METHANE HYDRATE NEWS

FIRE IN THE ICE

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NATIONAL ENERGY TECHNOLOGY LABORATORY

CONTENTS

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U.S. DEPARTMENT OF ENERGY

Viable Long-Term Gas Hydrate Testing Site Confirmed on the Alaska North Slope

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In December 2018, data acquired in a Stratigraphic Test Well drilled from the 7-11-12 pad in the western part of the Prudhoe Bay Unit (PBU), Alaska North Slope confirmed the occurrence of two high-quality reservoirs fully saturated with gas hydrate. The drilling was the initial phase of a three-well program designed to conduct an extended duration test of the response of gas hydrate reservoirs to controlled depressurization.

The Stratigraphic Test Well (formally "PBU Hydrate-01") was operated by PBU Operator BP Exploration, Alaska, Inc. (BPXA) using the Parker 272 rig (Figure 1) via a Drilling Services Agreement executed with Petrotechnical Resources of Alaska (PRA) in association with a contract

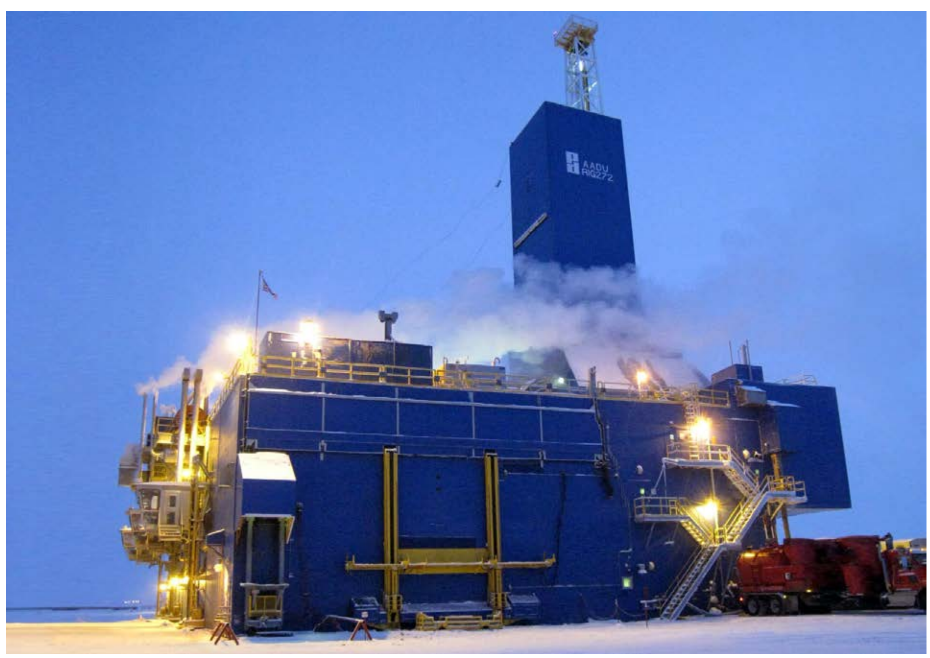

Figure 1. The Parker 272 rig on location at the 7-11-12 site, Prudhoe Bay Unit, December 2018.

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Interested in contributing an article to *Fire in the Ice*?

This methane hydrate newsletter now reaches 1600 individuals, representing 20 countries. If you would like to submit an article on research results likely to be of interest to the methane hydrate R&D community, please contact Fran Toro at frances.toro@netl.doe.gov or Karl Lang at klang@keylogic.com. We look forward to hearing from you.

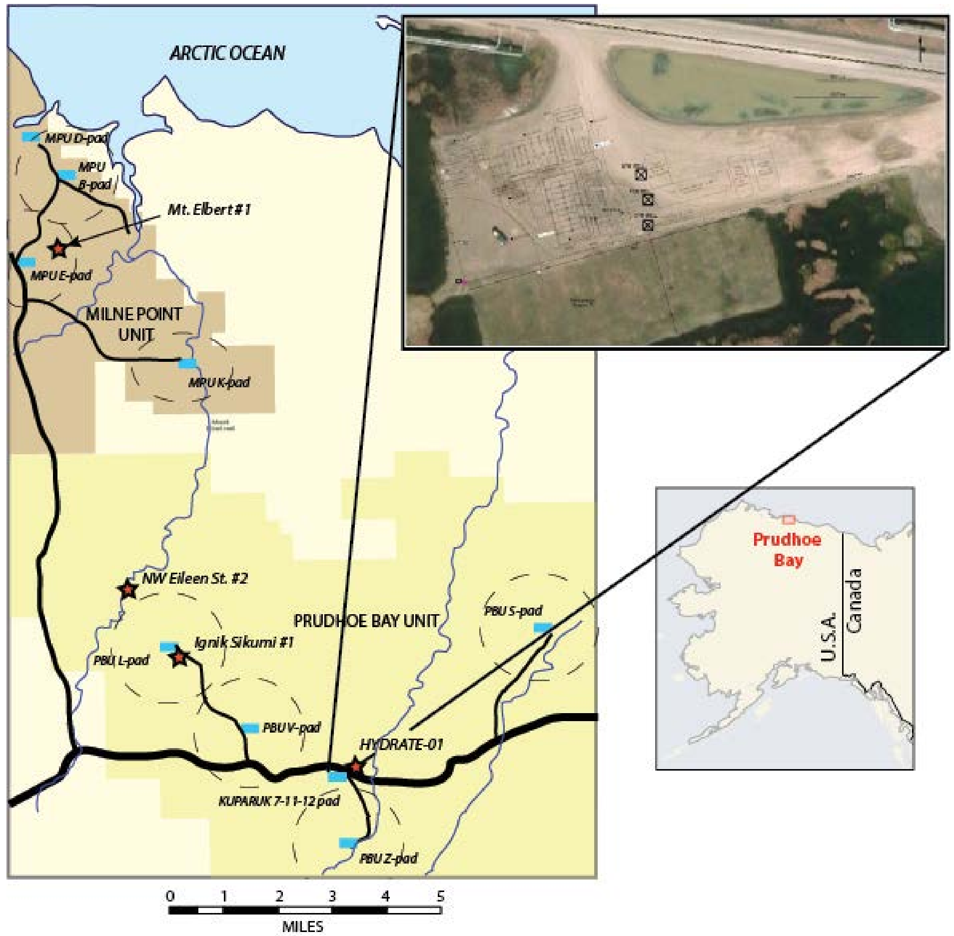
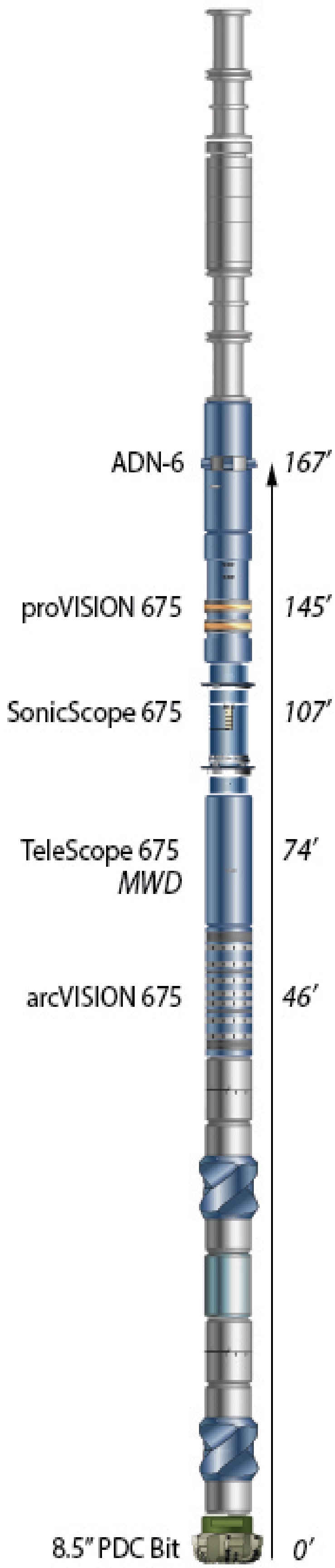


Figure 2. Location of the 7-11-12 pad in the Prudhoe Bay Unit, Alaska North Slope. Top inset shows the gravel pad adjacent and just south of the PBU Spine Road and includes preliminary design of a 3-well program and surface facility. Other important gas hydrate wells are denoted by red stars.

between NETL and PRA. The science program executed by BPXA was developed over a two-year period through extensive discussions and scientific evaluation undertaken by NETL, the Japan Oil, Gas and Metals National Corporation/Research Consortium for Methane Hydrate Resources in Japan (JOGMEC/MH21), the U.S. Geological Survey (USGS), and PRA. The effort also benefitted greatly from the support of the Alaska Department of Natural Resources (ADNR) and the PBU Working Interest Owners (WIOs).

Location

To be a viable site for long-term production testing within the PBU, a location was needed that provided strong evidence of high-quality gas hydrate-bearing reservoirs that could be accessed from an existing, but not currently operating, gravel pad located along existing roads. These criteria eliminated all the active production pads on the North Slope, which are also the locations with the most extensive well data. Initial seismic scoping studies conducted by ADNR and the USGS throughout the primary "Eileen" gas hydrate trend identified the PBU 7-11-12 pad as the most promising site (Figure 2). This location included an existing gravel pad and two abandoned exploration wells that had been drilled prior to



1985. Data from these wells suggested the presence of gas hydrate in two zones, referred to by the USGS as Unit D and Unit B, but the data were of limited quality. To further constrain geologic risk at the site, the WIOs agreed to a limited seismic data license, which enabled detailed review of existing 3D seismic data by PRA and the project partners. The work confirmed the site as promising and an optimal bottom hole location was selected roughly 700-feet east of the pad. This location targeted the structurally highest and least geologically complex location within the inferred hydrate occurrence and also sufficiently offset the well trajectories of the pre-existing wellbores. However, the occurrence of gas hydrate in suitable condition for testing had not yet been confirmed; therefore, the project owners agreed to drill an initial stratigraphic test well to confirm the viability of this site for a potential future long-term production test.

