NETL Methane Hydrate R&D Program

January 2020

PROGRAM HIGHLIGHTS 2000-2020

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

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CONTACT
Joseph Stoffa
Technology Manager—
Gas Hydrates R&D Program
(304) 285-0285
joseph.stoffa@netl.doe.gov

LEAD WRITER AND EDITOR
Frances Toro

CONTRIBUTORS
Rick Baker
Ray Boswell
Karl Lang
Yongkoo Seol
Carolyn Ruppel (USGS)
Mark White (PNNL)

GRAPHIC ARTIST
Mike Gipple

NATIONAL ENERGY TECHNOLOGY LABORATORY

METHANE HYDRATE PROGRAM SUMMARY

Since 2000, the U.S. Department of Energy (DOE), National Energy Technology Laboratory (NETL) has been leading a coordinated Methane Hydrate R&D Program, through collaboration with other federal agencies, public and private universities, other national laboratories, industry, and international partners. This publication aims to highlight some of the program's past successes and ongoing efforts.

Program successes (pp. 10-21) have ranged from establishing reliable hydrate prospecting, drilling, and sampling approaches in the Gulf of Mexico, to organizing international gas hydrate code comparison studies for improving hydrate reservoir simulators. Ongoing projects (pp. 23-25) include NETL inhouse research on pressure core characterization, as well as development of a long-term production test site on the North Slope of Alaska. Program outreach (pp. 26-27) has been important not just for communicating NETL activities and outcomes, but, more importantly, for developing and maintaining synergies with our external partners and supporting the next generation of methane hydrate researchers.

We hope you will enjoy this Program Highlights 2000-2020, which spotlights a selection of past and current successes of NETL's Methane Hydrate R&D Program!

ON THE COVER

Parker Drilling Rig 273, North Slope Alaska. An identical rig was used to drill the Hydrate-01 Well. **Read more on p. 24.**
Photo credit: Parker Drilling.

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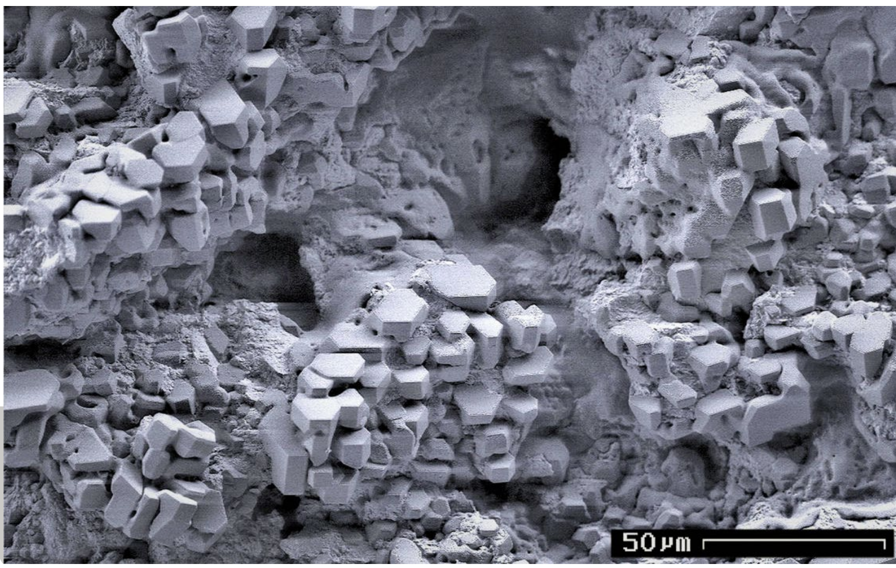
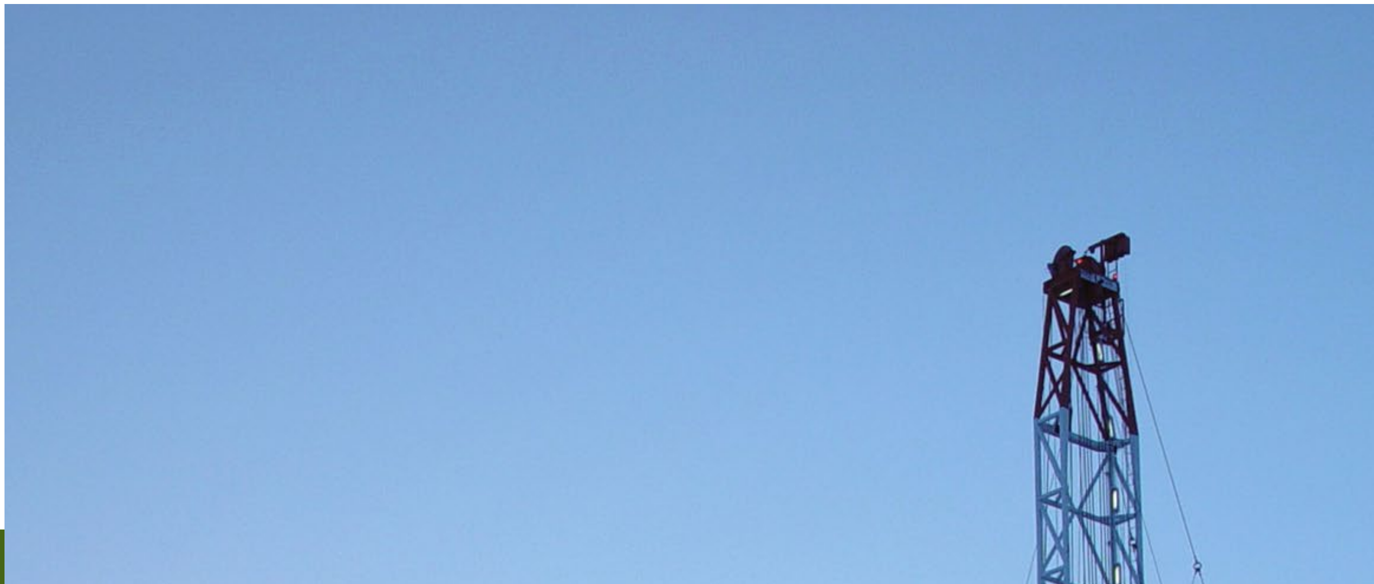


Scanning electron microscope image of gas hydrate crystals in a sediment sample. Scale at lower right is 50 microns. Photo credit: Laura Stern, U.S. Geological Survey (USGS)

Leading a coordinated Methane Hydrate R&D Program

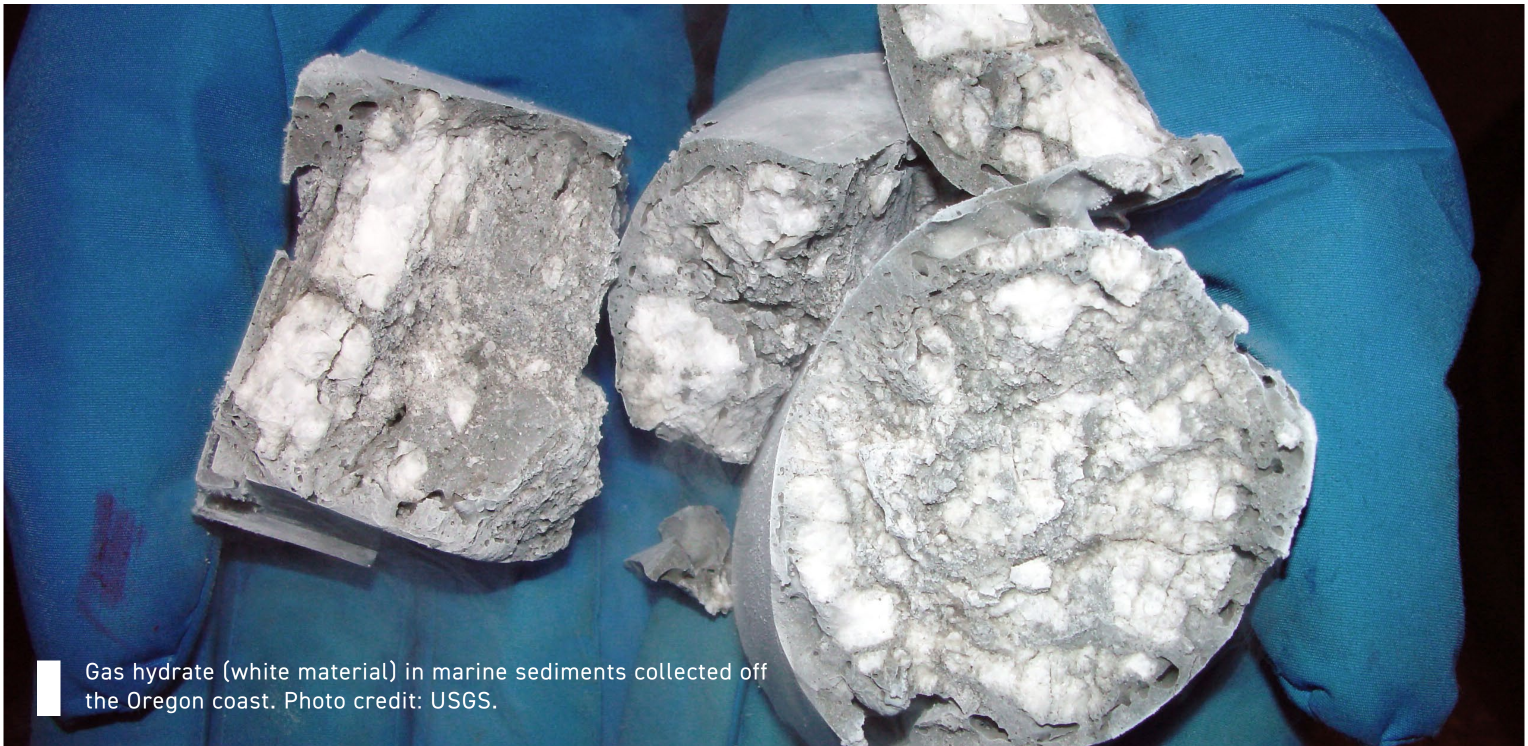
Since the passage of the Methane Hydrate Research and Development Act of 2000, DOE/NETL has led a coordinated Methane Hydrate R&D Program, in collaboration with universities, industry, international partners, and other federal agencies. The program mission has been to work with these entities to advance scientific knowledge of gas hydrates as they occur in nature, such that their resource potential, production approaches, and role in the environment can be more fully understood.

In pursuit of this mission, three high-level research areas were established. The first has been to conduct drilling and coring programs to confirm the nature and quantity of the potentially recoverable methane hydrate resource in the subsurface. The second has been to carry out integrated field, laboratory, and modeling efforts to develop technologies for safe production of methane from hydrates. The third research area has been to conduct studies that advance knowledge of the role of methane hydrates in the environment.



"…to advance scientific knowledge of gas hydrates as they occur in nature, such that their resource potential, production approaches, and role in the environment may be more fully understood."

Gas hydrate drill rig at Mallik test site in Canada's Mckenzie Delta region. Photo credit: Tim Collett, USGS.



Gas hydrate (white material) in marine sediments collected off the Oregon coast. Photo credit: USGS.

