Fall 2004

Fire in the Ice

THE NATIONAL ENERGY TECHNOLOGY LABORATORY METHANE HYDRATE NEWSLETTER

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AAPG Hedberg Research Conference on Gas Hydrates

Tim Collett, United States Geological Survey; Art Johnson, Hydrate Energy International

The American Association of Petroleum Geologists (AAPG) recently hosted a Hedberg Research Conference on gas hydrates. The conference, *Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards*, was convened in Vancouver, British Columbia, Canada from September 12 to 16, 2004.

What is a Hedberg Research Conference? A Hedberg Research Conference is one of the most respected research forums in the world. The AAPG Research Committee periodically selects a topic for critical examination. The committee invites scientists from various disciplines, including geology, geophysics, geochemistry, reservoir engineering and others, to discuss state-of-the-art concepts, methodologies, case histories and future directions related to the selected research topic. The focus of the Hedberg Research Conference in Vancouver was to assess the energy resource potential of gas hydrates and to characterize geologic hazards associated with gas hydrates in nature.

Photograph of the Mallik 5L-38 Gas Hydrate Production Test Well (Courtesy of the Mallik 2002 Gas Hydrate Production Test Well Program)

Specific objectives of the Hedberg Research Conference on gas hydrates were to critically examine the geologic parameters that control the occurrence and stability of gas hydrates, assess the volume of natural gas stored within known gas hydrate accumulations, assess exploration methods for identifying gas hydrate prospects, identify the technologies needed to economically produce gas from hydrates, assess possible marine slope stability hazards that can be attributed to the occurrence of gas hydrates, and analyze the effects of gas hydrates on drilling safety. Because of overwhelming interest, the AAPG expanded the conference registration beyond the normal limit to 122 participants, yet there was still a long waiting list. It was important to limit the number of conference participants, in keeping with the spirit of open communication and the exchange of ideas through both formal and informal group discussions.

Conference participants came from more than 13 different countries, reflecting the multi-national interest in gas hydrates. The 75 U.S. participants included 29 from government agencies, 26 from academia, and 20 from industry. The 47 participants from outside the U.S. had similarly diverse affiliations. The conference featured 43 oral presentations, 46 poster presentations, three formal discussion sessions, and a banquet keynote address by Marlan Downey entitled: *Boulders in the Path, Problems on the Way Towards the Gas Hydrate Rainbow*. The conference concluded with a panel discussion on geology and the energy resource potential of gas hydrates.

In the discussion and panel sessions, various participants expressed a sense that significant progress is being made in addressing some of the key issues on the formation, occurrence, and stability of gas hydrates in nature. The concept of gas hydrate petroleum systems, as they compare to conventional oil and gas petroleum systems, is gaining acceptance. In fact, the use of complex numerical modeling is allowing the components of gas hydrate petroleum systems (i.e., source, migration, trap, and timing) to be assessed and quantified. However, there is a growing appreciation that some of the processes leading to the formation of gas hydrates in marine versus permafrost environments may differ. For marine gas hydrate exploration, several groups expressed the growing need for better geophysical methods that would allow for the direct detection and evaluation of gas hydrate accumulations; the era of assessing marine gas hydrates through mapping of bottom simulating seismic reflectors (BSRs) alone is drawing to a close.

As reviewed during the conference, several recent studies estimate that the volume of gas trapped in global gas hydrate accumulations is significantly less than some widely cited early estimates. However, by all estimates, the volume of gas trapped in hydrates likely exceeds that trapped in all other conventional (non-gas-hydrate) accumulations. It was noted that none of the existing assessments have predicted how much gas can be produced from the world's gas hydrate accumulations, and it was concluded that much more work is needed to go beyond the existing in-place gas hydrate volumetric estimates. However, researchers involved in gas hydrate-related climate change studies expressed their continued need for accurate global estimates of the amount of gas trapped in gas hydrates. At the same time, industry representatives expressed the importance of relatively small, well-defined, gas hydrate accumulations in the 1 to 5 trillion cubic feet (TCF) range that can be drilled, tested, and possibly produced. Marlan Downey challenged the audience to "think bigger," and view gas hydrate production as a potential paradigm shift of global importance.

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INTENT

Fire in the Ice is published by the National Energy Technology Laboratory to promote the exchange of information among those involved in gas hydrates research and development.

