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Fire in the Ice

THE NATIONAL ENERGY TECHNOLOGY LABORATORY METHANE HYDRATE NEWSLETTER

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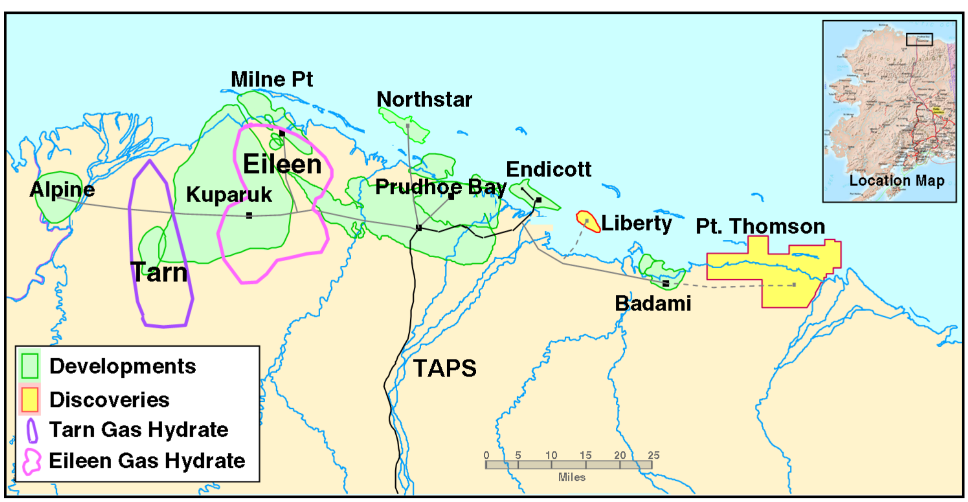
Characterization of Alaska North Slope Gas Hydrate Resource Potential

by Robert Hunter, Project Manager, Arctic Slope Regional Corporation Energy Services (ASRC)

Some interesting findings are coming from Phase I of a collaborative research project in the Alaska North Slope (ANS). The project is designed to determine if gas hydrate accumulations in the onshore ANS region can become an economic energy resource.

Results of the multi-task project highlight: (1) the importance of a complete characterization of reservoir and fluid compartmentalization prior to selecting the best sites for potential delineation and/or production testing, (2) the initial identification of apparent gas hydrate/free gas plays within the study area, (3) reservoir modeling evidence that depressurization of free gas zones can allow adjacent gas hydrates to dissociate at significant rates, and (4) a new laboratory method for measuring relative permeability in hydrate/sediment mixtures.

This cooperative project between BP Exploration (Alaska), Inc. (BPXA) and the U.S. Department of Energy (DOE) has facilitated a high level of collaboration among industry, government, and university researchers. The mutually beneficial research activities would not have been independently conducted by industry alone. When completed, this project will help identify technical and economic factors that must be understood for government and industry to make informed decisions about the resource potential of gas hydrate accumulations on Alaska's North Slope.



Note the currently identified gas hydrate trends within the Alaska North Slope producing field infrastructure. The Milne Point Unit study area lies within the Eileen trend.

The *Fire in the Ice* Newsletter is also available online at our website.

www.netl.doe.gov/scng/hydrate

INTENT

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

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

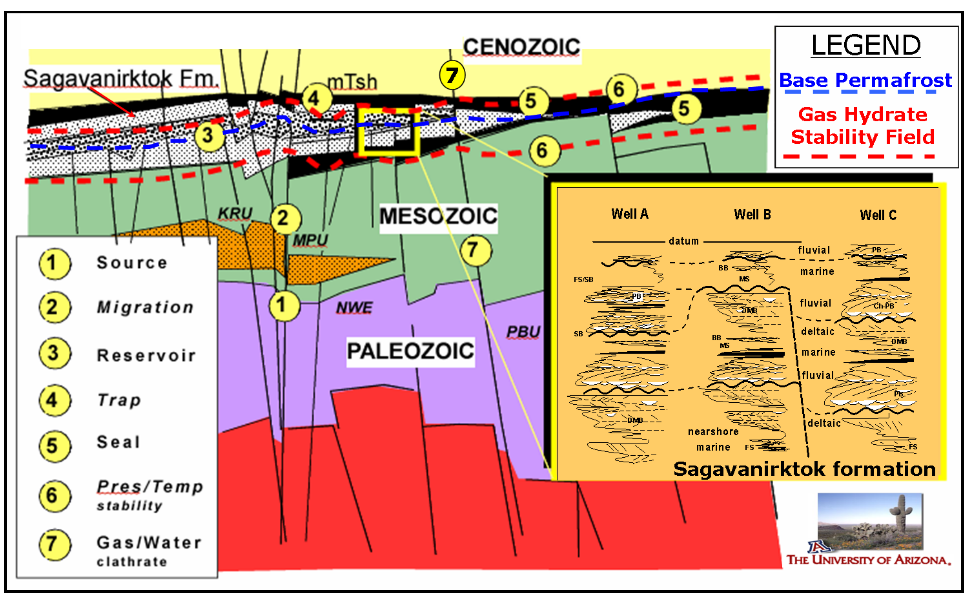
This newsletter now reaches nearly 480 scientists and other individuals interested in hydrates in sixteen countries. If you would like to submit an article about the progress of your methane hydrates research project, please contact the editor, Karl Lang (langkar@saic.com or 703-676-6547).

One of the important contributors to this effort is the U.S. Geological Survey (USGS), which has led ANS gas hydrate research for three decades. Dr. Timothy Collett of the USGS continues to promote the importance of this area to gas hydrate research and potential development. Shirish Patil of the University of Alaska Fairbanks (UAF) School of Mining and Engineering is leading reservoir and petroleum engineering research and supporting laboratory studies. Dr. Bob Casavant leads the reservoir and fluid characterization efforts at the University of Arizona. Associated projects at national laboratories include work on reservoir modeling by Dr. George Moridis at Lawrence Berkeley National Laboratory (LBNL) and on CO_2 injection potential by Dr. Pete McGrail at Pacific Northwest National Laboratory (PNNL).

