U.S. DEPARTMENT OF ENERGY

Fiscal Year 2018 Methane Hydrate Program

Report to Congress
September 2019

United States Department of Energy
Washington, DC 20585

Message from the Secretary

The U.S. Department of Energy (DOE) is required to submit to Congress an annual report on the actions taken to carry out gas hydrate research and development.[1]

I am pleased to submit the enclosed Report to Congress, *Fiscal Year 2018 Methane Hydrate Program*. DOE's Office of Fossil Energy (FE) prepared this report summarizing the progress made in this area of research.

FE is providing this report to the following Members of Congress:

- **The Honorable Michael R. Pence**
  President of the Senate

- **The Honorable Nancy Pelosi**
  Speaker of the House of Representatives

- **The Honorable Lisa Murkowski**
  Chairwoman, Senate Committee on Energy and Natural Resources

- **The Honorable Joe Manchin**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Eddie Bernice Johnson**
  Chairwoman, House Committee on Science, Space and Technology

- **The Honorable Frank Lucas**
  Ranking Member, House Committee on Science, Space and Technology

- **The Honorable Frank Pallone**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Greg Walden**
  Ranking Member, House Committee on Energy and Commerce

- **The Honorable Richard Shelby**
  Chairman, Senate Committee on Appropriations

- **The Honorable Patrick Leahy**
  Vice Chairman, Senate Committee on Appropriations

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[1] 30 U.S.C. § 2003(e)(5).

- **The Honorable Nita Lowey**
  Chairwoman, House Committee on Appropriations

- **The Honorable Kay Granger**
  Ranking Member, House Committee on Appropriations

- **The Honorable Lamar Alexander**
  Chairman, Senate Subcommittee on Energy and Water Development
  Committee on Appropriations

- **The Honorable Dianne Feinstein**
  Ranking Member, Senate Subcommittee on Energy and Water Development
  Committee on Appropriations

- **The Honorable Marcy Kaptur**
  Chairwoman, House Subcommittee on Energy and Water Development
  and Related Agencies
  Committee on Appropriations

- **The Honorable Mike Simpson**
  Ranking Member, House Subcommittee on Energy and Water Development
  and Related Agencies
  Committee on Appropriations

If you have any questions or need additional information, please contact me or Mr. Christopher Morris, Deputy Assistant Secretary for House Affairs or Mr. Shawn Affolter, Deputy Assistant Secretary for Senate Affairs, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450 or Ms. Jazmin Everett, Office of the Chief Financial Officer, at (202) 586-2499.

Sincerely,

Rick Perry

Rick Perry

Executive Summary

This report describes actions taken in Fiscal Year (FY) 2018 to implement the Department of Energy's (DOE) gas hydrate research and development (R&D) program.[2] This report outlines key activities and accomplishments of the program during FY 2018 and provides a bibliography of 42 peer-reviewed papers that appeared during the year. The Methane Hydrate Research and Development Act of 2000, as amended by Section 968 of the Energy Policy Act of 2005, directs the Secretary of Energy to annually send a report to Congress on the actions taken for the program.[3]

The Office of Fossil Energy's (FE) Office of Oil and Natural Gas manages the program and the National Energy Technology Laboratory (NETL) conducts the program's research. Similar to prior years, the fundamental goals and general nature of the program are to conduct collaborative R&D, and to deliver science and technology to further understand: the nature of gas hydrate deposits; the physical properties and characteristics of gas hydrate-bearing sediments; the energy resource potential of gas hydrates for the United States; and the environmental implications of naturally occurring gas hydrate.

In FY 2018, DOE allocated $20 million to the Gas Hydrates R&D program, per Congressional direction. With this funding, the program continued its cooperative efforts with the private sector, DOE's National Laboratories, and international partners to advance the science and technology associated with naturally occurring gas hydrate. The program's major efforts focused on:

- preparation for further deep-water characterization and pressure core sampling in the Gulf of Mexico
- development of long-term reservoir response experiment opportunities on the Alaska North Slope in partnership with Japan, private industry, the U.S. Geological Survey (USGS), and the Alaska Department of Natural Resources
- an initial evaluation of potential gas hydrate occurrence along the Atlantic Margin
- completion of efforts to assess gas hydrate's role in changing natural environments, and
- opportunities to collaborate with ongoing international programs, most notably with partners in India, Japan, and South Korea.

Gas hydrate is a cage-like lattice of ice that contains trapped molecules of methane, the chief constituent of natural gas. If a gas hydrate is warmed or depressurized, it reverts to water and natural gas. When brought to the earth's surface, one cubic foot of gas hydrate releases up to 180 cubic feet of natural gas, making it a potentially massive new energy source. Hydrate deposits occur under Arctic permafrost and beneath the ocean floor along continental margins, like the Mid-Atlantic.