Field Operations

Drilling plans advanced in early 2018 when BPXA proposed a synergy between PBU and DOE/JOGMEC interests in which the gas hydrate stratigraphic test well could be drilled as part of the rig "warm-up" activities, prior to the onset of the PBU 2019 drilling program. Ultimately, Hydrate-01 was spud by BPXA on December 10, 2018 and drilled as a deviated well to the planned target. Downhole data acquisition was completed on Christmas Day, and the rig moved off location on New Year's Day.

The primary well data featured a suite of Schlumberger logging-while-drilling (LWD) tools (Figure 3). Due to careful control of drilling rates, the use of M-I Swaco's oil-based mud, and the careful attention to maintain cold mud temperatures using DrillCool mud chillers, the main portion of the well was in very good condition and provided outstanding LWD data. To gather grain size and other data needed to inform the design of the production test well, sidewall pressure cores were collected using Halliburton's CoreVault™ tool (Figure 4). Those samples are currently undergoing evaluation at the Weatherford lab in Colorado for sedimentology and lithostratigraphy properties, and at AIST labs in Sapporo Japan for hydrate petrophysical and crystallography properties.

The Reservoirs

The LWD data confirmed the occurrence of highly-saturated gas hydrate-bearing reservoirs within both Unit B and Unit D. The deeper Unit B is well-sorted, very fine-grained sand to coarse silt. Gas hydrate saturation ranges from 65% to more than 80% in the upper 40-feet of the unit. The base of the unit grades uniformly into non-reservoir facies. Unit B occurs near the base of the gas hydrate stability zone at a temperature of at least 50°F and contains no free-water leg at the well location and is therefore very well suited for scientific production testing.

Figure 3. Bottom-hole assembly, including Schlumberger Logging-While-Drilling and Measurement-While-Drilling tools, used to drill and evaluate the main reservoir section in the Hydrate-01 well.

The shallower Unit D is also an outstanding reservoir with thickness and saturation similar to that of Unit B. Occurring at 40°F and with a water-bearing section at its base, Unit D-sand could provide opportunities to investigate additional scientific and well design issues as a potential follow-on to testing in the B-unit.

Completion as a Monitoring Well

In addition to confirming the site, the Hydrate-01 well is intended to serve as a monitoring well during future field operations. Therefore, two sets of fiber-optic cables, each including bundled Distributed Acoustic and Distributed Temperature sensors (DAS and DTS), were strapped to the outside of the well casing (Figure 4) and cemented in place. Careful design and placement of specially-constructed clamps enabled both sets of cables to survive deployment fully functional. In March 2019, the project team partnered with SAExploration to acquire DAS Vertical Seismic Profiling (VSP) data at the location.

Figure 4. Data acquisition activities at the Hydrate-01 well included CoreVault™ side-wall pressure coring (left) and deployment of twin DAS/DTS fiber-optic cables as strapped to the well casing during completion (right).

Next Steps

The project partners will continue the evaluation of the Hydrate-01 well data, the newly-acquired DAS VSP data, and the sidewall core samples to allow the refinement of future plans related to production testing at the site (Figure 5). In addition, the partners will continue to assess the most viable means to implement those plans in coordination with the PBU WIOs and the State of Alaska. The ultimate goal is to partner with an operator for the 7-11-12 site and finalize the design of two additional wells, surface production facilities, and testing procedures to allow the implementation of efficient and safe scientific production testing and monitoring that will address a range of first-order questions regarding the response of gas hydrate-bearing reservoirs to depressurization.

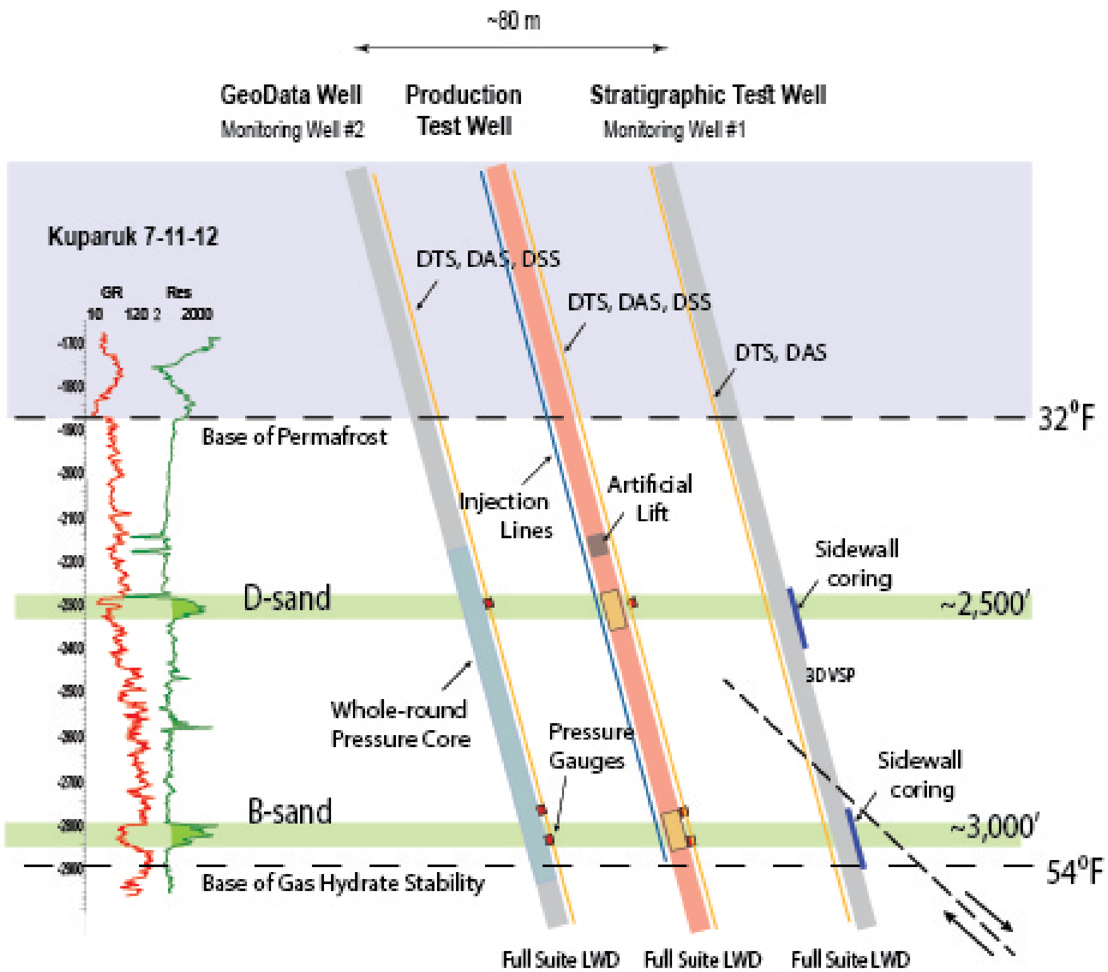


Figure 5. Schematic depiction of the planned design for monitoring and production test wells at the PBU 7-11-12 site.

U.S. Mid-Atlantic Resource Imaging Experiment (MATRIX) Constrains Gas Hydrate Distribution

C. Ruppel[1], N.C. Miller[1], M. Frye[2], W. Baldwin[1], D. Foster[1], W. Shedd[3], and S. Palmes[2]

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[3]Bureau of Ocean Energy Management, New Orleans, LA

The mean estimate for the volume of gas-in-place trapped in methane hydrate on the continental slope of the U.S. Atlantic passive margin is 21,702 trillion cubic feet (~6.14×10^{14} m^3) according to an assessment by the Bureau of Ocean Energy Management (BOEM). This figure slightly exceeds BOEM's mean estimate for the northern Gulf of Mexico, a world-class hydrocarbon basin where a dense mesh of modern 2D and 3D seismic data and hundreds of borehole well logs constrain the distribution of gas hydrate in sediments. In contrast, few exploration wells have been drilled on the U.S. Atlantic margin, and some parts of the continental slope have not been imaged by seismic surveys in more than 40 years. U.S. marine gas hydrates research is expected to expand from the northern Gulf of Mexico to other geographic areas in the coming years, and modern seismic data will play a critical role in identifying the best locations for further study.

To partially fill the U.S. Atlantic margin seismic data gap, the U.S. Geological Survey (USGS), with additional support from the U.S. Department of Energy and BOEM, completed the Mid-Atlantic Resource Imaging Experiment (MATRIX) over 19 days in August 2018. MATRIX collected more than 2000 line-km of modern multichannel seismic (MCS) data to characterize the distribution of methane hydrates and shallow gas between Hudson Canyon on the north and Cape Hatteras on the south and at water depths from the shelf-break (~100 m) to ~3700 m (Figure 1).

MATRIX MCS data were acquired with two to four airguns (maximum source size 420 in^3) and using tta ~1.2-km-long streamer with 112 to 160 channels. The airguns were powered with four portable diesel compressors installed by the USGS on the R/V *Hugh R. Sharp*, a 146-ft general purpose federal fleet research vessel operated by the University of Delaware. To measure water column and sediment velocities for improved MCS data processing, the USGS deployed 60 expendable sonobuoys at water depths greater than 1000 m, recording seismic signals at offsets as large as 15 km. Water column sonar data (EK80 with 38 kHz transducer) were continuously collected to image active methane plumes in both previously-identified methane seep fields and at locations not yet surveyed for seafloor methane emissions.