Gas Hydrate Resource Potential

Gas hydrates are present in many arctic regions and offshore areas around the world. In the United States, notable deposits of gas hydrates occur in the offshore Atlantic, Gulf of Mexico (GOM), offshore Pacific, offshore Alaska, and also onshore Alaska regions beneath permafrost. Dr. Collett estimated in 1998 that up to 590 trillion cubic feet (Tcf) of in-place ANS gas resources may be trapped in clathrate hydrates. Collett noted in 1993 that an estimated 44 to 100 Tcf of the total in-place gas resources may occur beneath an existing ANS production infrastructure. However, much like conventional oil and gas resources, economic production of gas from gas hydrate reservoirs will require a unique combination of factors, including all of the required petroleum system components (e.g., source, trap, seal, charge, reservoir), adequate industry infrastructure, industry access to acreage, familiar production technology, and favorable economics. In addition, industry must be able to estimate ultimate recovery potential, production rates, operating costs, and potential profitability within reasonable risk limits. Currently, the most likely areas for a favorable combination of these factors are the ANS and the Gulf of Mexico.

In this project, gas hydrates and associated free gas-bearing reservoirs in the Milne Point Unit of the ANS are being studied to determine reservoir extent, stratigraphy, structure, continuity, quality, variability, and geophysical and



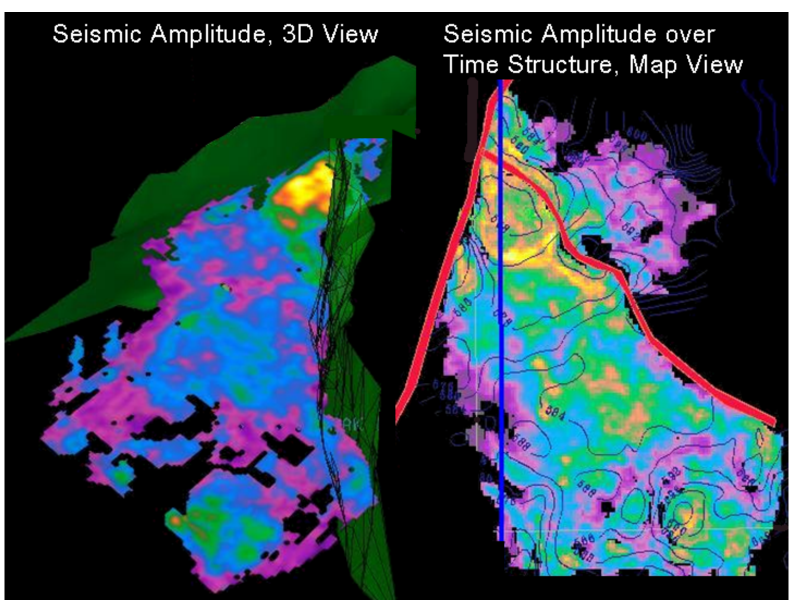
A gas hydrate prospect requires more than knowledge of the pressure/temperature equilibrium field for methane hydrate stability. All of the elements required for a conventional petroleum accumulation are also required petrophysical property distribution. The objective of Phase 1 (October 2002 to October 2004) is to characterize reservoirs and fluids, leading to estimates of the recoverable reserve and commercial potential, and the definition of procedures for gas hydrate drilling, data acquisition, completion, and production. Phases 2 (November 2004 to December 2005) and 3 (January 2006 to December 2006) will integrate well, core, log, and production test data from additional wells, if justified by the results of Phase I. Ultimately, the program could lead to development of a gas hydrate pilot project in the Milne Point area, and the determination of whether or not gas hydrates can become a part of the ANS gas resource portfolio.

Interim results from this project have identified play areas within the Milne Point Unit (MPU) where gas hydrates and free gas occur together. These areas have the most potential for production of hydrate-sourced natural gas, based on a preliminary understanding of the geology and potential production behavior.

Resource Characterization

The shallow gas hydrate-bearing reservoirs of the Tertiary Sagavanirktok formation are part of a complex fluvial-deltaic system complicated by structural compartmentalization within the Eileen trend. Stacked sequences of fluvial, deltaic, and nearshore marine sands are interbedded with both terrestrial and marine shales. Facies changes, intraformational unconformities, and high-angle normal faults disrupt reservoir continuity. Phase 1 work on volumetric assessment includes detailed well-log analyses and description of reservoir facies and fluids integrated with three-dimensional (3D) seismic data. In conjunction with structural analyses, the identification and mapping of net pay in discrete sand bodies improves understanding of resource quality, quantity, distribution, and continuity. This work helps refine volume estimates, reservoir models, and forecasts of recovery factors and production.

Interpretations of gas hydrates and associated free-gas resources within the study area correlate with gas hydrates that were originally cored and tested in the 1972 NW Eileen State 2 well. Geophysical attributes of gas hydrate occurrences are also under investigation. Seismic modeling of shallow (< 950

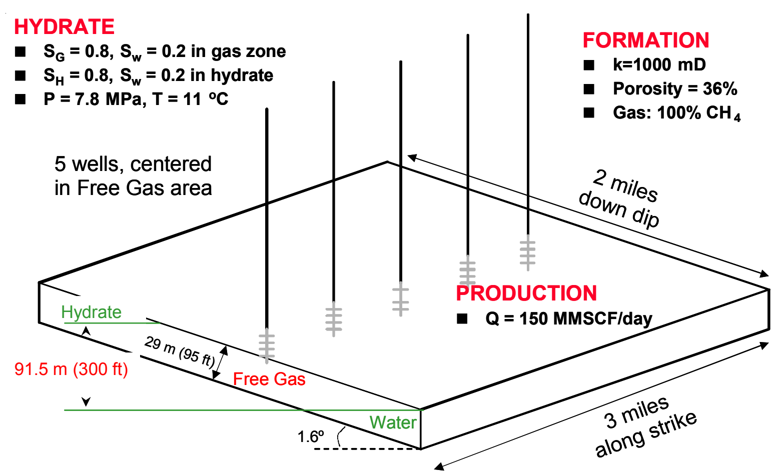


A seismic amplitude view (3-D view at left) and a structure map of seismic amplitude over time (at right) show a gas hydrate prospect within a fault-bounded trap of a gas hydrate-bearing reservoir within the Milne Point Unit.