RESOURCE CHARACTERIZATION

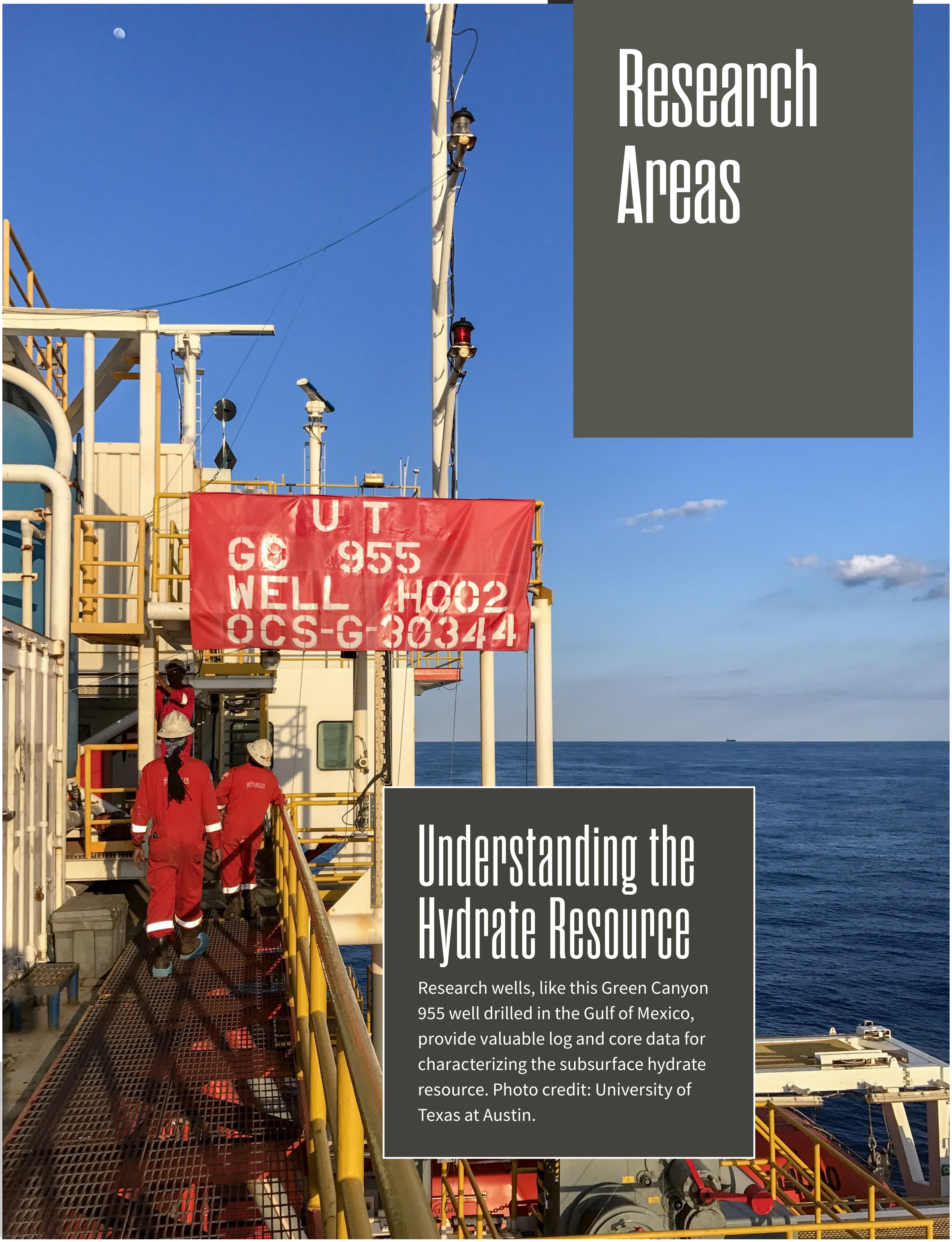
Defining the nature, quantity, and resource potential of methane hydrate in the U.S. and worldwide

The first research area is resource characterization, which involves developing techniques for identifying and characterizing methane hydrate resources in onshore and offshore regions of the U.S. A critical component of this research is the design and execution of field programs to collect data and samples of naturally-occurring hydrate deposits.

Methane hydrate accumulations in the U.S. represent a potentially significant source of natural gas for meeting the nation's future energy needs. The volume of methane trapped in resource-grade hydrate deposits in the U.S. is thought to be roughly 10,000 trillion cubic feet (TCF) in offshore marine deposits and several hundred TCF in onshore, permafrost-associated deposits. This estimate, though poorly constrained, far exceeds what is thought to be present in all the world's conventional gas reserves combined.

These estimates are based on limited data, so they carry large uncertainties. Resource volumes, especially in offshore areas, remain poorly defined. In fact, substantial areas of the U.S. outer continental shelf remain virtually unexplored with respect to methane hydrates. Only a handful of wells have been drilled for hydrate evaluation in the Gulf of Mexico and the Pacific and Atlantic margins. Additional logging, sampling, surveying, and analysis are needed to better constrain the methane hydrate resource.

Research Areas



Understanding the Hydrate Resource

Research wells, like this Green Canyon 955 well drilled in the Gulf of Mexico, provide valuable log and core data for characterizing the subsurface hydrate resource. Photo credit: University of Texas at Austin.

PRODUCTION TECHNOLOGIES

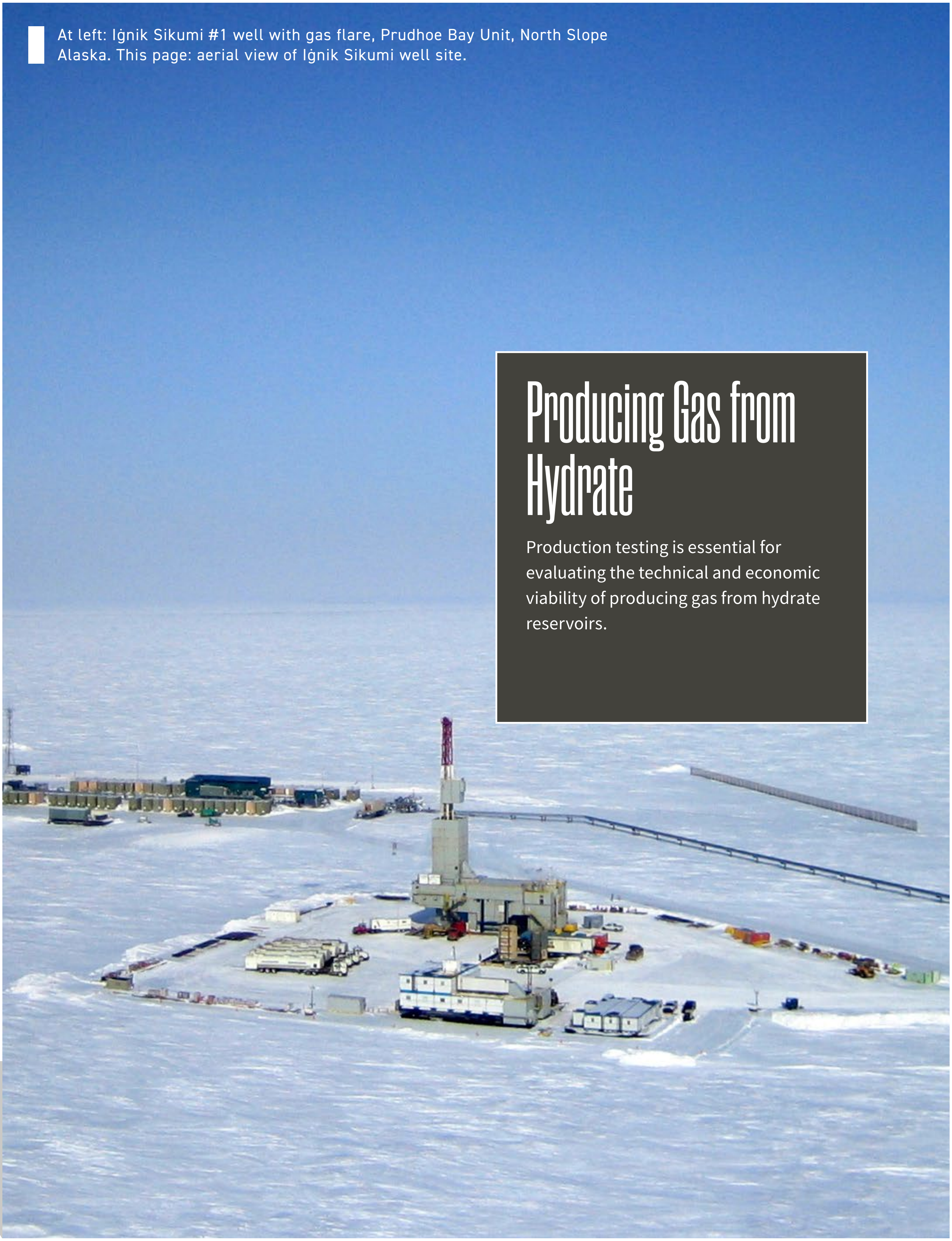
Developing technologies for safe and economic production of methane from hydrate reservoirs

The second research area is developing tools and techniques to economically produce natural gas from methane hydrate reservoirs. Several production strategies are being evaluated, and results to date indicate that simple depressurization holds the most promise for yielding viable production rates. However, CO_2 injection/exchange and thermal stimulation may also aid in optimizing production efficiency from hydrates.

By incorporating production test results into advanced numerical models, researchers are working to confirm that natural gas can be produced economically from methane hydrate reservoirs. Several production tests have been completed in recent years, including a North Slope production field trial in 2012, funded in part by DOE/NETL, in partnership with the Japan Oil, Gas and Metals National Corporation (JOGMEC); deepwater production tests off the coast of Japan in 2013 and 2017, funded by the Japanese government; and marine hydrate production testing in the South China Sea, funded and conducted by the Chinese government.