[2] Authorized by the Methane Hydrate Research and Development Act of 2000, 30 U.S.C. §2003, Public Law 106-193, as amended by section 968 of the Energy Policy Act of 2005, Public Law 109-58.
[3] 30 U.S.C. § 2003(e)(5).

FISCAL YEAR 2018 METHANE HYDRATE PROGRAM

Table of Contents

I. Legislative Language

This report describes actions taken in Fiscal Year (FY) 2018 to implement the Methane Hydrate Research and Development (R&D) Act of 2000, as amended by Section 968 of the Energy Policy Act of 2005. The Methane Hydrate Research and Development Act of 2000, as amended by Section 968 of the Energy Policy Act of 2005, also directs the Secretary of Energy to annually submit a report to Congress on the actions taken to carry out the program.

II. Summary of Accomplishments in FY 2018

In FY 2018, the program continued advancement of gas hydrate science and technology through various DOE National Laboratory projects, interagency agreements, contracts, and cooperative agreements with the private sector (primarily with universities). Among the most significant events and activities were the following:

- the conclusion of a number of cooperative agreements, addressing a wide range of gas hydrate research and development topics;
- preparation of plans for scientific drilling and production testing to occur within the greater Prudhoe Bay infrastructure area in collaboration with Japan, the U.S. Geological Survey (USGS), and the State of Alaska in early FY 2019;
- ongoing evaluation of samples collected during Expedition GOM2-1 in the Gulf of Mexico in FY 2017 and the development of scientific plans for a second drilling and coring program (GOM2-2); and
- further field evaluations in partnership with the USGS and the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) of gas hydrate occurrence and methane dynamics on the U.S. Atlantic Margin.

The following summarizes key activities in FY 2018 with respect to eight topical categories:

1. *Characterization of U.S. Gas Hydrate Resources*

A key goal of the program in FY 2018 was to continue its efforts to refine knowledge of the scale and nature of the occurrence of gas hydrate on the U.S. Outer Continental Shelf (OCS). From 2001 to 2014, the flagship project had been the Gas Hydrates Joint Industry Project (JIP). This JIP was a cooperative research program between DOE (in coordination with the USGS and BOEM), and an international consortium of industry and academic partners under the leadership of Chevron. A primary goal of the project was to test the ability to find and characterize gas hydrate through integrated geology and geophysics analyses, by selecting prospective sites and testing those selections through deep-water drilling and logging programs. The JIP 2009 "Leg II" drilling program was fully successful in this regard. Global gas hydrate exploration and evaluation now rely heavily on the JIP's concept of direct detection of gas hydrate through tailored application of established oil and gas prospecting approaches.

In the first quarter of FY 2015, the NETL awarded a new cooperative agreement to the University of Texas at Austin (UT-A) focused on further scientific drilling and the initial pressure-coring in the Gulf of Mexico. In FY 2017, the project completed GOM2-Expedition-1 from the Helix drillship Q4000, which was designed to test pressure-corer function at a site discovered by the JIP in 2009 in Green Canyon block 955. Expedition GOM2-1 successfully acquired extensive high-quality samples under pressure. Laboratory studies of those samples continued throughout FY 2018 at UT-A labs (Figure 1), with samples transferred to collaborating labs at NETL, and with additional preparations for further distribution of samples to the USGS and AIST (Japan). This collaborative program of laboratory studies is focused on assessing the in-situ petrophysical, geomechanical, and geochemical nature of deep-water marine gas hydrate-bearing sediments. These assessments will inform further evaluation of the geologic systems that generate high-concentration gas hydrate deposits, as well as their likely response to potential gas production activities. All project participants have committed to provide full reporting on scientific findings via two Special Volumes of the *Bulletin of the American Association of Petroleum Geologists* to be published no later than FY 2020 and FY 2021.

Figure 1: *Pressure Core storage and transfer facility (Courtesy of U. Texas-Austin)*

The UT-A effort continues to evaluate opportunities for a second drilling and coring expedition (GOM2-2) that will evaluate a range of reservoir settings with an integrated program of pressure-coring, geophysical logging, and short-duration reservoir response testing. In FY 2017, the UT-A team successfully proposed a scientific plan to conduct GOM2-2 at sites in the Terrebonne and Orca/Choctaw mini-basins onboard the research vessel *Joides Resolution* (the *JR*) under the framework of the Integrated Ocean Discovery Program. However, during FY 2018, it was determined that the JR did not meet the specifications for drilling in the U.S. OCS. At the end of FY 2018, the program was evaluating alternative options for GOM2-2 drilling.

