Vol. 5, Iss. 1

Fire in the Ice

THE NATIONAL ENERGY TECHNOLOGY LABORATORY METHANE HYDRATE NEWSLETTER

CONTENTS

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The *Fire in the Ice* Newsletter is also available online at our website www.netl.doe.gov/scngo/Natural%20Gas/hydrates

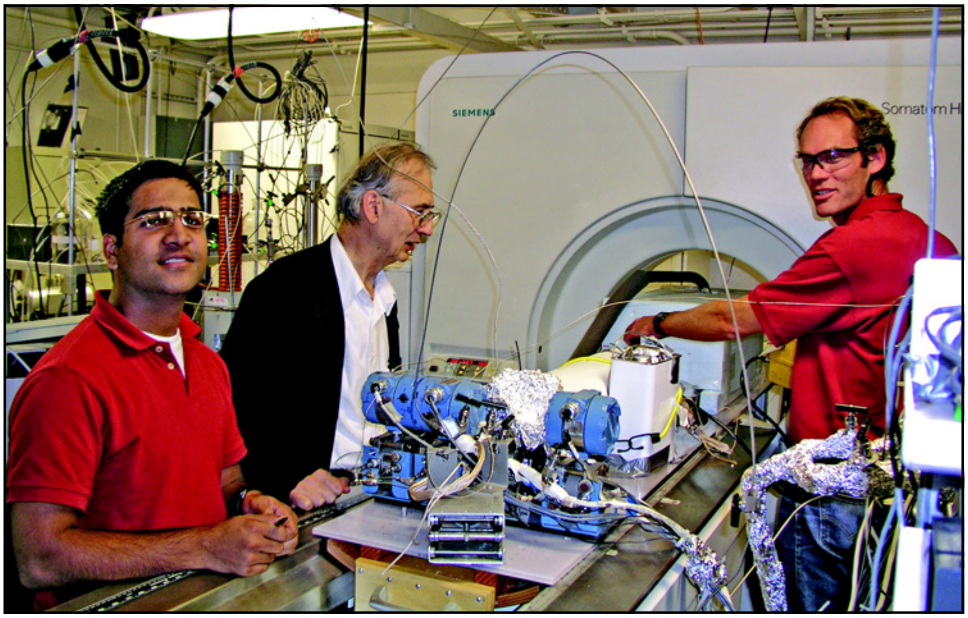
UNDERSTANDING METHANE HYDRATE BEHAVIOR USING X-RAY COMPUTED TOMOGRAPHY

Tim Kneafsey, George Moridis, Barry Freifeld, Liviu Tomutsa and Yongkoo Seol (Lawrence Berkeley National Laboratory), and Chuck Taylor (National Energy Technology Laboratory)

To understand hydrate behavior, either in a pure phase or in a porous medium, we measure its properties and responses to changes in conditions such as pressure, temperature, and chemistry. Natural hydrates occur at low temperatures and high pressures (substantially outside the range of ambient conditions), making observation difficult. Some investigators have successfully used pressure vessels with windows, but visual observations are limited to the outer appearance of the sample.

We use x-ray computed tomography (CT) scanning as a visualization technique to observe hydrate related laboratory processes occurring within the entire volume of laboratory samples. This activity is a component of our NETL-funded project in which we are determining (through history matching of laboratory data) parameters and processes of critical importance to the feasibility of gas production from hydrates.

In our tests, it is critical to understand what is occurring at each location within a sample to avoid misinterpreting local behavior for bulk behavior. Our work involves hydrate samples on multiple spatial scales. In the laboratory, we use



Arvind Gupta (Colorado School of Mines), Liviu Tomutsa, and Tim Kneafsey (LBNL) setting up an experiment on the modified medical CT scanner core-scale and smaller samples to gather data that can be extended to the field scale. We are also interested in processes at the pore scale, which may ultimately control the feasibility of producing natural gas from a hydrate-bearing reservoir.

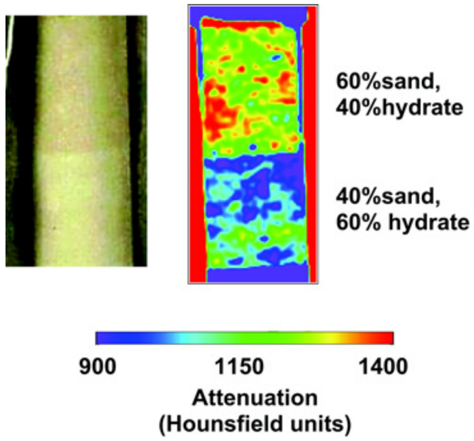
In CT scanning, x-rays are passed through the sample from many different directions, and detectors record the intensity of the x-rays passing through relative to direction. Materials within a sample absorb x-rays roughly in proportion to their density and (to a lesser extent) their atomic number, thus denser and higher-atomic-number materials absorb more x-rays than less dense, lighter materials. A density image can be calculated from the x-ray intensities. Such X-ray imaging can be performed without altering the sample, making it ideal for tracking both temporal and spatial changes.

Our visualization studies employ a variety of tools. We use a modified medical CT scanner (see figure), several lab-built CT scanners (including one featured in *Fire in the Ice*, Fall 2003), and perform microtomography using the bright soft x-rays at the Advanced Light Source (ALS) at Berkeley Lab. These instruments offer a variety of capabilities and resolutions - from rapid scanning and image computation of ~30 cm-scale samples at a resolution of ~ 250 microns, to very high resolution (~3 microns or less) scanning of cm-scale samples at the ALS, to portable equipment for scanning core-scale samples at field sites. All these tools provide an understanding of processes in different sample types and multiple scales. The results of several of the experiments in which we have used CT scanning are summarized below.