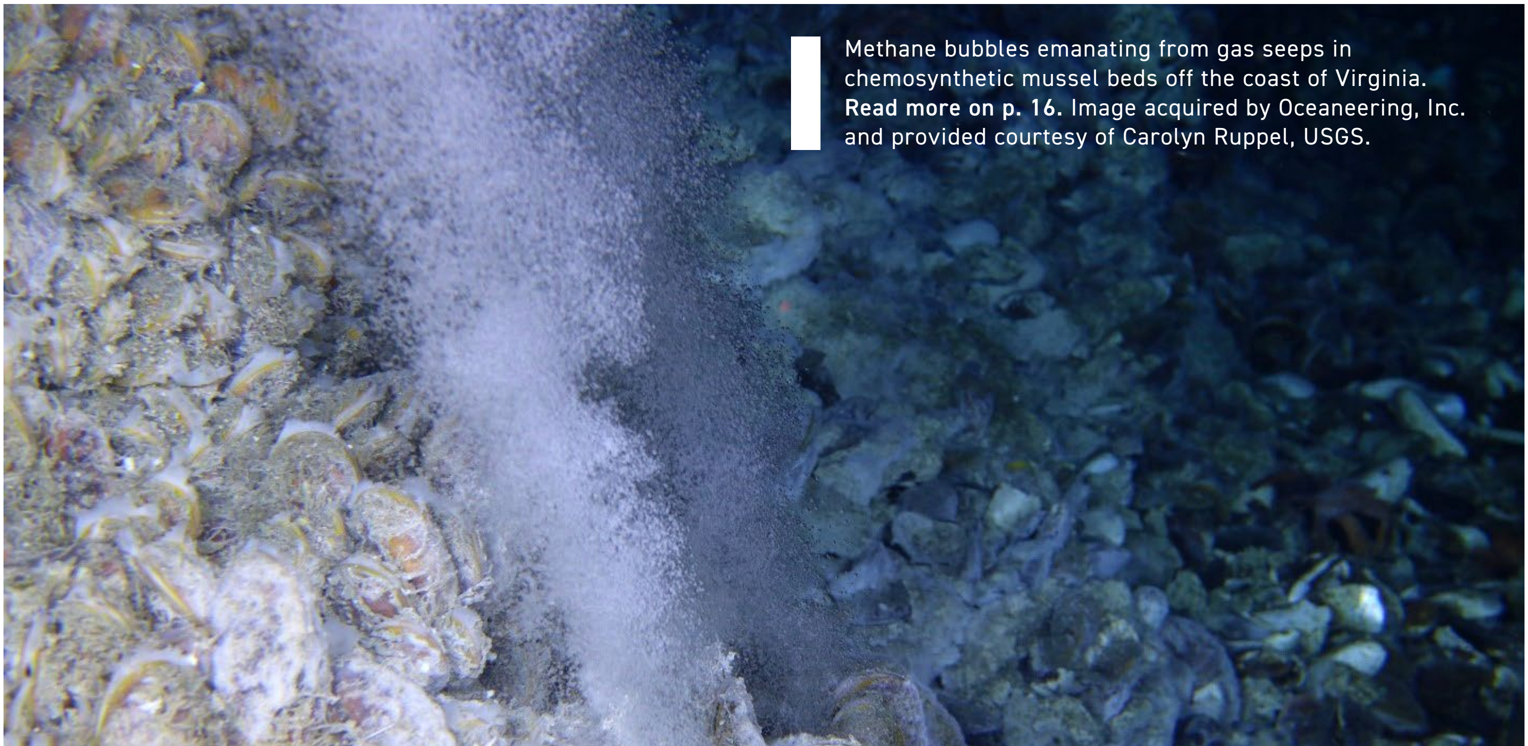
Additional international gas hydrate production testing is planned for offshore regions of Japan, China, and India. In addition, NETL and the USGS, in partnership with JOGMEC, Petrotechnical Resources of Alaska, and BP Exploration, Alaska, established a gas hydrate production test site in northern Alaska in late 2018, to be used for longer-duration production testing. Extended-duration production tests are needed to better constrain the rates at which methane can be produced from hydrate reservoirs, as well as volumes recoverable.

At left: Iġnik Sikumi #1 well with gas flare, Prudhoe Bay Unit, North Slope Alaska. This page: aerial view of Iġnik Sikumi well site.



Producing Gas from Hydrate

Production testing is essential for evaluating the technical and economic viability of producing gas from hydrate reservoirs.



Methane bubbles emanating from gas seeps in chemosynthetic mussel beds off the coast of Virginia. **Read more on p. 16.** Image acquired by Oceaneering, Inc. and provided courtesy of Carolyn Ruppel, USGS.

METHANE HYDRATE & THE ENVIRONMENT

Understanding the role of methane hydrate in the environment

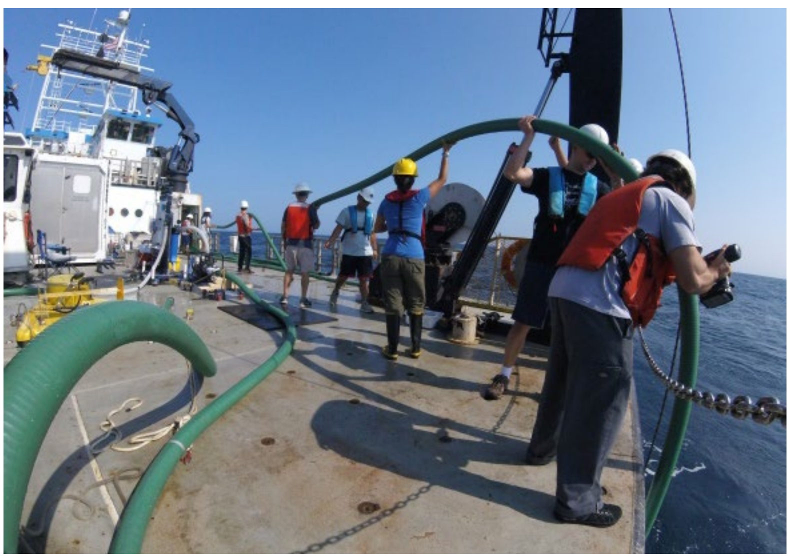
The third research area is improving the understanding of the role of methane hydrate in the environment.

Methane hydrate deposits hold immense volumes of methane gas, primarily in sedimentary strata in Arctic permafrost regions and in deepwater portions of the earth's continental margins. Methane itself is a potent greenhouse gas, many times more powerful as a heat-trapping gas than CO_2. Its abundance and potential to influence climate have raised concerns that rising global surface temperatures could trigger dissociation of gas hydrate and release of significant volumes of methane to the atmosphere.

However, recent studies indicate that the bulk of methane released from dissociating hydrates is captured in sediment and water column sinks and not transmitted to the atmosphere.

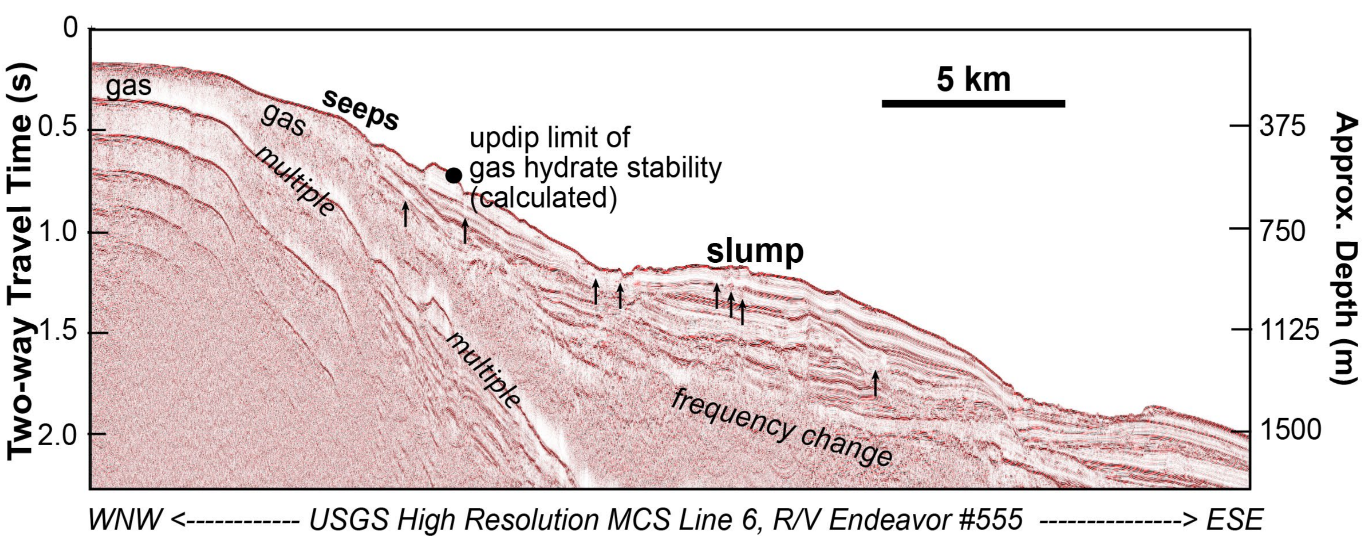
Collecting high quality observational data, performing rigorous laboratory experimentation, and conducting realistic modeling—these strategies will continue to advance our understanding of the role of hydrates in the earth's environmental processes.

Photos at upper right show equipment onboard the *R/V Hugh R. Sharp* used to sample and extract methane from seawater. Lower right figure is a migrated, multicomponent seismic (MCS) data profile used to detect gas migration features in the subsurface. Figures courtesy of Carolyn Ruppel (USGS) and John Kessler (University of Rochester).



Sampling Ocean Basins

Geophysical and geochemical data provide critical constraints on the role of marine hydrates in the ocean basins and atmosphere.



RESOURCE CHARACTERIZATION IN THE GULF OF MEXICO

Establishing reliable prospecting, drilling, and sampling approaches

In the Spring of 2009, the Gulf of Mexico Joint Industry Project (JIP), comprised of the U.S. DOE/NETL and an international industry consortium led by Chevron, conducted a logging-while-drilling program called JIP Leg II in the Gulf of Mexico, drilling a total of seven holes in Walker Ridge block 313, Green Canyon block 955, and Alaminos Canyon block 21. The objective of the program was to test a geological and geophysical data analysis approach for identifying gas hydrate prospects in sand reservoirs in the Gulf of Mexico.

Results of the JIP Leg II expedition proved the effectiveness of the prospecting approach that has since been adopted internationally. This prospecting approach integrates: (1) direct detection of hydrate using seismic data volumes and available log data; (2) mapping of hydrate stability field boundaries using available temperature and pressure estimates; and (3) classic petroleum system analysis, which includes identification of gas source, migration pathways, and reservoir facies. The 2009 drilling results also verified specific occurrences of high-saturation, hydrate-bearing sand reservoirs, effectively delineating field sites for later engineering and characterization studies.

In 2017, NETL and the University of Texas at Austin carried out a successful drilling and coring expedition, GOM^2 Expedition-1, at sites discovered by the JIP Leg II team in 2009. The objective of the 2017 program was to test the efficacy of two existing pressure-coring devices and retrieve high-quality samples of methane hydrate-bearing sands for specialized analyses in laboratories across the U.S.

The 2017 expedition included scientists from the USGS, Ohio State University, BOEM, University of New Hampshire, University of Oregon, University of Washington, and Columbia University. The science team targeted gas hydrate-bearing sandstone layers that had been identified in the previously drilled GC955-H well.