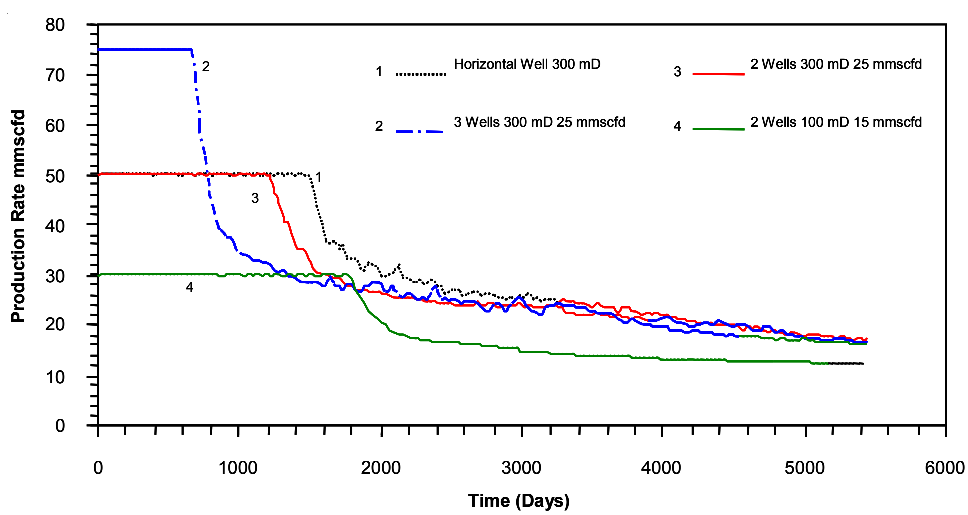
ms) velocity fields suggests both amplitude and waveform variations may help locate gas hydrate-bearing reservoirs. Permafrost can also complicate seismic identification of gas hydrates because of its similar acoustic properties. Identification of gas hydrate prospects within the MPU 3D seismic volume are based on seismic interpretation and modeling, gas hydrate-similar waveform classes, fault-seal geometries, and well log-derived properties. Fault blocks with significant in-place volumes within identified gas hydrate-bearing reservoirs will be further delineated, production tested, or both if the project proceeds into Phases 2 and 3.

Reservoir and Laboratory Modeling

Understanding the nature of fluid flow and permeability is critical to assessing the productivity of gas hydrates. As part of this project, UAF has developed a new method for measuring gas-water relative permeability for laboratory synthesized gas hydrates in porous media. This method provides input to reservoir and fluid flow modeling. Although no laboratory method can approach the time required to form natural gas hydrates, the experiment design allows



A schematic of a simplified gas hydrate-bearing reservoir in communication with an adjacent free gas-bearing reservoir illustrates a model used for simulation of gas hydrate production.



UAF reservoir model results highlight the differences in gas production profiles for a variety of permeabilities and well configurations.

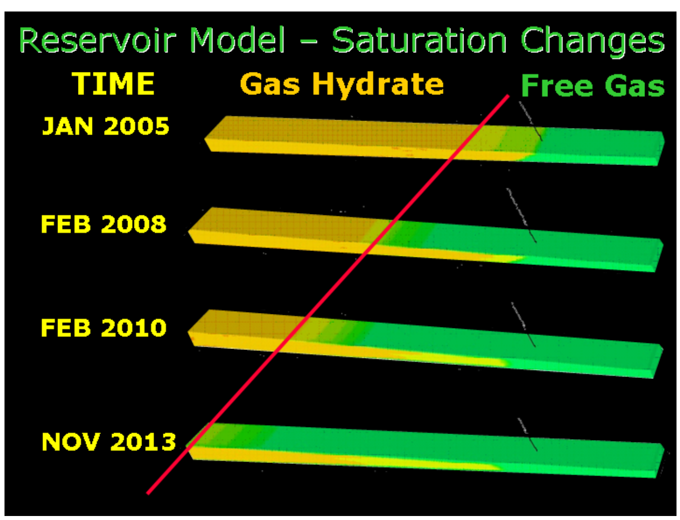
gas hydrates to form in porous media over relatively long periods of time and allows measurement of effective permeability and relative permeability for different saturation values. Some dissociation of gas hydrates occurs because of differential pressure across the core, but the low temperature decreases the rate of gas dissociation.

The experimental data obtained from this work will allow identification of gas hydrate stability zones, determination of flow behavior, and development of techniques for safe production of natural gas from gas hydrates. However, considerable additional experimental and theoretical work remain to develop an analytical or generalized model to predict relative permeability for simulation of gas hydrate reservoirs.

Under an associated project funded by the National Energy Technology Laboratory (NETL), LBNL continues to develop the TOUGH2-EOSHYD2 reservoir model to evaluate gas hydrates. Preliminary results from the reservoir model indicate that depressurization of a free gas reservoir adjacent to a gas hydrate accumulation can cause significant gas dissociation from the gas hydrates. However, cooling induced by this depressurization-induced gas hydrate dissociation decreases the temperature, a factor that could self-limit gas dissociation after the initial production years. Therefore, the depressurization production method may require some thermal stimulation assistance.