Interested in contributing an article to *Fire in the Ice*?
This newsletter now reaches nearly 480 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 301-354-2033

Numerous presenters reported on the results of the Mallik 2002 Gas Hydrate Production Research Well Program. It appears that the Mallik 2002 gas hydrate production testing and modeling effort has, for the first time, allowed the rational assessment of the production response of a gas hydrate accumulation. Gas hydrate production simulations, including those performed by Lawrence Berkeley National Laboratory and Japanese researchers, have shown that under certain geologic conditions, gas can be produced from gas hydrates at rates exceeding several million cubic feet of gas per day. The conference participants concluded that a key goal of industry should be to document that commercial rates of gas production from hydrates are possible. The Mallik test came close to addressing this issue, but it was not designed for commercial gas production rates. It is important to note that two independent studies of the deliverability of gas from gas hydrates on the North Slope of Alaska and the Canadian Arctic reported similar economics, and a gas delivery cost of about $4 to $5 (USD) per thousand cubic feet of gas. Several participants noted that gas hydrate production may require government incentives, much like the early days of coalbed methane production in the United States. But probably the most significant conclusion coming from the discussions in Vancouver was the strong statement that we need more dedicated and expanded field production testing to assess the ultimate resource potential of natural gas hydrates.

Some of the liveliest discussions during the conference focused on the potential hazards associated with gas hydrates, especially slope stability issues (both natural and human induced). One of the major conclusions of these discussions was the acknowledgment that more effort is needed to document case histories of actual gas hydrate-induced drilling and completion problems. On the issue of shallow water flow, a great deal of uncertainty remains about the role of gas hydrates with respect to the observed shallow water flow problems in the Gulf of Mexico.

For more information on the Hedberg Research Conference on gas hydrates please see the Education section of the AAPG website <http://www.aapg.org>. All of the extended abstracts published in the conference proceedings volume are posted on the AAPG website. More detailed meeting summaries are still being prepared for publication in the AAPG *Explorer* and on the AAPG-EMD website.

The conference was a great success. Financial sponsorship from the Gulf of Mexico JIP, Schlumberger, and especially the U.S. Department of Energy was greatly appreciated. The Energy Minerals Division of the AAPG was also a co-sponsor, in keeping with their long history of support for gas hydrate research and development issues. The Canadian Association of Petroleum Geologists and the Geological Survey of Canada also contributed to the organization of the conference.

Tim Collett of the USGS and Art Johnson of Hydrate Energy International organized the Hedberg Research Conference in Vancouver.

Photograph of a gas-hydrate-bearing sediment core from the Mallik 5L-38 Gas Hydrate Production Test Well. The white material in this photo is the gas hydrate. (Courtesy of the Mallik 2002 Gas Hydrate Production Test Well Program)

GAS HYDRATE BOOK PROPOSAL

As an extension of the Hedberg Research Conference in Vancouver, the conveners are soliciting contributions to a special publication on gas hydrates. The planned publication will follow the goals of the Hedberg Conference; however, the contents of this special publication will be expanded to include all aspects of gas hydrates in nature, including supporting laboratory studies and related climate change studies. The Hedberg Conference organizers are soliciting the submission of both long topical summaries and short, focused research papers. Contributions can draw directly from the Hedberg Conference presentations, or can be on any other relevant topic. Submissions from non-conference participants are welcome. Additional co-editors will also be invited to help with this effort. This book will likely be published in the AAPG Memoir series. Depending on the number of submissions and the final format of the publication, the length of the submitted papers should be in the range of 6,000 to 10,000 words, with possible additional room allotted for significant summary contributions. The manuscript submission deadline for this book is August 1, 2005. If you would like to contribute to this effort, please contact either Tim Collett (tcollett@usgs.gov) or Art Johnson (art_johnson@hydrate-energy.com).

Oak Ridge Facilities Well Suited for both Education and Collaborative Research

By Tommy J. Phelps and Claudia J. Rawn, Oak Ridge National Laboratory

Researchers at Oak Ridge National Laboratory (ORNL) have developed extensive facilities well suited for the extreme environments required to form, maintain, and examine natural gas hydrates. These facilities include the Seafloor Process Simulator (SPS), a pressure cell with geometric considerations appropriate for use in a neutron powder diffractometer, and an x-ray powder diffractometer equipped with a closed cycle helium refrigeration apparatus capable of reaching temperatures as low as 15 K. Some of these facilities were developed with ORNL Laboratory Directed Research and Development funds, with enhanced capabilities and multidisciplinary collaborative research supported by the Department of Energy's Fossil Energy (DOE-FE) Methane Hydrate research program.