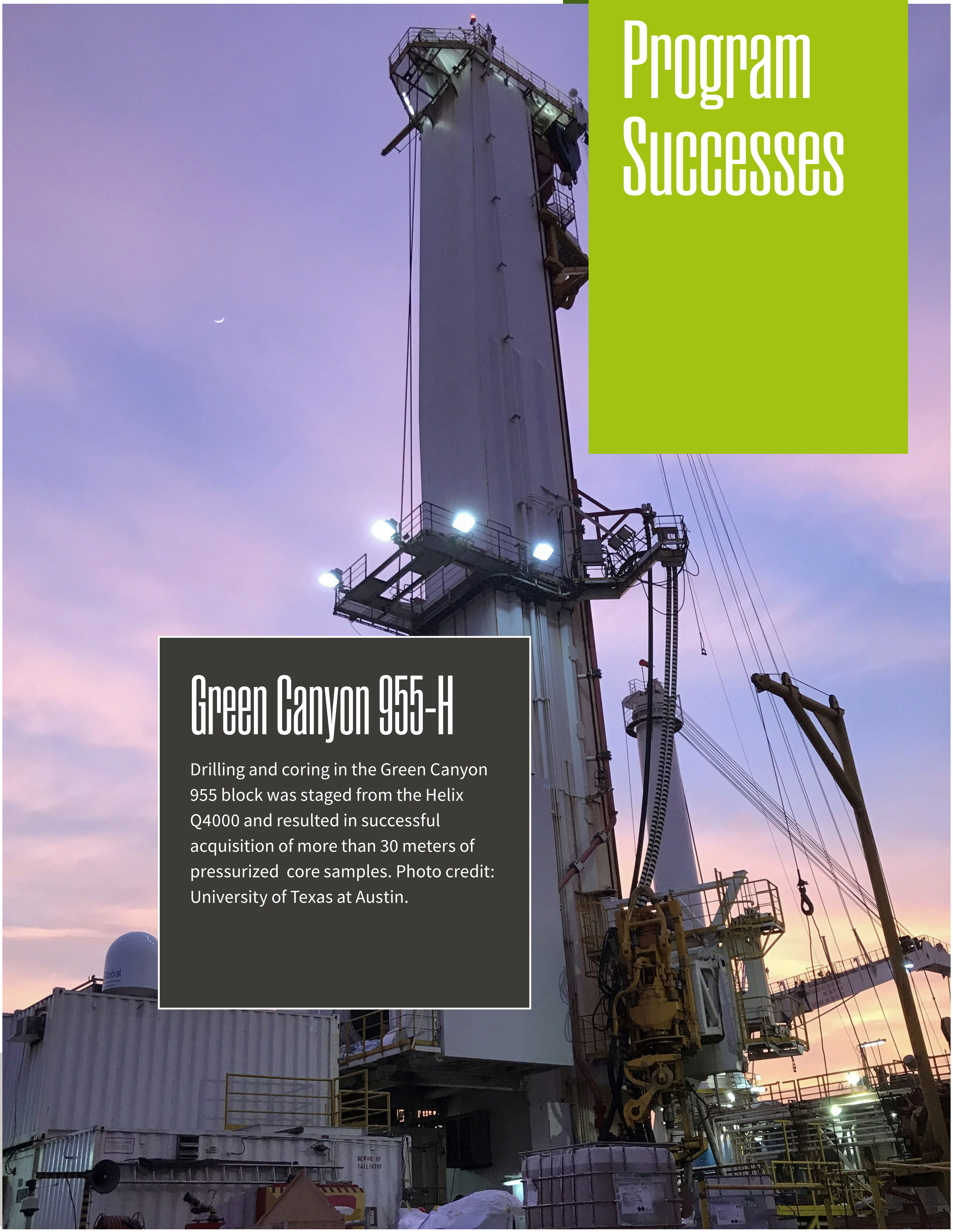
Coring was conducted in two closely-spaced offset wells, using two versions of the Pressure Core Tool with Ball valve (PCTB), both designed to maintain core samples at in-situ reservoir pressure conditions during core retrieval, subsampling, and transfer to pressurized storage vessels. The 2017 expedition was successful in obtaining high-quality, pressurized hydrate-bearing core samples for further laboratory analyses.

The science and technology results from the two expeditions are relied upon by the international methane hydrate R&D community to guide ongoing marine hydrate expeditions.

FURTHER READING

Boswell, R., Shipp, C., Reichel, T., Shelander, D., Saeki, T., Frye, M., Shedd, W., Collett, T., McConnell, D., 2016. Prospecting for marine gas hydrate resources. Interpretation, v. 4 (1), pp. SA13-SA24.

Program Successes



Green Canyon 955-H

Drilling and coring in the Green Canyon 955 block was staged from the Helix Q4000 and resulted in successful acquisition of more than 30 meters of pressurized core samples. Photo credit: University of Texas at Austin.

MATRIX: Mid-Atlantic Resource Imaging Experiment

Multichannel seismic data collection and analysis

In August of 2018, the USGS, with support from DOE/NETL and the U.S. Bureau of Ocean Energy Management (BOEM), completed the Mid-Atlantic Resource Imaging Experiment (MATRIX). This program acquired over 2000 kilometers of modern multichannel seismic (MCS) data to characterize methane hydrate and shallow gas accumulations on the U.S. Atlantic margin, between New York and North Carolina. The results are being used to refine BOEM's maps of inferred hydrate distributions, which were based on legacy seismic data collected mostly in the 1970s and 1980s.

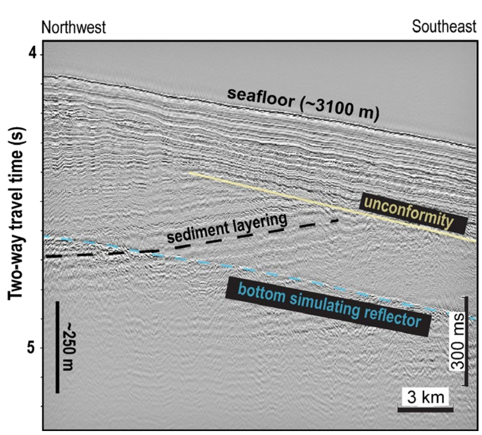
MATRIX MCS data were collected from the *R/V Hugh R. Sharp*, using up to four airguns and a 1.2-km-long streamer with 112 to 160 recording channels. Sixty deepwater sonobuoys were deployed to better constrain water column sound velocities. In addition, the USGS continuously imaged the water column to locate active methane plumes emanating from known seep fields and to map previously undiscovered seafloor seeps.

Initial analysis of MATRIX data confirms strong bottom simulating reflectors (BSRs) beneath a large area of seafloor seaward of Hudson Canyon. Offshore New Jersey to Virginia, BSRs are more subtle. The USGS is using both conventional and machine learning approaches to delineate the BSRs.

Despite being an important gas hydrate province, the Mid-Atlantic margin has had few exploration wells and limited modern seismic data targeted for high resolution imaging at the depth of gas hydrates. MATRIX data will allow a more detailed and reliable estimate for the volume of gas hydrate than was possible with legacy data.

FURTHER READING

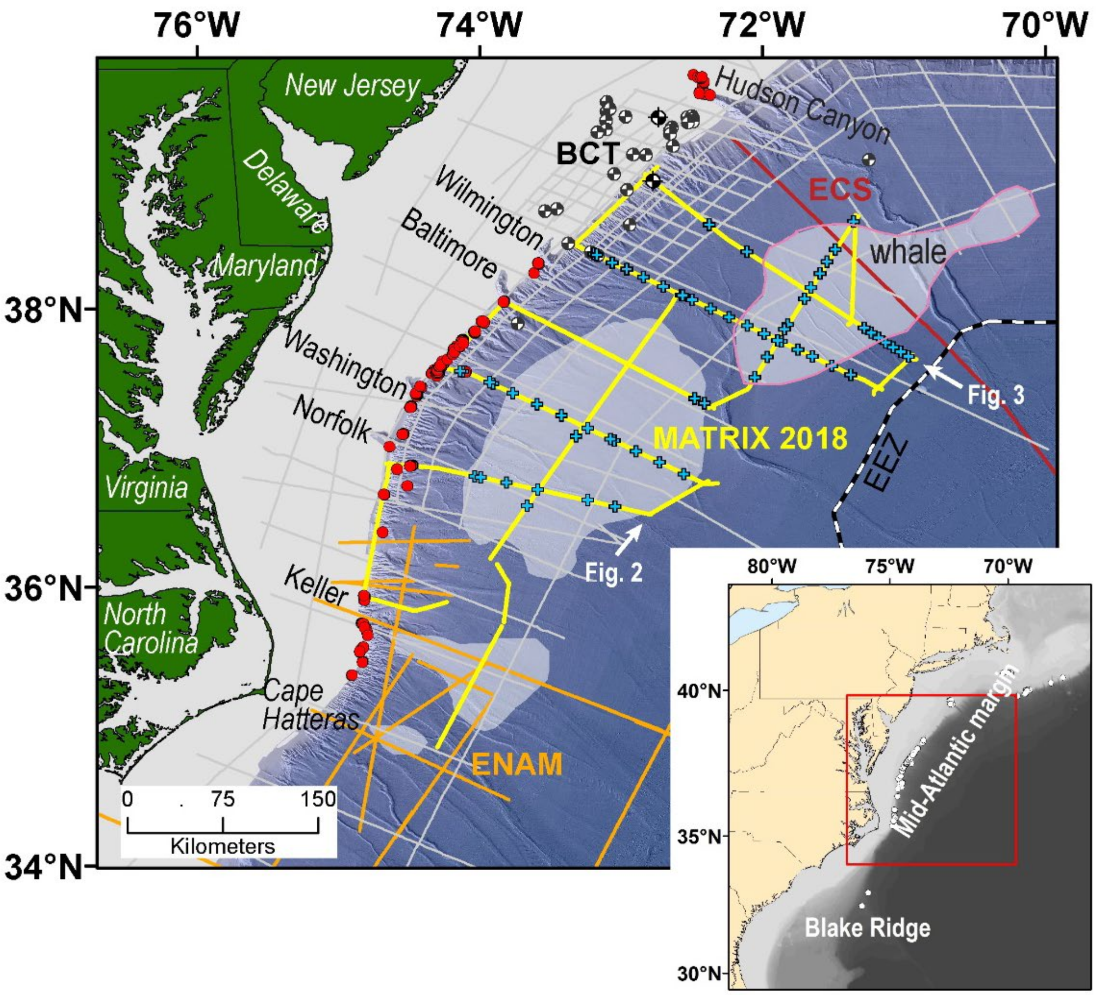
Ruppel, C., Miller, N., Frye, M., Baldwin, W., Foster, D., Shedd, W., and Palmes, S., 2019. U.S. Mid-Atlantic Resource Imaging Experiment (MATRIX) constrains gas hydrate distribution. Fire in the Ice, v. 19 (1), pp. 6-8.