Within the ANS BPXA-DOE project, UAF has adapted a commercial simulator (CMG-Stars) to model gas hydrate dissociation caused by depressurization of an adjacent free gas accumulation in an ANS gas hydrate accumulation. Preliminary results also demonstrate the potential of the depressurization production method by dissociation of gas hydrates adjacent to free gas. UAF modeling indicates that as gas is produced at rates of up to 25 millions of cubic feet per day (MMcf/d) per well, the free gas zone depressurizes and the adjacent gas hydrate accumulation begins to release significant additional gas.

Phase 1 of the project is scheduled for completion by November 2004.



Modeling at UAF illustrates that a well within the free gas zone can depressurize adjacent gas hydrates, decreasing the saturation of gas hydrates and increasing the saturation of free gas over time.

Gas Hydrates in Detail

by Allen Reed, Naval Research Laboratory, Stennis Space Center; Friedrich Abegg, University of Bremen; Abraham Grader, University of Pennsylvania; and Bill Winters, USGS

Take the highest-resolution micro-focus computed tomography (CT) system that can be housed in a laboratory, place small-diameter sub-samples of gas hydrates dredged from the seafloor in front of the x-ray beam, and what do you get?

The answer is: the highest resolution volumetric x-ray images of gas hydrates ever achieved!

The remarkable small-scale details observed in these high-resolution volumetric images are giving us new insights into gas hydrate structure. They may also help answer persistent questions on gas hydrate formation, stability, and dissolution. Ultimately, images such as these will help researchers achieve a better understanding of the role gas hydrates play in Earth's climate systems and the role they might play as a hydrocarbon resource.

This feat was accomplished late last fall at the Naval Research Laboratory (NRL) through the combined efforts of Drs. Grader (Pennsylvania State University), Abegg (German Research Center for Marine Geosciences—GEOMAR), Winters (U.S. Geological Survey—USGS, Woods Hole Oceanographic Institute—WHOI), and Reed (NRL), with assistance from Drs. Kennedy, and Bower (both from NRL). The feat also included hard work and dedicated efforts of a multinational task force that operated for over 2 months in the Gulf of Mexico, and cooperative efforts from Gerhard Bohrmann (GEOMAR) and Ian MacDonald (Texas A&M University—TAMU, Corpus Christi).

Dr. Abegg searches for gas hydrates in a seafloor sample deposited on deck by the grab sampler (upper left)

Sampling Cruise in the Gulf of Mexico

Gas hydrate samples were collected during the research vessel (*R/V) Sonne* cruise SO174 - OTEGA II, offshore Louisiana at the Bush Hill site (500 to 600 m water depth), at Green Canyon Block 415 (1,000 m water depth), and at a location in the Bay of Campeche at Sigsbee Knolls (3,000 m water depth), from October 25 to November 12, 2003. A remote video-aided, grab-sampling device provided a shipboard view of the ocean floor as gas hydrate samples were collected.

The sample collection process may take as much as 4 hours for the hydrate sampler to descend, collect a sample, and return to deposit its contents on the ship deck. Upon the return of the grab sampler, mud and hydrates are dumped on deck and in a frenzy of activity, hydrate samples are collected from the mud, sub-sampled, and either immediately evaluated on deck or quickly stored and preserved in liquid nitrogen-cooled dewars. Large pieces of gas hydrates are cut and sub-sampled for further study.

Piston cores were also collected during the cruise. These cores are pressure-sealed and therefore retain the same internal pressure upon their return to the surface as they do on the seafloor, a feature that helps to stabilize the hydrates during evaluation at the surface.

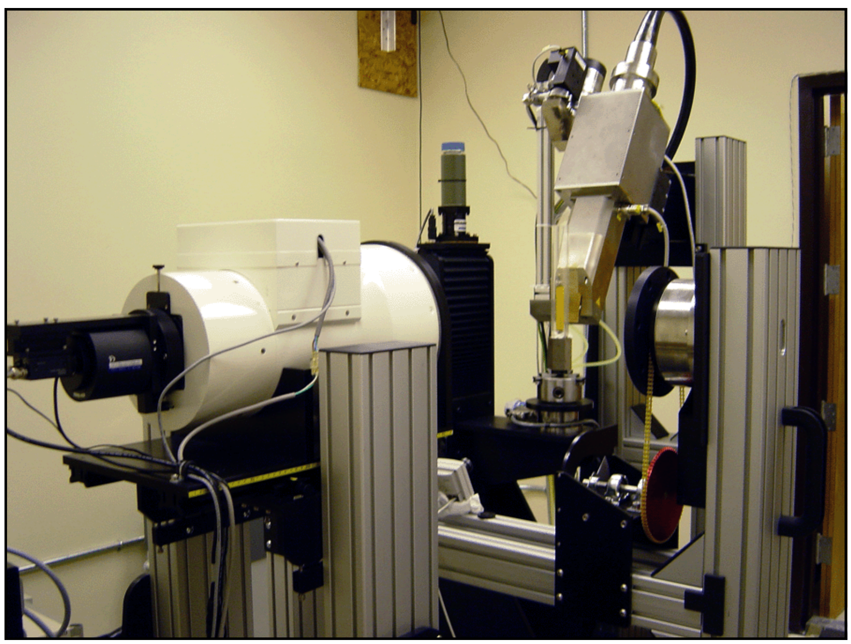
A portable CT scanner onboard the *R/V Sonne* was used to obtain an early evaluation of the piston cores. The equipment was a rented medical CT scanner housed in a portable van that analyzed the pressure-sealed cores before any pressure disturbances could alter the structure of the hydrates within the sediments. The ~440 μm image resolution of the portable medical scanner permitted evaluation of sand- to pebble-sized objects, allowing the scientists onboard to evaluate the shape and volume of the gas hydrates as well as other seafloor constituents such as mud and shells.

A portable medical CT scanner used to evaluate piston cores onboard the R/V Sonne is ably operated by Hans-Jurgen Hohnberg (foreground), Friedrich "Fritz" Abegg (midground), and Ms. Kornelia Gräf (background).