The MATRIX data contribute to an understanding of the total petroleum system for gas hydrates on the U.S. Mid-Atlantic margin, imaging (a) free gas beneath hydrate zones; (b) pathways for gas migration into the hydrate stability zone; (c) traps formed by fine-grained sediments, hydrate-bearing sediments, or structural features; and (d) the hydrate reservoir itself. The MATRIX MCS data have vertical resolution of ~15 m near the seafloor and image 1 km (upper slope) to 3 km (>3000 m water depth) beneath the seafloor, capturing more than the full predicted thickness of the hydrate stability zone (maximum several hundred meters) throughout the survey area (Figure 2).

The initial analysis of the MATRIX data reveals strong bottom simulating reflectors (BSRs) that cut across stratigraphy (Figure 3) in the "whale" gas hydrate prospect (location in Figure 1), which straddles the deepwater part of Hudson Canyon. To the south, between Wilmington and Norfolk Canyons, BSRs are more subtle and commonly oriented parallel to stratigraphy and/or discontinuous. The MATRIX data also image the structure and gas plumbing beneath deepwater (>1000 m) methane seeps that lie within the gas hydrate stability zone on the Virginia margin. Once fully interpreted, the MATRIX data should produce a new estimate for the volume of gas hydrate on the U.S. Mid-Atlantic margin. Public release of the seismic data is scheduled for summer 2020.

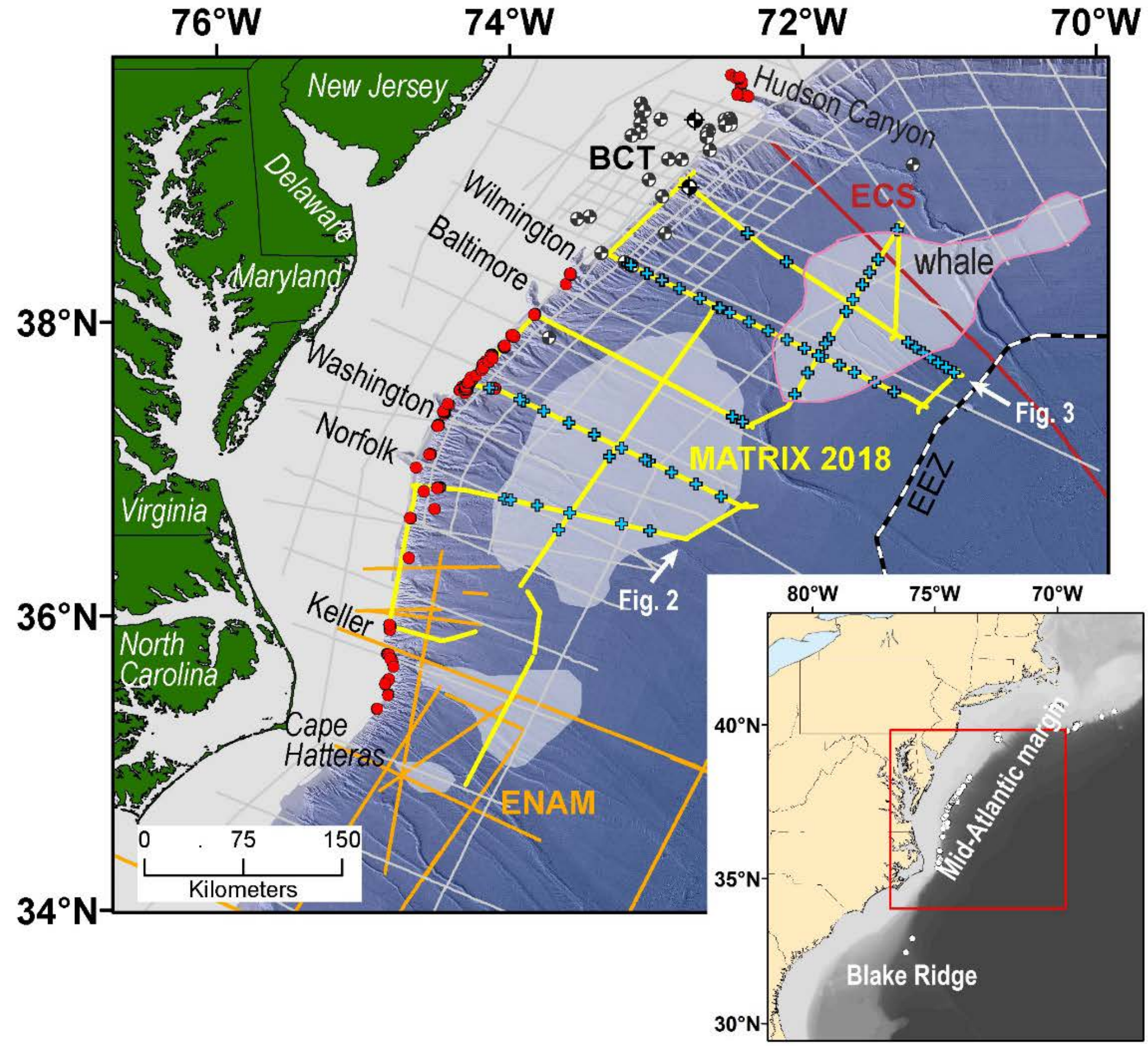

Figure 1. (Inset) Location map for U.S. Mid-Atlantic margin. Open circles indicate locations of seafloor methane seeps as of 2014. (Large map) The MATRIX project acquired MCS data along the yellow lines parallel and perpendicular to the margin. Blue crosses indicate sonobuoy deployments. MATRIX seismic lines fill the gap between the burgundy and orange MCS lines, which were collected by the R/V Langseth using a much larger airgun source for the U.S. Extended Continental Shelf (ECS) and Eastern North American Margin (ENAM) projects, respectively. Gray lines show legacy airgun seismic data collected primarily by the USGS and its collaborators starting in the 1970s. Red circles mark methane seeps known in 2014. The gray-shaded polygons denote areas with BSRs that were mapped by BOEM based on legacy seismic data. The whale feature, which is outlined in pink, is the northernmost of these gas hydrate prospects. Locations of exploratory wells and boreholes are shown in crossed circle pattern, mostly in the vicinity of the Baltimore Canyon Trough (BCT). Names in black on the shelf denote the major shelf-break canyons of this part of the margin. Arrows indicate the lines from which data in Figures 2 and 3 were taken.

Acknowledgments

This research was supported by the USGS Coastal/Marine Hazard and Resources Program, USGS-DOE Interagency agreement DE-FE0023495, and USGS-BOEM Interagency Agreement M17PG00041. We thank University of Delaware Marine Operations for its professionalism in supporting this project, Scripps Institute of Oceanography and Lamont-Doherty Earth Observatory for equipment loans that were facilitated by the U.S. National Science Foundation, and USGS staff in Woods Hole and Santa Cruz for technical, operational, and data processing expertise. RPS, Inc. supplied protected species visual observers, and the National Marine Fisheries Service and U.S. Fish and Wildlife Service assisted with marine mammal/endangered species permitting.

SUGGESTED READING

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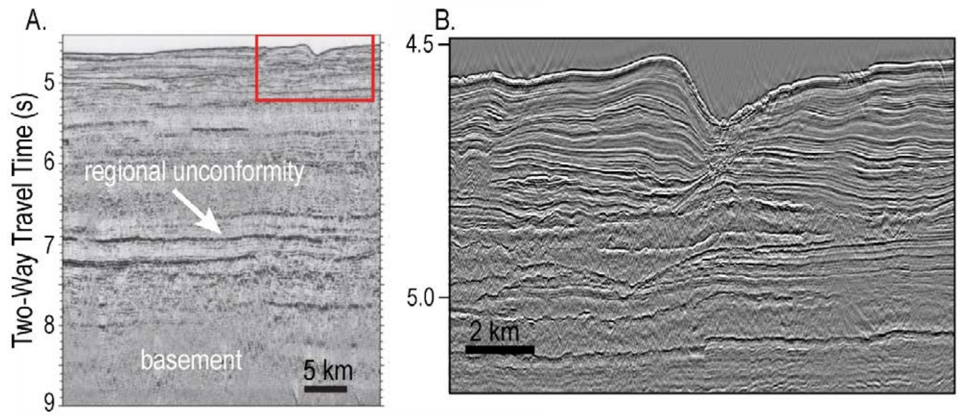

Figure 2. Sample of MATRIX multichannel seismic data along a strike line, highlighting the (A) penetration and (B) resolution obtained. In (A), the 420 in³ airgun source imaged up to 3.25 km beneath the seafloor. The reflector at ~7 s is the regional North Atlantic Au unconformity, and the data also image acoustic basement. The red box indicates the data subset shown in (B). Location of data is shown in Figure 1.

