U.S. Department of Energy • Office of Fossil Energy • National Energy Technology Laboratory

# Fire in the Ice

Winter 2007 Methane Hydrate Newsletter

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## CONTACT

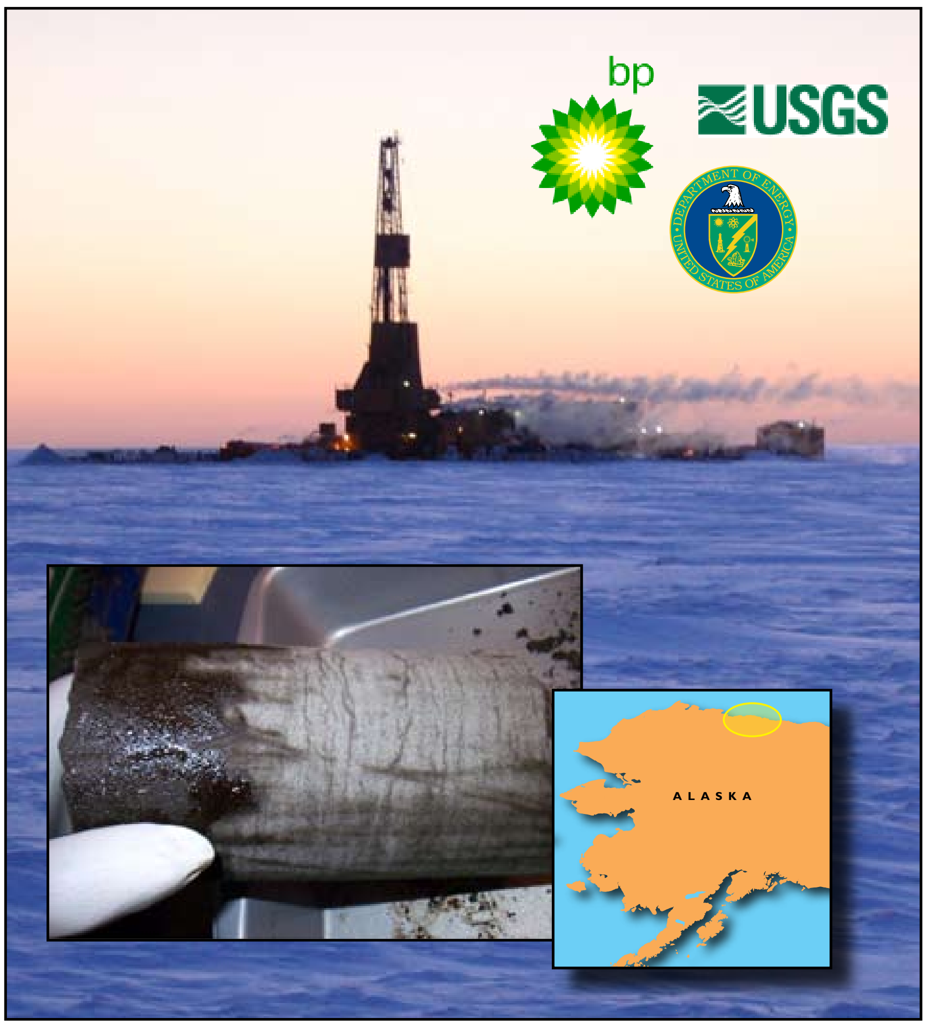
**Ray Boswell**
Technology Manager—Methane Hydrates, Strategic Center for Natural Gas & Oil

304-285-4541
ray.boswell@netl.doe.gov

# Alaska North Slope Well Successfully Cores, Logs, and Tests Gas-Hydrate-Bearing Reservoirs

*By the "Mount Elbert" Science Team*

On February 18, 2007, a team of scientists concluded an extensive data collection program at a gas hydrate stratigraphic test well drilled in the Milne Point area on the Alaska North Slope (ANS). The science program successfully achieved all of its objectives, resulting in the generation of one of the most comprehensive datasets yet compiled on a naturally-occurring gas hydrate accumulation.




*The Doyon 14 rig at Milne Point, February 2007 (insert shows gas-hydrate-bearing core sample).*

## National Energy Technology Laboratory

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

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

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

One West Third Street, Suite 1400
Tulsa, OK 74103-3519
918-699-2000

Visit the NETL website at:
**www.netl.doe.gov**

Customer Service:
**1-800-553-7681**

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

This newsletter now reaches more than 700 scientists and other individuals interested in hydrates in sixteen countries. If you would like to submit an article about the progress of your methane hydrates research project, please contact Karl Lang at 301-670-6390 ext. 129 (karl.lang@netl.doe.gov)

### Pre-Drilling Preparation

The successful program at Milne Point was the result of several years of regional geologic, geophysical, and engineering evaluation and planning. This work began in earnest in 2002, following BP Exploration Alaska Inc.'s (BPXA) response to a Department of Energy request for proposals to evaluate the gas hydrate resources on the ANS. Over the following three years, the project team conducted regional geological, engineering, and production modeling studies through collaborations with the University of Alaska (Fairbanks), the University of Arizona, and Ryder-Scott Company. In 2005, extensive analysis of BPXA's proprietary 3-D seismic data and integration of that data with existing well log data (enabled by collaborations with the U.S. Geological Survey, the Bureau of Land Management, and Interpretation Services, Inc.), resulted in the identification of more than a dozen discrete and mappable gas hydrate accumulations within the Milne Point area. Because the most favorable of those targets was a previously undrilled, fault-bounded accumulation, BPXA and the DOE decided to drill a vertical stratigraphic test well at that location (named the "Mount Elbert" prospect) to acquire critical reservoir data needed to support BPXA and DOE's decisionmaking regarding longer-term production testing.

### February 2007 Field Operations

The Mount Elbert No. 1 Well was planned at a cost of roughly $4.2 million and included a 22-day program for the acquisition of cores, well-logs and downhole test data. The rig arrived at the ice pad location on February 3rd (see figure). The rig-up and drilling of the 12 1/4-inch surface hole went smoothly, and on February 8th the 9 5/8-inch surface casing was set and cemented at the unusually shallow depth of 1950 feet.