High-Resolution CT Analysis

At the end of the cruise, the gas hydrate samples stored in liquid nitrogen dewars were brought to NRL for evaluation with a CT system that has higher resolution than the medical scanner. The Universal Systems HD-500 CT system (microCT) at NRL is capable of resolving small sediment grains (~30 µm image resolution). The sample stage manipulator moves in x, y, and z directions at very precise increments so that high resolution can be achieved on small samples. Furthermore, there is plenty of free space in the system to accommodate large environmental chambers, such as the one used for gas hydrate samples.

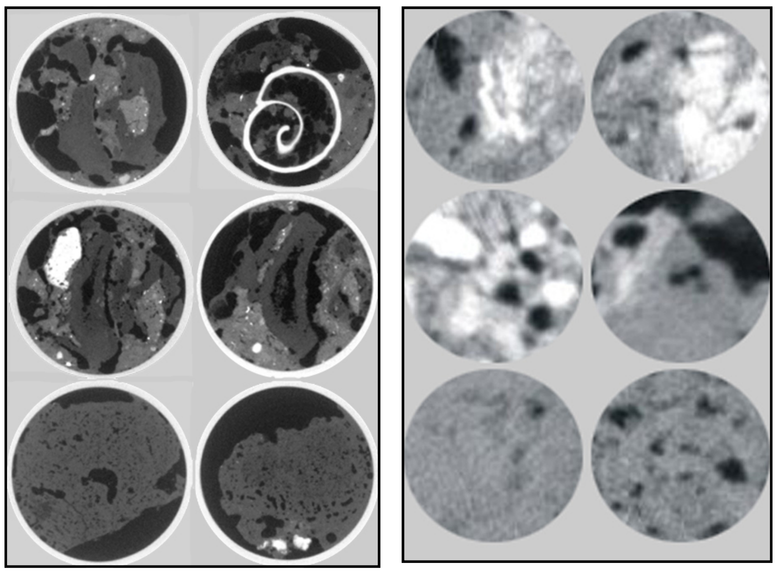
The trick to scanning the hydrates is to maintain the sample in a solid state long enough for at least an inch of the hydrates to be imaged. This was accomplished using an insulated aluminum chamber designed by NRL support staff that could exhaust gaseous nitrogen out through a chimney. Samples of gas hydrates placed within the center of the chimney remained frozen because of the cold nitrogen gas flowing around them. This “smoke stack” system allowed gas to be pumped long enough to keep the sample frozen for ~1.5 hours, enabling collection of high-resolution images.



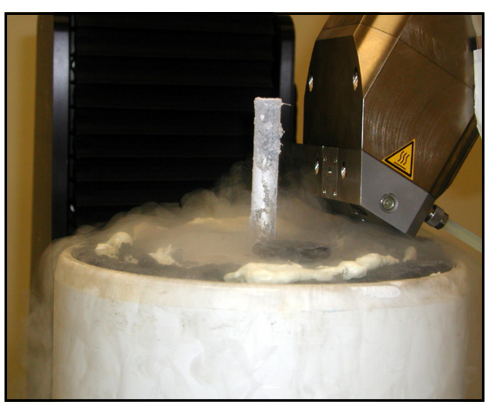
This is the HD-500 microCT system at NRL used for high-resolution imaging of gas hydrate samples.

The microCT images provide increased resolution, a sharper image, and therefore a new scale at which to evaluate gas hydrate constituents and processes. The increased clarity of the boundaries among carbonate, gas hydrate, mud, and free gas indicate that microCT is well suited for evaluating gas hydrate formation and gas hydrate interaction with sediment grains, free gas, and fresh water. Because the microCT is an open system that can accommodate odd-sized environmental chambers, the potential for creating and imaging gas hydrates in model situations (e.g., with different sediment types or variable pressures and temperatures) is quite feasible. Therefore, the system should be very useful in helping us improve our understanding of gas hydrate stability and the potential for gas hydrates as an energy source.

Anyone with an interest in using the HD-500 for scanning gas hydrates should contact Allen Reed at the Naval Research Laboratory by phone (228-688-5473), fax (228-688-5433), or email (allen.reed@nrlssc.navy.mil). Details of the HD-500 specifications are available online at www7430.nrlssc.navy.mil/facilities/CTScanner/index.htm.



High-resolution CT scans of 14-mm diameter samples (left) reveal fine details that are obscured in a lower resolution medical CT scan, such as those on the right collected in a piston core. Carbonate nodules and seashells (swirl pattern) have the highest density and appear white. Lower density gas hydrates appear dull gray, and lowest density gas is black.

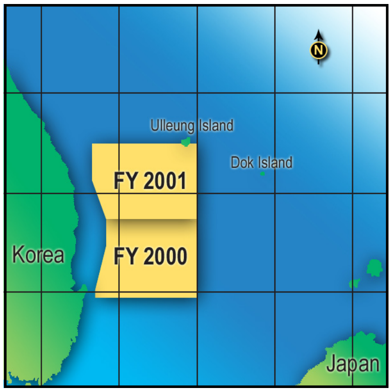


The liquid-nitrogen-cooled sample container is designed to permit CT scanning of frozen gas hydrate samples.

Evidence of Natural Gas Hydrates Observed in Korea's East Sea

by Jeong-Hwan Lee, Korea Gas Corporation

Korea Gas Corporation researchers have found seismic indicators of gas hydrates off the coast of Korea. Their multi-year data gathering and analysis project is the first step in assessing the potential size and character of Korea's hydrate resource.



Seismic data have been acquired in the Ulleung Basin of the East Sea during 2000 and 2001.

An ongoing geophysical research program has determined that bottom simulating reflectors (BSRs), characteristic of marine gas hydrate accumulations, are present in several regions of the Ulleung Basin in the East Sea (Sea of Japan) of Korea.