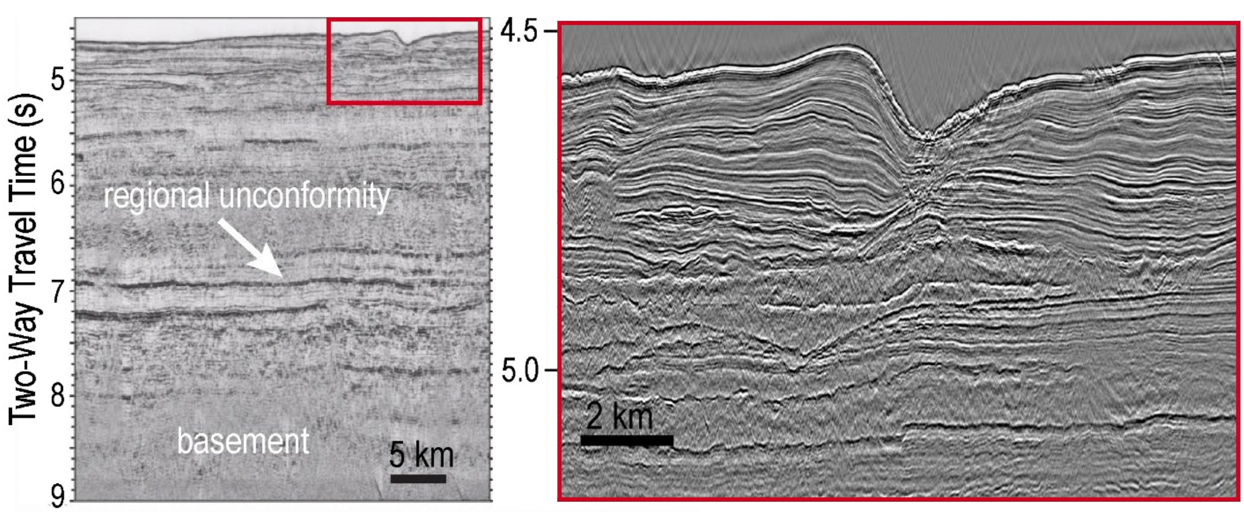
This page: sample of MATRIX seismic line in the whale gas hydrate prospect, showing bottom simulating reflector and its relationship to stratigraphy. Courtesy of C. Ruppel and N. Miller, USGS.

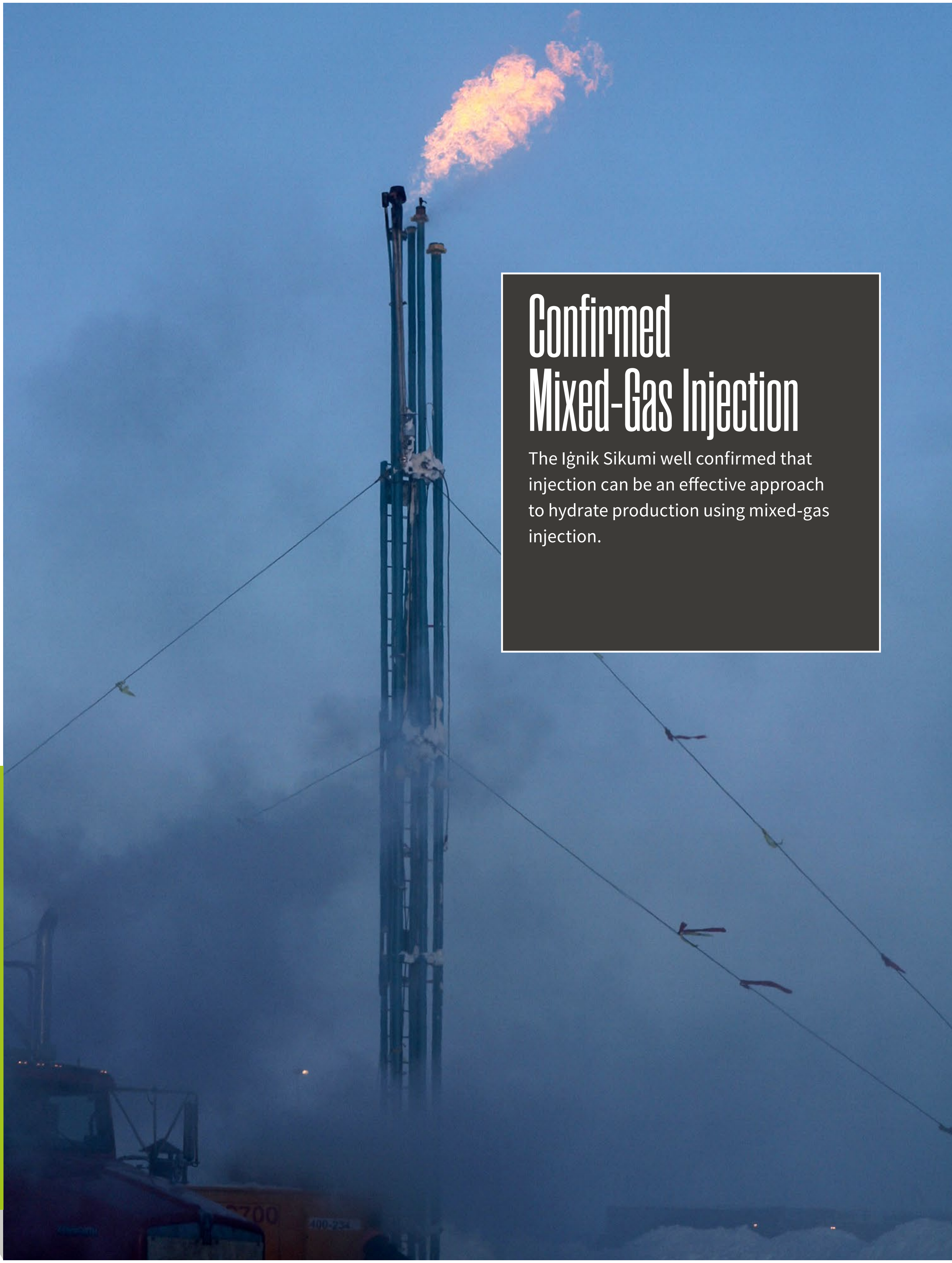
Facing page: sample of MATRIX multichannel seismic data along a strike line. The red box indicates the data subset shown on the right. Courtesy of C. Ruppel and N. Miller, USGS.

PROGRAM SUCCESSES



Location map showing MATRIX seismic lines (yellow lines) acquired in 2018, as well as ECS (red lines), ENAM lines (orange lines), and 1970s legacy seismic data (gray lines). Solid red circles indicate known methane seeps as of 2014. White arrows indicate locations of the seismic data samples shown below left and below right. Figure courtesy of Carolyn Ruppel, USGS.





Confirmed Mixed-Gas Injection

The Iġnik Sikumi well confirmed that injection can be an effective approach to hydrate production using mixed-gas injection.

IĠNIK SIKUMI WELL

A methane hydrate production field trial on the North Slope of Alaska

In 2011 and 2012, the Iġnik Sikumi field trial was carried out on the North Slope of Alaska by ConocoPhillips, in partnership with the U.S. DOE/NETL, Japan Oil, Gas, and Metals National Corporation (JOGMEC), and the USGS. The field program was designed to test the technical feasibility of producing gas from a methane hydrate reservoir using a CO_2-CH_4 exchange methodology. Prior to the field program, this methodology had only been tested in a laboratory setting.

The Iġnik Sikumi field program included well drilling and geophysical logging during 2011, followed by production testing in 2012. Based on careful analysis of log data acquired in 2011, a 30-foot thick section of hydrate-bearing sand was selected for production testing in 2012.

The production field trial was conducted in three phases: (1) injection of CO_2 + N_2 gas containing chemical tracers; (2) production of reservoir fluids at pressures exceeding methane hydrate stability; and (3) extended production (thirty days) at pressures below the methane hydrate stability threshold. The highly successful field program was the first of its kind and resulted in a wealth of drilling, logging, and production test data to inform future production efforts.

The Iġnik Sikumi well confirmed the presence of multiple gas hydrate-bearing sand reservoirs in the Eileen trend of the Prudhoe Bay Unit, with gas hydrate in the target interval occupying up to 80% of reservoir pore volume. More importantly, from a production perspective, the project confirmed that the tested hydrate reservoir responds quickly to downhole pressure changes and is not prone to run-away destabilization. Production test results also illustrate the need to manage water and sand production in future hydrate production wells, and the fact that future wells may need to be equipped with heat and/or inhibitors to prevent hydrate formation in the wellbore. From an operations perspective, the program demonstrated that injection can indeed be effective under mixed-gas conditions, although gas exchange processes are complex.

FURTHER READING

Boswell, R., Schoderbek, D., Collett, T., Ohtsuki, S., White, M., Anderson, B., 2016. The Iġnik Sikumi field experiment, Alaska North Slope: design, operations, and implications for CO_2-CH_4 exchange in gas hydrate reservoirs. Energy & Fuels, v. 31 (1), pp. 140-153.

INTERACTION OF METHANE HYDRATES WITH THE ENVIRONMENT

With an example from the mid-Atlantic margin

For decades, researchers have debated whether gas hydrate breakdown due to a warming environment could release large amounts of methane to the atmosphere. In the mid-2000s, DOE/NETL and our interagency partners began to address this question via research that incorporates gas hydrates into models of global carbon cycling. DOE/NETL also funded field programs designed to investigate this issue in marine and permafrost hydrate settings, including the Alaskan North Slope and the U.S. Atlantic, Pacific, and Gulf of Mexico margins.

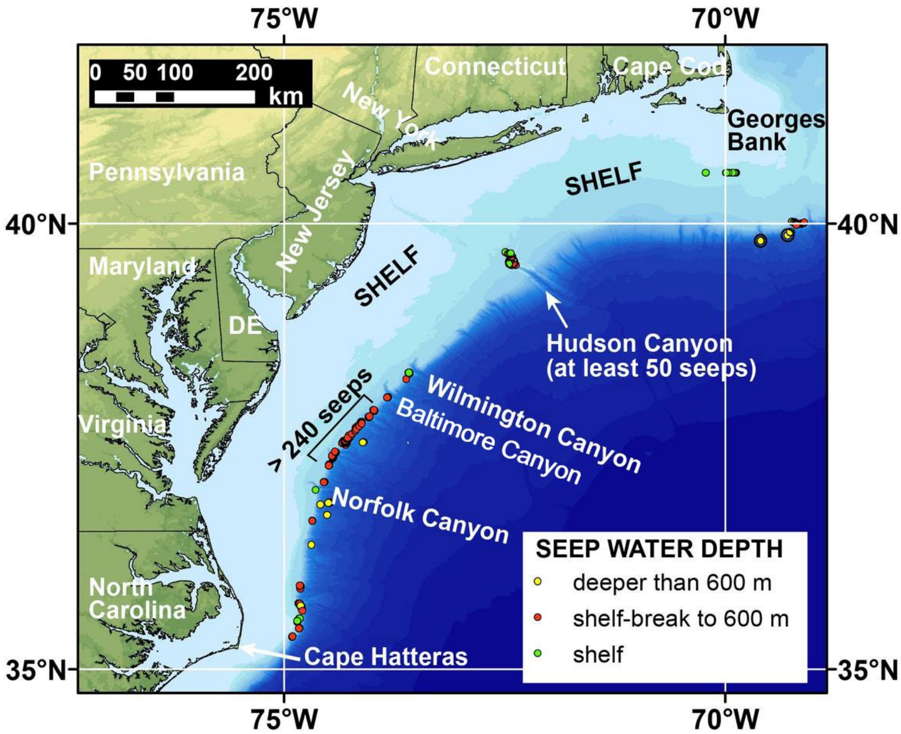
In 2017, DOE/NETL-funded researchers from the USGS and University of Rochester published a definitive review of scientific knowledge of interactions between gas hydrates and the environment. Based on available data and literature, the researchers concluded that gas hydrate is likely breaking down in only a few places on the earth, such as upper continental slopes at water depths of 500-700 meters. However, there is no evidence that the methane released from hydrate breakdown at these sites reaches the atmosphere; instead, the released methane dissolves in ocean water and is consumed by bacteria, producing carbon dioxide. In deeper parts of the ocean and in permafrost areas, hydrate may also break down, but the methane probably remains trapped in sediments, as it has no path to reach the seafloor or ground surface to be emitted to the atmosphere.