*Gas hydrate-bearing fine-grained sandstone samples*

***Coring:*** The well was continuously cored to a depth of 2494 feet with chilled oil-based drilling fluid using the ReedHycalog *Corion* wireline-retrievable coring system. This system delivered 85 percent recovery of 3-inch diameter core through 504 feet of gas hydrate and water-bearing shales and fine-grained sandstones (see figure). The coring team processed these cores on site, collecting and preserving roughly 250 subsamples for analyses of pore water geochemistry, microbiology, gas chemistry, petrophysical properties, and thermal and physical properties (see figure). In addition, 11 samples were immediately stored in liquid nitrogen or transferred to pressure vessels charged with methane for future study of the preserved gas hydrates.

***Wireline-logging:*** After coring, the well was reamed and deepened to a depth of 3000 feet, and the science team worked with Schlumberger engineers to complete a full research-level wireline logging program including magnetic resonance and dipole acoustic logging, resistivity scanning, borehole electrical imaging, and advanced geochemistry logging (see figure). Excellent hole conditions resulted in an extremely high-quality dataset. Caliper logs showed the hole to be within one inch of gauge. This excellent outcome was a result of the team's earlier decision to employ a fit-for-purpose formulated mineral oil-based drilling fluid (provided by M-I SWACO) and the outstanding performance of the DrillCool engineers in maintaining drill fluids at temperatures typically near 30° F.

***Modular Dynamic Testing (MDT) Program:*** Following logging, Schlumberger and RPS-APA engineer Steve Hancock began the execution of an ambitious plan for the first open-hole tests of a gas hydrate bearing reservoir. Four stations in two sandstone reservoirs were tested for periods of up to 13 hours using the Modular Dynamic Test tool (see figure). Each test consisted of flow and shut-in periods of varying lengths. The detailed pressure responses obtained will be analyzed to determine small-scale petrophysical aspects of the reservoir. Gas was produced from the gas hydrates in each of the tests. The effort included the first continuous monitoring of sand-face temperature and the collection of multiple water and gas samples for subsequent analysis.

The success of the entire program was due, in large part, to the outstanding performance of the equipment and crew of the Doyon 14 rig.

*Logging tools: the science effort included a research-level open-hole wireline well logging program*

*Science Team Co-lead Tim Collett subsamples gas-hydrate bearing core*

## MOUNT ELBERT PROJECT TEAM MEMBERS

Larry Vendl, Mikie Weeks, Scott Digert – BP Exploration, Alaska

Bob Hunter – ASRC Energy Services

Tim Collett, Bill Winters, William Waite, Tom Lorenson, Warren Agena, Myung Lee, John Miller – USGS

Ray Boswell, Kelly Rose, Eilis Rosenbaum – DOE/National Energy Technology Laboratory

Marta Torres, Rick Colwell – Oregon State University

Steve Hancock – RPS-APA Energy Canada

Tanya Inks – Interpretation Services, Inc.

Scott Wilson – Ryder Scott Company

### Findings and Implications

The successful well test at Milne Point is a landmark in the scientific investigation of gas hydrates for several reasons.

Operationally, the program demonstrated the safe and effective application of advanced technologies in the shallow, largely unconsolidated sediments just below permafrost in the Alaska North Slope. The program showed the value of correct well-bore fluid selection and cooling, and the efficacy of two ANS "firsts:" wireline-retrievable coring and open-hole MDT testing in gas-hydrate-bearing reservoir sands.

Scientifically, the program demonstrated a successful gas hydrate exploration methodology when it encountered gas hydrates largely as predicted by the pre-well geologic/geophysical investigations. Gas hydrates were expected and found in two primary horizons. The upper zone, (the "D" Unit) contained ~46 feet of gas hydrate-bearing reservoir-quality sandstone. The lower zone (the "C" Unit), contained ~53 feet of gas hydrate-bearing reservoir. Both zones displayed saturations that varied with reservoir quality as expected, with typical values between 60 percent and 75 percent. This result conclusively demonstrated the soundness of the ANS gas hydrate prospecting methods developed primarily at the U.S. Geological Survey.

### Next Steps

BPXA, the DOE, the USGS, and its research partners in the US and Canada will now begin the process of fully analyzing and integrating all aspects of this dataset, including re-calibration of the initial geological and seismic models for the site. These data will then be used by BPXA and the DOE to determine if, where, and when to proceed into the next phase of the project—currently envisioned as a long-term production testing program to determine reservoir deliverability under a variety of production/completion scenarios. This effort will include reservoir simulations of gas hydrate production responses and evaluation of various production testing options as part of the ongoing DOE-sponsored International Code Comparison (see following article in this issue of FITI).

*The Doyon 14 crew rigs up Schlumberger's Modular Dynamic Tester*

# International Methane Hydrate Code Comparison Project Simulates Relevant Problems

*By the Gas Hydrate Simulator Comparison Team*

The National Energy Technology Laboratory (NETL) and the U.S. Geological Survey (USGS) are guiding a collaborative, international effort to compare gas hydrate reservoir simulators. The intentions of the effort are: (1) to exchange information regarding gas hydrate dissociation and physical properties enabling improvements in reservoir modeling, (2) to build confidence in all the leading simulators through exchange of ideas and cross-validation of simulator results on common datasets of escalating complexity, and (3) to establish a depository of gas hydrate related experiment/production scenarios with the associated predictions of these established simulators that can be used for comparison purposes.

Thus far, five problems have been developed for comparison purposes and have been simulated by five different reservoir simulators, CMG STARS, HydrateResSim, MH-21 HYDRES, STOMP-HYD, and TOUGH+/HYDRATE. The five problems range in complexity from one-dimensional to three-dimensional (with radial symmetry), and in horizontal dimensions from 20 meters to 1 kilometer. Each of the problems and the results of the comparisons to date are described below.

### Problem 1: Base Case (Non-isothermal Multi-fluid Transition to Equilibrium)

This problem involves a horizontal, one-dimensional, closed domain initialized with gradients in pressure and temperature such that half of the special domain is water saturated while the other half contains both water and gas. The simulation proceeds to an equilibrium condition in pressure and temperature dictated by the initial mass and energy contents of the system. This problem is a non-gas hydrate case designed to test basic mass and heat transfer capabilities in the codes, and excellent agreement was observed among the five models.