A strong BSR associated with an anticline structure was observed at one location. This BSR occurrence is the clearest evidence of the presence of gas hydrates in the Ulleung Basin. In some areas, a small velocity decrease is observed below the BSR, an indication that free gas may be present below the base of the gas hydrate stability zone. In addition, several strong seismic blank zones ("chimneys") up to 1,000 m across have been observed. Elsewhere, such structures have been associated with shallow gas hydrate concentrations near the seafloor. Initial estimates, while only approximate, indicate that natural gas hydrate concentrations of 40 percent or more may be present in the chimney structures just below the seafloor.

Korea's National Hydrate Research Effort

In 1999, Korea Gas Corporation (KOGAS) and the Korean Institute of Geology, Mining and Materials (KIGAM) began planning a basic exploration research effort focused on developing a better understanding of Korea's natural gas hydrate resource. Subsequently, a 5-year national project was initiated in 2000 with the sponsorship of the Ministry of Commerce, Industry and Energy (MOCIE). Total funding is about $2.5 million, with KOGAS investing about $1.4 million.

The research program is focused on exploration for evidence of natural gas hydrates using seismic surveys, characterization of any identified natural gas hydrate accumulations, and development of a utilization technology for any potential methane hydrate resource. As part of this project, a seismic survey in the East Sea within the declared Korean territory was performed by KOGAS and KIGAM using the research vessel *Tamhae II*. The main objective of the seismic work was to confirm the location and potential magnitude of natural gas hydrates in Korean offshore areas.

Over a 3-year period from 2000 to 2002, KOGAS surveyed an area comprising about 25,125 km^2 in the East Sea and obtained promising results that indicated strong possibilities of the existence of natural gas hydrates. Analysis of the survey results revealed clear examples of BSRs, gas columns, subsea mounds, and pockmarks. In addition, 28 deep-sea core samples taken in the same area as part of a geological and geochemical survey showed muddy sediments with silty sand, tephra, and ash layers. Analysis of the wet sediment samples showed that total organic carbon (TOC) ranged from 1.27 to 7.3 percent, an indicator of favorable conditions for natural gas hydrate formation. Furthermore, hydrocarbon gas within the sediments was found to be 98 percent methane.

Predicting Possible BSR Depths

Analysis of seismic data from the 2000 and 2001 acquisition cruises included mapping of BSRs, identification of debris-flow deposits, identification of seismic blank zones, and regional and detailed velocity analyses on selected lines. A thermal model was used to calculate potential BSR depth, based on assumptions on thermal conductivity, seismic velocity and bottom-water temperatures.

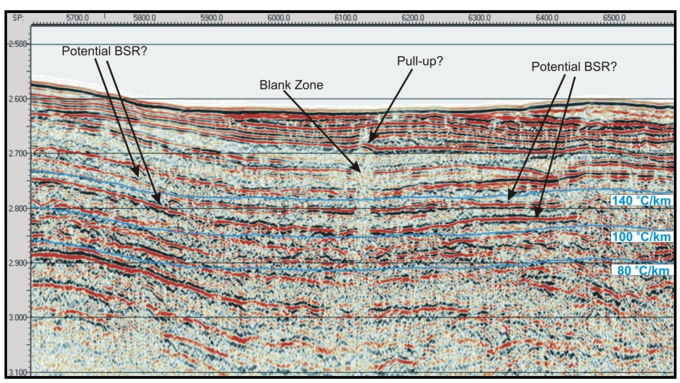
Assuming several different thermal gradients based on heat flow data (80, 100 and 140 ºC/km), the depth to a potential BSR was calculated for seismic velocities of either 1,550 or 1,600 m/s (in the upper 300 m below the seafloor) and bottom-water temperature of 1 to 2 ºC. A biogenic source for the methane hydrates was also assumed (thermal-sourced gas hydrates containing higher hydrocarbons have a very different stability field and extend deeper than biogenic gas hydrates). With these assumptions, the velocity effect on the depth of the BSR isotherms was found to be relatively small, and the difference between 1,550 and 1,600 m/s was on the order of 30 m/s two-way time (TWT).

The Tamhae II was used to acquire seismic data in 2000 and 2001.

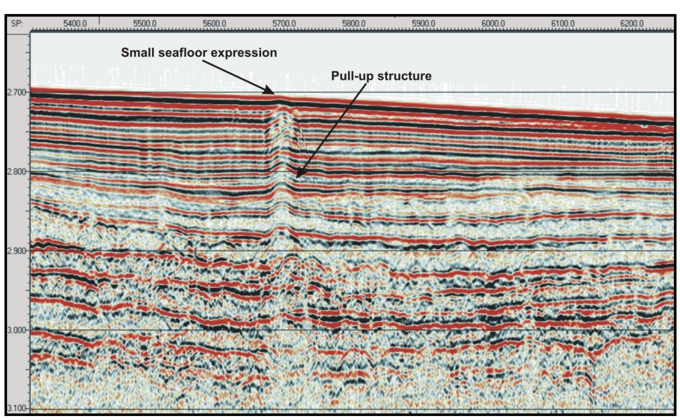
Stacked seismic data were used to identify apparent BSRs in the general area. The seismic lines showed strong reflectivity in the upper 500 m/s TWT. Deeper reflectivity, where reflectors are less continuous, could not be well resolved.. The upper sediment package consists of several strong reflectors that, in some cases, also show reversed polarity relative to the seafloor and could be potential BSR reflections. However, these layers do not consistently follow the predicted BSR depth trend (assuming no strong lateral changes in the heat flow regime). For example, along line 00GH-08A, two reflectors with opposite reflection polarity lie between the 100 and 140 ºC/km isotherms.

Blank Zones Could Indicate Gas Hydrates

Along this same line, in the central part of the data section, the sediments are interrupted by a blank-zone that extends from 2,650 to 2,850 m/s TWT between shot points 6100 and 6200. This kind of blank zone is typical for areas with gas hydrates in the sediments and has been reported at many continental margins. The top of this blank zone is also associated with a small pull-up structure.