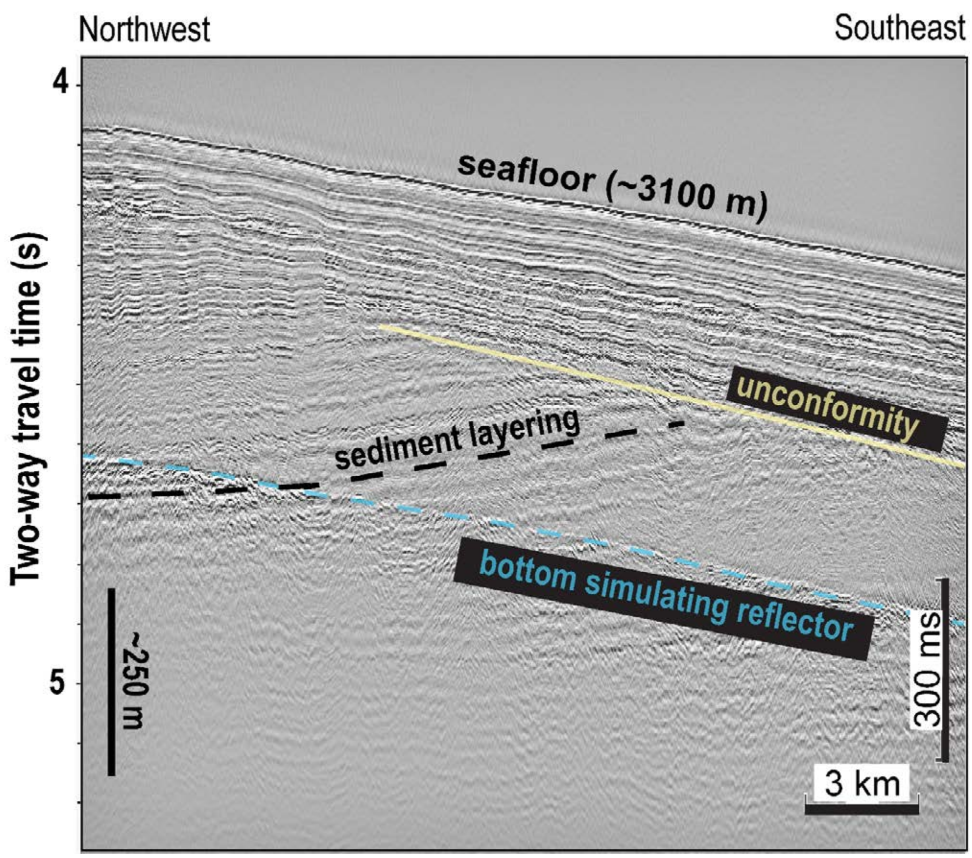

Figure 3. Example of a bottom simulating reflector and relationships to stratigraphy imaged by MATRIX in the whale gas hydrate prospect, whose location is shown in Figure 1. The seismic line from which these data were taken is also shown in Figure 1.

The Second Offshore Production Test of Methane Hydrates in the Eastern Nankai Trough and Site Characterization Efforts

Koji Yamamoto[1], Kiyofumi Suzuki[1], Xiaoxing Wang[1], Tatsuya Matsunaga[1], Itoyuki Nishioka[1], Yoshihiro Nakatsuka[1], Jun Yoneda[2]

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[2]National Institute of Advanced Industrial Science and Technology (AIST)

Four years after the world's first gas production attempt from offshore gas hydrate deposits (2013; *Fire in the Ice*, Vol. 13, Issue 2), a second test was conducted at an adjacent location in the eastern Nankai Trough (2017). The objective of the second test was to achieve longer-term production duration and overcome technical challenges revealed in the first production test. Stable depressurization over a period of several weeks was needed to obtain reservoir response data for evaluating long-term behavior of gas hydrate dissociation and gas production. The second production test was conducted in May and June of 2017, in combination with intensive site characterization efforts and data acquisition programs.

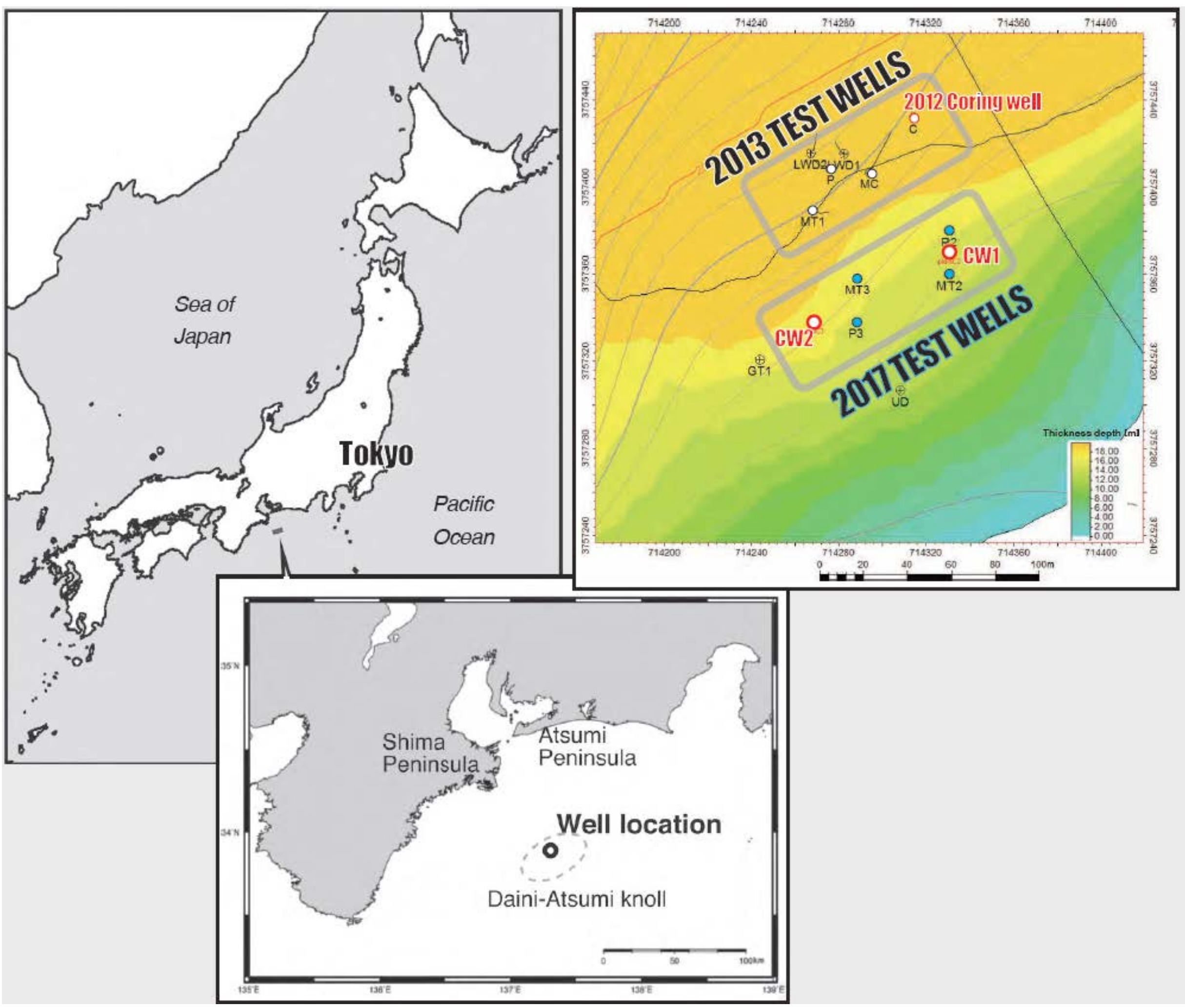


Figure 1. Test well locations for 2013 and 2017 offshore production testing in the eastern Nankai Trough. The wells are located on the northwest slope of the Daini-Atsumi knoll. The sand-dominated turbidite sequence contains high concentrations of gas hydrates, primarily pore-filling and load-bearing morphology type.