Tracking the Dissociation Front: Thermal Dissociation

Collaborators: Laura Stern and Steve Kirby (USGS)

In this test, we observed and measured hydrate dissociation occurring within a 2.5 cm diameter sample with two regions having different mixtures of pure methane hydrate and silica sand. The success of this study hinged on our ability to use CT to distinguish between hydrate and the ice produced upon dissociation. The figure shows a photo and an initial CT scan of the sample. We allowed the sample to warm from the top and scanned while continuously measuring temperature and the volume of gas produced. To identify the changes in the sample, we observed the differences in x-ray attenuation from the initial condition (see figure). As the hydrate dissociates from the top to the bottom, the mass is reduced by the loss of methane, showing a decrease in attenuation (blue and purple colors). From these images, we can track the dissociation front and correlate it with temperature and volume data.



X-ray CT image of the methane hydrate/sand sample. Photo courtesy of Laura Stern, USGS.

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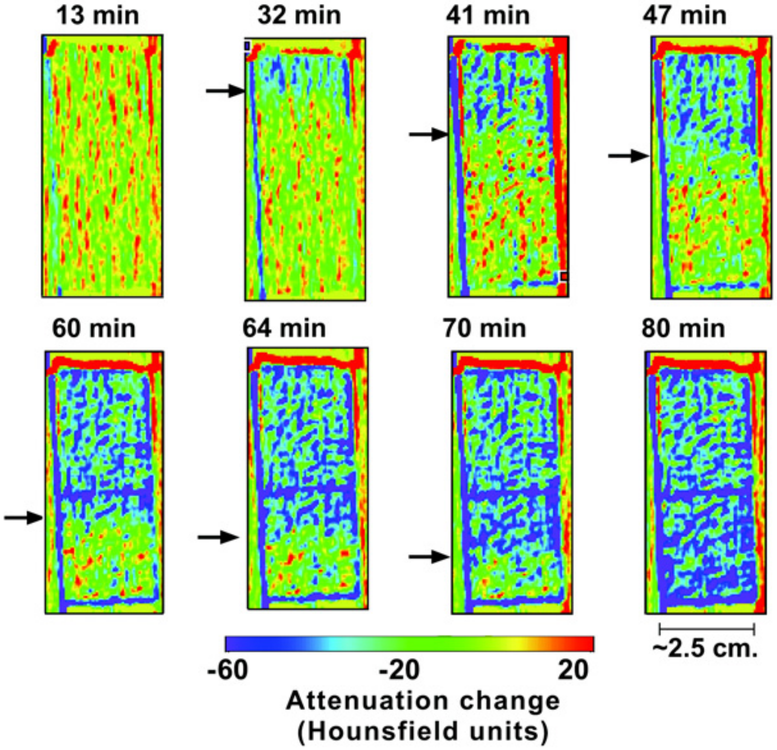
INTENT

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*?

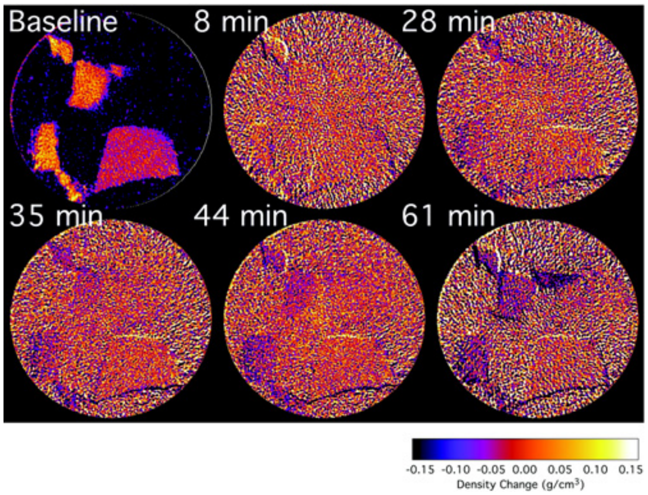
This newsletter now reaches nearly 500 scientists and other individuals interested in hydrates in sixteen countries. If you would like to submit an article about the progress of your methane hydrates research project, please contact
Karl Lang at 301-354-2033
(klang@hartenergy.com)



Attenuation changes as the dissociation front (at arrow) progresses from top to bottom in the sample

Methane Hydrate Dissociation: Portable X-ray CT System

In another experiment, we placed cold, stable methane hydrate, ice, and silica sand in a 7.6 cm inner diameter (ID) aluminum vessel and allowed ambient heat to warm the vessel and cause dissociation. This experiment was performed to test the Berkeley Lab's portable CT system, which is able to scan as much as 10 cm of core length at one time with about 200 micron resolution. The figure here shows the initial CT scan (baseline) and the changes that occur over time. In the baseline case, sand is the densest material and the darkest in the image. The ice is the magenta object in the lower right quadrant, while the hydrate chunks are the irregularly shaped yellow-orange objects. Over time, as dissociation occurs the hydrate becomes less dense (more purple in color), while the sand and ice maintain a constant density.



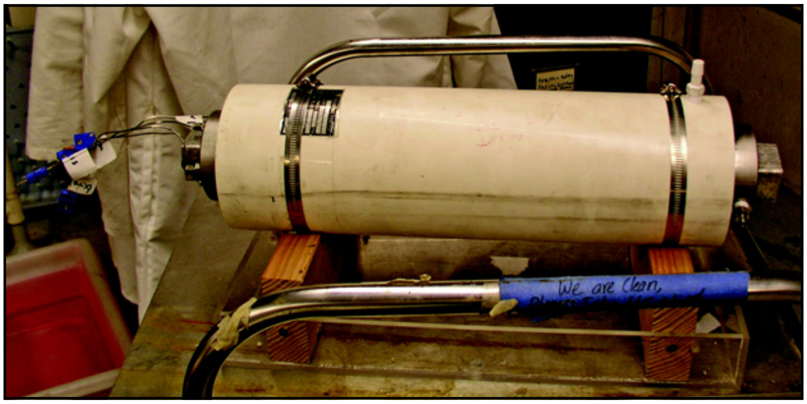
Baseline CT image (top left) and images at time intervals showing changes in density over time for a vessel containing sand, hydrate and ice. The scale bar does not apply to the baseline image, but only to the density changes.