A project with the University of California at San Diego's Scripps Institution of Oceanography gathered 359 line-kilometers of controlled source electromagnetic (CSEM) data that were used to determine the locations for drilling expeditions in FY 2017 (Green Canyon 955) and for the planning of prospective Expedition GOM2-2. Analyses of this data, and their ultimate ground-truthing through future drilling, will inform the broader assessment and characterization of gas hydrates in the Gulf of Mexico. The laboratory results will help refine the field interpretations and further evaluate the potential of CSEM to contribute to gas hydrate energy resource evaluation.

In FY 2018, UT-A concluded a regional geologic systems model study focused on methane migration and hydrate accumulation in the coarse-grained sands in the Walker Ridge Block 313 (WR313) in the northern Gulf of Mexico. This study concluded that microbial methane is capable of charging marine deposits such as those at WR313. Furthermore, results suggest that locally generated gas is sufficient to charge thin sands and relatively young (shallow) sands. However, those thicker sands and more deeply buried likely incorporate gas derived from advective migration over long distances to counteract the decreasing rate of the formation of methane by microbes with depth and hydrate dissolution due to increasing solubility.

The gas hydrate community has recognized the U.S. Atlantic Margin (extending offshore from New England to Florida) as highly prospective for gas hydrate resources, highlighted by a 2012 BOEM assessment that assigned more than 10,000 trillion cubic feet (Tcf) of gas in place likely to occur in sand reservoirs. To advance the appraisal of this potential occurrence, the USGS, in collaboration with BOEM and NETL, acquired over 2,000 kilometers (km) of marine seismic data stretching from the upper continental slope to deep-water areas offshore New Jersey to North Carolina from the research vessel *Hugh Sharp* in FY 2018 (**Figure 2**). The Mid-Atlantic Resource Imaging Experiment (MATRIX), produced data that fills a gap in modern seismic data acquisition along the U.S. Atlantic Margin, and is expected to reveal new information about the distribution and nature of gas hydrates in the U.S. Atlantic.

Figure 2: *USGS scientists retrieve a pair of airguns and the gun hanger during the 2018 MATRIX cruise. The seismic streamer is coiled on the blue winch in the foreground. (Courtesy of USGS).*

2. *Gas Hydrate Production Technologies*

Throughout FY 2018, the program continued efforts to develop opportunities to conduct scientific reservoir response experiments on the Alaska North Slope (ANS) in partnership with Japan, the USGS, ANS industry, Petrotechnical Resources Alaska (PRA), and the State of Alaska. Focused experimental and numerical simulation work conducted at DOE's National Laboratories supported this effort.

Field programs aiming towards production technology development and testing began in Alaska in FY 2004 with an initial test well (in partnership with Maurer-Anadarko). The "Mt. Elbert" test well, drilled in partnership with BP Exploration Alaska (BPXA), in the Milne Point Unit in FY 2007, confirmed the program's exploration approach and the ability to conduct research safely and non-disruptively within an area of ongoing industry operations. From 2008–2010, the effort focused on a broader industry partnership that holds the leases over highly prospective field sites within the Prudhoe Bay Unit (PBU). In 2010, plans for a long-term reservoir response experiment from a gravel pad within the PBU were generated. However, due to site access issues, those plans were modified to enable a short-duration test focused on chemical exchange in partnership with ConocoPhillips and Japan in 2011 and 2012.

In FY 2014, the Prudhoe Bay partners indicated no continuing interest in collaborative field R&D in Alaska. In an effort to further support gas hydrate science, the Alaska Department of Natural Resources (DNR) and DOE's Office of Fossil Energy signed a Memorandum of Understanding (MOU) in FY 2014 designed to facilitate gas hydrate field programs on the ANS. The Alaska DNR set aside tracts of unleased lands adjacent to the Milne Point and Prudhoe Bay Units until DOE could determine if a feasible gas hydrate field experiment could be conducted.

In FY 2015, NETL collaborated with Japan Oil, Gas, and Metals National Corporation (JOGMEC) and the USGS to review the available data and assess the presence and nature of gas hydrate within the set-aside acreage. That review concluded that the state lands sites were not conducive for long-term testing due to high costs and high risks, respectively, associated with lack of infrastructure (roads, pads, power, gas and liquid gathering lines, etc.) and an uncertain occurrence of gas hydrate.

