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Quarterly Research Performance Progress Report

(Period Ending 12/31/2018)

Coupled Hydrologic, Thermodynamic, and Geomechanical Processes of Natural Gas Hydrate Production

Project Period (10/01/2018 to open)

Submitted by:

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RESEARCH PERFORMANCE PROGRESS REPORT

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ACCOMPLISHMENTS:

BP1-Task 1.0 Project Management

This project is a companion project to one funded by the Korea Institute for Geoscience and Mineral Resources (KIGAM) under the Joint Korea and U.S. Gas Hydrate Research Program. The KIGAM project is currently investigating nitrogen and air injection as a production technology for suboceanic deposits of gas hydrates, such as those found in the Ulleung Basin of the Korean East Sea. During this quarter an annual technical report was submitted to KIGAM, entitled “Numerical Assessment of Natural Gas Hydrate Production via Nitrogen Injection.” This report documented numerical simulation work completed by PNNL, using the STOMP-HYDT-KE simulator, under two objectives: 1) Verification of the GEOMech Module with Hydrate Dissociation and Formation, and 2) Scoping Simulations of Nitrogen Injection for Natural Gas Hydrate Production at the UBGH2-6 Site. The results from the second series of simulations demonstrated the potential for using N₂ injection as a production technology, in particular for scenarios involving initial depressurization, followed with low-pressure N₂ injection, with a potential sequential water flood. Additional simulations will be conducted to understand the merits of this approach.

BP1-Task 2.0 IGHCCS

During this quarter the fifth benchmark problem was finalized, and problem descriptions have been developed and posted on the NETL EDX system. The first benchmark problem is championed by Mark White at PNNL, USA and involves straight hydrate dissociation via either thermal stimulation or depressurization. This problem was part of the 1st International Gas Hydrate Code Comparison Study, and does not include a geomechanical component. Eight teams submitted solutions to Benchmark Problem 1; University of Texas, Austin (UTA), Lawrence Berkeley National Laboratory (LBNL), University of California Berkeley (UCB), Pacific Northwest National Laboratory (PNNL), Jilin University (JLU), National Energy Technology Laboratory (NETL), Lawrence Livermore National Laboratory (LLNL), and GEOMAR Kiel (GEOMAR). Those solutions were compared during the IGHCCS2 teleconference series. The second problem is championed by Shubhangi Gupta, GEOMAR Kiel, Germany and is an extension of the classical Terzaghi Problem with four cases. The first case maintains the temperature outside of the hydrate stability zone; the second case yields hydrate formation and dissociation, the third case alters composite mechanical strength of the hydrate bearing layer, and the fourth case considers rapid hydrate formation and dissociation

kinetics. Five teams submitted solutions to Benchmark Problem 2: GEOMAR Kiel (GEOMAR), University of California Berkeley (UCB), Pacific Northwest National Laboratory (PNNL), Lawrence Livermore National Laboratory (LLNL), and GEOMAR Kiel (GEOMAR). Submitted solutions were compared during the IGHCCS2 teleconference series. The third benchmark problem is championed by Matt Reagan, Alejandro Queiruga, and George Moridis, at LBNL, USA and considers coupled flow, transport and geomechanics in a radial domain. Eight teams submitted solutions to Benchmark Problem 3; Lawrence Berkeley National Laboratory (LBNL), University of California Berkeley (UCB), Jilin University (JLU), National Energy Technology Laboratory (NETL), and Lawrence Livermore National Laboratory (LLNL). The fourth benchmark problem is championed by Sayuri Kimoto at Kyoto University, Japan and is modeled after the Nankai Trough field experiment. The fifth benchmark problem is championed by Shun Uchida at Rensselaer Polytechnic Institute, and considers isotropic consolidation with hydrate dissociation. This problem is particularly interesting as a code comparison study problem, as it requires solution on a single grid cell. To date, no solutions have been submitted against this problem. The study currently comprises 55 participants, representing 25 teams, from 5 countries (i.e., United States, United Kingdom, Germany, Korea, Japan, and China). A recent addition to the study is Maria de la Fuente Ruiz, from the National Oceanography Centre, UK. A workspace within the NETL EDX system has been created for the study, and accounts have been granted for requesting participants. Four study teleconferences were held during the quarter:

- Teleconference #22: October 18, 2018
 - Benchmark Problem 5
 - Isotropic consolidation test with hydrate dissociation
 - Problem Champion: Shun Uchida (RPI)
 - IGHCCS2 Benchmark Problem 3
 - Review of submitted solutions
 - Lawrence Berkeley National Laboratory (LBNL)
 - Lawrence Livermore National Laboratory (LLNL)
 - Jilin University (JLU)
 - National Energy Technology Laboratory (NETL)
 - University of California, Berkeley (UCB)
 - Open Discussions
- Teleconference #23: November 8, 2018
 - Benchmark Problem 4
 - Geomechanical parameter resolution
 - Xiang Sun (U.C. Berkeley)
 - Eugene Myshakin (NETL)
- Teleconference #24: December 6, 2018
 - New Look for the EDX System
 - Revisions and Clarifications on Benchmark Problem 4
 - Problem Description for Benchmark Problem 5
 - AGU Presentation
 - Problem Solution Submissions
 - Benchmark Problem 1
 - University of Ulsan (Ulsan)
 - Benchmark Problem 2
 - University of Ulsan (Ulsan)
 - Jilin University (JLU)

- Benchmark Problem 4
 - University of Kyoto (Kyoto)
 - University of Ulsan (Ulsan)
- Teleconference #25: December 20, 2018
 - Overview of the Code-Bright-Hyd Simulator
 - Maria de la Fuente Ruiz, National Oceanography Centre, UK
 - Problem Description for Benchmark Problem 5
 - Shun Uchida, Rensselaer Polytechnic Institute, USA
 - Problem Solution Submissions
 - Benchmark Problem 4
 - University of Kyoto (Kyoto)
 - Lawrence Livermore National Laboratory (LLNL)
 - University of California (UCB)

The study teleconferences were principally focused on code descriptions and establishing initial benchmark problems. All teleconferences were recorded, and those recordings were posted on the NETL EDX system, along with the slide decks from the presentations. A logo for the study was created based on the infamous burning gas hydrate photo taken by Bill Lawson.

BP1-Task 3.0 STOMP-HYDT-KE Parallelization

No accomplishments to report for this task during the first quarter of FY19.

MILESTONES:

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
Nitrogen Injection (KIGAM-funded, Separate, Coordinated PNNL Project #68908)	Conduct a series of numerical simulations using its STOMP-HYDT-KE simulator to assess the feasibility of the nitrogen injection technology for production natural gas.	6/30/2018	Partially completed	Simulations with STOMP-HYDT-KE against a series of nitrogen injection experiments. Dr. Won Suk Lee visiting PNNL during April to discuss next steps. Progress report submitted on 11/30/2018.
IGHCCS2: Benchmark Problems	Complete the submission and reviews of the five benchmark problems.	12/31/2018	Partially completed	Solution submissions continued to arrive from participants, and reviews are being conducted during the teleconferences. New close date anticipated for end of April 2019.
IGHCCS2: Challenge Problems	Develop and issue two challenge problems.	6/30/2019	Not started	Discussions have occurred about what a challenge problem involves.
IGHCCS2: Journal Paper	Draft a journal paper on the four	6/30/2019	Not started	Paper will be started with the completion of the benchmark

	benchmark problems.			problem submissions and reviews.
Parallelization: OpenMP	Demonstrate the execution of STOMP-HYDT-KE on eight cores with an OpenMP linear system solver.	12/31/2018	Not started	Not started.
Parallelization: GA	Develop a set of Global Array equivalent subroutines in MPI.	06/31/2019	Not started	Not started.

PRODUCTS:

A presentation entitled "Modeling of Coupled Thermal, Hydrologic, and Geomechanical Processes in Gas Hydrate Bearing Porous Media: The 2nd International Gas Hydrate Code Comparison Study," was made at the 2018 AGU Fall Meeting, as an invited talk in the session OS23C: Modeling of Gas Hydrate-Related Systems 1.

IMPACT:

No significant impacts occurred this quarter.

CHANGES/PROBLEMS:

The IGHCCS2 is progressing with benchmark problems being developed and submissions being review. Participants are joining the regularly scheduled teleconferences, but discussions are minimal.

SPECIAL REPORTING REQUIREMENTS:

No special reporting requirements occurred during this quarter.

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)
\$22,084	\$22,084	\$151,151	\$129,067	\$22,084	\$151,151	\$129,067

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