Hydrate Formation and Dissociation in a Core-Scale Partially Saturated Sand

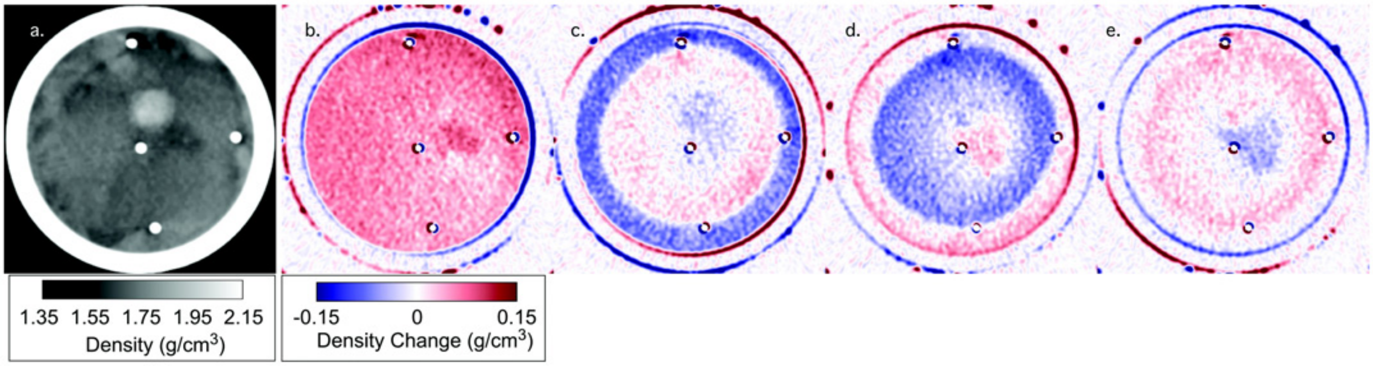
Collaborators: Chuck Taylor (NETL) and Arvind Gupta (Colorado School of Mines)

In this test, we formed methane hydrate in wet sand (not fully water saturated) in a 7.6 cm ID by 25 cm long aluminum vessel (see figure). We built this vessel to perform hydrate studies using CT scanning, and it includes multiple thermocouple ports allowing us to collect temperature data at four locations and a fluid jacket for temperature control. After forming the hydrate, we dissociated some of it by heating from the outside, formed hydrate again, and then dissociated it by depressurization and heating (see figure). The resulting density changes are indicative of the physical/chemical and hydrological processes that occurred during the formation and dissociation of the hydrate. Through the CT scanning we can see water saturation changes, the locations where hydrate forms and dissociates, and even gas pressure changes. Thermal properties and dissociation kinetics parameters are being determined by history matching using the TOUGHFx/HYDRATE code developed at Berkeley Lab.

CT scanning is a valuable tool for hydrate research, one that can be used to help understand processes occurring in hydrate formation and dissociation in the laboratory, as well as in characterizing natural cores. CT scanning, in conjunction with pressure and temperature measurements, provides a means for better understanding hydrates, as well for developing data sets for numerical model extension and validation.



Core-scale pressure vessel in a water jacket for temperature control. Thermocouples extend from the left side.



Initial scan (a.) and subsequent scans showing changes at one location caused by hydrate formation (b.), thermal dissociation (c.), second hydrate formation (d.), and dissociation by depressurization and heating (e.) White circles indicate thermocouple locations.

QUANTITATIVE ASSESSMENT OF MARINE GAS HYDRATES UNDERWAY AT MMS

Pulak K. Ray, Chief Geologist, Minerals Management Service

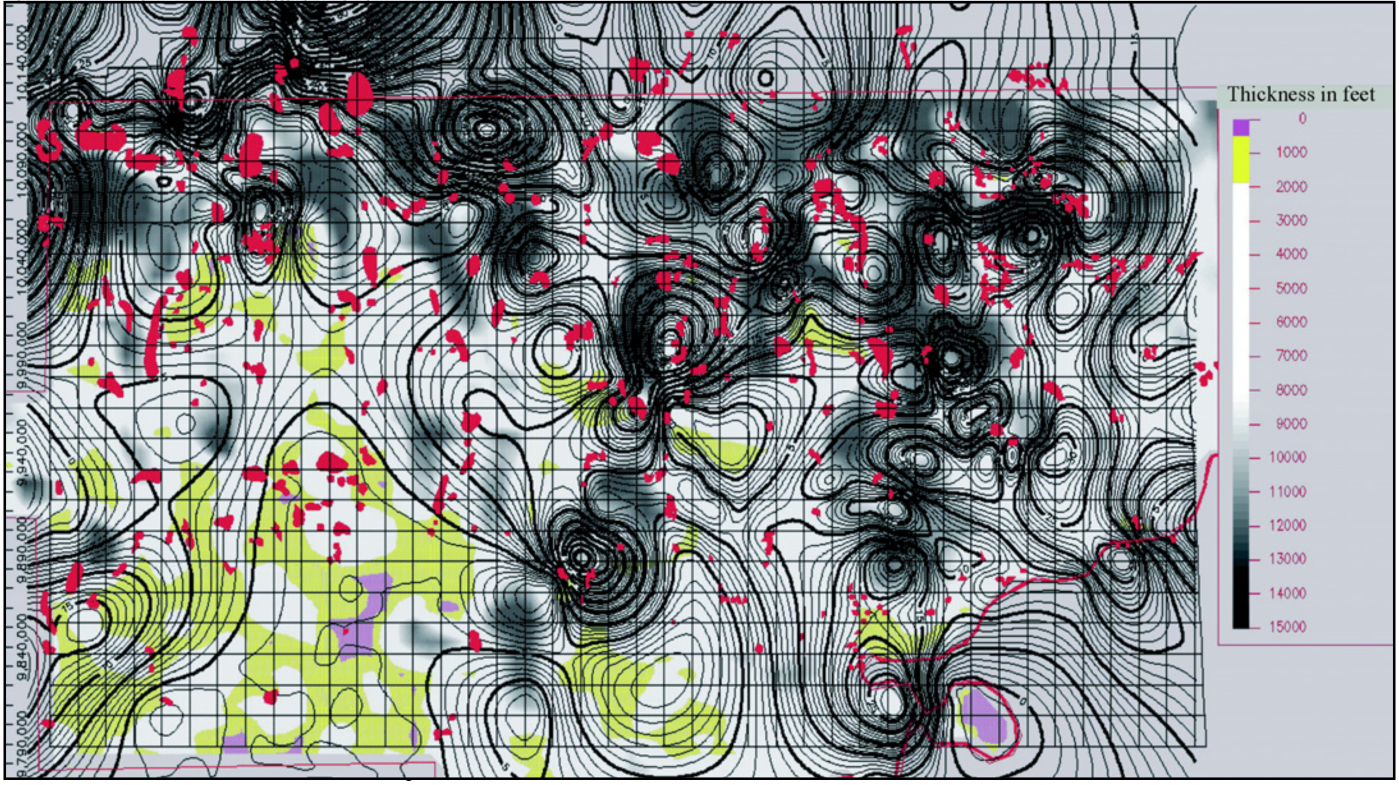
While full scale commercial production of gas hydrates is not anticipated in the U.S. in the next 15-to-20-year time frame, it is plausible that small scale production of gas hydrates may occur near term at either onshore Alaska locations or in the Gulf of Mexico from existing platforms. The Minerals Management Service (MMS) of the Department of the Interior is responsible for assuring the management of oil and gas production in an environmentally safe manner and the receipt of fair market value for production from Outer Continental Shelf (OCS) areas. In anticipation of eventual gas hydrate production from the OCS, MMS initiated an assessment of the gas hydrate resources in the U.S. OCS area in 2003. The first step was a series of brainstorming sessions and workshops where resource assessors and statisticians experienced in both conventional oil and gas and non-energy minerals participated. These experts, representing agencies of the U.S. Government, consulting firms and academic institutions, helped to establish a framework for the assessment of gas hydrate resources. The actual assessment will be done by MMS staff with guidance from and in consultation with experts from other U.S. Government agencies and non-government entities.