### Problem 2: Base Case with Gas Hydrate (Closed-Domain Gas Hydrate Dissociation)

This second problem uses the same closed horizontal domain as in Problem 1, but includes gas hydrate in the half of the spatial domain that only contained water in Problem 1. The initial conditions are such that for long times the system approaches an equilibrium state in which all of the hydrate has dissociated via the thermal energy available in the half of the special domain initially containing only gas and water. From the specified initial conditions, the simulation proceeds to an equilibrium temperature and pressure state resulting from the complete dissociation of the gas hydrate initially present in the reservoir. Again, there was excellent agreement among the five simulators tested in terms of the rates of movement of the gas hydrate front as well as the predicted phase saturations.

## Researchers Involved in the Study

Brian Anderson - West Virginia University

Joseph W. Wilder - The University of Akron

Timothy Collett - U.S. Geological Survey

Robert Hunter - ASRC Energy Services

Masanori Kurihara - Japan Oil Engineering Co., Ltd.

Yoshihiro Masuda - The University of Tokyo

Pete McGrail - Pacific Northwest National Laboratory

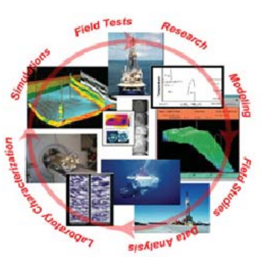
George Moridis - Lawrence Berkeley National Laboratory

Hideo Narita - National Institute of Advanced Industrial Science and Technology

Mehran Pooladi-Darvish - Fekete Associate Inc/University of Calgary

Mark White - Pacific Northwest National Laboratory

Scott Wilson - Ryder Scott Company, Petroleum Consultants




Additional details on the code comparison study can be found on the NETL website at

http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/MH_CodeCompare/MH_CodeCompare.html/.

## Problem 3: Dissociation in a One-dimensional Open Domain

The third problem again involves a one-dimension spatial domain. While Problem 2 explores the behavior of the simulators when gas hydrate dissociates in the (larger) closed domain of Problem 1, the intent of Problem 3 is to explore fine-scale effects of gas hydrate dissociation in a system open to gas release from the origin. To explore the range of potential behavior, three separate cases were defined and compared: (1) dissociation due to thermal stimulation, (2) dissociation due to depressurization to a pressure above the quadruple point (ensuring that no ice forms in the reservoir), and (3) dissociation to a pressure below the quadruple point (allowing the formation of ice). While good agreement was generally observed among the simulators for the first two cases, the third case (which resulted in the formation of ice in some portions of the reservoir) revealed differences in the location of the hydrate dissociation front over time (see Figure 1). The observed differences most likely are the result of the different manners in which the appearance and effects of ice are modeled in the various simulators.

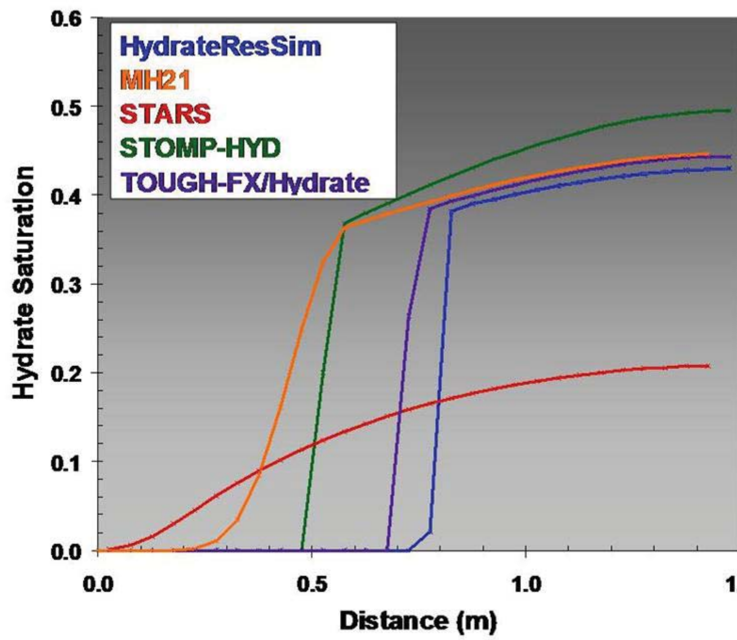



*Figure 1: Problem 3 sample results–Depressurization below the quadruple point (after 20 minutes)*

## Problem 4: Gas Hydrate Dissociation in a One-dimensional Radial Domain

The fourth problem models gas hydrate dissociation in a one-dimensional radial domain. The fine discretization utilized in this problem is needed to accurately capture the simulated front during thermal dissociation. As with Problem 3, this problem explores the fine scale effects of hydrate disassociation in a non-closed system. This problem was designed to take advantage of the fact that under proper conditions, hydrate dissociation results in solutions that are of the form of "similarity solutions." These solutions are ones in which the observed values of any variable (e.g., temperature, pressure, saturation, etc.) depend only on the ratio $r^2/t$ (where r is the radial distance from the well and t is time). This implies that if one plots results from different times on a single plot using $r^2/t$ as the independent variable, all of the curves should lie on top of each other (except for small variations due to transient behavior at small values of t). This example is the closest to a problem with a "known" solution for hydrate systems (see Figure 2). The observation that the tested simulators (HydrateResSim, MH-21 HYDRES, STOMP-HYD, and TOUGH+/HYDRATE) showed the same similarity solution-type behavior is an indication that they all are capturing the same physical process which leads to this behavior.