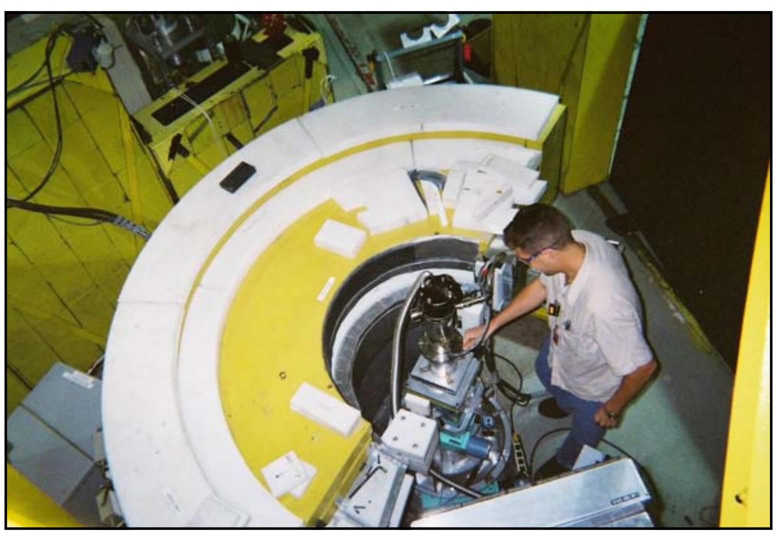
Since mid-2000, ORNL has been utilizing its unique facilities to perform multiple research tasks related to methane hydrates, as part of the DOE-Fossil Energy Methane Hydrate program. The objectives have been to use samples of naturally occurring, as well as synthetic gas hydrates, to characterize the thermodynamics and kinetics of hydrate formation and dissociation. ORNL has developed an experimental methodology to characterize structural and interfacial properties of natural gas hydrates and implemented that methodology to characterize both natural and synthetic gas hydrates on a mesoscopic scale (dimensions intermediate between macroscopic and atomic). An important task has been the determination of hydrate thermal transport properties needed to model and simulate hydrate behavior under subsea and permafrost conditions. ORNL has also been involved in biochemically characterizing hydrate samples from ODP Leg 204 and cores from the Mallik 2002 well drilled in the Canadian Arctic. The results of these efforts will be summarized in subsequent articles, but here we will give some examples of how ORNL's unique equipment is being utilized to support academic research.

Image of methane hydrate forming in the sapphire vessel at 280 K and 13.8 Mpa.

Neutron and X-ray Powder Diffraction Facilities

A pressure cell fabricated from single crystal sapphire (shown on previous page in the process of forming methane hydrate) was designed for use on the ORNL's High Flux Isotope Reactor (HFIR) neutron powder diffractometer. Neutron diffraction is well suited for the study of hydrates because it is sensitive to the hydrogen and oxygen atoms that form the hydrate's crystalline framework, and to the hydrogen, oxygen, and carbon atoms that are often found in the guest gas molecules trapped within the lattice. Neutron diffraction can be used to identify the phases present and study the atomic structure of hydrates, as a function of both temperature and pressure. These studies can provide information about the thermal expansion and bulk modulus of the hydrates. Earlier studies at ORNL using neutron powder diffraction as a function of temperature, focused on determining the motion of the guest molecule and cage, and the thermal expansion of samples provided by Laura Stern and Sue Circone of the USGS. An X-ray diffractometer, configured for low temperature data collection (15 K to 300 K) complements the neutron powder diffraction by allowing for quick phase identification and the lattice parameters as a function of temperature. Environmental samples retrieved from the Green Canyon locations in the Gulf of Mexico were evaluated using low temperature X-ray powder diffraction. Examination of these samples by Roger Sassen (Texas A&M), identified the hydrate as Structure II with ice and sediments present.

The facility at ORNL is also well suited for graduate research. For example, Michael Eaton used similar diffraction facilities currently available at the National Institute of Standards and Technology (NIST) in Maryland, to obtain data related to the support of his Master's thesis at the Colorado School of Mines. Michael was studying the effect of formation temperature on structural changes in the hydrate framework and the fractional occupancy of its guest molecules. Both methane and xenon guests were evaluated inside a deuterated framework, with formation temperatures of 263 and 283K. In the former case, the use of neutrons was integral in analyzing the non-deuterated methane guest. Funds from the ORNL DOE-FE project were used to access the NIST facilities, while the HFIR powder diffractometer at ORNL was being upgraded.



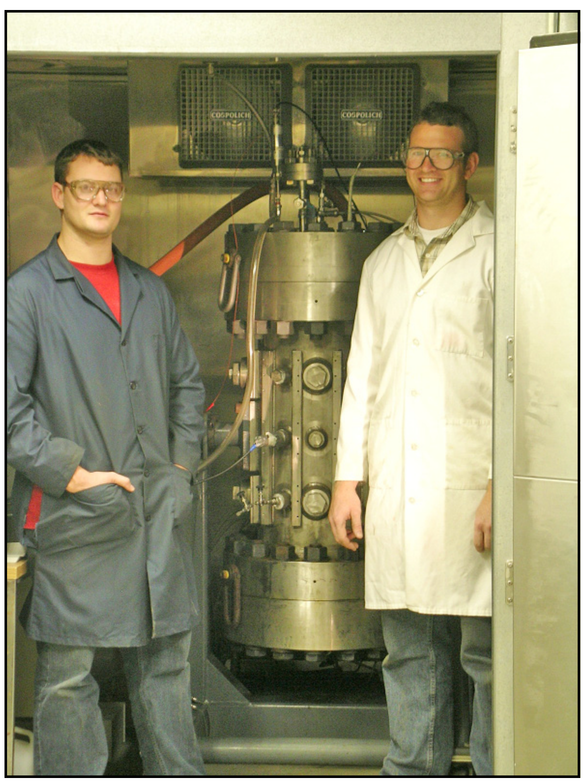
Michael Eaton from CSM using the BT1 powder diffractometer at NIST in collaboration with researchers from ORNL.