For conventional natural gas, a methodology for the probabilistic assessment of technically recoverable resources is well established. A probabilistic quantitative estimation of gas hydrates, however, poses a significant challenge due to the lack of a thorough understanding of the genesis of naturally occurring gas hydrates, absence of a well established methodology for their characterization, and a scarcity of empirical data. Most of the past work in assessing gas hydrates has been done on a global scale by estimating in-place volume, which is an estimate of crustal abundance and does not consider any minimum density or accumulation size limit, essential for defining hydrate viability as a resource.

In 1995 Tim Collett (USGS) estimated the gas hydrate volume of the OCS by applying a methodology used for conventional oil and gas. For the Gulf of Mexico (GOM) alone, Collett estimated a gas hydrate volume of about 0.7 x 10^{15} cubic meters (24,700 Tcf). In 2001 Milkov and Sassen estimated the volume of gas hydrates in structurally-focused accumulations and bacterial sources to be ~10-14 x 10^{12} m^3 (350-395 Tcf), based on geologic setting, water depth and the location of the gas hydrate stability zone (HSZ). Variance of several orders of magnitude clearly indicates the need for a fresh look at assessment methodology.

Realizing that the formation of gas hydrate accumulations is geologically much different than that of conventional oil and gas deposits and perhaps more akin to the formation of sedimentary ore deposits or hydrothermal deposits, MMS adopted a methodology (currently in the process of refinement) which is a simplification of the size/number model at the core of the "prospect-counting" play analysis approach, with a change in the emphasis on volumetrics. Due to the lack of a thorough understanding of the underlying process of hydrate accumulation and scant empirical data, a probabilistic approach is essential.

A combination of simplicity and complete transparency is the keystone of the MMS methodology. Researchers such as Sloan, Sassen, and McDonald, have recognized three different types of structures of gas hydrates: Structure **I**, which is primarily methane and is of bacterial origin, Structure **II** (which contains methane through isobutene) and Structure H (which contains methane through isopentane) which are primarily of thermogenic origin. While the assessment will include all three of these structure types, homologs higher than C_2H_6+ and free gas trapped under gas hydrates will be excluded. Possible hydrate occurrences will be classified as “autochthonous” where methane is generated within the HSZ from bacterial sources, and “allochthonous” where methane is generated outside of the HSZ and migrates into the HSZ to form gas hydrate. The methane source can be of thermogenic or biogenic origin. Volumes of autochthonous and allochthonous marine gas hydrates will be estimated separately, because physical properties such as density, aerial extent, range of methane homologs and trapping mechanisms are expected to be different. The results of the assessed values of the amount of gas hydrates will be presented as distributions for autochthonous and allochthonous deposits for both in-place and technically recoverable quantities.



An example of the combination of data types necessary for methane hydrate assessment by MMS. This example includes: sand percent isopach, total sediment thickness (indicated by color bar at right), and the location of ocean bottom anomalies (in red). The data is from the Green Canyon Area of the Gulf of Mexico. The Sigsbee Escarpment is delineated by the red line in the lower right corner.

Details of the methodology will be published elsewhere but a synopsis is included here. The assessment process will be divided into seven distinct steps:

1) definition of study areas;
2) estimation of the HSZ;
3) estimation of the areas of hydrate accumulations within the HSZ;
4) estimation of the thicknesses of hydrate accumulations within the HSZ;
5) estimation of methane density within hydrate accumulations;
6) estimation of the number of accumulations within the HSZ; and finally,
7) estimation of the total volume within the study area.