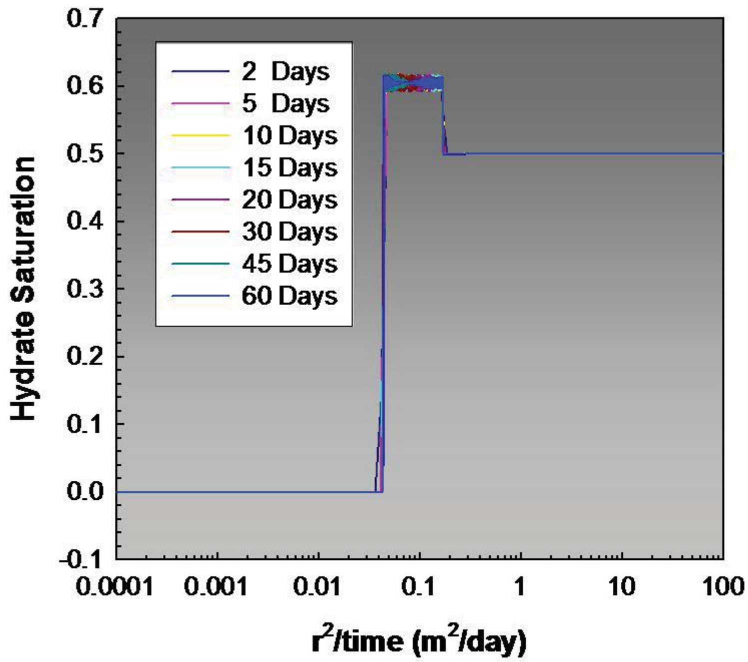



*Figure 2: Problem 4 sample results–Similarity solution for radial dissociation in a non-closed system using HydrateResSim*

**Problem 5: Gas Hydrate Dissociation in a Two-dimensional Radial Domain**

The fifth problem models gas hydrate dissociation in a two-dimensional radial domain. In this problem, a 10 meter-thick gas hydrate-bearing sandstone is bounded vertically by two 25 meter-thick shales. The length and height of the domain are 1000 meters by 60 meters with four different discretization models. Problem 5 seeks to investigate a range of behavior by simulating two separate cases: (Case A) 80 percent initial methane hydrate saturation, and (Case B) 70 percent initial methane hydrate saturation. Analysis of the results of these cases and the comparative performance of the simulators is expected to be completed shortly.

**Next Steps**

The next step in this study is the development and analysis of a problem based on detailed characterizations of actual accumulations on the Alaska North Slope. One of the problems will be based on the data recently obtained at the BP-DOE-USGS stratigraphic test well at Milne Point (see article in this issue of Fire in the Ice). It is hoped that the results of these analyses will help to further constrain the range of possible gas hydrate production responses and enable a more effective evaluation of potential production tests.

The Code Comparison Study Team provides updates on model outputs and detailed scenario definitions to the methane hydrate R&D community through the NETL methane hydrate web site (http://www.netl.doe.gov/scngo/NaturalGas/hydrates/index.html). To obtain more information about this study, please contact Brian Anderson (brian.anderson@mail.wvu.edu), Joseph W. Wilder (wilder@uakron.edu), or Kelly Rose (kelly.rose@netl.doe.gov).

# New Sensing Technology at Oak Ridge National Lab Expands Capabilities for Meso-Scale Hydrate Research

*By Megan Elwood Madden, Oak Ridge National Laboratory*

The Seafloor Process Simulator (SPS) at Oak Ridge National Laboratory (ORNL) is a unique experimental facility designed to conduct meso-scale experiments which bridge the gap between traditional laboratory experiments and extensive field-based production tests and experiments (see Figure 1 and Table 1). The 72-liter (L) vessel volume is sufficiently large to: mitigate wall effects on reaction kinetics, allow investigation of large-scale heterogeneities, and provide a controlled environment for physical testing of scaling effects and numerical production models. Methane hydrate accumulation and dissociation kinetics, thermodynamic stability, and mechanical properties relevant to gas production, seafloor stability, and environmental change, have all been investigated within the vessel.

Last fall, the tool set available for monitoring hydrate formation/dissociation within large sediment volumes using the SPS was significantly expanded with the addition of a fiber optics-based distributed sensing system (DSS) capable of measuring time-resolved temperature and stress changes in three dimensions at the centimeter (cm) scale. Within the SPS, synthetic sediment systems will be constructed within a 1 cm resolution frame-supported DSS grid of optical fibers to measure hydrate accumulation and dissociation processes.

With this new tool set, it will be possible to monitor methane sequestration or release rates within large sediment volumes (50-70 liters) by measuring hydrate accumulation and dissociation rates through a combination of high resolution temperature data (+/- 0.1 degree and 1 cm spatial resolution) and pressure observations in the system. Sediment stability during hydrate accumulation and dissociation can also be monitored using strain measurements collected by the DSS, permitting better assessment of the seafloor stability issues associated with hydrate production or environmental changes. Experiments can also be conducted using natural sediment core samples, either by integrating the DSS along the walls of the core or by inserting optical fibers through the core.

| SPS SPECIFICATIONS |
|---|
| 72 L internal volume |
| Corrosion-resistant hastelloy construction |
| 36 observation/access ports |
| 0.1 to 20 MPa pressure range |
| 0 to 20 °C temperature control |
| **OBSERVATION AND ANALYSIS TOOLS** |
| Observation possible through 12 sapphire windows |
| 3-D temperature and strain mapping |
| Boroscope |
| pH and conductivity electrodes |
| Gas flow meters |
| HPLC/Syringe pumps for fluid injection/sampling |
| Multiple thermocouples |
| High resolution pressure monitoring |

*Table 1: Tools and Specifications of the SPS at ORNL*

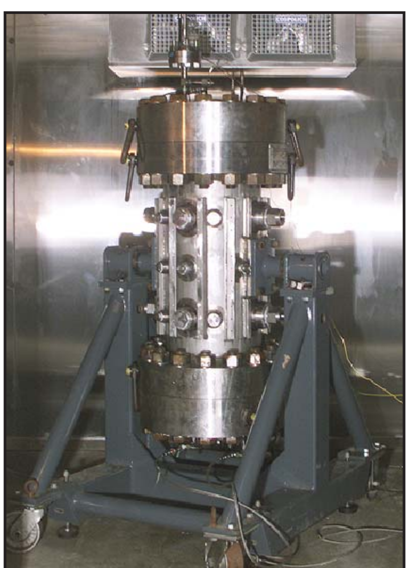


*Figure 1: ORNL's 72-liter SPS is designed to conduct meso-scale gas hydrate accumulation and dissociation studies.*

## How Fiber Optics Are Used to Measure Temperature and Pressure in the SPS

The new DSS measures temperature and strain through a system of fiber Bragg grating sensor arrays distributed at 1 cm intervals along the optical fibers making up the grid. A fiber Bragg grating is a short segment within an optical fiber with periodically spaced zones in the fiber core that have been altered to have different refractive indexes slightly higher than the core. This structure selectively reflects a narrow range of wavelengths while transmitting others, and can thus be used to filter out a particular wavelength. Fiber Bragg gratings are commonly used to stabilize the output of a laser or to filter out wavelengths in systems that use multiple lasers to transmit several wavelengths of light simultaneously over a single optical fiber, where each signal (e.g., text, voice, video, etc.). travels within its unique color band. Each fiber Bragg grating acts as a mirror, but only for a specific wavelength ($\lambda_R$) which is determined by the refractive index (n) of the fiber and the grating period ($\Lambda$), such that $\lambda_R = 2n\Lambda$ (see Figure 2).