The Seafloor Process Simulator (SPS)

The Seafloor Process Simulator (SPS) is a high-pressure vessel with a 72-liter volume that is used to examine physical, geochemical, and biogeochemical processes affecting the formation and stability of methane hydrates. The SPS is a unique experimental facility that bridges the gap between typical laboratory-scale hydrate vessels of two-liter-or-less-sized volumes, and seafloor experiments requiring the use of ships. The SPS is housed in an explosion proof cold room, and the vessel is ASME-stamped for a working pressure of 21 MPa (3,000 psi), making it well-suited for the examination of coupled kinetic, thermophysical, mechanical, biogeochemical, and scale-up properties related to methane and other hydrates. The mass of the SPS provides excellent temperature stability with variations of ~0.5 K within experiments.

The SPS is fabricated from a nickel-based alloy, Hastelloy C-22, to avoid corrosion. A 2.54 cm (1 in.) thick sheet of Hastelloy was rolled and welded to create the cell body, providing an internal diameter of 31.75 cm (12.5 in.) and a length of 91.1 cm (35.9 in.). End plates weighing 317.5 kg (700 lb) each are held in place by 16 bolts, each torqued to 2508 N•m (1,850 ft-lb). Forty vessel ports provide locations for gas and liquid exchanges, inputs for monitoring instrumentation, or visualization windows, making the SPS a unique, highly instrumented facility. Several of the ports are equipped with sapphire windows (typically protected by a Lexan shield). Routine monitoring can include video, photography, Raman spectroscopy, microscopic examination (~ 10 mm resolution), temperature, pressure and pH. Internal as well as external recirculation pumps are available.

Like the HFIR, the SPS can be utilized for graduate research. David Riestenberg accomplished his Master's research by using the SPS to conduct studies on the effects of sediment surfaces on methane hydrate formation and stability. Hydrate formation experiments were conducted by bubbling methane through a column with slurries of various colloidal particles, such as bentonite and silica. It was observed that the sediment surfaces dramatically lowered the



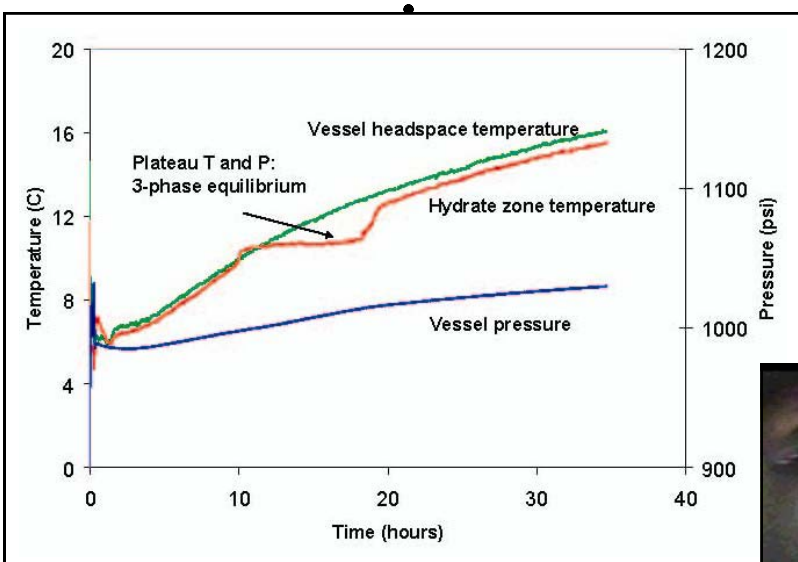
Scott McCallum (left) and David Riestenberg (right) in the cold room with the SPS.

overpressure required for hydrate formation. Hydrate stability studies were conducted by slowly warming the SPS that contained the previously formed hydrate, while monitoring the temperature of the hydrates with thermocouples. The temperature of the hydrates remained at the 3-phase equilibrium temperature for more than 5 hours. This technique provided an effective way to determine hydrate equilibrium conditions. It was found that while sediment surfaces affect hydrate formation conditions, they do not appear to affect hydrate stability.