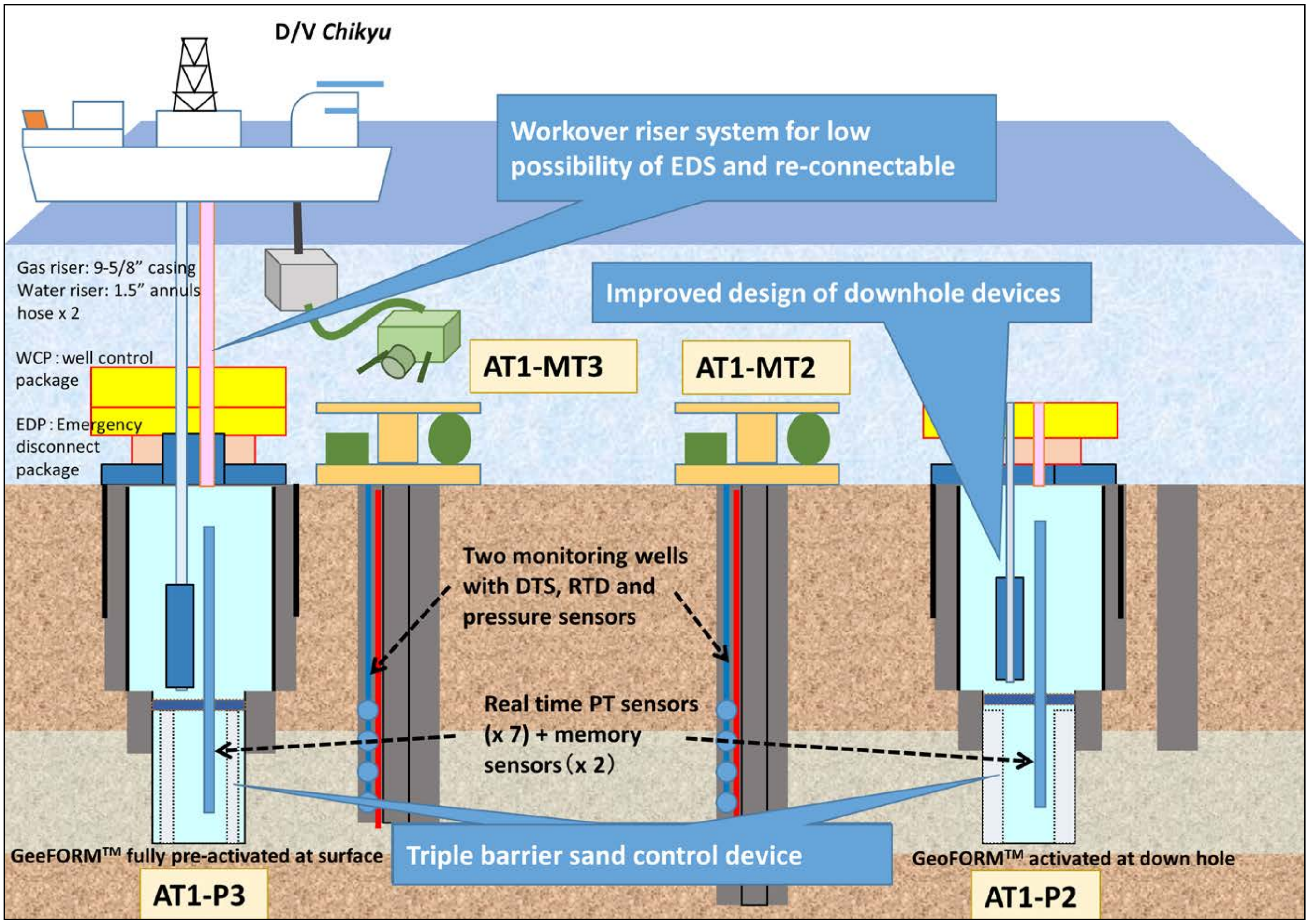


Figure 2. Well and completion schematic of the 2017 test, including two producing wells (AT1-P2 and AT1-P3) and two monitoring wells (AT1-MT2 and AT1-MT3).

Technologies for the Second Offshore Production Test

During the 2013 production test, we encountered several technical issues which interfered with the stable flow of gas from the reservoir to the surface. Prior to the 2017 test, efforts were made to rectify these issues.

To improve downhole gas/liquid separation, the geometry and arrangement of the well casing and downhole devices were redesigned. To minimize the chance of an emergency disconnect due to rough sea conditions, a workover riser system was employed to extend the operational limits of the drillship; the workover riser system also allows quick and safe disconnect and reconnect of the riser with electrical power and sensor cables.

Finally, the sand production that ultimately terminated gas flow during the first production test was addressed by installing a triple barrier sand control device with a shape memory polymer (GeoFORM™†), mesh screen, and metal bead insert. Two producer wells were drilled to install two different expansion processes of GeoFORM™.

Flow Test Operations

Well locations are shown in Figure 1, and the well placement and completion plan for the four dedicated boreholes is shown in Figure 2. The locations of the holes were selected to optimize data acquisition. Two monitoring boreholes (AT1-MT2 and AT1-MT3) were drilled one year prior to the flow test (May to June, 2016) for long-term pressure and temperature (PT) sensing.

After drilling the producing wells and installing necessary downhole devices, including PT sensors, a gas flow test was conducted in each well sequentially. In the first well (AT1-P3), stable depressurization was achieved for a period of twelve days. Intermittent sand production did occur, and operations were finally terminated in order to protect downhole devices.

After diagnosing the cause of the sand trouble, supplemental sand management measures were implemented. The flow test in the second well (AT1-P2) was initiated and continued for twenty-four days, with a short interruption during a planned disconnect due to rough weather. The operation record is shown in Table 1 and Figure 3.

Along with gas and water flow rates, downhole PT data were collected in the producing and monitoring boreholes, including two years of PT data in the monitoring holes (Figure 4) to track the temporal and spatial advance of the hydrate dissociation region.

Pressure Core Sampling with a New Tool

One year after the flow test, the plug and abandon operation of all wells and supplemental data acquisition including drilling of two new boreholes were conducted. From those new wells, pressure cores were recovered using an updated version of the pressure corer (HPTC-III). Location of one of the new holes (AT1-CW1) was chosen where the influence of the flow test was predicted to be minimal (20m west of AT1-P3) and the other hole (AT1-CW1) was drilled between AT1-P2 and AT1-MT2 to evaluate property changes of the flow test.

After coring operations were completed, wireline logging tools were run in the holes. The coring operations resulted in record-breaking success with high recovery rates and nearly perfect pressure conservation (Table 2). The recovered samples were transferred to the PCATS™‡ tool, and they were cut and scanned.

A detailed cut and analysis plan was established, based on X-Ray images of the core. Analyses and on-board testing were performed in the PNATs system (Figure 5), which was developed by AIST. Pressure cores, 25m total, were stored in pressurized storage chambers for further onshore laboratory analysis. Others were cryo-frozen under pressure or analyzed after quantitative degassing.

Conclusions and Next Steps

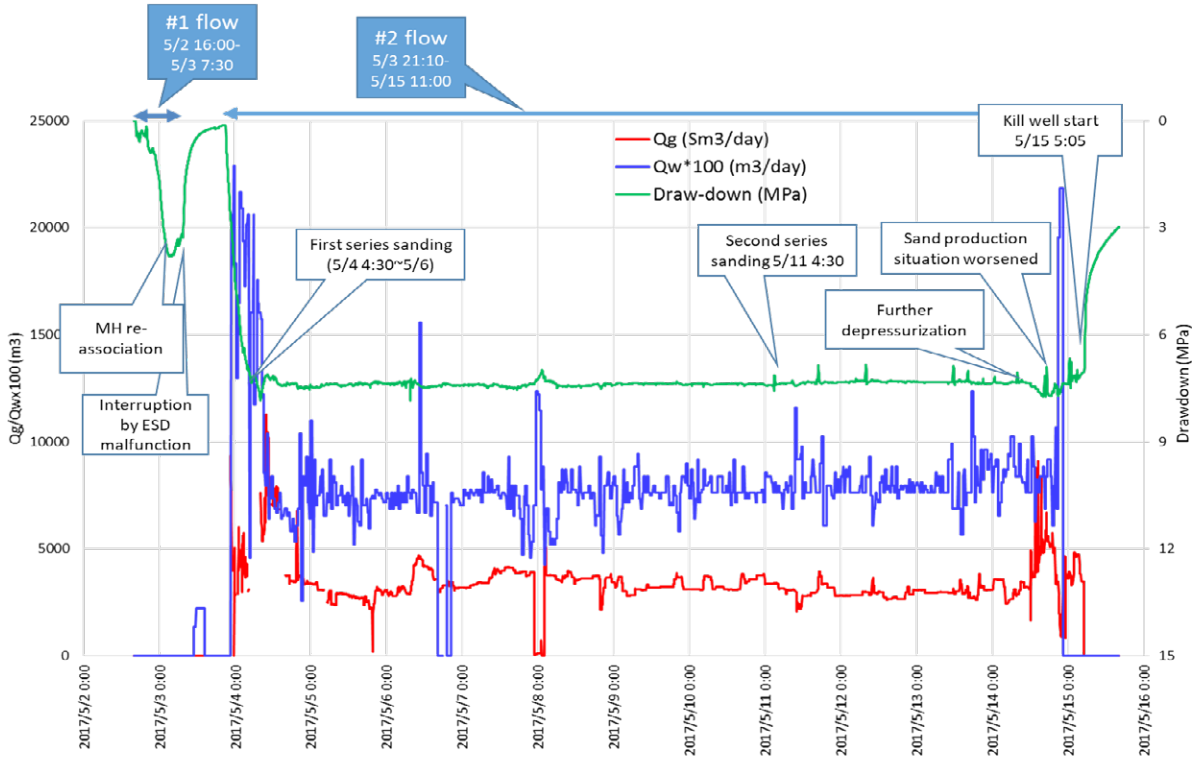
This three-year drilling and testing program in the eastern Nankai Trough succeeded in delivering comprehensive data on the geology, petrophysics, and reservoir response to depressurization of a methane hydrate reservoir. Measures taken to solve technical issues encountered in the 2013 test worked fairly well and allowed several weeks of stable gas flow in the 2017 test. Some new issues were revealed, however, including some discrepancy between observed and predicted production behaviors. An increasing trend in gas flow rates under constant pressure was expected but not observed. The acquired data are being analyzed in detail, for reservoir characterization and an improved understanding of processes and mechanisms of gas production from marine hydrate deposits.