The fiber Bragg gratings can be used to sense temperature or stress changes because even small changes in temperature result in a systematic change in the refractive index of the fiber, as well as small changes in the grating period due to thermal expansion, thus changing the wavelength of the reflected light. Mechanical stress will also alter the grating period and refractive index due to photoelastic effects. Each optical fiber contains hundreds to thousands of Bragg gratings which can be used to independently measure temperature/strain at each discrete point along the fiber.

Using optical frequency domain reflectometry, the DSS sweeps a wide spectrum of light through the optical fiber, interrogating each Bragg grating along its length. The reflected light from each Bragg grating interferes uniquely with light from a standard reflector. Based on the differences in the wave path of each reflected unit with respect to the standard reflector, the modulated signal can be analyzed to determine both the refracted wavelength and the source location of each reflection along the optical fiber, resulting in a spatially resolved temperature/strain measurement.

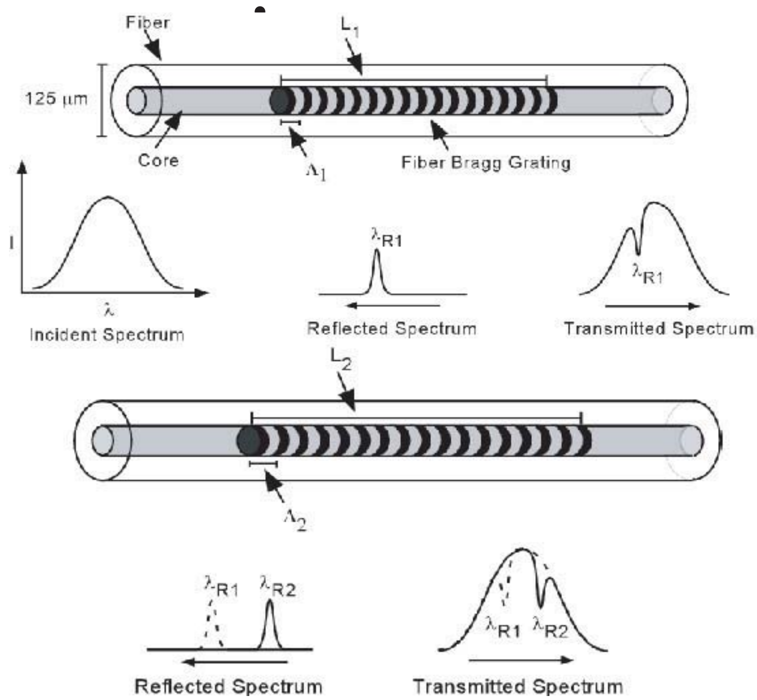



Figure 2: Schematic illustrating the fiber Bragg gratings used in the DSS (from Duncan et al. 2004). Each of the Bragg gratings along the optical fiber acts as a reflector, but only for a specific wavelength of light ($\lambda_R$) which is determined by the refractive index (n) of the fiber and the grating period ($\Lambda$). The resulting wavelength shift is directly related to temperature and/or mechanical stress experienced at each discrete Bragg grating along the fiber.

## Applications of the DSS to Methane Hydrate Research

Initial experiments using the DSS will focus on conducting meso-scale production experiments for validating numerical production models. High resolution monitoring of temperature changes throughout the 72-liter vessel will provide a basis for direct observation of hydrate accumulation and dissociation throughout the sediment system as well as for observation of ice and secondary hydrate formation near the production well, allowing for direct comparison with the behavior predicted by numerical production models. In addition, these experiments will provide a platform for examining the effects of spatial scale on hydrate production kinetics through comparison with both traditional small-scale laboratory experiments and large-scale field tests.

First, methane hydrate will be synthesized in homogeneous sediments within the SPS using partially water-saturated sand. The initial production experiment will be conducted once hydrate synthesis is complete and the system comes to P-T equilibrium within the hydrate stability zone conditions relevant to the hydrate-bearing permafrost environment being investigated. Possible spatial heterogeneities in hydrate accumulation will be assessed by monitoring exothermic hydrate formation via temperature changes observed with the DSS.

Second, the sediment/hydrate system will be depressurized using a single permeable pipe inserted into the SPS to simulate a production well (see Figure 3). The produced gas will be captured in a secondary pressure vessel and its volume determined through P-T measurements. The DSS will monitor evolving temperature conditions within the sediment/hydrate system to evaluate hydrate production throughout the volume of the vessel. The resulting time resolved 3-D temperature map will be available to the modeling community for use as a validation tool. In addition, insights gained from these meso-scale production experiments can be used to develop more efficient production practices that can be tested in the field.

Further experiments are planned to investigate the impact of sediment heterogeneity (i.e. void spaces, sand lenses, fine layering) on methane hydrate accumulation and dissociation processes within natural and synthetic sediments. The effects of pressure, temperature, slope, and/or wave perturbations, as well as secondary gas flushing on hydrate stability and dissociation kinetics within a meso-scale system may also be investigated in the near future.