An example of the sort of data needed for steps 3 and 4 was presented at the 2004 Hedberg Conference in Canada by J. L. Hunt and B. Shedd, for a study area in the GOM. The accompanying figure from that presentation combines three sets of data for the Green Canyon Area of the GOM. It includes: a sand percent isopach (from mud line to top salt with a 1 percent contour interval), total sediment thickness indicated by color (purple for less than 500 feet of thickness, yellow for 500 to 2000 feet, darker shades for greater than 9000 feet), and the location of ocean bottom amplitude anomalies (red areas). The red line at lower right marks the edge of the Sigsbee Escarpment. Superposition of the HSZ and incorporation of methane density with this type of data will ultimately allow estimation of possible volumes of hydrate occurrence. The final results of the assessment will be released in late 2006.

NEW METHOD MAY HOLD PROMISE FOR GAS HYDRATE PRODUCTION AND CARBON SEQUESTRATION

Pete McGrail (Pacific Northwest National Laboratory), Tao Zhu (University of Alaska – Fairbanks), and Bob Hunter (ASRC Energy Services, Inc.)

Presently, depressurization, thermal stimulation, and a combination of these methods are being evaluated as a possible means of gas hydrate production. Depressurization and thermal stimulation have been used recently to produce a small amount of gas from the Mallik 5L-38 research well located on the Mackenzie Delta, Northwest Territories, Canada. Considerable uncertainties remain as to the economic viability of any of these methods for commercial production of gas hydrates.

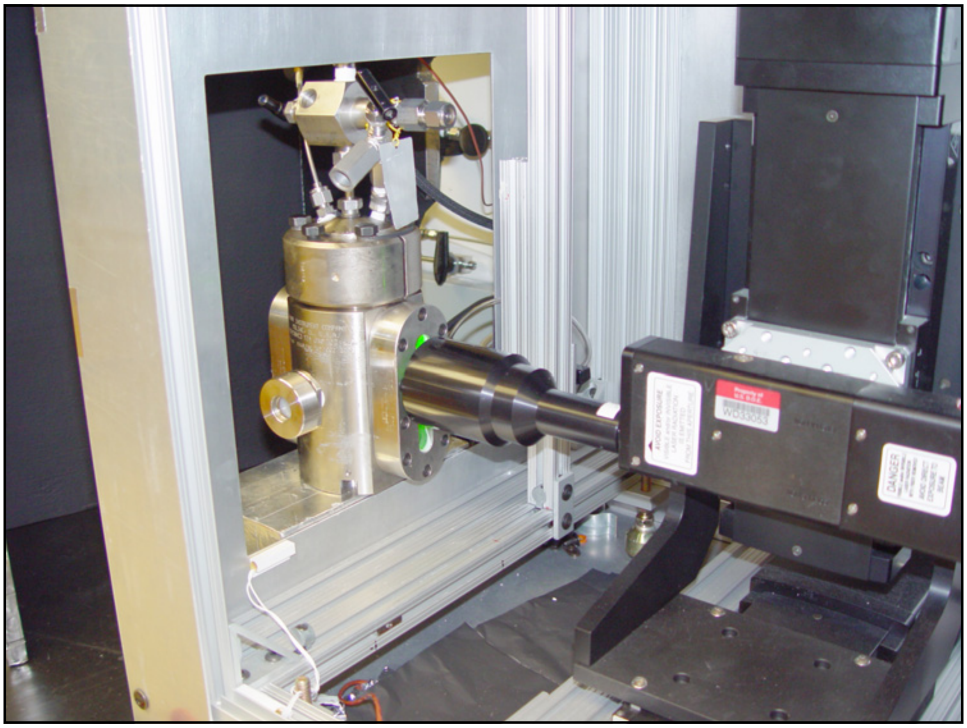
Another method that has been discussed for gas hydrate production involves the injection of CO_2 into the hydrate zone. The idea of swapping CO_2 for CH_4 in gas hydrates was first advanced by several Japanese researchers such as K. Ohgaki, S. Nakano, and others. It has a number of attractive features:

1) CO_2 displacement of CH_4 from gas hydrate is thermodynamically favorable,
2) the heat of formation of CO_2 hydrate is 20 percent greater than the heat of dissociation of methane hydrate; thus, formation of CO_2 hydrate more than offsets cooling from CH_4 hydrate dissociation on a mol per mol basis,
3) refilling pore space with CO_2 hydrate is expected to maintain the mechanical stability of gas-producing sediments, thus enhancing safety during gas production, and
4) the process is climate friendly in that it provides a sink for CO_2 removed from the atmosphere while simultaneously producing clean-burning natural gas.

The original concept advanced by Japanese researchers involves injecting CO_2 gas, which is then allowed to equilibrate with methane hydrate along the three-phase equilibrium boundary. Because of the difference in chemical affinity for CO_2 versus methane in the sI hydrate structure, the mol fraction of methane would be reduced to approximately 0.48 in the gas hydrate and rise to a value of 0.7 in the gas phase at equilibrium. However, the important issue of the kinetics of the reaction was not addressed until T. Uchida and H. Lee experimentally confirmed the guest-molecule swapping reaction. However, these studies still did not directly address the exchange kinetics beyond the first few hundred nanometers at the gas-solid interface.

To address this issue, we conducted a series of experiments to directly measure the rate of penetration of CO_2 into bulk methane hydrate. Using a scanning laser Raman LIDAR system developed at Pacific Northwest National Laboratory, (see figure) the penetration depth of CO_2 into a methane hydrate layer was traced as a function of time and temperature, using the signature symmetric stretching mode vibration at 1384 cm^{-1} for CO_2 in the hydrate phase. For those interested in using this simple method for gas hydrate production, the results were disappointing. We observed rapid exchange of CO_2 for CH_4 at the gas-hydrate interface, as had been previously observed, but the exchange rates deeper into the gas hydrate were slow, less than a few mm/h at temperatures up to 4°C. It appears highly unlikely that practicable gas hydrate production can be accomplished using a simple gas exchange method.