In FY 2016, NETL, JOGMEC, the USGS, and the Alaska DNR collaborated with the PBU partners to assess specific drill sites within the Unit. As a result, the team identified a specific location at the site of an unused exploration pad, and they developed a draft plan for a three-well production testing operation.

In FY 2017 and 2018, the team continued to review and refine this plan (**Figure 3**) through numerical simulations at both JOGMEC and NETL, through consultation with a range of technology providers, with Alaska engineering firm PRA, and through partnership with PBU Operator BPXA. In FY 2018, they identified an opportunity to drill the first of the desired three wells early in FY 2019.

A key initiative related to gas hydrate production evaluation is engagement with international programs. Lessons learned in the offshore Japanese testing programs in 2013 and 2017 are informing the program's collaborative plans for testing in Alaska. Further, in FY 2015, engagement and support of the USGS, Japan, DOE's Lawrence Berkeley National Laboratory (LBNL), the government of India, and others in the evaluation of data acquired offshore of India is providing invaluable insight into the complex nature of gas hydrate reservoirs. In FY 2018, the first scientific reports on the collaborative analyses of samples and data acquired offshore India in FY 2015 appeared as part of a Special Issue of the *Journal of Marine and Petroleum Geology* (see Appendix A).

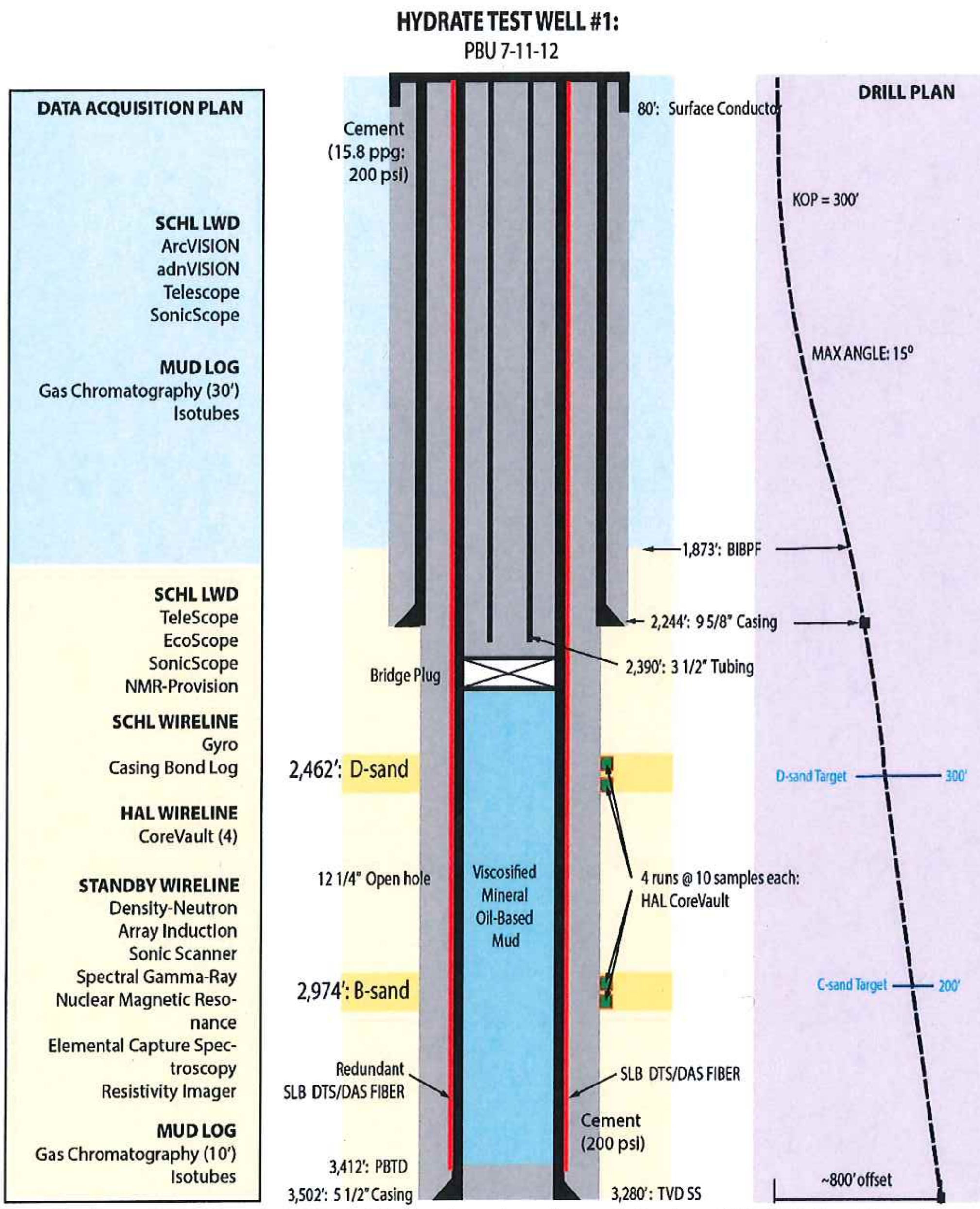

Figure 3: *Well design and data acquisition plan developed during FY2018 for Stratigraphic Test Well drilling on the Alaska North Slope (NETL)*

