DOE Award No.: FWP 72688

Quarterly Research Performance Progress Report

(Period Ending 12/31/2019)

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

Project Period (10/01/2018 to open)

Submitted by:
Mark White

Signature

Pacific Northwest National Laboratory
DUNS #: 32987476
P.O. Box 999
Richland, WA 99352
Email: mark.white@pnnl.gov
Phone number: (509) 372-6070

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RESEARCH PERFORMANCE PROGRESS REPORT

DISCLAIMER

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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 the work on the KIGAM project has been focused on developing a mathematical model to compute the equilibria of compositional hydrates, in particular CO2-N2-CH4 and O2-N2-CH4 mixtures. This work supports the numerical investigations of using gas injections to produce natural gas from the UBGH2-6 Site. A year-end project report, entitled “Numerical Assessment of Natural Gas Hydrate Production via Nitrogen Injection,” and draft paper, entitled “Modeling Methane Hydrate Reservoir Production using Air and Flue Gas with Self-consistent Kihara Parameters,” was submitted to Dr. Won Suk Lee at KIGAM on December 31, 2019. A poster was presented at the AGU Fall Meeting, entitled “Kinetic Parameter Determination for Natural Gas Hydrate Production via Gas Injection,” which documents collaborative work conducted by KIGAM and PNNL over the last three years.

BP1-Task 2.0 IGHCCS
A draft copy of the manuscript, entitled “An International Code Comparison Study on Coupled Thermal, Hydrologic and Geomechanical Processes of Natural Gas Hydrates,” which documents the IGHCCS2 study and outcomes was completed and circulated to Bill Waite (USGS), Tim Kneafsey (LBNL) and Yongkoo Seol (NETL) for review. This copy of the manuscript is missing final submissions from three benchmark champions, but a final submission version was received earlier this month from Shubhangi Gupta, the problem champion for BP2. For the publication the benchmark problems were renumbered from their original chronological order to an order of problem dimensionality and complexity. I anticipate releasing a draft copy of the full manuscript with the final submissions from all problem champions this quarter. An article was written for the Fire in the Ice publication entitled, “Modeling on the International Scale,” which describes the IGHCCS2 study and participants. An informal IGHCCS2 dinner was held at John’s Grill in San Francisco during the AGU Fall Meeting with the following attendees: Matt Reagan (LBNL), Alejandro Queiruga (LBNL), Jun Yoneda (AIST), Shun Uchida (Pitt), Sayuri Kimoto (University of Kyoto), Masaki
Yoshimoto (University of Kyoto), Michael Nole (SNL), Isaac Ju (LLNL), Signe White (PNNL), and
Mark White (PNNL). Two IGHCCS2 teleconferences were held this quarter:

Teleconference #34: October 3, 2019
• Manuscript Review

Teleconference #35: November 17, 2019
• Manuscript Review

BP1-Task 3.0 STOMP-HYDT-KE Parallelization
No accomplishments to report for this task during this quarter.

MILESTONES:

<table>
<thead>
<tr>
<th>Milestone Title</th>
<th>Milestone Description</th>
<th>Planned Completion Date</th>
<th>Actual Completion Date</th>
<th>Status / Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Injection (KIGAM-funded, Separate, Coordinated PNNL Project #68908)</td>
<td>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.</td>
<td>6/30/2018</td>
<td>Partially completed</td>
<td>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.</td>
</tr>
<tr>
<td>IGHCCS2: Benchmark Problems</td>
<td>Complete the submission and reviews of the five benchmark problems.</td>
<td>12/31/2018</td>
<td>Partially completed</td>
<td>Solution submissions continued to arrive from participants, and reviews are being conducted during the teleconferences. New close date anticipated for end of April 2019.</td>
</tr>
<tr>
<td>IGHCCS2: Challenge Problems</td>
<td>Develop and issue two challenge problems.</td>
<td>6/30/2019</td>
<td>Not started</td>
<td>Discussions have occurred about what a challenge problem involves.</td>
</tr>
<tr>
<td>IGHCCS2: Journal Paper</td>
<td>Draft a journal paper on the four benchmark problems.</td>
<td>6/30/2019</td>
<td>Not started</td>
<td>Paper will be started with the completion of the benchmark problem submissions and reviews.</td>
</tr>
<tr>
<td>Parallelization: OpenMP</td>
<td>Demonstrate the execution of STOMP-HYDT-KE on eight cores with an OpenMP linear system solver.</td>
<td>12/31/2018</td>
<td>Not started</td>
<td>Not started.</td>
</tr>
<tr>
<td>Parallelization: GA</td>
<td>Develop a set of Global Array equivalent subroutines in MPI.</td>
<td>06/31/2019</td>
<td>Not started</td>
<td>Not started.</td>
</tr>
</tbody>
</table>
PRODUCTS:

No products to report this quarter.

IMPACT:

No significant impacts occurred this quarter.

CHANGES/PROBLEMS:

No significant changes or problems, other than the pace of the code comparison study is slower than anticipated. The slower pace is principally due to competing project work for the study participants.

SPECIAL REPORTING REQUIREMENTS:

No special reporting requirements occurred during this quarter.

BUDGETARY INFORMATION:

<table>
<thead>
<tr>
<th>Actual Cost (this quarter)</th>
<th>Actual Cost (cumulative for BP)</th>
<th>Funds available (for the BP)</th>
<th>Balance of unspent funds (for the BP)</th>
<th>Actual Cost (cumulative for the full FWP)</th>
<th>Funds available (for the full FWP)</th>
<th>Balance of unspent funds (for the full FWP)</th>
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<td>$16,449</td>
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