DOE/NETL has funded several field projects to examine the fate of methane released at seafloor gas seeps at depths close to those where gas hydrate may be breaking down. On a 14-day research cruise in 2017, researchers from the University of Rochester and the USGS collected geochemical and geophysical data on the U.S. Mid-Atlantic margin, where the USGS co-discovered hundreds of previously-unknown methane seeps.

The data are being used to determine whether the methane in the water column originates at seeps or from the activity of plankton at shallow depths in the ocean; to quantify the amount of methane emitted to the atmosphere from the sea surface; and to assess whether carbon dioxide produced from the seep methane builds up in deep ocean waters along the mid-Atlantic margin.

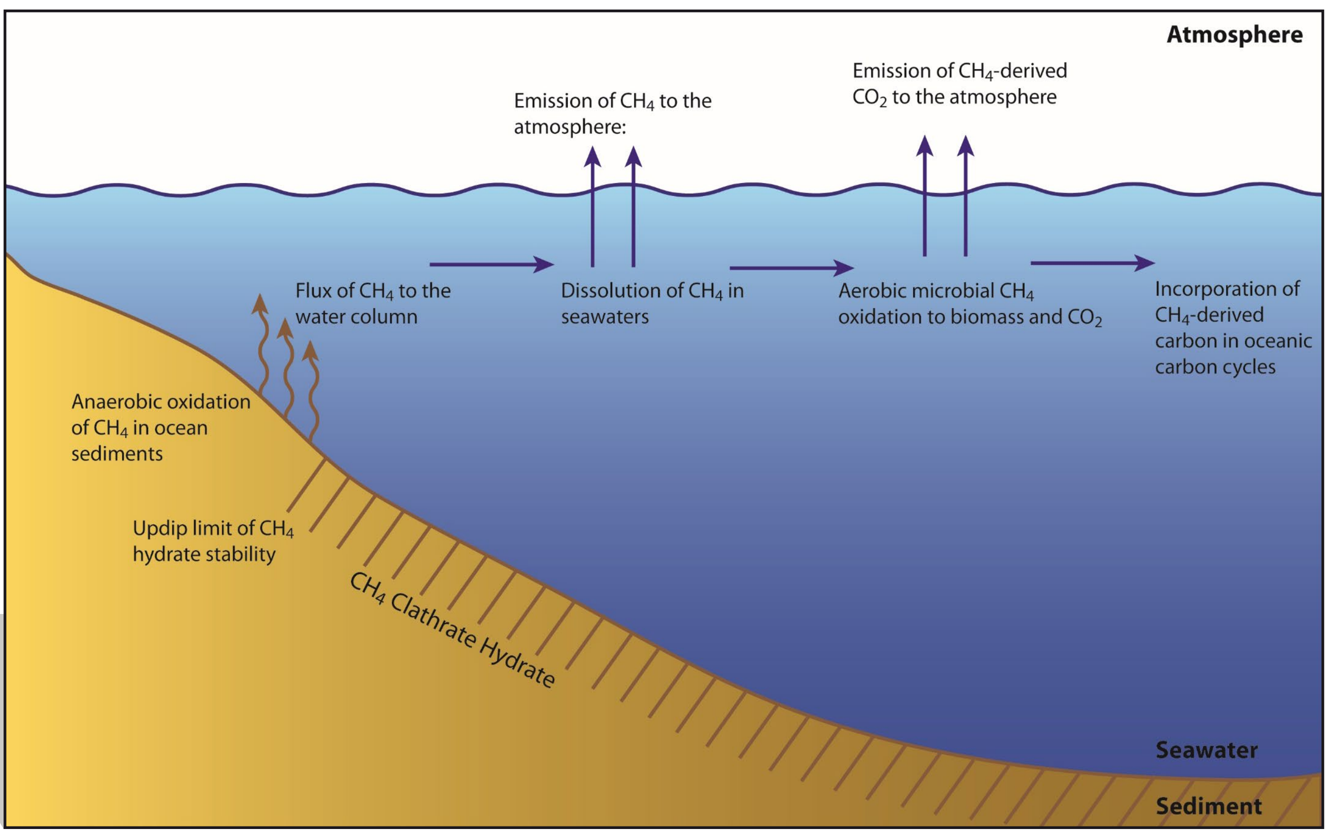
FURTHER READING

Ruppel, C. and Kessler, J., 2017. The interaction of climate change and methane hydrates. Reviews of Geophysics, v. 55 (1), pp. 126-168.



Natural Methane Seepage on the Mid-Atlantic Margin

How much methane from seafloor sources is transmitted to the atmosphere?



Map of natural methane seeps on the U.S. Atlantic Margin (top) and schematic diagram showing potential sources and pathways of methane released from the seafloor and into the water column (bottom). Figures courtesy of C. Ruppel (USGS) and J. Kessler (University of Rochester).

INTERNATIONAL FIELD EFFORTS

Synergies with international drilling, sampling, and production testing expeditions

The DOE/NETL Methane Hydrate Program, in partnership with the USGS, has collaborated extensively with international gas hydrate R&D programs in the planning and execution of major field expeditions around the globe. This engagement has created opportunities to advance emerging scientific concepts and test new hydrate-specific field technologies. It is largely through these coordinated field programs that the U.S. and our international partners have attained a more complete understanding of naturally-occurring hydrate deposits across a wide variety of geologic settings.

Some international field studies have focused on onshore hydrate accumulations in Arctic permafrost environments; others have examined and tested offshore hydrate deposits in deep marine settings. International programs include the first onshore gas hydrate program, which was initiated by Canada and Japan at the Mallik site in Arctic Canada (1998, 2002). Continued collaboration with Japan has been central to the development of advanced gas hydrate pressure coring technologies and numerical simulation strategies. More recent efforts with Japan have focused on gas hydrate production testing on the Alaska North Slope, including collaboration in the 2011/2012 Iġnik Sikumi test well and ongoing efforts to establish a long-term production test site, essentially a field laboratory, for studying the response of gas hydrate reservoirs to controlled depressurization.

Collaboration with both South Korea and India has been in offshore, deep marine drilling and testing expeditions. India carried out drilling and testing in the Arabian Sea, Bay of Bengal, and Andaman Islands (2006 and 2015); while South Korea's drilling program has been in the Ulleung Basin region (2007 and 2010). For the Indian and Korean national programs, NETL and USGS collaborated on international research teams to provide expertise to support the selection of drill sites, based on experience gained from our own site selection and drilling efforts in the Gulf of Mexico. In addition to site selection, we contributed to post-expedition evaluation and reporting of scientific results. Our involvement in these programs has been immensely beneficial for advancing our understanding of gas hydrate systems in marine environments and refining concepts for identifying gas hydrate prospects through integrated geological and geophysical analyses.

Lessons learned from these international programs have led to substantial advances in methane hydrate science and technology, particularly in the areas of resource characterization and production technologies.

D/V Chikyu Bay of Bengal

The *D/V Chikyu* was designed by the Japanese government to support international scientific drilling operations (photo courtesy of JAMSTEC, Japan Agency for Marine Earth Science and Technology).

Mallik Well Arctic Canada

The Mallik gas hydrate production research well. Photo credit: Suzanne Weedman, USGS.

International collaboration on methane hydrate field trials has advanced every aspect of methane hydrate technology development—from pressure coring, to global resource evaluation, to production optimization.

INTERNATIONAL GAS HYDRATE CODE COMPARISON STUDIES

Collaborative efforts to improve hydrate reservoir simulators

NETL has taken an active role in facilitating international collaboration and shared learning among researchers engaged in development and testing of gas hydrate reservoir simulators. These efforts have been aimed at: (1) fostering the exchange of information relating to hydrate reservoir modeling, (2) building confidence in leading reservoir simulators, and (3) optimizing strategies for safe and economic production of gas from hydrate-bearing reservoirs.

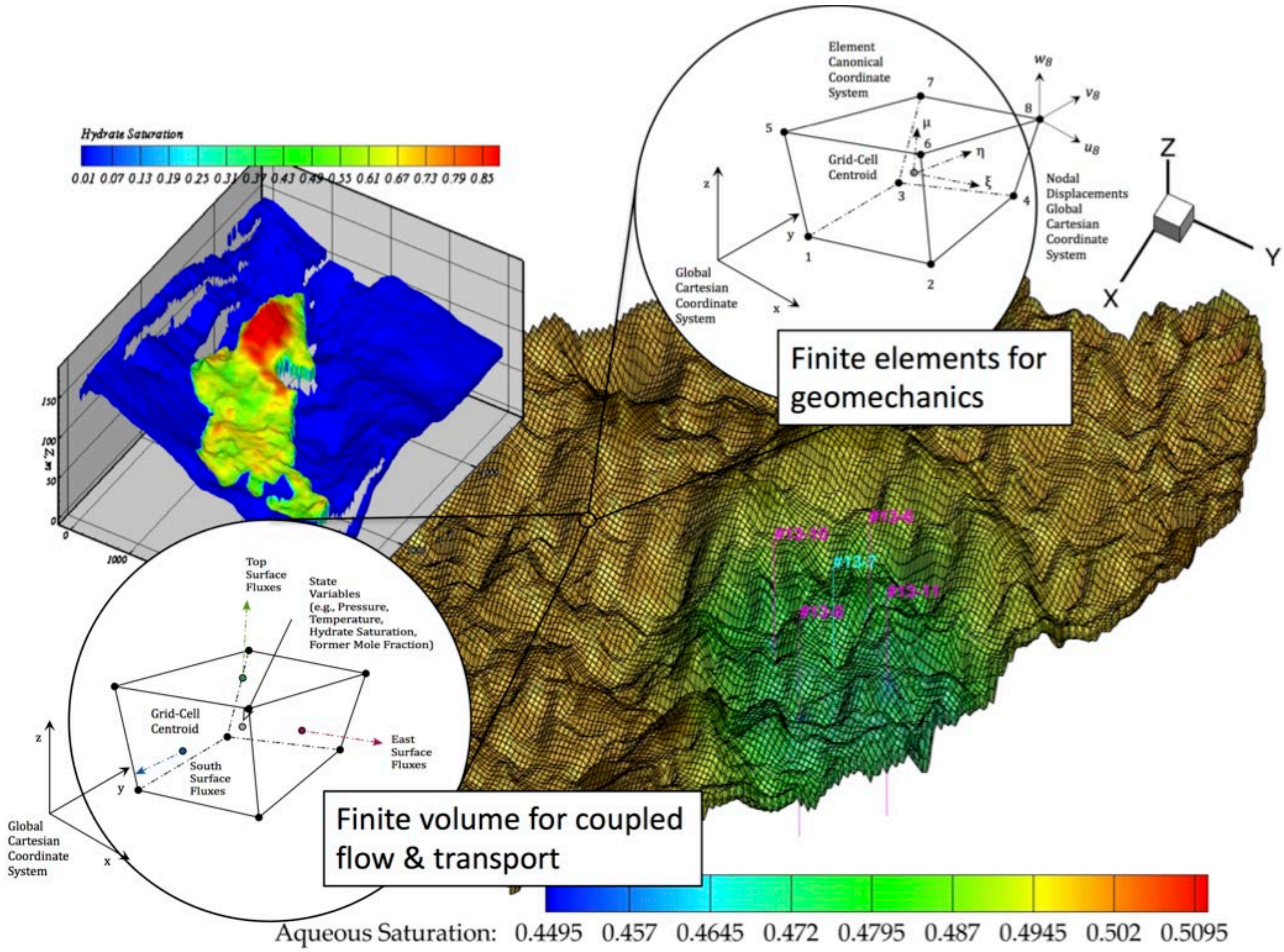
In recent years, scientists from Pacific Northwest National Laboratory (PNNL), Lawrence Berkeley National Laboratory (LBNL), and NETL have led a collaborative project known as the 2nd International Gas Hydrate Code Comparison Study or IGHCCS2. This project has been successful in establishing a community of participants from 21 institutions from around the world, to test and compare different reservoir simulator codes using a set of well-defined benchmark problems.