Other experiments revealed that when as little as 5 percent of recently frozen water was added to the SPS, the overpressure required for hydrate formation was reduced by an average of 50 percent, when compared to untreated fluids. The degree of overpressure affected hydrate morphology, with low overpressures forming hydrates at the gas water interface, while high overpressures formed massive hydrates abruptly. Once hydrate formation was initiated, the morphology was dependent on the degree of overpressure.

Ways to Collaborate with ORNL

There are a variety of ways for student researchers to collaborate with the researchers and access the facilities described here. One approach is direct project collaboration with ORNL investigators through the DOE-FE Methane Hydrates program. Postdoctoral and postmaster's degree students, and visiting scientists typically collaborate through the Oak Ridge Institute for Science and Education (ORISE) administered by the Oak Ridge Associated Universities (ORAU). Thus far, the DOE-FE Methane Hydrates program has supported 2 graduate students, 3 post-master's, and 2 post-doctoral researchers through ORISE. In addition, the neutron powder diffractometer can be accessed through the High Flux Isotope Reactor (HFIR) Center for Neutron Scattering Research user program, while the low temperature X-ray diffractometer can be accessed through the High Temperature Materials Laboratory (HTML) user program.



Hydrate 3-phase equilibrium is identified by the flat line on the temperature versus time curve, developed from SPS-acquired data.

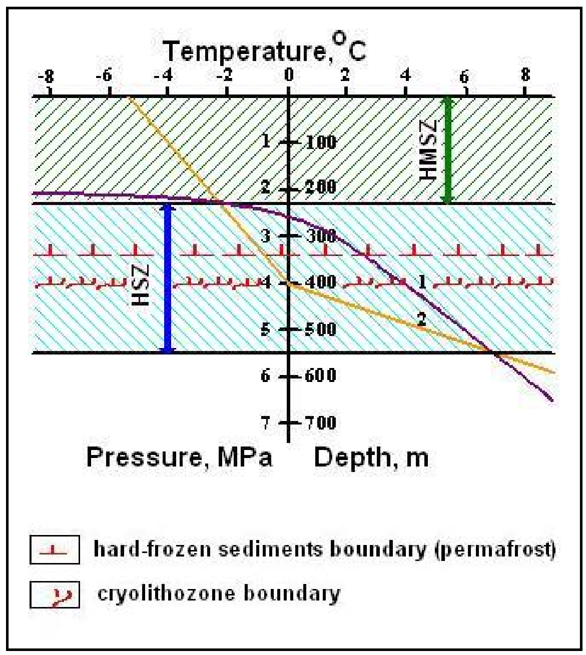
Image of massive hydrate formation in the SPS

Relic Gas Hydrates of Northwestern Siberia

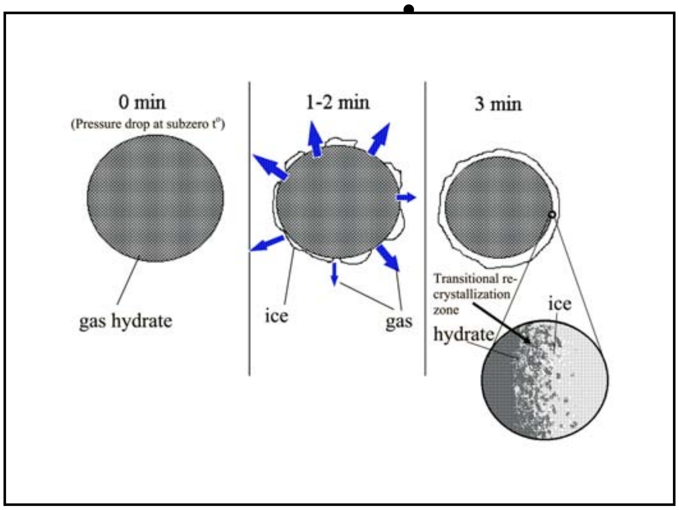
Vladimir Yakushev – Research Institute of Natural Gases and Gas Technologies (VNIIGAZ), Gazprom, Russia

Laboratory simulation of frozen hydrate-bearing sediments conducted at VINIIGAZ in the mid and late 1980s predicted the existence of metastable (relic) hydrates in nature. Formed when thermodynamic conditions in the subsurface were favorable for hydrate formation, metastable hydrates can exist at subzero temperatures, even if overall thermodynamic conditions are no longer within the range of hydrate stability. The phenomenon termed "gas hydrate self-preservation" results from the formation of an ice film at the hydrate interface following a pressure drop. Hydrate formed during conditions of hydrate stability remains stable, sealed by the ice, when these conditions change, but the temperature remains subzero.