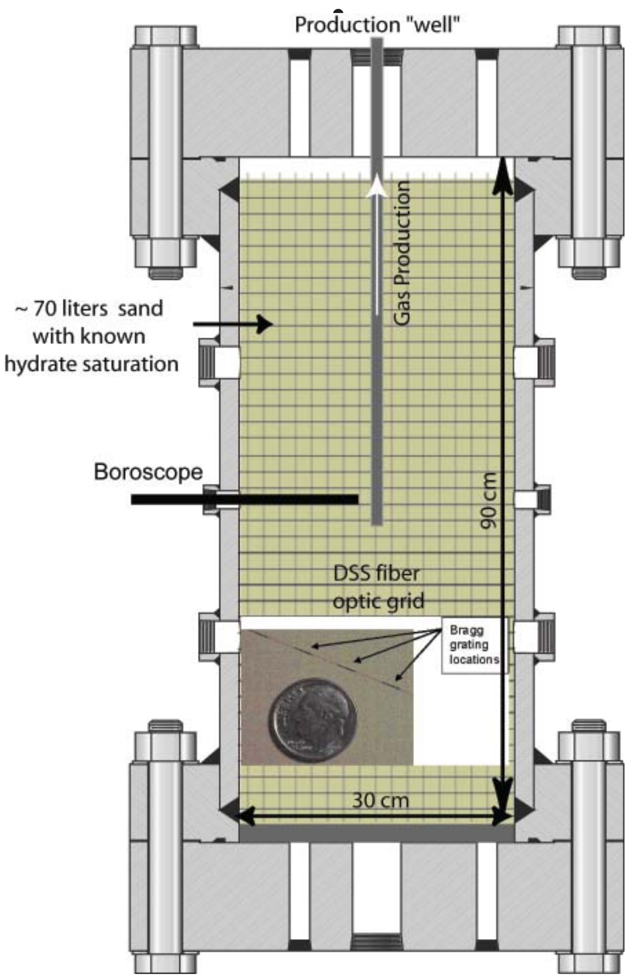



*Figure 3: Schematic illustrating a meso-scale methane hydrate production experiment within the SPS.*

## HYACINTH HISTORY

The HYACE ("HYdrate Autoclave Coring Equipment system") project was funded by the European Commission from 1998 to 2001. HYACE was primarily an engineering development project, during which two types of wireline pressure coring tool - a percussion tool (FPC) and a rotary tool (HRC) - were developed together with the means of transferring the core without loss of pressure into a laboratory chamber where it could be evaluated using geophysical logs. The HYACE wireline coring tools had their first sea trials on Ocean Drilling Project (ODP) Leg 194 in January 2001.

Prior to the end of the HYACE project a new proposal (HYACINTH, or Deployment of HYACE tools In New Tests on Hydrates) was submitted to carry forward the work. A smaller consortium was assembled for this phase and Geotek Ltd. took over the role of coordinator from the Technical University of Berlin. The EC funded the project beginning in December 2001.

The integrated suite of HYACINTH coring tools and analysis equipment has been deployed from the ODP drillship JOIDES Resolution as well as from geotechnical drilling vessels. The HYACINTH system now includes the two pressure coring tools (FPC & HRC) and pressurized chambers for storage and shipping, nondestructive core analysis, and core subsampling and transfer. HYACINTH equipment can be easily mated to third-party pressure chambers for additional measurements or core transport using standardized fittings and quick-clamps.

# HYACINTH Pressure Cores from India: Analysis and Subsampling Reveals Detailed Methane Hydrate Structures

*By Peter Schultheiss (Geotek Ltd.), Carlos Santamarina (Georgia Tech), Pushpendra Kumar (DGH), and Timothy Collett (USGS)*

The first Indian National Gas Hydrate Program drilling expedition took place onboard the drillship *JOIDES Resolution* (JR) in the summer of 2006, led by the Indian Directorate General of Hydrocarbons (DGH) and the U.S. Geological Survey (USGS). The expedition was designed to investigate the gas hydrate resource potential of sites around the Arabian Sea, the Bay of Bengal, and the Andaman Sea (see article in Fall 2006 issue of *Fire in the Ice*). As part of the program of scientific coring, 49 cores were recovered under pressure and analyzed at sea. The onboard pressure core analysis included routine core measurement in Geotek Ltd.'s Pressure Multi-Sensor Core Logger (MSCL-P), a device that provides continuous profiles of P-wave velocity and gamma density at *in situ* pressure and temperature conditions as well as high-resolution two-dimensional X-ray images. Most of the pressure cores were depressurized after MSCL-P analysis to determine the exact methane content and hence the gas hydrate saturation. Pressure cores are considered the "gold standard" for gas hydrate quantification and as such are used to calibrate other methods of gas hydrate detection.

### CT Scanning Provided View of Hydrate Vein Structure

Five pressure cores were not depressurized but instead were transferred under pressure to HYACINTH storage chambers (see photo) for further pressurized analysis and subsampling (see sidebar for background on HYACINTH). At the end of October 2006, a small team led by Geotek and partially funded by the DOE/Chevron Gulf of Mexico Joint Industry Project, set up cold working laboratories in Singapore and moved the cores there from the JR cold storage area. Each core was relogged in the MSCL-P in detail at different orientations (every 15 degrees) to investigate the detailed nature and anisotropy of the gas hydrate vein structure. The cores were transferred back into the storage chambers and transported in a refrigerated truck to a local hospital, where X-ray computed tomography (CT) scans were performed (see photo). The data obtained from the CT and MSCL-P data clearly demonstrated that the hydrate veins in these fine-grained sediments are particularly complex in nature, forming a dense honeycomb structure (see photos).