The prior effort, IGHCCS1, was initiated in 2006 and guided by NETL and the USGS. Participating research teams tested their simulators using five benchmark and field-scale problems and focusing primarily on gas hydrate production via depressurization and thermal stimulation. More recent efforts, under IGHCCS2, have also focused on gas hydrate production via depressurization and thermal stimulation, but the new studies incorporate geomechanical coupling as well.

Results have been favorable and have led nearly all participating study teams to make technical advancements to their hydrate reservoir simulators. Key conclusions are that benchmark problems are essential for resolving differences between modeling results. In addition, these studies have confirmed that overcoming technical barriers to the realization of commercial-scale production of natural gas from hydrates requires sophisticated simulation codes that address the complexity of gas hydrate systems via rigorous treatment of their coupled thermal, thermodynamic, hydrologic, and geomechanical processes.

FURTHER READING

White M., Kneafsey, T., and Seol, Y., 2018. Modeling of coupled thermal, hydrologic, and geomechanical processes in gas hydrate bearing porous media: The 2nd International Gas Hydrate Code Comparison Study. American Geophysical Union, Fall Meeting 2018, Dec. 10-14, Washington, D.C.



Schematic diagram illustrating sequential coupling of thermal-hydrologic processes with geomechanical processes in a gas hydrate reservoir simulator. Diagram courtesy of Mark White, PNNL.

Ongoing Projects

The DOE/NETL program has a project portfolio that includes field and laboratory efforts aligned with the research areas described above. Current projects are designed to fill remaining gaps in the program, while pushing methane hydrate R&D to the next level. Two examples of ongoing projects are highlighted below.

NETL's effective stress chamber (this page) is used to measure acoustic, mechanical, and hydraulic properties of pressure core specimens while maintaining *in situ* pressure and temperature conditions. The pressure core cutting chamber (facing page) is designed to cut core samples while maintaining *in situ* pressure conditions up to 4500 psi.

BUILDING WORLD-CLASS HYDRATE RESEARCH FACILITIES

Building state-of-the-art capabilities for laboratory testing of hydrate samples

The DOE/NETL Research and Innovation Development Center (R&IC) has developed facilities for laboratory testing of pressurized natural and synthetic methane hydrate samples. Facilities include: (1) a multi-property characterization chamber (MPCC) and mini-MPCC for real-time sample observation with CT scanners, and (2) a multi-component pressure core characterization and x-ray CT visualization toolset (PCXT).

The MPCC is capable of measuring permeability, hydrate saturation, acoustic velocities, and mechanical properties using 2.5-inch diameter core specimens. The Mini-MPCC is designed for pore-scale testing and uses 0.375-inch diameter specimens cut from the larger cores. Both the MPCC and Mini-MPCC can be transported to one of NETL's onsite CT scanners for real-time, 3D imaging during experimental steps. Testing and imaging of hydrate-bearing samples at both scales helps to bridge the knowledge gap between pore-scale and core-scale characterization.

The PCXT is an apparatus designed by NETL to retrieve, transfer, cut, sub-core, and characterize natural pressure cores at *in-situ* reservoir pressure and temperature conditions. Its operation occurs in a cold room, and pressure is regulated with high-precision pumps. It is used to measure mechanical and hydraulic properties of hydrate-bearing specimens while performing pore-scale imaging.

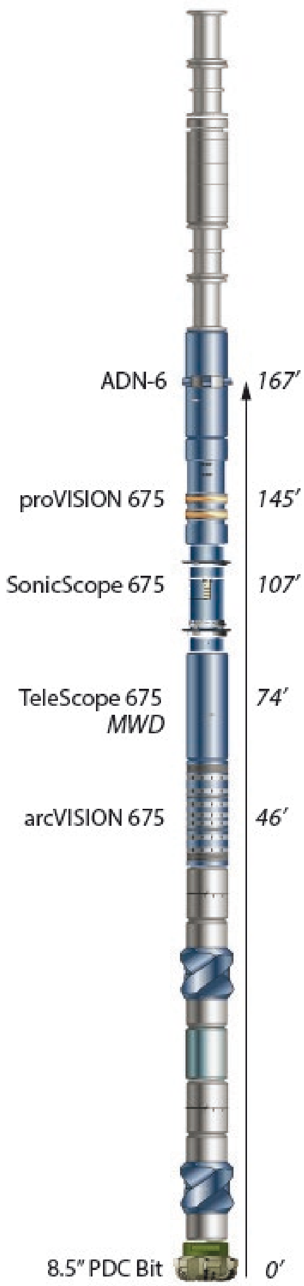
These R&IC facilities are an important step toward building NETL's capabilities for fundamental research on methane hydrate samples. Data and results from the lab will ultimately be used to constrain hydrate production models and guide strategies for producing gas from hydrate reservoirs while minimizing environmental and safety concerns.

Recent experimental studies have focused on pore-scale processes occurring during hydrate formation and dissociation, under a range of pressure and temperature conditions. Results confirm that injection of free methane into water-saturated sediments is an effective method for creating high-saturation, synthetic hydrate specimens. In addition, dissociation experiments reveal that high-saturation reservoirs are prone to flow path clogging during depressurization alone, and this problem can be mitigated with thermal stimulation.

FURTHER READING

Lei, L. and Seol, Y., 2019. High-saturation gas hydrate reservoirs—A pore scale investigation of their formation from free gas and dissociation in sediments. Journal of Geophysical Research: Solid Earth, online version.

ESTABLISHING A LONG-TERM PRODUCTION TEST SITE, ALASKA NORTH SLOPE



Initiating a multi-well program to test and observe the response of gas hydrate reservoirs to controlled depressurization

This project builds on prior program successes to establish a site for long-term production testing of methane hydrate reservoirs on the North Slope of Alaska. A long-term production test plan was developed through collaboration between DOE/NETL and Japan Oil, Gas and Metals National Corporation (JOGMEC), with technical and scientific expertise provided by the USGS.

In order to select a test site with high-quality, hydrate-bearing reservoirs, project scientists analyzed a wealth of geological, geochemical, and geophysical data from the region.

The site was selected in the Eileen trend, in the western Prudhoe Bay Unit, and a highly successful stratigraphic test well, Hydrate-01, was drilled in December 2018 by BP Exploration Alaska (BPXA) under a contract through Petrotechnical Resources Alaska (PRA). Logging-while-drilling (LWD) data acquired in the well confirmed the presence of two highly-saturated gas hydrate reservoirs. The deeper reservoir is at a depth near the base of the gas hydrate stability zone and is considered an excellent candidate for long-term production testing.

Hydrate-01 will serve as a monitoring well during long-term production testing. It is the first of a multi-well program designed to answer first-order questions regarding the response of gas hydrate-bearing reservoirs to depressurization.

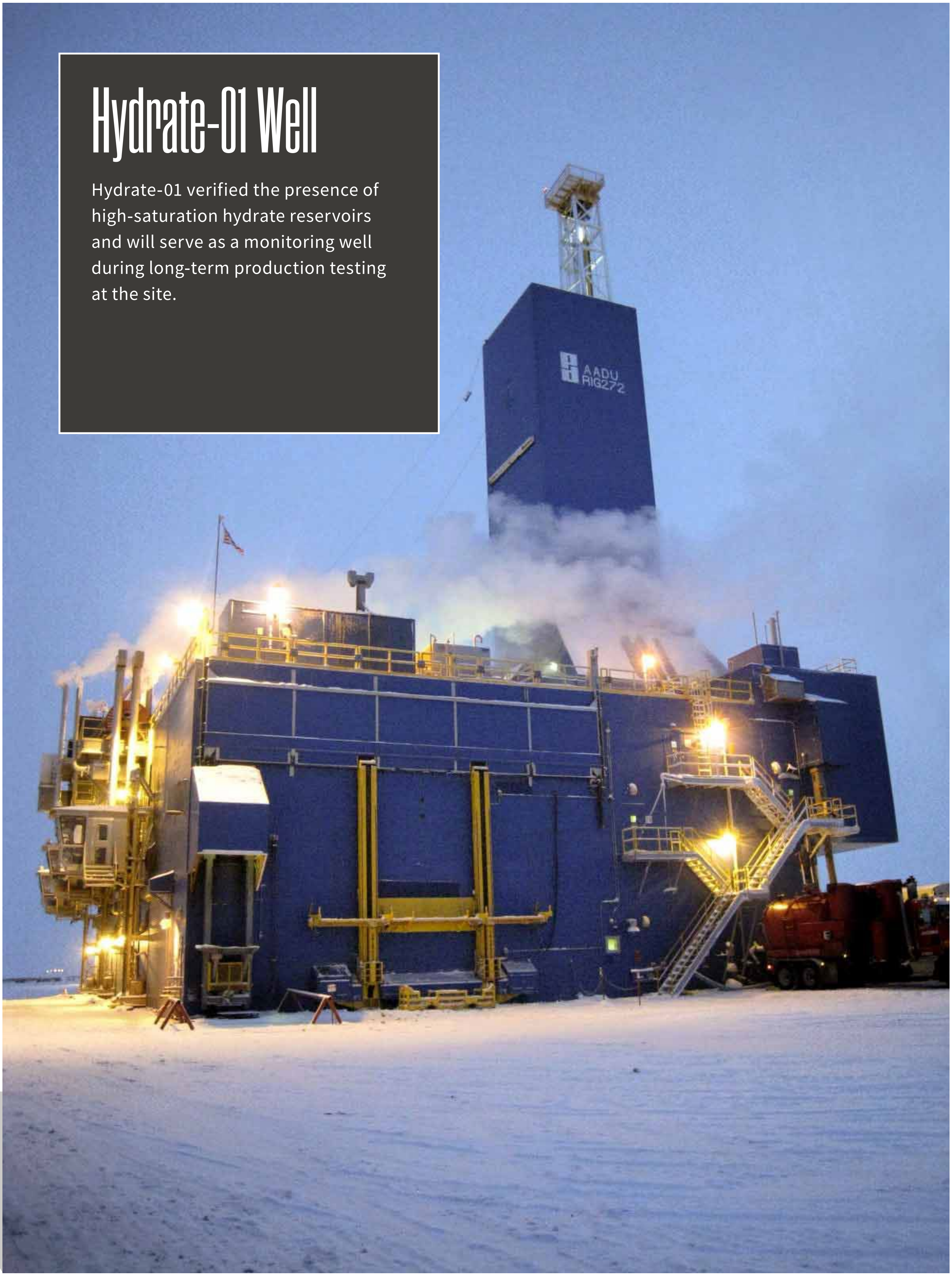
FURTHER READING

Boswell, R., Marsteller, S., Okinaka, N., Wakatsuki, M., Collett, T., Hunter, R., Walsh, T., Minge, D., Itter, D., and Crumley, S., 2019. Viable long-term gas hydrate testing site confirmed on the Alaska North Slope. Fire in the Ice, v. 19 (1), pp. 1-5.