This phenomenon has resulted in a reconsideration of the general model of gas hydrate existence in permafrost regions, and the introduction of a new depth interval related to gas hydrate: the Hydrate Metastability Zone (HMSZ). The HMSZ includes all frozen sediments from the bottom of the seasonal defrost layer down to a depth corresponding to the top of the usual Hydrate Stability Zone (HSZ). Theoretically then, the entire permafrost section, including that above the conventional HSZ, can be considered favorable for gas hydrates. Within this interval however, metastable hydrates can only exist in sediments that contain ice and are (or once were) permeable enough for gas migration.



Schematic illustrating the Methane Hydrate Stability Zone (HSZ) and the Hydrate Metastability Zone (HMSZ) in permafrost regions. Curve 1 depicts equilibrium conditions for methane hydrate while curve 2 shows actual P/T conditions in the geologic section.

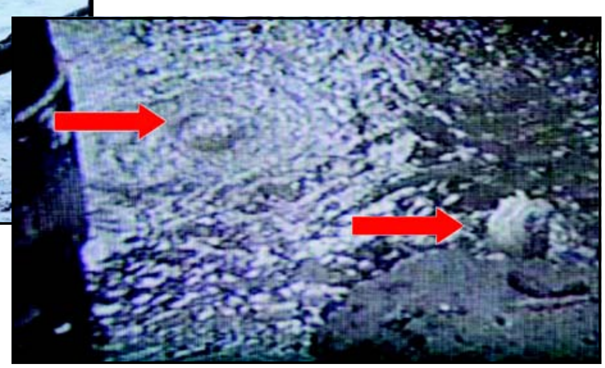


Schematic illustrating the mechanism of self-preservation for a gas hydrate particle during a pressure drop at subzero temperatures.

The liberation of gas from defrosting permafrost during drilling operations has been observed for some time. Some features of these liberations (and in some cases, blowouts) correspond to the behavior of melting gas hydrates. The first indications of the existence of relic hydrates in the permafrost of Western Siberia were documented in the late 1980s and early 1990s, in the area of the Yamburg Gas Field. These were visible gas liberations from permafrost drill cores recovered from depths of less than 150 m and thawed in kerosene or warm water. These cores contained fine-grained sand with very small pore volume available for free gas, yet the volume of gas liberated during defrosting was many times the available pore volume. The same situation occurred more recently with drill cores recovered from a depth of 119 m at the 92GSC Taglu well in Northern Canada. The presence of relic gas hydrates is proposed as the source of the gas in both of these cases.

The most advanced studies of relic gas hydrates have been conducted at the Bovanenkovo Gas Field in the Yamal Peninsula of Northwestern Siberia. These studies included the drilling of wells, recovery of permafrost cores, observation and analysis of permafrost gas liberation (from the wells), and the laboratory measurement of drill core hydrate content. While gas hydrates were not found in all of the drill cores studied, some of them contained hydrate volumes totaling between 0.5 and 3 percent of the pore space volume, based on measurements of the volume of gas liberated during sample thawing in water. The most interesting observation was that hydrate-containing sediments often were found adjacent to intra-permafrost gas-bearing formations. Gas flow rates at wells reached more than 10,000 m^3/day (353 Mcfd) from a depth of 60 to 120 m (200 to 400 ft). Analysis of the produced gas revealed a microbial genesis of the methane liberated from both the hydrates and the free gas in the permafrost. This finding provides some basis to suppose that the free gas accumulations could result from gradual decomposition of the intra-permafrost metastable gas hydrates.

Permafrost gas flare during drilling of a shallow well in Siberia.



Permafrost gas bubbling through water surrounding warm casing of producing gas well.