3. Fundamental Experimental and Modeling Studies

In FY 2017, DOE kicked off the 2nd International Gas Hydrate Code Comparison Study (IGHCCS2), which includes participation from all known gas hydrate modeling groups (Figure 4). The 1st International Gas Hydrate Code Comparison Study (2008–2011) was very successful in aligning and advancing models for the purpose of thermodynamic and flow modeling of gas hydrate.

In FY 2018, the program continued its support for focused experimental and numerical modeling studies designed to provide foundational science regarding the nature of hydrate-bearing sediments and their potential response to production activities or other changes in their environment. DOE's Pacific Northwest National Laboratory (PNNL), is coordinating the IGHCCS2 with support from LBNL and NETL; the event includes over 50 participants representing 24 teams from five countries. The effort leads participants through a series of simulator code overviews, as well as the development and solution of four benchmark problems of increasing complexity. This study focuses on the need to integrate advanced thermodynamic/flow models with complex geomechanical processes that play a key role in determining the response of hydrate reservoirs to depressurization.

Figure 4: *Logo map of participants in the 2nd International Gas Hydrate Code Comparison Study under the guidance of PNNL, LBNL, and NETL.*

An ongoing laboratory-focused project at UT-A is evaluating GOM2-1 pressure cores to first demonstrate the capability to reliably and repeatedly form synthetic hydrate. It's also examining its ability to control hydrate saturations and then use gas hydrate-containing cores recovered from the Gulf of Mexico in 2017 to assess those natural cores at the micro and macro scale. In FY 2018, the work transitioned from use of synthetic cores into evaluations using preserved samples from GOM2-1. In associated work, NETL developed an image processing capability, as well as techniques to enhance the quality of X-ray CT images to gain 3D insight into sediment pores (**Figure 5**). In FY 2018, NETL applied this imaging processing technique to the UT-GOM2-1 samples to understand and describe the mixed water and gas flows in hydrate-bearing sediments.

Louisiana State University and the USGS collaborated to complete an assessment of the impact of sand migration and clogging on pore fluid chemistry on samples from the Krishna-Godavari Basin (offshore of India). Fine particles tend to collect at gas/water interfaces created by the multiphase flow of gas and water. Thus, as methane and fresh water flow from the hydrate-dissociation toward the production well, fine particles in the reservoir sands, interbedded fine-grained layers, and seal layers can be swelled, migrated, or both—potentially clogging pathways and limiting flow to the production well. The project has contributed an increase in fundamental scientific understanding of hydrate system behavior during production. The results from this research directly informs DOE-funded reservoir modeling work being undertaken for the most promising National Gas Hydrate Program (NGHP) field sites in preparation for an NGHP production test.

NETL developed a new experimental setup to estimate relative permeability of hydrate-bearing sediment and experimental measurements for parameters of relative permeability. NETL published a new relative permeability model to improve the understanding of multi-phase flow in producing gas hydrate reservoirs. Unlike conventional, fully empirical models that are commonly used to predict relative permeabilities and are only reliable at known gas hydrate saturations, the new model allows experimental measurements to be incorporated into numerical simulators for reliable prediction of gas production.