Acknowledgments

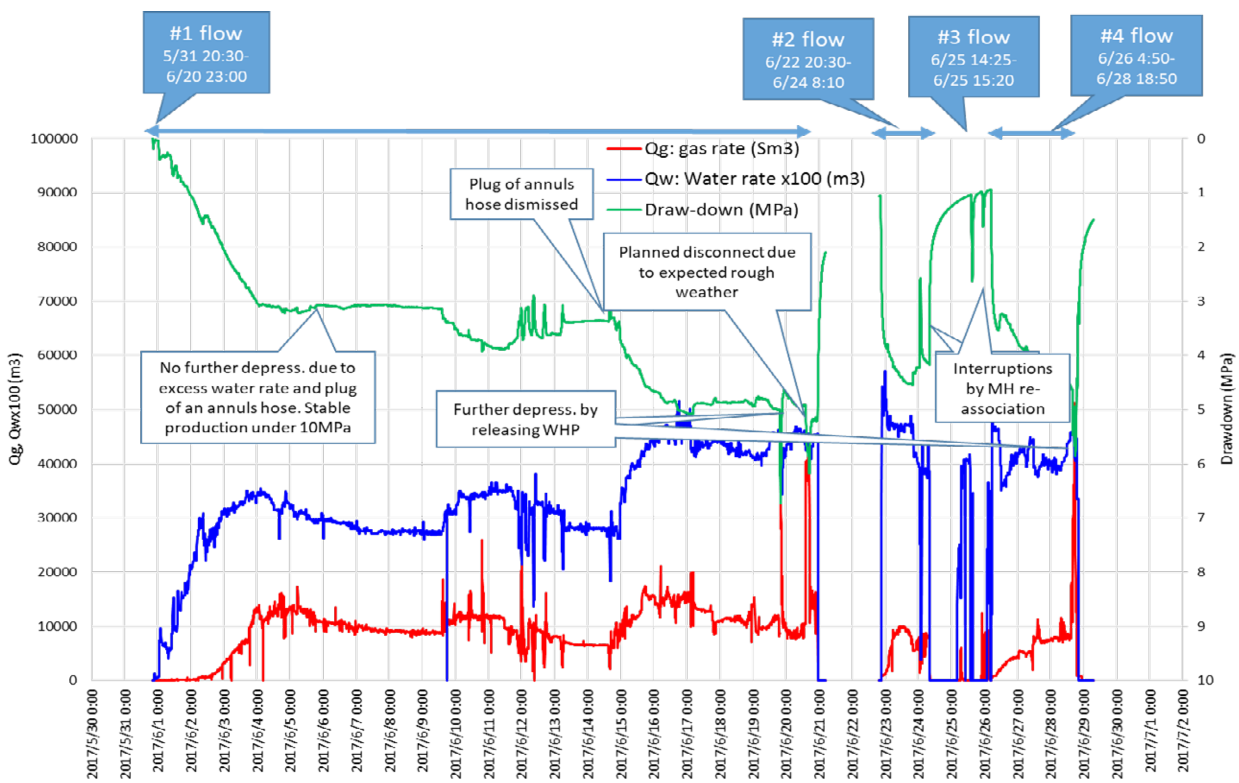
The second offshore test was a part of the MH21 research program funded by the Ministry of Economy, Trade and Industry. The operations were conducted by Japan Methane Hydrate Operating Co. Ltd. and D/V *Chikyu* crews. The authors acknowledge the assistance of all people involved.

†Baker Hughes, A GE Company

‡GEOTEK Ltd.



a) AT1-P3 well



b) AT1-P2 well

Figure 3. Production histories and major events during the operation of the AT1-P3 and AT1-P2 wells.

	AT1-P3	AT1-P2
Test duration*	16:00 May 2, 2017 to 11:00 May 15, 2017 #1 flow 5/2 16:00-5/3 7:30 (0d15h30m) (Interruption by ESD failure activation) #2 flow 5/3 21:10-5/15 11:00 (11d13h50m) Total flow duration: 12d5h20m	20:30 May 31, 2017 to 18:50 June 28, 2017 #1 flow 5/31 20:30-6/20 23:00 (20d2h30m) (Planned disconnect) #2 flow 6/22 20:30-6/24 8:10 (1d11h40m) (Work on flow assurance issue) #3 flow 6/25 14:25-6/25 15:20 (0d0h55m) (Work on flow assurance issue) #4 flow 6/26 4:50-6/28 18:50 (2d14h0m) Total flow duration: 24d4h5m5m
Level of drawdown	7.85MPa (13.0MPa – 5.15MPa)	Instantaneous: 6.73MPa (13.0MPa – 6.27MPa) Stable: 5MPa (13.0MPa – 8MPa)
Cumulative production volume	Gas: 40,849.9Sm^3 Water: 922.5m^3	Gas: 222,587.1 Sm^3 Water: 8246.9m^3
Events	Sand detected during #1 5/4 4:30~5/6 6:00, and #2 5/11 5:00~5/15 5:00.	No sand production Planned disconnect and reconnect 6/21 6:15-6/22 11:30

Table 1. Summary of the production test in 2017 **Time is in JST (UTC+9 hours)*

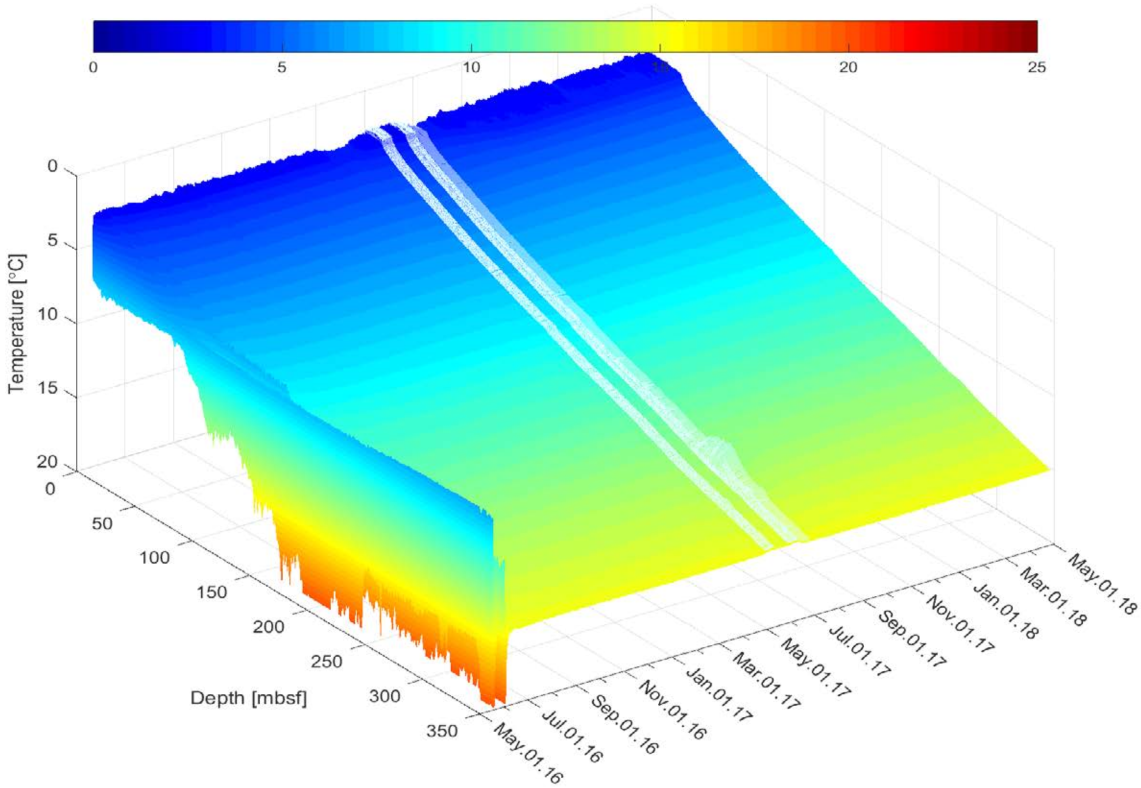


Figure 4. Two years of temperature data obtained in AT1-MT2 well by DTS that could monitor the effect of cementing, base-line temperature, influences of fluid motion and gas hydrate dissociation, and the post-test recovery process. Shaded sections in white correspond to each period of P3 and P2 operations.

Hole	AT1-CW1	AT1-CW2
Date	4/7 - 4/12/2018	3/30 - 4/4/2018
Drilled interval (below rotary table	1,280.0m-1,330.9m and 1,339.8m-1,350.9m	1,286.5m-1,343.7m and 1,356.6m-1,362.7m
Total drilled Interval	61.9m	63.3m
Number of cores	24 (20 + 4)	25 (23 + 2)
Number of successful pressure boost > bottom-hole pressure > PT inside of GH stability	 23 24	 23 25
Total length of cores recovered	46.1m	50.3m
Recovery rate	74.5%	79.1%

Table 2. Summary of pressure core recovery operations and results from 2018.