*Melanie Holland of Geotek Ltd. displays five pressure cores stored in the hold of the JOIDES Resolution.*

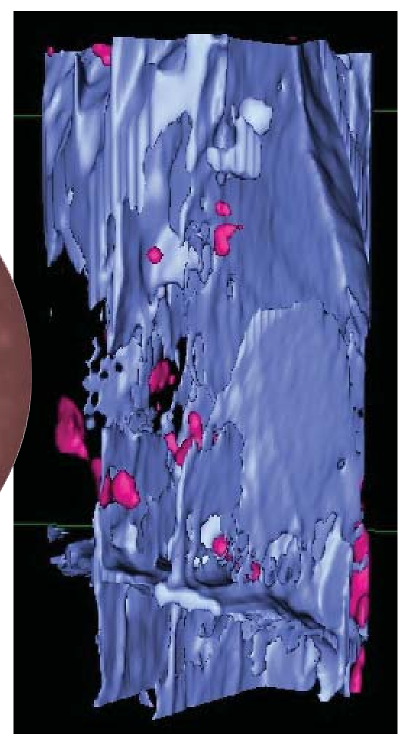
## Core Property Measurements Obtained Using IPTC

After the cores were CT scanned, a team of scientists from Georgia Tech joined the effort in Singapore, where the physical properties of three of the five pressure cores were determined using the Instrumented Pressure Testing Chamber (IPTC). One at a time, cores were transferred from the storage chambers back into the HYACINTH transfer system, where the IPTC was mated to the transfer system—allowing the core to be moved under pressure into the IPTC. The test sequence involved automated core movement, manual liner drilling at diametrically opposed points along the core, and measurements through the holes in the liner. All transfers and measurements were conducted under pressure and at low temperature so that cores remained within the hydrate stability field. Measurements of P-wave velocity, S-wave velocity, electrical resistance, and strength of the sediment were made at regular intervals along the three pressure cores (see photo).

Upon completion of the measurements using the IPTC cell, the cores were X-rayed to verify the location of the measurement points and to assess possible effects of sensor invasion. One core was retested along a perpendicular plane to assess anisotropy. A 40-centimeter-long section of a second core was monitored in the IPTC while the core was subjected to a "mini-production test" involving controlled depressurization. During this test, researchers observed changes in pressure, temperature, electrical resistance, P-wave velocity, and generated gas as functions of time. The results from this study provide an unprecedented wealth of information related to the properties of hydrate-bearing fine-grained sediments, particularly as they relate to formation characterization, production monitoring, and sediment instability problems. Ongoing developments will extend the capabilities of the IPTC, allowing it to accommodate new sensors (e.g., thermal conductivity, resistivity tomography) and, most importantly, allow for the restoration of *in situ* effective stress on pressure cores.


*Pressure core being X-ray CT scanned at the Gleneagles Hospital in Singapore.*

*Horizontal slice through one of the pressure cores. Hydrate veins are white; clay sediments are dark.*



*Three-dimensional reconstruction of a short section of core. Sediment is transparent, gas hydrate is blue, carbonate is pink. Hydrate veins in the pressure cores were generally subvertical, but at varied orientations.*

## Cores Shipped to Labs for Additional Testing

After measurement in the IPTC, the cores were subsampled and shipped to laboratories in the United States and the United Kingdom. Five subsamples (each about 20 cm long) were cut at *in situ* pressure and temperature conditions in the HYACINTH PRESS system (operated by the Technical University of Berlin) and transferred into modified Parr vessels (see photos). Three of these vessels containing pristine gas hydrate cores were shipped to the USGS Science Center at Woods Hole, MA, for geomechanical testing, and two were shipped to the University of Cardiff for detailed microbiological experiments. The remainder of the samples were rapidly depressurized, cut into short sections, and stored under liquid nitrogen. X-ray CT scans of a frozen sample have shown that a quick transfer (less than 90 seconds from full pressure to liquid nitrogen immersion) will preserve the detailed gas hydrate structures. Samples in liquid nitrogen were shipped to USGS offices at Woods Hole MA, Lawrence Berkeley National Laboratory at Berkeley, CA, and Southampton University in the U.K., where a variety of experiments will be performed.

This complex post-cruise operation demonstrates the versatility of pressure cores that can be stored, experimentally measured, and subsampled in a controlled fashion at *in situ* pressure and temperature conditions. While it is expected that the complexity of onboard pressure core measurements and manipulations will increase on future expeditions, there will always be the need to send pristine samples back to laboratories for more sophisticated testing.

*Experimental set-up for obtaining measurements using the IPTC.*

*Subsectioning pressure cores with the PRESS system.*

*A 20-cm subsection under pressure in a transportable Parr vessel.*

## Announcements

### Gulf of Mexico JIP Well Log Data Available

The well logs from Leg 1 of the 2005 cruise are now publicly available on the JIP website. To access the log files, go to https://cpln-www1.chevron.com/cvx/gasjip.nsf and click on the library item labled "LDEO Log Files (Jones-EMRY) - modified" at the bottom of the page.

### Gas-Hydrate Observatories Workshop Scheduled for July 2007

Joint Oceanographic Institutions is sponsoring a Gas-Hydrate Observatories Workshop on July 18-20 in Portland, Oregon, to develop strategies for monitoring gas-hydrate deposits using instrumented boreholes. The workshop will bring together scientists and engineers to discuss possible observatory designs and deployment strategies with the goal of successful implementation within the next several years.

To participate in this workshop, visit www.joiscience.org/GHOBS. All interested scientists, researchers, engineers, and students are encouraged to apply. Participation will be limited to optimize workshop goals. Partial travel support is available. Applications are due May 22, 2007. Please contact co-convenors Marta Torres (torres@coas.oregonstate.edu), Anne Trehu (trehu@coas.oregonstate.edu), or Michael Riedel (mriedel@eps.mcgill.ca) for further information.

### Methane Hydrate Advisory Committee Meeting to be Held in Golden, Colorado.

A meeting of the Methane Hydrate Federal Advisory Committee has been scheduled for April 24-25 in Golden, Colorado. The 14-member Advisory Committee provides advice to the Secretary of Energy and assists in developing recommendations and priorities for the Department of Energy's methane hydrate research and development program. For further information please contact Edith Allison, U.S. Department of Energy, Office of Oil and Natural Gas, Washington, DC. Phone: 202-586-1023.

### AGU Joint Assembly Features Hydrates

*Acapulco Convention Center, site of May 2007 AGU Session on Hydrates*

The upcoming American Geophysical Union (AGU) Joint Assembly meeting in Acapulco, Mexico, on 22-25 May, 2007 will feature a session titled "Gas Hydrates in the Americas" (Session NS10). The intent of the session's co-convenors, Debbie Hutchinson (USGS) and Roberto Figueroa (PEMEX), is to provide an opportunity to present and exchange the latest research on naturally occurring gas hydrates in the Americas. Numerous field, laboratory, and modeling studies are revealing the distribution and properties of natural gas hydrates in ways that are beginning to answer questions about the ways to produce them for energy, the processes that form and dissociate them from local to regional scales, the nature of fluid fluxes in the hydrate reservoir, and how to best measure and observe these varied phenomenon. Additional information about the meeting and this session can be found at http://www.agu.org/meetings/ja07/.