SUGGESTED READING

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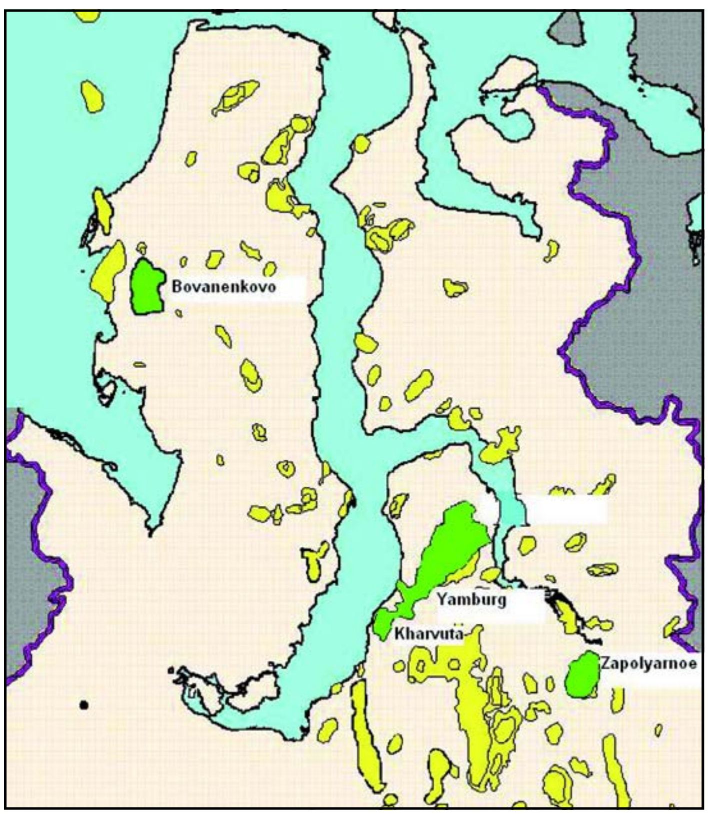
According to isotopic and chemical analysis, the gas found within the permafrost intervals at both the Yamburg and Bovanenkovo fields is completely different from the gas found in the productive reservoirs of the fields. This means that gas hydrate and associated free gas accumulations found within the permafrost interval can have their own independent mechanism of gas generation, accumulation and conservation. Probably, microbial gas was generated and partially dissolved in pore waters before section freezing took place. Subsequent freezing of the geologic section could then concentrate the gas, and in certain situations, result in local hydrate formation. The hydrates thus formed then came to a metastable state with changing conditions over time and this process was accompanied by free gas accumulation in neighboring permeable layers. While we cannot precisely evaluate the total gas resource related to intra-permafrost metastable gas hydrates and free gas accumulations at the Yamal peninsula location, a first estimate of the resource density at Bovanenkovo is at least 100,000 m^3/km^2 (5000 Mcf/acre) for the 60 to 120 m (200 to 400 ft) depth interval. This value is determined based on measurements of the total volume of gas liberated at the test wells. Taking into account the low permeability of the drill cores evaluated, we can assume that only a relatively small portion of the resource in this interval was liberated by the well and that the actual value of the resource density may be much greater (perhaps by one or two orders of magnitude).

Additional studies of intra-permafrost gas hydrates and free gas accumulations have begun recently in two other Western Siberia gas fields: Zapolyarnoe and Kharvuta. The same evaluation procedures are being applied there as were applied at Bovanenkovo. Although strong gas releases from permafrost intervals have been observed during drilling, only 2 drill cores out of more than 15 recovered and transported to a Moscow laboratory have shown gas liberations when thawed in water. The study is continuing, and additional cores are being obtained.



Map of Northwestern Siberia gas fields with intra-permafrost gas hydrate study areas shown in green.

Fugro Explorer to Drill JIP Tests in the Gulf of Mexico

Fugro Explorer

The field cruise portion of *Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities* will get underway in early April 2005. Researchers will drill wells at two deep-water gas hydrate sites—Atwater Valley and Keathley Canyon—on the outer continental shelf. The project is funded by the ChevronTexaco Gas Hydrate Joint Industry Program (JIP) and the Department of Energy.

Two well pairs are planned at both the Atwater Valley and Keathley Canyon locations at a water depth of approximately 4,300 ft (1,300 m). Each pair will consist of a logged well and a nearby (~50 to 75 ft, or 13 to 23 m) offset cored well for correlation and instrumentation. The researchers selected the drilling sites based on maps of gas hydrate indicators and an interpretation of the geologic framework of the selected sites. This information was the result of the high-resolution multichannel seismic (MCS) data collected during Phase I of the project, combined with three-dimensional MCS data provided by industry.

The research team will be aboard the *Fugro Explorer*, completely refitted in 2002 and now one of the most technologically advanced geotechnical drilling vessels available. The vessel is fully equipped for geotechnical, geological/ stratigraphic, and reservoir characterization investigations, and is capable of operating in water depths up to 10,000 ft (3,000 m).

The plan will be to begin by drilling the two drill-and-log wells, first at Keathley Canyon, then at Atwater Valley. The crew will rig down the drilling equipment and rig up for coring operations, return to Keathley Canyon to core the two offsets, and then finish the cruise by coring the two offsets at Atwater Valley. A twelve-person research team will participate in what is expected to be a 30-day cruise.

The project is a multi-year collaborative effort to develop technology and collect data to characterize naturally occurring gas hydrates in the deep-water Gulf of Mexico. JIP industry partners include ChevronTexaco, ConocoPhillips, Total E&P USA, Schlumberger, Halliburton Energy Services, the Minerals Management Service (Gulf of Mexico Region), the Japan National Oil Corporation, and India's Reliance Industries. Academic collaborators include the Georgia Institute of Technology, the Scripps Institute of Oceanography, and Texas A&M University through the Joint Oceanographic Institute.