Blank zone and possible pull-up along with BSRs are highlighted on this seismic data (line 00GH-08A). Blue lines show expected BSR depths for three assumed thermal gradients and an assumed seismic velocity of 1,600 m/s.



The graphic shows a blank zone and pull-up structure from line 00GH-10

If the blanking were caused by free gas only, an opposite effect (pull-down) caused by a reduction in seismic velocity would be expected. This pull-up structure may indicate localized gas hydrates.

Several other blank zones were identified in the region, all in water depths between 1,500 and 2,000 m. These were fairly small with dimensions of less than 400 m and did not fully penetrate to the seafloor. However, several of those zones are associated with pull-up structures indicative of the presence of high-velocity hydrates. Such extreme pull-up structures can be associated with high-velocity gas hydrates or can be the result of vertical fluid flow. In general, this type of blank zone is less common, but it is also difficult to identify the zones because of the generally less coherent reflectivity of the sediments in these areas. Reflectors are often short, discontinuous, and offset by many small-scale faults. This means that more blank zones could be present than have been mapped to date.

The magnitude of the pull-up of the sedimentary horizons in the chimney structures allows an estimate of the increase in interval velocity as a function of depth. The velocity enhancement in turn can be used to estimate the hydrate concentration as a function of depth. The pull-up structure observed on line 00GH-10 was used to estimate the velocity field and associated hydrate concentrations. In this case, it was assumed that the change in depth of the layers traceable through the blank zone was entirely a velocity effect, (i.e. the actual depth of the layers did not change). Initial estimates of natural gas hydrate concentrations in the chimney structures are only approximate, but they indicate that these structures may contain significant concentrations of hydrates of up to 40 percent or more just below the seafloor.

Detailed BSR Velocity Studies

Additional velocity analyses were conducted over representative parts of lines that showed a potential BSR. For example, at several locations on line 00GH-25, a velocity drop of up to 60 m/s was detected for the first layer beneath the apparent BSR. Interval velocities then increased again with greater depth and followed the general background profile. This velocity drop may indicate small concentrations of free gas below the BSR; however, the drop is not always observed and is often smoothed in a general continuous velocity increase with depth. At locations with a well-pronounced BSR reflection, a distinct velocity drop is observed, while at areas with small BSR reflection coefficients, no strong velocity decrease can be seen.

Next Steps

KOGAS, with the support of the Korean government, is now planning the second phase of the national natural gas hydrate research project. Over the next year, detailed exploration, including a two-dimensional seismic survey with long offset and a three-dimensional seismic survey, will be carried out in the area where BSRs indicate the highest potential for natural gas hydrates. Subsequently, a drilling program to confirm the existence of natural gas hydrates will be conducted.

AAPG Hedberg Research Conference on Gas Hydrates

The American Association of Petroleum Geologists (AAPG) is sponsoring the Hedberg Research Conference *Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards,* to be held in Vancouver, BC, Canada September 12 to 16, 2004.

Co-conveners Tim Collett (U.S. Geological Survey—USGS) and Art Johnson (Hydrate Energy International) have organized this meeting of 80 to 100 invited participants to discuss state-of-the-art concepts, methodologies, case histories, and the future of gas hydrates as an energy resource. Topics are grouped into three categories: Geology of Gas Hydrate Accumulations, Gas Hydrate Energy Assessment, and Seafloor Stability and Safety. More than 60 paper abstracts had been received as of the March 31 deadline.

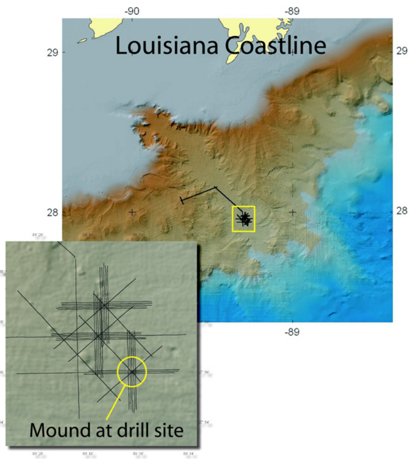
Six identified goals of the conference are to: (1) critically examine the geologic parameters that control the occurrence and stability of gas hydrates, (2) assess the volume of natural gas stored within known gas hydrate accumulations, (3) assess exploration methods for identifying commercial gas hydrate prospects, (4) identify the technologies needed to economically produce gas from hydrates, (5) assess possible marine slope stability hazards that can be attributed to the occurrence of gas hydrates, and (6) analyze the effects of gas hydrate on drilling safety.

The meeting will comprise 3 days of oral and poster presentations and a 1-half day wrap-up session. Oral presentations will be 30 minutes in length, with discussion by all attendees following each presentation. The poster sessions will be linked to the oral presentations. Results of the conference will be published in a compendium research volume.

While the abstract deadline has passed, if you are interested in attending, contact Debbi Boonstra by email at debbi@aapg.org or by fax at 918-560-2678. Attendance will be limited, and there will be a registration fee.

Gulf of Mexico Hydrates JIP Drilling Delayed until Fall 2004

The original plan to drill several methane hydrate test wells this spring in the Gulf of Mexico (GOM) has been revised. An EPA General Discharge Permit required under the Clean Water Act could not be issued in time for the original spring drilling cruise timeframe. Rules governing the issuance of General Discharge Permits expired in November 2003 and have not yet been renewed, but it is anticipated that the EPA process will be completed in August or September. The drill ship selected for the cruise, the *Fugro Explorer,* will return to the GOM in September of this year and the ChevronTexaco-led JIP has already begun planning to conduct operations in the October/November time frame. The JIP is preparing a special EPA permit request to operate in the event the new General Discharge Permit is not issued in the anticipated timeframe.