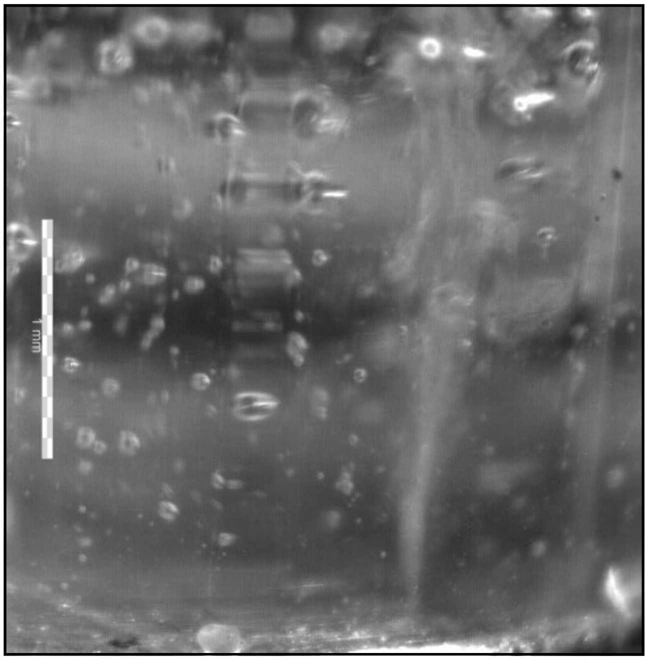
After trying a number of alternative approaches, we developed a concept we term EGHR (Enhanced Gas Hydrate Recovery), that was revealed to the gas hydrate community at the AAPG Hedberg Conference in Vancouver, BC in September of 2004. EGHR takes advantage of the physical and thermodynamic properties of a H_2O-CO_2 system combined with the controlled multiphase flow, heat transfer, and mass transport processes that occur in hydrate-bearing porous media. The key to this process was the development of a chemical-free method of producing transiently-stable microemulsions of liquid CO_2 and water. The two-phase microemulsion is injected into the hydrate-bearing strata at a temperature higher than the stability point of methane hydrate, which upon contacting the methane hydrate, decomposes its crystalline lattice and releases the enclathrated gas. The freed gas is recovered at an extraction well. Sensible heat of the emulsion and heat of



Scanning Laser Raman LIDAR (Light Detection And Ranging) System and pressure cell equipped with a sapphire window formation of the CO_2 hydrate provide a low-grade heat source for further dissociation of methane hydrate away from the injectate plume. Conversion of the microemulsion to CO_2 hydrate occurs over time as controlled by heat transfer, diffusion, and the intrinsic kinetics of CO_2 hydrate formation. Process control is afforded by variation in the temperature of the emulsion, ratio of CO_2 and water, and droplet size of the discrete CO_2 phase.

Using a high-speed digital camera capable of capturing up to 1,000 frames per second, we attempted to observe the fine structure of the CO_2 emulsion as it exited one of the injector nozzles. However, no detail on the emulsion structure was observed (see figure). The liquid CO_2 droplets are too small and moving too fast to be imaged at this frame rate, an outcome that is consistent with the design of the injector.

We have used the microemulsion injector to conduct a laboratory-scale simulation of the EGHR process. A microemulsion formed at 15°C was injected into a column packed with sand containing methane hydrate initially held at 2°C. Gas samples were obtained from the outlet port of the column and analyzed using gas chromatography. No CO_2 was contained in the extracted gas phase, only methane. A series of thermocouples arrayed along the column was used to track temperature changes. After injection was terminated, the temperature declined back to the original control point until a thermal spike was observed roughly four hours post-injection. This temperature spike was interpreted as a sign that CO_2 hydrate had formed in the sand. A photograph of a sample of the sand extracted from near the top of the column after terminating the experiment reveals how the pore space is almost completely filled with CO_2 hydrate (see photo).



High speed digital photo of microemulsion injector enclosed in a sapphire tube. Conditions are 21°C, 1000 psig, and ratio of CO_2 *to* H_2O *of 1:2. The microemulsion stream can be seen entering at bottom center right.*

While these early laboratory-based studies are extremely encouraging, there is obviously still considerable additional work needed to demonstrate the process, especially at reservoir scale, and to assess the overall economic potential. The Alaska North Slope appears to be ideally suited for a trial application of this method as significant gas hydrate deposits have been identified, potential future CO_2 sources are nearby, and infrastructure exists (or is being planned) that could bring the produced gas to market.

This work was supported by a grant from the Arctic Energy Technology Development Laboratory, Fairbanks, Alaska.

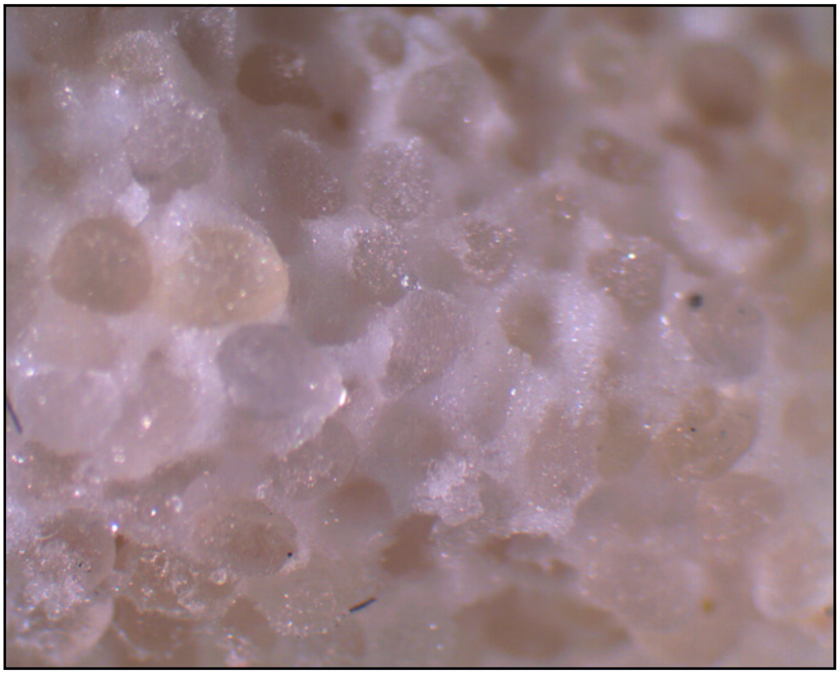


Photo of sand sample extracted from a column after being injected with a microemulsion of CO_2 and water to extract methane from methane hydrate.