Planning Workshop Slated for Early Next Year

The National Energy Technology Laboratory is currently planning to conduct a workshop in Houston, Texas in early February 2005 to present and discuss a draft 5-year R&D plan for the Department of Energy's Methane Hydrate R&D program. The workshop will be open to all interested members of the hydrates R&D community. Please be sure to check back to the DOE methane hydrates website for more information as plans for the meeting are finalized.

INGO PECHER

New Zealand Institute of Geological and Nuclear Sciences

As a geophysicist, Ingo Pecher got his introduction to hydrates when his Ph.D. advisor, Roland von Huene, suggested that he "do something" about bottom simulating reflections off Peru. This was at a time when the first results from waveform inversion of BSRs were being published, and gas hydrates research was just starting to take off. "*Admittedly, BSRs were initially mostly interesting to me as an ideal target for modern seismic techniques – essentially, for playing with new toys*," says Pecher. "*The substance in the seafloor causing BSRs however, gas hydrate, increasingly came to fascinate me, because it appeared to be so widespread, and yet we knew so little about it*."

And for the moment, Ingo Pecher continues to follow the advice of his thesis advisor and is "doing something" about understanding the almost uncharted territory (as far as gas hydrates are concerned) of offshore New Zealand.

Spotlight on Research

Ingo Pecher, GNS

Ingo received his German "Diplom" (roughly equal to an M.Sc.) from the Institute for Geophysics at the University of Kiel, Germany, in 1991 and his Ph.D. from Geomar, Kiel, in 1995. After a post-doctoral position at the Woods Hole Oceanographic Institution and a position as a research associate at the Institute for Geophysics at the University of Texas at Austin, he joined the Institute of Geological & Nuclear Sciences in New Zealand in 2001. Since arriving in New Zealand, Ingo has been focusing on getting New Zealand's exciting gas hydrate provinces "on the map" for global research, in particular the Hikurangi Margin east of the North Island, where excellent examples of gas hydrate-related seafloor instability can be observed.

"*For me, the timing was very fortunate regarding my research area, and a major paradigm shift in our view of how gas hydrates and the free gas beneath them accumulate*," adds Pecher. The theoretical work of Carolyn Ruppel and Wenyu Xu (at Georgia Tech) as well as Bruce Buffet and Olga Zatsepina (at the University of British Columbia) in the late 1990s suggested that gas hydrates and free gas at BSRs exist in a steady state relationship with methane being supplied from below and being lost into the ocean. The occurrence of BSRs and high concentrations of gas hydrates require high rates of methane flux (and hence, fluid flow)—a very different situation than the traps associated with conventional gas reservoirs. "*Shortly after that work had been published, we detected one of the clearest examples yet for a link between BSR occurrence and focusing of fluid flow during a research cruise of the R/V Sonne off Peru in 2000*," explains Pecher. In addition to BSRs, Ingo is also actively interested in shear wave studies of methane hydrate deposits and remains involved in the analysis of data from two major experiments he helped to launch while in Texas.

When asked to comment on the future of methane hydrate research, Pecher remarks that the scientific community is still missing a major piece of the gas hydrates puzzle. "*We still need to explain why gas hydrates form in some settings and not in others. The answer to this question may evolve incrementally … we have in fact progressed a long way in the last few years … but I personally think that a major part of this jigsaw puzzle is likely to come from a breakthrough discovery.*"

He also sees a need for the research community to become more specific, adding that "*I think it's safe to say that it is the general view of most of the gas hydrates community that we have to move on from Keith Kvenvolden's higher-end, 1988 estimate of the amount of carbon being stored globally in gas hydrates to establish the amount of recoverable gas from gas hydrates at specific sweet spots. We need to learn exactly how gas hydrates may affect slope stability, how much gas may be released due to temperature fluctuations at specific margins, and how this gas may affect climate changes*." He also sees a need to study the organisms that form methane, determining what "feeds" them, and estimating how much they contribute to gas hydrates at specific locations (with a strong caveat that he remains only vaguely familiar with the related microbiological questions). However, the most pressing question, in his view, may well be the effect of gas hydrates on seafloor and borehole stability during deep-water hydrocarbon production. "*This production is happening now. We need to learn how to be certain that we can safely produce oil and gas through gas hydrate-bearing layers.*"

What does he like most about his involvement in methane hydrates research? "*The enthusiasm of people like Roland von Huene, Steve Holbrook and Bill Dillon, for the pursuit of new and unconventional ideas. And I particularly enjoy the truly multi-disciplinary aspects of gas hydrates research … the collaboration of marine geophysicists like myself with geologists, geochemists, and biologists, among others.*"