This page: schematic diagram of the bottom-hole assembly, including Logging-While-Drilling and Measurement-While-Drilling tools used to drill and evaluate the main reservoir section in the Hydrate-01 well. Facing page: the Parker 272 rig on location at the Hydrate-01 well site, Prudhoe Bay Unit, December 2018.

Hydrate-01 Well

Hydrate-01 verified the presence of high-saturation hydrate reservoirs and will serve as a monitoring well during long-term production testing at the site.



Methane Hydrate Fellowship Program

In 2007, NETL and the National Academies of Sciences, Engineering, and Medicine (NAS), launched a highly successful research fellowship program designed to support highly qualified graduate and post-graduate researchers in methane hydrate science. Fellowship scientists are selected through a competitive process, and successful recipients are provided 2-3 years of funding to conduct laboratory and field research under the direction of a faculty mentor or research advisor at a university or other research institution. The idea is to support research scientists at an early stage of their careers and, by doing so, to help attract highly qualified individuals to pursue careers in methane hydrate research.

NAS/NETL hydrate fellowships have been granted to 11 scientists, since the first one was awarded in 2007. Scientists supported through this program include:

Monica Heintz, 2007-2010, UC Santa Barbara, for her research on “Biological Control of the Flux of Methane from Marine Hydrates to the Atmosphere.”

Evan Solomon, 2008-2009, UC San Diego SCRIPPS, for his study “Constraining Rates of Biogeochemical Reactions and Methane Generation Offshore India: Implications for Fluid and Gas Sources, Transport Processes, and Gas Hydrate Formation.”

Laura Lapham, 2008-2010, Florida State University, for work on “Controls on Hydrate Stability in Methane Depleted Sediments: Laboratory and Field Measurements.”

Hugh Daigle, 2009-2010, Rice University, for his work on “Heterogeneous Hydrate Accumulations: Influence of Pore- and Fracture-Scale Processes.”

Ann Cook-Yockey, 2010-2011, Columbia University, Lamont Doherty Earth Observatory, for her work “Investigating Gulf of Mexico gas Hydrate reservoirs Using LWD Images and Logs.”

Laura Brothers, 2010-2012, USGS Woods Hole Sciences Center, “Arctic Continental Shelf Response to Global Climate Change: A Geophysical Study of Permafrost Degradation and Potential Hydrate Dissociation in Nearshore Beaufort Sea.”

Rachel Wilson, 2012-2014, Florida State University, for her work “Factors Influencing Hydrate Dissolution Rates within the Hydrate Stability Zone: Interaction with Sand Substrates and Surface Armoring.”

Jeffrey Marlow, 2013-2015, California Institute of Technology, for his work on “Geobiological Controls on the Abundance and Stability of Methane Hydrates.”

Jennifer Frederick, 2014-2016, UC Berkeley and Desert Research Institute, for her work on “Pore Fluid and Gas Migration Patterns Within Arctic Shelf Sediments Associated with Degrading Relict Gas Hydrate and Submarine Permafrost.”

Benjamin Phrampus, 2016-2018, Oregon State University, for his work “Analysis of Cascadia Margin Hydrate Destabilization in Response to Contemporary Ocean Temperature Warming.”

Claire McKinley, 2019-2021, University of Washington, for her research ”Evaluating the extent of Microbial Fe-Reduction and its Role in the Global Methane Cycle.”

The fellowship program has been highly successful, resulting in significant research outcomes. Fellowship recipients have typically presented their research results at international meetings and published their findings in refereed technical journals. A substantial number of fellowship recipients have gone on to become faculty or research mentors themselves at highly regarded universities and research institutions.

FIRE in the ICE

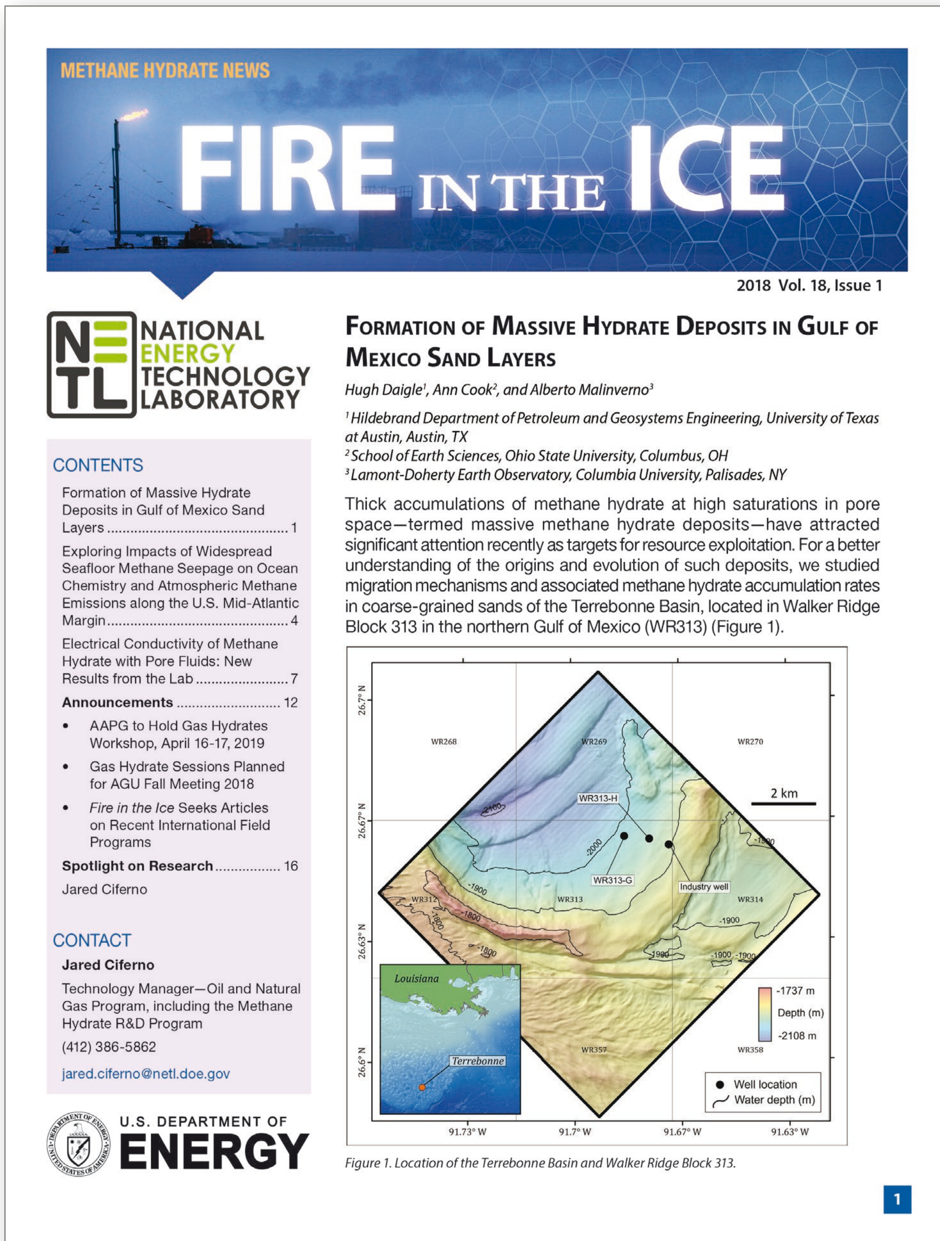
Methane Hydrate Newsletter

In 2001, NETL created "Fire in the Ice," the methane hydrate newsletter that serves the entire international community. The newsletter provides timely articles and announcements on recent developments and newsworthy events in the world of methane hydrate R&D. This highly regarded newsletter now reaches approximately 1600 scientists, engineers, and other individuals interested in methane hydrate science and technology development.

The intent of the newsletter is to promote the exchange of information among those involved in research and development and/or policy decisions related to gas hydrates—as a resource, as a future production challenge, and as a factor in the global environment.

The subscribers are a highly international group, representing 20 different countries, including New Zealand, India, Japan, Korea, Mexico, China, Norway, Sweden, Germany, Canada, and others.

Fire in the Ice has become an effective medium for publicizing field program results, research news, funding opportunities, meetings, and other events of interest to the methane hydrate R&D community.



METHANE HYDRATE NEWS

FIRE IN THE ICE

2018 Vol. 18, Issue 1

NATIONAL ENERGY TECHNOLOGY LABORATORY

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Jared Ciferno

CONTACT

Jared Ciferno

Technology Manager—Oil and Natural Gas Program, including the Methane Hydrate R&D Program

(412) 386-5862

jared.ciferno@netl.doe.gov

U.S. DEPARTMENT OF ENERGY

FORMATION OF MASSIVE HYDRATE DEPOSITS IN GULF OF MEXICO SAND LAYERS

Hugh Daigle[1], Ann Cook[2], and Alberto Malinverno[3]

[1] Hildebrand Department of Petroleum and Geosystems Engineering, University of Texas at Austin, Austin, TX
[2] School of Earth Sciences, Ohio State University, Columbus, OH
[3] Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY

Thick accumulations of methane hydrate at high saturations in pore space—termed massive methane hydrate deposits—have attracted significant attention recently as targets for resource exploitation. For a better understanding of the origins and evolution of such deposits, we studied migration mechanisms and associated methane hydrate accumulation rates in coarse-grained sands of the Terrebonne Basin, located in Walker Ridge Block 313 in the northern Gulf of Mexico (WR313) (Figure 1).

Figure 1. Location of the Terrebonne Basin and Walker Ridge Block 313.

1

Mount Elbert gas hydrate stratigraphic test well on the North Slope of Alaska.
Photo credit: Mount Elbert Scientific Research Team, USGS.

NATIONAL ENERGY TECHNOLOGY LABORATORY

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

Program staff are also located in **Houston, TX** and **Anchorage, AK**.

Visit us: www.NETL.DOE.gov

@NationalEnergyTechnologyLaboratory

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