INTERNATIONAL HYDRATES WORKSHOP TO FOCUS ON COLLABORATIVE RESEARCH PLANS

The Fourth Workshop of the International Committee on Gas Hydrates is scheduled for 9-11 May 2005 in Victoria, British Columbia, Canada. Invited agency representatives and researchers will convene to assess research needs and promote international collaboration on methane hydrate R&D. This workshop is being organized by the Centre for Earth and Ocean Research at the University of Victoria, the Marine Biogeochemistry Section at the Naval Research Laboratory, the Hawaii Natural Energy Institute of the University of Hawaii, and in cooperation with the Energy Technology Research Institute (AIST) of Japan, the Department of Physics and Technology at the University of Bergen in Norway, the Office of Naval Research-Global and the United States Department of Energy.

The 2 ½-day workshop will include plenary lectures and a panel discussion, and will be conducted as a working event where participants will jointly develop collaborative methane hydrate studies. At previous meetings, the focus has been on presentation of national research program results. This year, a primary goal is to launch discussions on developing plans for collaborative scientific work among the nations represented. A session chair, assisted by a rapporteur, will oversee each session. Topics will include: Methane Hydrate Resource Characterization and Distribution, Methane Hydrates Kinetics, Dissociation and Biogeochemistry, Environmental Concerns: Seabed Stability and Ecosystem Health, and Methane Hydrate Future Development.

To facilitate interaction among participants, the number of attendees is being limited to between 75 and 100 individuals. The plan is to invite two speakers for each session and spend the remaining time discussing the workshop topics. Individual research efforts will be presented via posters during evening conversations. If you have any questions please contact Ms. Sonia Wolff at Sonia_Wolff@onr.navy.mil, Dr. Ross Chapman at chapman@uvic.ca or Dr. Richard Coffin at rcoffin@ccs.nrl.navy.mil.

CHIBA AND HEDBERG CONFERENCE ABSTRACTS NOW AVAILABLE

Interested persons can now download a PDF file of the abstracts from the Mallik 2002 Gas Hydrate Production Research Well International Symposium held December 2003 in Chiba, Japan at http://www.mh21japan.gr.jp/english/index.html/. The file is about 15 Mb and includes 129 pages of detailed abstracts, including figures and photos, covering more than 40 presentations.

The abstracts from the Hedberg conference on gas hydrates held September 12-16, 2004 in Vancouver, BC, Canada are now posted on the AAPG website at http://www.aapg.org/education/hedberg/past/index.cfm/.

Mallik 2002
Gas Hydrate Production
Research Well Program

Mallik International Symposium
in Makuhari

December 8 to 10, 2003

Program & Abstracts

From Mallik to the Future

Technology Research Center Japan National Oil Corporation
www.gashydrate.com www.mh21japan.gr.jp

Vancouver
HEDBERG

Chemists Highlight Gas Hydrate Research in San Diego

The 229th National Meeting of the American Chemical Society (ACS), to be held at the Hyatt Regency in San Diego, CA on March 13-17, will include two days of presentations in a session titled “Symposium on Gas Hydrates and Clathrates.” A total of 25 papers will be presented on topics ranging from methane hydrate exploration along the mid Chilean coast to methane hydrate utilization by anaerobic methane oxidizing microbes to the effect of amphiphilic compounds on hydrate formation kinetics. This is the first time that the ACS has devoted this much time to the topic of hydrates at a national meeting, evidence that the degree of interest in hydrate research is widening.

NETL Solicitation for Methane Hydrate Research Proposals

Funding opportunity announcement number DE-PS26-05NT42405 entitled “Gas Hydrate” can be accessed through the NETL website, where the solicitation can be found at http://www.netl.doe.gov/scngo/Natural%20Gas/index.html by clicking “Solicitations” on the lefthand toolbar. The objective of this funding opportunity is to receive applications for cost-shared research projects that will develop new methane hydrate exploration and production tools and technologies, and that will provide a better understanding of hydrates in the natural environment. Specifically, the DOE wishes to support efforts to improve the tools and technologies needed to appraise the distribution, nature, concentration and production potential of hydrate deposits. In parallel with attempts to enable methane extraction from hydrates, the DOE also wishes to understand better the nature and occurrence of hydrates, and the geological and hydrological systems that produce hydrate deposits. In particular, the DOE is interested in supporting studies and the development of numerical models that will advance our understanding of hydrate’s dynamic role in the natural environment, including its interaction with the deep sea floor, the oceans and the atmosphere, including connections to both past and future global climate change. The application deadline is April 18, 2005.

JOIDES Resolution

IODP PLANNING TWO CRUISES

The Integrated Ocean Drilling Program (IODP) is planning two expeditions of the *JOIDES Resolution* riserless drilling vessel to areas that have been the location of past hydrate research cruises. The first, to study stratigraphy and fluid flow in the Gulf of Mexico, has been scheduled for May 31 to July 6, 2005. At this stage, the plan is not to focus on hydrates specifically, but to explore the hydrogeology of overpressured systems. The study team will drill, core, and make geotechnical measurements in boreholes within the Brazos-Trinity #4 (Magellan) mini-basin and in the overpressured Ursa Basin. More detailed information can be found at http://hydro.geosc.psu.edu/Odp/odp589.html/. This experiment will explore the hydrogeology of overpressured systems.