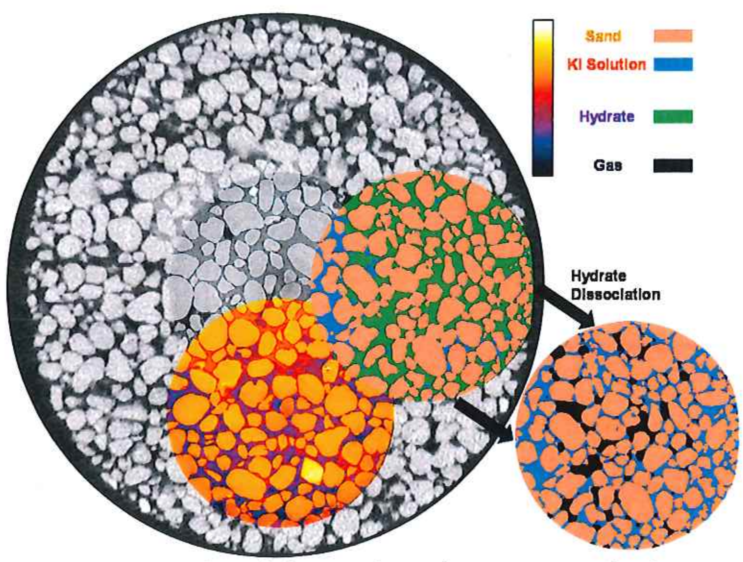

Figure 5: *X-ray CT image demonstrating the ability to directly image gas hydrate at the pore-level within sand-rich reservoirs (courtesy NETL).*

Texas A&M University, in partnership with LBNL and the Korea Institute of Geoscience and Mineral Resources (KIGAM), continued to progress efforts focused on the investigation of the geomechanical response of depressurized gas hydrate systems. In 2018, the project completed assessments of existing KIGAM lab data, and conducted new experimental studies of geomechanical changes from effective stress during dissociation. These results were used to update the fundamental physics in numerical models to better capture geomechanical behaviors.

In FY 2018, LBNL researchers continued their focus on specific lab-based assessments targeting better understanding of fundamental characteristics and behaviors of hydrate-bearing systems. This year's activities included the development of new laboratory tools and techniques and their use in performing tests to examine hydrate system behavior in increasingly more realistic environments, such as controlled thermal and chemical gradients, lab-scaled hydrate well configuration analogs, and layered hydrate systems.

4. Gas Hydrate Environmental and Global Climate Studies

In FY 2018, DOE continued to support a range of studies designed to determine the sources, sinks, and fluxes of methane in gas hydrate-bearing environments that may be sensitive to environmental change. The primary goal is to understand the role gas hydrate might play in natural geohazards, in the global cycling of carbon over long time frames, and in the potential nearer-term feedbacks in response to changing climates. This effort reflects the intent of the Methane Hydrate Research and Development Act of 2000, which directs DOE to work with our interagency partners to enable research across a broad range of gas hydrate issues, including the impacts of natural dissociation of gas hydrates.

In recent years, a consensus has begun to emerge within the scientific community that gas hydrate is likely not a major source of methane emissions at the present time. There is also evidence that longer-term geologic phenomena and not near-term environmental change are driving those methane emissions observed within gas hydrate-bearing systems. Key to this finding is work supported by DOE to contribute to efforts underway in Germany and Norway, respectively, to study the response of gas hydrates to environmental change on the Svalbard Continental Margin in the northern Atlantic. Samples and data collected from seven expeditions that encompassed extensive water column surveys, gravity coring, remotely operated towed instrumentation, and seafloor drilling campaigns were published in FY 2018. The conclusion was that long-term geologic processes, including glacial rebound from ice ages, and not recent ocean warming, are most responsible for observed seafloor methane releases in the region.

The University of Rochester, along with the USGS, continued its efforts to investigate the fate of methane released at the seafloor either accidentally during the production of methane from a deep-water gas hydrate well or with the more natural decomposition of gas hydrate systems. This research is field-based, with investigations conducted along the U.S. continental margin in geographic locations where seafloor methane emission has been documented near the upper boundary of gas hydrate stability. During FY 2018, geochemical analyses of water samples collected during a FY 2017 expedition were completed, and four scientific articles were published detailing the scientific expedition, analytical methods, and representative results of the investigations along the U.S. Atlantic Margin. The work indicates that seafloor methane emissions have limited potential to reach the atmosphere and limited acute impact on ocean acidification. Also during FY 2018, Texas A&M University adapted a computer model, the Texas A&M Oil Spill Calculator, to evaluate data collected previously at NETL to predict the behavior of natural gas seep bubbles in the deep ocean.

5. International Collaboration

In FY 2018, DOE maintained active engagement and discussion with the world's leading international gas hydrate R&D programs. These collaborations provide the Department access to critical data and insights on the performance of gas hydrate exploration and sampling technologies, and the varying geologic nature of gas hydrate deposits. Data sharing is facilitated through formal departmental-level agreements with the governments of Japan (Ministry of Economy, Trade, and Industry); India (Ministry of Petroleum and Natural Gas and Directorate General of Hydrocarbons); and South Korea (Ministry of Knowledge Economy). Lastly, NETL maintains informal contacts with researchers in many other nations (Mexico, Brazil, New Zealand, China, and others), and will continue to monitor opportunities to expand international collaboration.