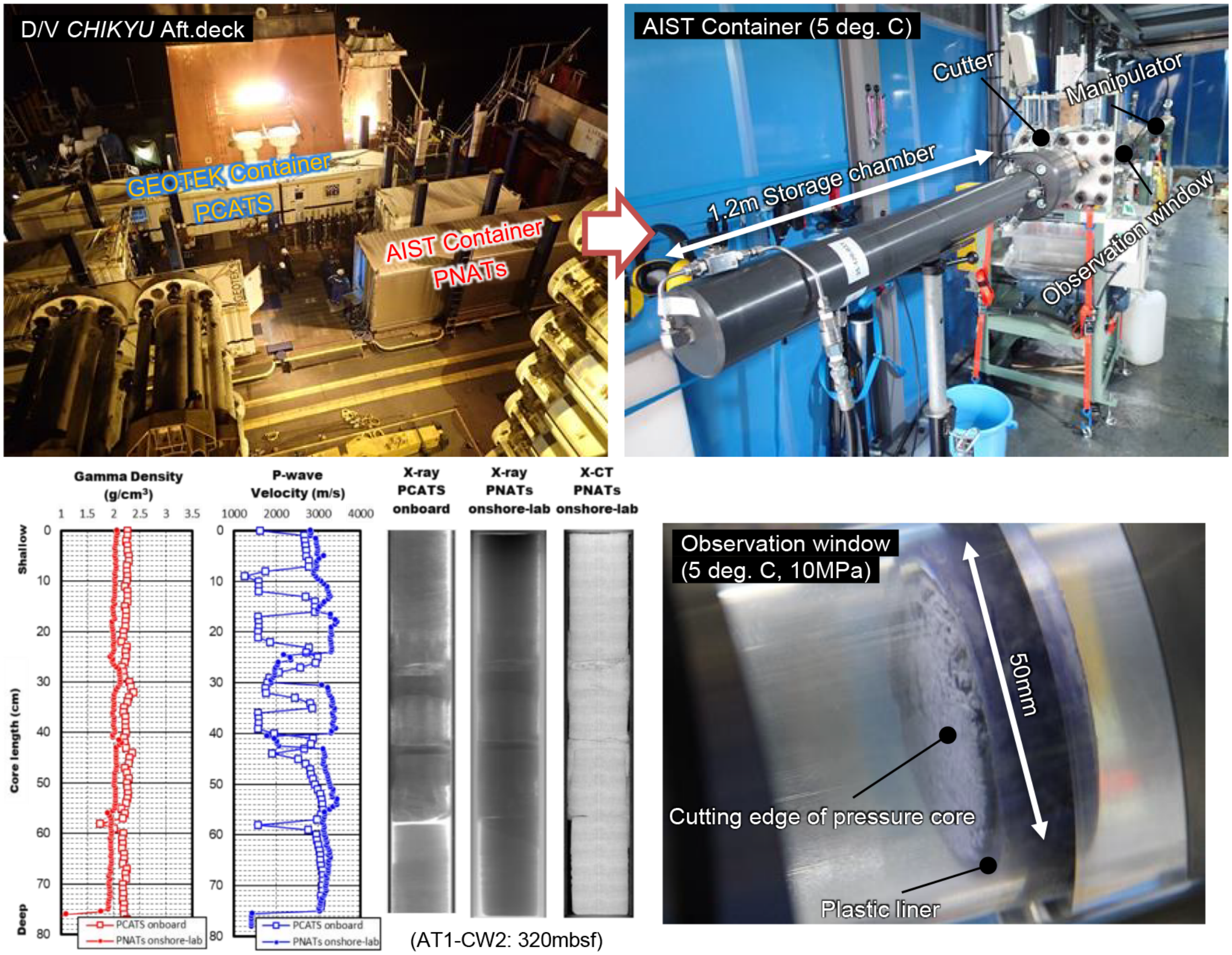


Figure 5. Recovered core samples and PNATs system

Suggested Reading

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Micro-CT Visualization of Hydrate-Bearing Sediments to Aid Integrated Mechanical-Hydraulic-Thermal-Chemical Characterization

Yongkoo Seol and Liang Lei

National Energy Technology Laboratory, U.S. Department of Energy, Morgantown, WV

Computed Tomography (CT) is a non-destructive technique to visualize the inner structure of an object. It seems well-suited to the investigation of the inner structure of gas hydrate-filled sediments, which must be held under high pressure and low temperature to maintain thermodynamic stability. However, CT visualization of methane hydrate samples has been challenging due to difficulties in distinguishing methane hydrate from pore fluid in the CT image. A recent technique developed at NETL overcomes this challenge by adding salts with high atomic number elements as doping agents to the water, and using phase-contrast micro-CT methods to enhance the contrast along the intersecting edges of different materials. Four different phases can be clearly distinguished in the 3D reconstructed CT images: sand particles, brine, methane hydrate, and methane gas.

This new technique enables the pore-scale study of methane hydrate under different geological conditions, and the investigation of the behavior of methane hydrate and its hosting sediment matrix when subjected to environmental changes such as a reduction in pore pressure during gas production. These changes are inherently complicated by coupled mechanical-hydraulic-thermal-chemical processes—for example, pore pressure drop and effective stress increase, temperature response and heat flow, multi-phase flows of fluid and solid, sediment compaction and shear, and pore water dilution with chemistry changes.

To understand the coupled physics behind these integrated processes, NETL has built an integrated system (Figure 1a) that enables the visualization of methane hydrate in sediment pores (Figure 1b) during the laboratory replication of these coupled processes carried out in both synthesized and natural pressure cores. This system enables the independent control of temperature and pressure for influent and effluent pore fluids (deionized water, brine or gas). It also allows for the control of lateral and vertical effective stress, the combination

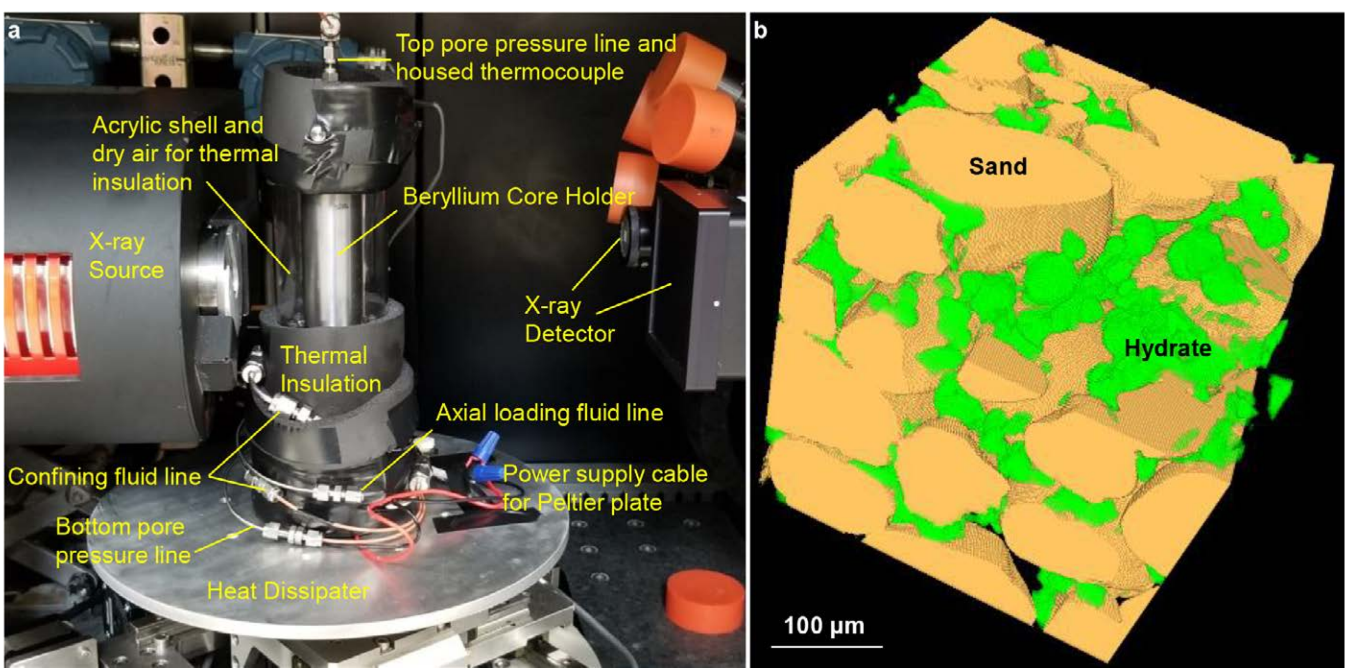

Figure 1. (a) Experimental configuration; and (b) methane hydrate particles in 3D pore space.

of which enables large degrees of freedom for exploring various scenarios of hydrate-bearing sediment evolution.

The system allows NETL researchers to conduct triaxial experiments with hydrate-bearing cores under in-situ pressure and temperature conditions. For example, methane hydrate was formed as an initial test under excess gas conditions with constant lateral effective stress to maintain a stable sediment skeleton, and the resulting hydrate was mainly cementing and grain-coating. Several days after the formation, when the hydrate was assumed to have reached its stable condition, the core was loaded vertically until it failed.

Figure 2 shows the status of a laboratory-synthesized hydrate-bearing specimen before and after a triaxial shear test. By gradually adding axial load, while maintaining constant lateral confining pressure, the specimen can be seen to get shorter and fatter. The specimen bears an increasing load, until it reaches its maximum capacity, known as the specimen strength. Additional loading on the specimen results in decreasing load-bearing capacity with increasing strain or deformation. The specimen forms shear bands (e.g., the area outlined in yellow dashed line in Figure 2a) and collapses. Because the top loading bar does not have a lateral support, it can therefore shift horizontally.

A low-resolution scan provides a general overview of the specimen, while high-resolution scans zoom into the specimen to provide high-fidelity information on the pore-scale behavior of methane hydrate. Figures 2c and 2d are high-resolution scans of the areas corresponding to the red outlined frames in Figures 2a and 2b respectively. The relative location of sand particles A, B, and C clearly show evidence of specimen deformation during the triaxial test. Further 3D analysis reveals the behavior of different sediment components, including hydrate particles and sand grains, with respect to external loading. This behavior includes grain pushing, grain rolling, hydrate detachment and phase changes.