## US-Japan Cooperation on Energy Security Includes Hydrates Research

When Secretary of Energy Bodman met with Akira Amari, Minister of Economy, Trade and Industry of Japan on January 9 in Washington to review current and prospective cooperative activities in the energy field, methane hydrates was one of the topics on the list. Both agreed to continue ongoing efforts for cooperation and information exchange on methane hydrates. Given the complex challenges associated with methane hydrate R&D, enhanced cooperation will substantially accelerate the feasibility of commercial methane hydrate production.

## Japanese Hydrate Researchers Expand Offshore and Arctic Efforts

Japan's Ministry of Economy, Trade and Industry (METI) has announced that surveys of a section of the Nankai Trough have revealed a methane hydrate deposit with 1.1 trillion cubic meters of gas-in-place (39 trillion cubic feet) within a 5,000 square kilometer (km) area about 50 km off the country's eastern coast. As a result, METI intends to broaden the scope of its seabed exploratory efforts this spring, with testing of exploitation methods to start in 2009 in hopes of beginning commercial production by 2017.

Last October, METI announced that Japan Oil, Gas and Metals (JOGM) and the Canadian Department of Natural Resources planned to conduct additional methane research above the Arctic Circle in northwestern Canada. The group drilled an exploratory well during February and JOGM announced that during a 2-week period in mid-March it would be testing depressurization as a method for producing gas from the hydrate deposits encountered. Another test utilizing the same process is already being considered for winter 2008.

## AAPG Convention to Include Three Papers on Gas Hydrates

AAPG ANNUAL CONVENTION & EXHIBITION
UNDERSTANDING EARTH SYSTEMS
PURSUING THE CHECKERED FLAG
APRIL 1-4, 2007 LONG BEACH, CA

The AAPG Annual Convention and Exhibition to be held April 1st through 4th in Long Beach, California, will include three papers related to methane hydrates. Two of them will be presented during a session titled "Alternative Energy Sources: Promises and Pitfalls," on the morning of Tuesday April 3rd. These are: "Gas Hydrate Resource Potential" by R. B. Hunter, S. A. Digert, S. J. Wilson, T. Collett, and R. Boswell, and "Dispelling the Myths: Exploration and Development of Natural Gas Hydrate" by A. H. Johnson and M. D. Max. On Wednesday afternoon, during a technical session on Faults as Seals and Flow Conduits, a paper titled "Active Faulting, Gas Hydrate Formation, and the Growth of Seafloor Blisters in Santa Monica Basin, California" by C. K. Paull, W. R. Normark, W. Ussler, III, D. W. Caress, and R. Keaten will also be presented.

## Spotlight on Research

**PUSHPENDRA KUMAR**

Institute of Engineering & Ocean Technology

Oil and Natural Gas Corporation Ltd.

pushpendrakumar_2005@yahoo.com

When not studying gas hydrates, Pushpendra focuses on spiritual pursuits and practices yoga.

### Successful Hydrate Cruise Marks Milestone for ONGC Scientist

Pushpendra Kumar's interest in gas hydrates started in 1997, when the Government of India launched its National Gas Hydrate Program. With a Ph.D. in chemistry from the University of Allahabad, India, Pushpendra had been working for Oil & Natural Gas Corp. Ltd. (ONGC) as a well site chemist in northeast India and in the giant Mumbai High oil and gas field off the country's west coast.

"Initial data indicated the presence of large amounts of gas hydrate, on both the east and west coasts of India," says Dr. Kumar. "I submitted a project proposal to the Government of India, which was quickly approved, and I started working on gas hydrates in 1998. I have been actively involved in gas hydrate research in India since then." Pushpendra also completed one year of study and research at the Center for Research on Hydrates at Colorado School of Mines.

Dr. Kumar is currently Head of Gas Hydrates at ONGC's Institute of Engineering & Ocean Technology (IEOT) in Mumbai and a Core Group Member of the Indian National Gas Hydrate Program (NGHP). This effort is being coordinated by the Directorate General of Hydrocarbons and steered by the Ministry of Petroleum & Natural Gas. His responsibilities include creating an infrastructure for gas hydrate research under NGHP, advising the NGHP Technical and Steering Committees regarding the development of gas hydrate as an energy resource in India, conducting studies on gas hydrates, and planning and executing exploratory efforts for gas hydrates offshore India.

In this capacity, Pushpendra served as NGHP Project Manager on two legs of the successful gas hydrate coring/drilling program off the coast of India during the summer of 2006 (Leg 1 in the Kerala-Konkan basin on the west coast, and Leg 3A in the Krishna-Godavari basin on the east coast.

"During the first leg the level of excitement and anticipation was very high … we were anxiously waiting for the recovery of solid gas hydrate with almost every core length that was pulled," recounts Pushpendra. But the team did not find any indications of hydrate over 300 meters. "Although we did not get hydrate samples, we got very valuable geologic information from this leg."

Based on this experience, there was not as much excitement during the coring operations on Leg 3A; in fact the team did not expect to see any solid gas hydrate samples on the catwalk due to the high surface temperatures. Pushpendra recalls that, "At the second site in this area, we suddenly started getting solid massive gas hydrate samples from about 32 meters below seafloor … and this continued to a depth of 200 meters. Tim Collett, the co-chief scientist onboard, informed me that this was probably the thickest and most concentrated gas hydrate layer ever discovered. This was the most satisfying experience for me on the entire cruise."

Planning and executing the offshore coring/drilling program was a three-year challenge to find and organize a suitable ship, specialized tools, and an experienced crew and scientific staff. In Dr. Kumar's opinion, the next big challenge facing gas hydrate researchers is to begin to develop a cost-effective technique for the safe recovery of gas from hydrate deposits. Although that prospect is still considered a long-term goal, the discovery of hydrates off the east coast has spurred the Indian Government to upgrade the priority for gas hydrates, along with other unconventional energy sources such as coalbed natural gas, underground coal gasification, and hydrogen.