As reviewed above, the primary focus of collaboration with Japan continues to be the pursuit of field testing programs on the ANS. Partner interaction during FY 2018 was extensive, including biweekly web-based conferences. Collaboration with India focused on joint evaluation of drilling sites and operational plans for a proposed third Indian National Gas Hydrate Program Expedition intended to focus on gas hydrate production testing. In addition, NETL, the USGS, and LBNL continue to support the development of geologic models and production testing simulations for the most prospective sites. The ongoing modeling effort is supported by collaboration between the USGS and AIST (Japan) scientists in the advanced evaluation of pressure cores collected during the Indian government's FY 2015 expedition in the Bay of Bengal; numerous research articles describing these findings and their implications were published in FY 2018.

In FY 2018, research efforts at PNNL and LBNL in continued to emphasize collaborative numerical modeling efforts with KIGAM as enabled by the Korean National Gas Hydrate Development Organization. The PNNL effort addressed the efficacy of gas hydrate production using nitrogen injection. The LBNL work with KIGAM focused on improving understanding of the future production of methane from hydrate deposits in the Ulleung Basin (UB).

6. Support for Education and Training

NETL, through its cooperative agreements with academia, is currently supporting dozens of students obtaining advanced degrees across a wide range of scientific disciplines. In addition, in cooperation with the National Academies of Science, Engineering, and Medicine, NETL established the National Gas Hydrate R&D Program Fellowship in 2007. Although the program is slated to continue, no new fellows were selected in FY 2018.

7. *Program Management and Oversight*

Throughout FY 2018, DOE continued to manage a broad portfolio of R&D projects but conducted no new project solicitations. DOE continued to engage its Methane Hydrate Advisory Committee in the evaluation of gas hydrate R&D priorities and progress by conducting a thorough review of program activities at meetings in Houston, Texas in March 2018. Meeting presentations and minute are available at https://www.energy.gov/fe/downloads/methane-hydrate-advisory-committee-meetings.

8. *Technology Transfer*

DOE and its research partners continued to disseminate research results to the scientific community during FY 2018. Appendix A provides a press release related to the completion of USGS-operated MATRIX seismic data acquisition program along the U.S. Atlantic Margin. Appendix B lists 42 peer-reviewed publications and reports that were released during FY 2018 that resulted in information and findings stemming from DOE support.

In addition, the DOE/NETL Gas Hydrate Newsletter, *Fire in the Ice*, continued to report on global developments in gas hydrate R&D. This periodic publication is distributed to approximately 1,500 subscribers in more than 35 countries.

9. *Conclusion*

This report describes the activities and accomplishments of DOE's Gas Hydrate R&D Program in FY 2018. DOE effectively managed its international collaborations, its work with the National Laboratories, its collaboration with other Federal and State agencies, and its portfolio of ongoing work with the private sector to further advance the science and technology needed to improve our understanding of the occurrence, nature, resource potential, and behavior of naturally occurring gas hydrates.

A highlight of FY 2018 was the identification of a gas hydrate drilling opportunity in Alaska and the finalization of scientific data acquisition plans for an initial Stratigraphic Test/monitoring well in close collaboration with partners in Japan, the USGS, Alaska industry, Prudhoe Bay Working Interest Owners, and the State of Alaska DNR. Another highlight was the initiation of a program of collaborative advanced laboratory study at UT-Austin, NETL, USGS, and AIST (Japan) of pressure core samples collected in FY 2018 for gas hydrate reservoir-quality sands in the Gulf of Mexico.

The program's international activities featured ongoing and extensive collaborations with Japan, India, and Korea. Collaborative work with Japan included an ongoing effort to develop long-term gas hydrate field-testing programs on the ANS, an effort that NETL continues to coordinate with the State of Alaska and the USGS. Collaboration with India and Japan (as well as the USGS and others) also featured the publication of a series of technical reports in the journal of *Marine and Petroleum Geology* that synthesize the findings of India's NGHL-02 drilling expedition in 2015.

These reports document the latest developments within the global gas hydrate community in the field of gas hydrate numerical simulation, pressure-core evaluation, and well-log evaluation.

DOE and research partners continued to disseminate research results to the scientific community during FY 2018 through an extensive technology transfer program, including a widely read newsletter.

Information on DOE's Gas Hydrate Program, including detailed summaries of all active and completed projects as well as reports and publications resulting from DOE-funded investigations, are regularly updated and can be found at http://www.netl.doe.gov/research/oil-and-gas/methane-hydrates.

Further information on the program, including reports and activities of the Methane Hydrate Advisory Committee, are available at http://energy.gov/fe/science-innovation/oil-gas-research/methane-hydrate.

