing

One new submitted publication in this quarter:

White, M.D., Kneafsey, T.J., Seol, Y., Waite, W.F., Uchida, S., Lin, J.-S., Myshakin, E.M., Gai, X., Gupta, S., Reagan, M.T., Queiruga, A.F., Kimoto, S., IGHCCS2 Participants, "An International Code Comparison Study on Coupled Thermal, Hydrologic and Geomechanical Processes of Natural Gas Hydrate-Bearing Sediments," *Marine and Petroleum Geology*, in review.

One new presentation was given this quarter:

"Preliminary Analysis of System Behavior During a Planned Long-Term Production Test at a Permafrost-Associated Hydrate Deposit in Alaska," (poster) 2020 Gordon Research Conference on Natural Gas Hydrate System, Galveston, TX, 23-28 Feb 2020.

Conference travel to date:

1. Mastering the Subsurface, Carbon Storage and Oil and Natural Gas Conference, Pittsburgh, PA 13-16 August 2018.
2. Machine Learning in Solid Earth Geoscience, Santa Fe, Nevada, March 2019
3. SIAM Conference on Mathematical & Computational Issues in Geosciences, Houston, Texas, March 2019

4. Addressing the Nation’s Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting, Pittsburgh, PA, 26-30 August 2019.
5. AGU Fall Meeting 2019 (2 presentations)
6. 2020 Gordon Research Conference on Natural Gas Hydrate System, Galveston, TX, 23-28 Feb 2020.

Milestone Table

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
PMP	Maintenance and update of the Project Management Plan	August 30, 2019	Revised March, 2020	Submitted
Deliverable	Updated versions serial and parallel versions of the T+H/Milestone code	June 30, 2020		
Deliverable	A report/presentation describing in detail the evolution of the system behavior for the reference case.	April 30, 2020		
Deliverable	A report/presentation describing in detail the system sensitivity to the reservoir fluid properties.	May 31, 2020		
Deliverable	A report/presentation describing in detail the system sensitivity to production operational properties	May 31, 2020		
Deliverable	A report/presentation describing in detail the system sensitivity to the reservoir geomechanical properties.	July 31, 2020		
Deliverable	A report/presentation describing in detail the system sensitivity to three-dimensional heterogeneity.	August 31, 2020		
Deliverable	Updates to the confidential reports, as well as refereed publications	September 30, 2020		
Deliverable	Completion of analyses and participation in the code comparison study, as listed in the SOPO. Publication of results of current and additional studies.	September 30, 2020		Paper submitted March, 2020
Deliverable	Attendance at conferences, submission and revision of peer-reviewed publications, submission of quarterly reports.	September 30, 2020		

PRODUCTS:

Publications to date (this FWP):

1. Moridis, G.J., Reagan, M.T., Queiruga, A.F., (2019) “Simulation of Gas Production from Multilayered Hydrate-Bearing Media with Fully Coupled Flow, Thermal, Chemical and

- Geomechanical Processes Using TOUGH+Millstone, Part I: The Hydrate Simulator,” *Transport in Porous Media*, **128**, 405-430, doi: 10.1007/s11242-019-01254-6.
2. Queiruga, A.F., Moridis, G.J., Reagan, M.T., (2019) “Simulation of Gas Production from Multilayered Hydrate-Bearing Media with Fully Coupled Flow, Thermal, Chemical and Geomechanical Processes Using TOUGH+Millstone, Part II: Geomechanical Formulation and Numerical Coupling” *Transport in Porous Media*, **128**, 221-241, doi: 10.1007/s11242-019-01242-w.
 3. Reagan, M.T., Queiruga, A.F., Moridis, G.J., (2019) “Simulation of Gas Production from Multilayered Hydrate-Bearing Media with Fully Coupled Flow, Thermal, Chemical and Geomechanical Processes Using TOUGH+Millstone, Part III: Application to Production Simulation,” *Transport in Porous Media*, **129**, 179-202, doi: 10.1007/s11242-019-01283-1.
 4. Moridis, G.J., Reagan, M.T., Queiruga, A.F., Collett, T.S., Boswell, R., (2019) Evaluation of the Performance of the Oceanic Hydrate Accumulation at the NGHP-02-9 Site of the Krishna-Godavari Basin During a Production Test and Under Full Production, *J. Marine and Petroleum Geology*, in press, doi: 10.1016/j.marpetgeo.2018.12.001.
 5. Moridis, G.J., Reagan, M.T., Queiruga, A.F., Kim, S.J., (2019) System response to gas production from a heterogeneous hydrate accumulation at the UBGH2-6 site of the Ulleung basin in the Korean East Sea, *J. Pet. Sci. Eng.*, **178**, 655-665. doi: 10.1016/j.petrol.2019.03.058.
 6. White, M.D., Kneafsey, T.J., Seol, Y., Waite, W.F., Uchida, S., Lin, J.-S., Myshakin, E.M., Gai, X., Gupta, S., Reagan, M.T., Queiruga, A.F., Kimoto, S., IGHCCS2 Participants, (2020). “An International Code Comparison Study on Coupled Thermal, Hydrologic and Geomechanical Processes of Natural Gas Hydrate-Bearing Sediments,” *Marine and Petroleum Geology*, in review.

Presentations to date (this FWP):

1. “Numerical Studies for the Characterization of Recoverable Resources from Methane Hydrate Deposits,” Mastering the Subsurface, Carbon Storage and Oil and Natural Gas Conference, Pittsburgh, PA 13-16 August 2018.
2. “Numerical Studies for the Characterization of Recoverable Resources from Methane Hydrate Deposits,” project wrapup meeting. 28 September 2018.
3. "Machine Determination of Better Representations of Multiphase Equation of States for Subsurface Flow Simulation" at Machine Learning in Solid Earth Geosciences, 18-22 March 2019 in Santa Fe, NM.
4. “Fully Coupled Multimesh Algorithms for Nonisothermal Multiphase Flow and Mechanics in Geological Formations,” **(invited)** SIAM Conference on Mathematical & Computational Issues in Geosciences, Houston, Texas, March 2019.
5. “Numerical Studies for the Characterization of Recoverable Resources from Methane Hydrate Deposits,” Addressing the Nation’s Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting, Pittsburgh, PA, 26-30 August 2019.

6. "A Trainable Simulator: using unsupervised learning in conjunction with computational methods to rewrite our equations, applied to multiphase flow." IN44A, AGU Fall Meeting, San Francisco, CA, 9-13 December 2019.
7. "Validation And Testing Of Coupled Flow-Thermal-Mechanical Hydrate Reservoir Models," OS34A, AGU Fall Meeting, San Francisco, CA, 9-13 December 2019.
8. "Preliminary Analysis of System Behavior During a Planned Long-Term Production Test at a Permafrost-Associated Hydrate Deposit in Alaska," (poster) 2020 Gordon Research Conference on Natural Gas Hydrate System, Galveston, TX, 23-28 Feb 2020.

SPECIAL REPORTING REQUIREMENTS:

N/A

BUDGETARY INFORMATION:

Actual Cost (this quarter)	Actual Cost (cumulative for BP)	Funds available (for the BP)	Balance of unspent funds (for the BP)	Actual Cost (cumulative for the full FWP)	Funds available (for the full FWP)	Balance of unspent funds (for the full FWP)
\$115,565	\$660,020	\$900,000	\$239,980	\$660,020	\$900,000	\$239,980

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