A Cascadia Margin cruise specifically focused on hydrate research has been proposed for an August 24 to October 7, 2005 timeframe. A science plan based on a 22-day on-site schedule is designed to be the first part of a two-expedition program, with the hope that a subsequent expedition will address remaining measurements and studies. The program includes five drill sites that form a margin-perpendicular transect across the Northern Cascadia accretionary prism covering several different stages in the evolution of the gas hydrate stability field. In addition to the five transect-sites, one additional site is proposed in a cold-vent setting.

The Cascadia Margin hydrate expedition proposal presents a significant opportunity to continue on with the hydrate technology development and research that began through the DOE cooperative agreement with JOI based on the previous expeditions offshore Peru (ODP Leg 201) and on Hydrate Ridge offshore Oregon (ODP Leg 204). There are discussions about the possibility of replacing/installing a CORK (circulation obviation retrofit kit) in one of the ODP holes as part of this expedition, but at this time neither the funding nor the time for this activity is available.

More information about these expeditions is available online at http://www.iodp.org/.

To apply to sail as a U.S. scientist on one of these expeditions, see http://www.usssp-iodp.org/Science_Support/Sailing_Information/default.html/.

Caldive, Inc's Uncle John *semi-submersible drilling vessel*

MAJOR HYDRATE EXPEDITION PLANNED FOR THE GULF OF MEXICO

A 30 day cruise to study hydrates in the Gulf of Mexico will leave port in mid March from Mobile, Alabama. The plan is to drill wells at two deep-water gas hydrate sites—Atwater Valley and Keathley Canyon—on the outer continental shelf. The project *Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities* is funded by the 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 logging-while-drilling 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, combined with three-dimensional MCS data provided by industry. The Scripps Institute of Oceanography is organizing the cruise and shipboard scientific staff. The research team will be aboard Caldive, Inc.'s *Uncle John* semi-submersible drilling vessel. The project is a 4-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 Data & Consulting Services, Halliburton Energy Services, the U.S. Minerals Management Service (Gulf of Mexico Region), the Japan Oil, Gas & Metals National 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.

HYDRATE RESERVOIR SIMULATOR TRAINING COURSE OFFERED

The Lawrence Berkeley National Laboratory (LBNL) and NETL are holding a training course in the use of the TOUGH-Fx/HYDRATE v1.0 code for the simulation of gas production from natural hydrate deposits and system behavior in hydrate-bearing porous media. The course will be held in Berkeley, CA from March 28 through April 1, and will include the development and analysis of real-life problems of interest to the participants. For more information please contact George Moridis at LBNL (510-486-4746 or GJMoridis@lbl.gov) or Kelly Rose at NETL (304-285-4157 or Kelly.rose@netl.doe.gov). Information and registration is also available online at http://esd.lbl.gov/TOUGH-FxHydrate_Training/.

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Scientific cruises to understand marine hydrates are not unlike the planetary exploration we read about in today's headlines: in both cases, scientists face harsh environments that require special equipment and careful planning to reach, and in both cases there is a sense of excitement and surprise at each new discovery. It shouldn't be surprising then, that a young boy interested in rock-collecting and space travel would eventually find himself deeply involved in voyages to submarine locations to study methane hydrates.

Spotlight on Research

FROM DEEP SPACE TO DEEP WATER

"My father was involved in the design of the ships used to track and communicate with the Apollo spacecraft," says Frank Rack, Director of Ocean Drilling Programs and DOE Programs for Joint Oceanographic Institutions, Inc. (JOI). *"That early exposure to the leveraging of technology for voyages of discovery probably had a lot to do with my subsequent career choices."*

Frank Rack came to JOI in 1998 from the University of New Brunswick where he worked in the Ocean Mapping Group of the Department of Geodesy and Geomatics Engineering. While in Canada he also participated in two Ocean Drilling Program (ODP) expeditions to the Norwegian-Greenland Seas and North Atlantic Ocean and an IMAGES expedition to the same region, to study the geologic and paleoceanographic history of northern hemisphere glacial cycles and their impact on Earth systems.

Frank received his doctorate in geological/geophysical oceanography from the Department of Oceanography of Texas A&M University where he studied and worked with the Ocean Drilling Program from 1983 until 1992. He participated in five ODP expeditions during this period, logging time as a marine technician, physical properties scientist, and staff scientist, and spent more than 10 months at sea on the R/V JOIDES Resolution.

"Prior to starting graduate school, I worked for five years as a seismic survey navigator, and I also spent time on Alaskan fishing boats, so my path had already turned towards oceanography," adds Rack. *"When I first arrived at Texas A&M University I was introduced to hydrates by researchers like Bill Bryant, Mahlon Kennicutt and Keith Kvenvolden, who were working with gas hydrate samples collected by the Deep Sea Drilling Project (DSDP). This interest was rekindled when I arrived at JOI, where I saw opportunities to implement new technologies in scientific ocean drilling to add to the understanding of hydrates."*

At JOI, Frank has managed the cooperative agreement with DOE/NETL that has played a part in mobilizing a wide range of new technologies and measurement systems to study methane hydrates, including: infrared thermal imaging systems, X-ray CT scanning, microbiological sampling protocols, and newly developed pressure coring systems.

Asked his thoughts on the future of hydrate research, Frank responds, *"We have a lot to learn and this will take both additional funding and technological innovation. The international research community needs to continue to work together. There have been many collaborative hydrate research efforts over the past few years, and more are being planned."* Rack also believes that we need to work towards a holistic understanding of hydrate environments that integrates the physical, chemical, and biological processes that are interacting in a dynamic way over time. *"This will require careful planning and imaginative approaches to acquire in situ data at appropriate temporal and spatial scales of resolution. Ocean observing systems specifically focused on hydrate environments will help to achieve this advancement in our present capabilities."*

Frank feels fortunate to have worked with so many outstanding researchers, who have advanced our understanding about marine hydrates as well as other ocean processes. *"My primary mentors were Philip Rabinowitz and William Bryant at Texas A&M University and Larry Mayer at UNH, who helped me to develop a global view of marine geoscience research and the study of sediment physical properties; but many others have shared their knowledge and experience with me over the years, and for that I am extremely grateful."*