Appendix A: "DOE-NETL-Supported Research Cruise Racks Up Gas Hydrate Data Successes"

News Release: September 20, 2018

A recent interagency federal research cruise on the vessel Hugh R. Sharp—which sailed along the Mid-Atlantic Margin to characterize gas hydrate deposits—yielded 2,000 km of Multi-Channel Seismic (MCS) System data that confirmed previously detected gas hydrates and discovered new deposits.

Gas hydrate is a cage-like lattice of ice that contains trapped molecules of methane, the chief constituent of natural gas. If a gas hydrate is warmed or depressurized, it reverts to water and natural gas. When brought to the earth's surface, one cubic foot of gas hydrate releases up to 180 cubic feet of natural gas, making it a potentially massive new energy source. Hydrate deposits occur under Arctic permafrost and beneath the ocean floor along continental margins, like the Mid-Atlantic.

This Federal research effort to characterize gas hydrate deposits included the U.S. Geological Survey (USGS), the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM), and the U.S. Department of Energy's (DOE) Office of Fossil Energy. Under an interagency agreement with USGS, DOE, through the National Energy Technology Laboratory (NETL), is providing more than $1.6 million over four years for continuing gas hydrate research. The funding includes this 2018 research cruise, known as the Mid-Atlantic Resource Imaging Experiment (MATRIX) cruise.

The 2018 MATRIX program is the first airgun program of this size managed wholly by the USGS since 1990s. The streamer deployed for MATRIX was also the longest that the USGS has used on non-specialized vessels since the 1990s.

Researchers acquired six seismic lines running down the continental slope from the shelf-break to waters as deep as approximately 12,100 feet (3,700 meters) offshore New Jersey, Delaware, Maryland, Virginia, and North Carolina. MATRIX also completed three upper continental slope lines and three deep-water (more than 8,860 feet [2,700 meters] water depth) lines oriented parallel to the coastline in this sector.

The work of the cruise fills a gap in modern seismic data acquisition along the U.S. Atlantic Margin and will be used by academic collaborators and other researchers.

"USGS researchers have been involved for decades in investigations that are helping us understand the full extent of the hydrate resource," according to Skip Pratt, NETL Project Manager. "We are pleased that we were able to support a project that is making important advances in understanding gas hydrates. USGS, BOEM, and DOE experts, along with the private sector and academic institutions, are all working together to gain a better understanding of the nature and distribution of marine gas hydrates."

Appendix B: CY 2018 Peer-Reviewed Publications and Reports

Ajayi, T., B.J. Anderson, Y. Seol, R. Boswell, and E.M. Myshakin. "Key aspects of numerical analysis of gas hydrate reservoir performance: Alaska North Slope Prudhoe Bay Unit 'L-Pad' hydrate accumulation." *Journal of Natural Gas Science and Engineering* 51 (2018): 37–43. https://doi.org/10.1016/j.jngse.2017.12.026.

Boswell, R., J. Yoneda, and W.F. Waite. "India National Gas Hydrate Program Expedition 02 summary of scientific results: Evaluation of natural gas hydrate-bearing pressure cores." *Marine and Petroleum Geology* (2018). https://doi.org/10.1016/j.marpetgeo.2018.10.020.

Boswell, R., E.M. Myshakin, G. Moridis, Y. Konno, T. Collett, M. Reagan, T. Ajayi, and Y. Seol. "Scientific Results of Numerical Simulation of Gas Hydrate Reservoirs in the Offshore of India: National Gas Hydrate Program Expedition-02." *Marine and Petroleum Geology* (2018).

Cao, S.C., J. Jang, J. Jung, W.F. Waite, T.S. Collett, and P. Kumar. "2D micromodel study of clogging behavior of fine-grained particles associated with gas hydrate production in NGHP-02 gas hydrate reservoir sediments." *Marine and Petroleum Geology* (2018). https://doi.org/10.1016/j.marpetgeo.2018.09.010.

Chen, X. and D.N. Espinoza. "Ostwald ripening changes the pore habit and spatial variability of clathrate hydrate." *Fuel* 214 (2018): 614–22. https://doi.org/10.1016/j.fuel.2017.11.065.

Chen, X., R. Verma, D.N. Espinoza, and M. Prodanović. 2018. "Pore-Scale Determination of Gas Relative Permeability in Hydrate-Bearing Sediments Using X-Ray Computed Micro-Tomography and Lattice Boltzmann Method." *Water Resources Research* 54, no. 1 (2017): 600–8. https://doi.org/10.1002/2017WR021851.

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