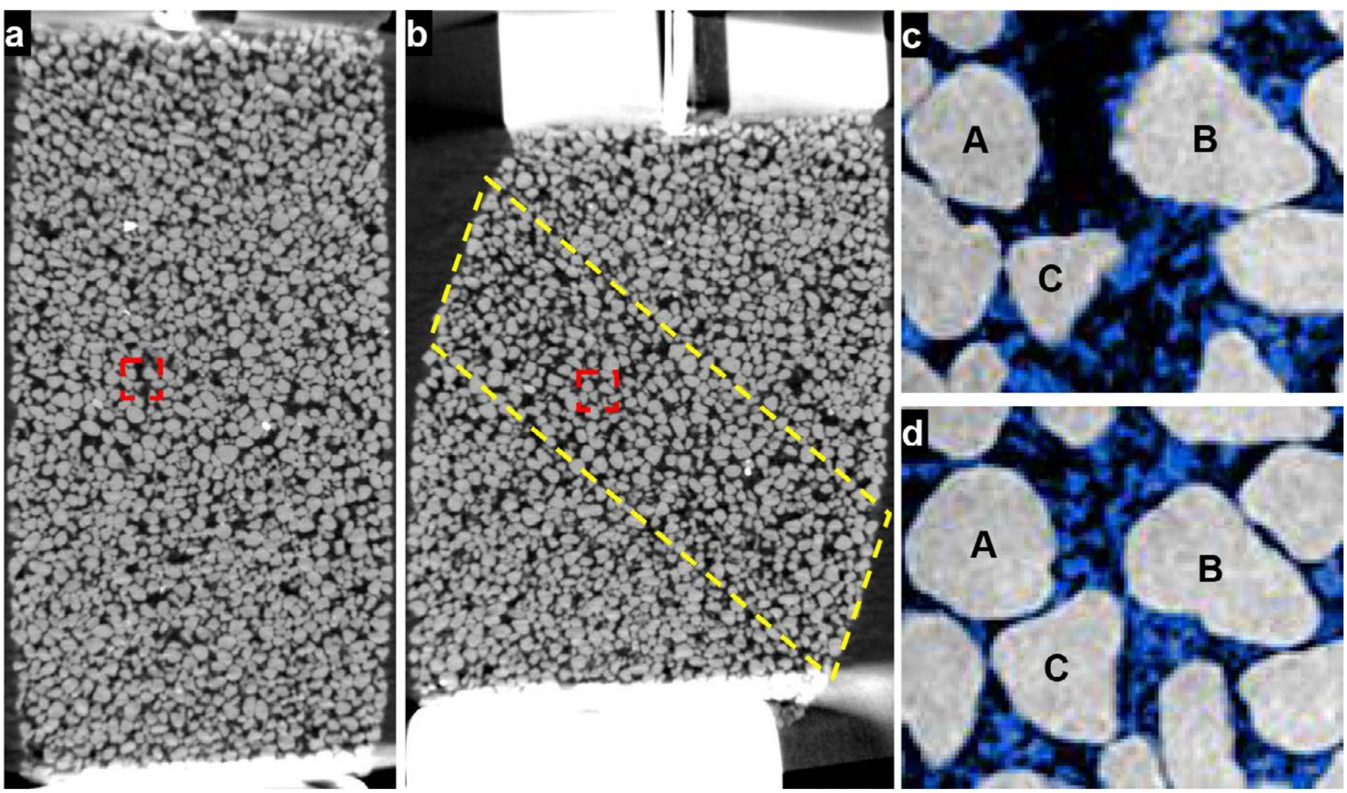

Figure 2. (a) and (b) Vertical cross-sections showing the 3D structure of hydrate-bearing sediments before and after triaxial tests; (c) and (d) are high-resolution views of selected regions of interest corresponding to the red rectangles in (a) and (b), respectively. Note the locations of particles A, B and C before and after the triaxial test. Methane hydrate is shown in blue, methane gas in black, and sand particles in gray.

The NETL hydrate laboratory is currently expanding its capability to handle natural pressure cores. A new tool set has been developed to drill a mini-core from pressure cores of hydrate-bearing sediments retrieved from the Gulf of Mexico and transfer the mini-core to the micro-CT system for further analysis. The results are expected to enhance our understanding of hydrate-bearing sediments formed in the natural environment. The micro-CT system in conjunction with the pressure core handling tool set—together called the Pressure Core Characterization and X-ray CT visualization tool (PCXT)—will be utilized to study hydrate behavior at both core- and pore-scale, and to study linkages between core-scale physical properties and pore-scale observations.

Acknowledgments

The authors would like to thank Jeong-hoon Choi and Karl Jarvis (Leidos Research Support Team) for their help in performing the experiments described in this article. Liang Lei is supported under an Oak Ridge Institute for Science and Education (ORISE) fellowship granted by NETL.

SUGGESTED READING

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CELEBRATING
50 YEARS
1969–2019

OTC 2019 to Host Gas Hydrate Events on Wednesday May 8th

This year's Offshore Technology Conference (OTC 2019) is quickly approaching and is scheduled to host two oral sessions on gas hydrate research, as well as a luncheon on gas hydrate R&D history. All three events will take place on Wednesday, May 8th:

9:30 am – noon Technical Session: New Developments in Gas Hydrate Production

International drilling and coring programs are making significant contributions to our understanding of the energy resource potential of gas hydrates. Results of some of the major international efforts will be presented during this session. Chaired by George Moridis, Lawrence Berkeley National Laboratory and Greg Easson, University of Mississippi.

12:15 pm -1:45 pm Luncheon: Gas Hydrate R&D History as a Guide to the Future

The luncheon session will include a brief history of hydrate science and engineering, followed by a discussion of landmark achievements from major hydrate flow assurance laboratories. The potential for hydrates as an energy resource will be discussed from a historic perspective, and lessons of the past will be summarized as a guide to future innovation. Chaired by Timothy Collett, US Geological Survey; Moderated by Norman Carnahan, Carnahan Corporation; Speaker E. Dendy Sloan, Professor Emeritus, Colorado School of Mines.

2:00 pm - 4:30 pm Technical Session on Advances in Gas Hydrate Production Technology

Because conventional production technologies favor sand-dominated reservoirs, these are considered the most viable economic target for gas hydrate production. Talks in this session will focus on past and future gas hydrate production studies and production technologies. Chaired by Norman Carnahan and Timothy Collett.

For more information on these events and the OTC meeting, please visit the OTC 2019 Technical Program at http://2019.otcnet.org/seminar.

Gordon Research Conference on Gas Hydrate Systems, February 23-28, 2020

Gordon Research Conferences
Frontiers of Science

The 2020 Gordon Research Conference (GRC) will be held in February, 2020 on "Nonequilibrium Controls on the Formation and Dissociation of Gas Hydrates in Natural and Engineered Systems." The conference is intended to bring together academic, government, and industry researchers to discuss gas hydrate formation, evolution, and destruction in natural and engineered systems. The conference program this year will consist of nine sessions:

- Keynote Session: Dynamic Controls on the Formation and Dissociation of Gas Hydrates
- Thermodynamic and Kinetic Properties of Multicomponent Gas Hydrate Systems
- Processes Controlling Multiphase Gas Hydrate Systems in Nature
- Gas Hydrate Related Physical, Chemical and Biological Processes
- Detection and Characterization of Gas Hydrate Systems
- Impact of Gas Hydrate Occurrence and Dissociation on Their Host Environment
- Planetary Ices and Gas Hydrates
- Characterization of Various Types of Gas Hydrate Occurrences and Systems
- Integrated Modeling of Gas Hydrate Systems from Formation to Dissociation

The GRC 2020 will be held at the Hotel Galvez in Galveston, TX. The GRC 2020 chair is Timothy Collett, and the vice chair is Zachary Aman. The preliminary program for the GRC will be available July 1, 2019.

Applications for the meeting must be submitted by January 26, 2020, but early applications are strongly encouraged!

For more information, please visit https://www.grc.org/natural-gas-hydrate-systems-conference/2020/

10TH INTERNATIONAL CONFERENCE ON GAS HYDRATES IN SINGAPORE, JUNE 21-26, 2020

ICGH10
21 - 26 JUNE 2020
SINGAPORE

The Tenth International Conference on Gas Hydrates (ICGH10) will be held in Singapore on June 21-26, 2020 at the Suntec Singapore International Convention and Exhibition Centre. The event is jointly organized by the National University of Singapore, InPrEP Pte Ltd., and AIChE Singapore Local Section.

ICGH10 is intended as an active platform for the international gas hydrates community to review research developments that have occurred over the previous three years, to foster synergistic collaboration and professional networking, and to plan near-term and long-term research objectives. The organizers anticipate topics related to all facets of gas hydrate research, including gas hydrate fundamentals, gas hydrate technologies, gas hydrate exploration and recovery, flow assurance, and environmental impacts.

Additional information and periodic updates are available at www.icgh10.com

Spotlight on Research

ANN COOK

School of Earth Sciences
Ohio State University

Ann Cook describes herself as an observational earth scientist. She is dedicated to understanding subsurface gas hydrate systems through meticulous observation. Whether she is examining a core specimen, a seismic volume, or *in-situ* logs from a borehole, she is determined not to miss a thing. Based on these types of observational data, she builds computational and conceptual models and creates a narrative of what happened to form a particular hydrate accumulation.

Ann recalls learning the importance of careful observation in her high school chemistry class. Sister Harriett, an intimidating chemistry teacher with spiky hair and an ever-inquiring, broken pointer finger, was not happy when Ann and her classmates described their chemistry lab results in an incomplete way. The students had recorded changes in color but had failed to note changes in temperature, in their descriptions of chemical reactions between different compounds. Nearly all the lab reports were given a 'C' grade, because the temperature changes were important, and they had completely missed that!

Ann takes this mistake to heart and continually asks herself: "what am I missing?" As a professor and thesis advisor, she challenges her students to ask the same question in their research projects. When asked what she likes least about her work, Ann says "being patient!" She explains that she has been waiting impatiently to get back to a field site in the Gulf of Mexico since 2009; she is extremely eager to collect core to provide firm ground truth to log data collected 10 years ago.

Would she recommend a career in academia to the next generation of earth scientists? Ann is quick to say, "have a back up plan." She explains that there are few tenure-track positions that become available each year and winning one of those positions includes some luck. She urges students to be prepared to work in industry or environmental consulting, for example, if a suitable research position is not available when they hit the job market.

Ann does not gloss over the time commitment that is required of an academic scientist. She explains that, for her, having a husband who is a stay-at-home dad has helped her juggle her jobs as professor, advisor, principal investigator, collaborator, and mother of two. It has given her the flexibility to travel to conferences, participate in research cruises, and stay late at work when needed.

When not teaching or doing research, Ann enjoys time with her husband and children, whether it is a family breakfast, dinner with neighbors, or a road trip to visit relatives. One of her favorite recent adventures was ziplining at Niagara Falls.

If you or someone you know would like to be the subject of the newsletter's next "Spotlight on Research," please contact Karl Lang (klang@keylogic.com) or Fran Toro (frances.toro@netl.doe.gov). Thank you!