NRL Targets Atwater Valley During July 2004 Gulf Cruise

Three teams from the Naval Research Laboratory (NRL) will conduct research aboard the Texas A&M University Department of Geosciences Research Vessel (*R/V) Gyre* this July in an effort to obtain more detailed data on one of the possible sites for drilling the ChevronTexaco Joint Industry Project (JIP) gas-hydrate test well.

A team headed by Dr. Joseph Gettrust will deploy NRL's Deep Tow Seismic System (DTAGS) near two small mounds in Atwater Valley Block 14 of the Gulf of Mexico. Anomalous amplitudes indicative of chemosynthetic communities on the mound surfaces and seismic data wipeouts below the mounds have been observed in existing seismic data. The high lateral resolution provided by DTAGS will improve the interpretability of the edges of both of these phenomena, and may give important insight on potential hazards. If the case can be made to the Minerals Management Service (MMS) that the mounds can be safely drilled with minimal damage to chemosynthetic communities, this could significantly increase the knowledge gained in this drilling program. Furthermore, the acquisition of DTAGS in this area would allow analysis and interpretation of seismic data using an unprecedented breadth of frequency range, from the low tens of hertz (existing industry data), through the low hundreds of hertz (U.S. Geological Survey surface tow data), to the high hundreds of hertz (DTAGS).

During the same cruise, an NRL geochemistry team headed by Dr. Richard Coffin will seek to acquire and analyze piston cores collected at the Atwater site. Piston core sampling had been planned at this site during the August 2003 cruise, but a hurricane resulted in its cancellation. The cores will be analyzed for pore water chemistry (sulfate, chlorinity, and stable carbon isotope analysis of carbon in pore waters and organic and inorganic carbon in sediments) and the source of the methane in any recovered gas hydrates. Sulfate and chlorinity profiles can be used to assess the vertical migration of methane, while stable carbon isotope analysis can be used to determine if the methane is thermogenic or biogenic in origin. The selection of specific Atwater Valley 14 core sites will be made after the DTAGS survey is completed.

A third NRL team headed by Dr. Joan Gardner will collect, process and interpret high-resolution heat-flow data profiles co-located by both the DTAGS seismic survey and by sediment cores. Coupling the heat flow data with the seismic, geochemical, and geologic data (eventually obtained from the JIP-conducted drilling) will help to further refine models for the generation of hydrate mounds, their vertical extent, and their potential for rapid release of methane into the ocean.

Even More Eyes on Atwater Valley

Naval Research Laboratory (NRL) scientists will not be the only ones vacationing at Atwater Valley this summer. The U.S. Geological Survey (USGS) is helping to run a short cruise to one of several possible ChevronTexaco Joint Industry Project (JIP) drilling sites.

During a 4-day cruise (June 20 to 24) on the Research Vessel (*R/V) Pelican*, bottom photography and seafloor resistivity data will be collected to verify

whether chemosynthetic communities and near-surface hydrates exist on and around the gas hydrate mound targeted for drilling. Chief scientist for the cruise is Robert Evans from the Woods Hole Oceanographic Institution (WHOI), who will operate the resistivity experiment. A streamer towed along the sea floor measures electrical resistivity to a depth of about 20 m in the sediment. It also collects continuous measurements of bottom water salinity and temperature, which can provide evidence of fluid expulsion along the sea floor.

The resistivity data can give a measure of shallow sediment porosity, and can potentially indicate the presence of hydrates (which have a much different resistivity than normal sediments). Dan Fornaria, also from WHOI, will be in charge of the bottom photography work. Both the photographic and resistivity surveys will be conducted with equipment towed on a steel sled at slow speeds. The U.S. Department of Energy (DOE) is supporting the camera work and part of the ship time, WHOI is supporting the resistivity work, and the USGS is supporting both the navigation and bathymetric profiling. The *R/V Pelican* is operated by the Louisiana Universities Marine Consortium (LUMCON).

New International Hydrate Consortium Forming

A new gas hydrate consortium is being established through APEC (Asia Pacific Economic Cooperation), a forum for facilitating economic growth, cooperation, trade and investment in the Asia-Pacific region. Plans for the consortium were announced last November in Chile at the 2003 International Gas Hydrate Workshop and the project was endorsed by 15 of the 21 APEC member-economies (including People's Republic of China and Japan) at a recent APEC meeting. As currently envisioned, the consortium will focus on Pacific Rim gas hydrates and individual projects (e.g., seismic acquisition, coring, and sampling) are envisioned to be less than one year in duration and less than $1 million in total cost. An organizational meeting is being planned for fall of 2004; most likely in San Francisco. There may be a minimal charge for joining the consortium.

MMS GOM Resource Assessment Methodology Outlined

The US Minerals Management Service (MMS) has finalized a methodology for assessment of gas hydrate resources that will take a petroleum systems approach and will evaluate four play types separately. The MMS plans to evaluate well and seismic data, map potential reservoir sands, and evaluate any indications of gas and gas hydrate. The goal is a set of 3D maps and probabilities for each of the four play types presented in a GIS-based format. Seeps and mounds were determined not to be producible and will not be part of the assessment. An initial component of the project will be an isochron from water bottom to top salt. Low gas hydrate probability areas will be identified, including thick minibasins without indications of thermogenic-derived gas and/or with shallow (50-100 ms) salts. Areas with a high probability for gas hydrates will also be identified. These include salt edges, amplitude anomalies, and associated hydrocarbon seepage areas. The assessment will begin with a test area, and then expand to the entire deepwater Gulf. Preliminary results to be presented at the Hedberg Research Conference this September will include mapped amplitudes and bathymetry. The complete GOM assessment is due in December, 2005.

Spotlight on Research

ANNE TREHU–OREGON STATE UNIVERSITY

DR. ANNE M. TREHU

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Outside of her academic and research responsibilities, Anne enjoys hiking, biking and skiing with her family (which includes her husband, John Nabelek, who is an earthquake seismologist, and her two teenage sons, Marc and Patrik). She also is involved in the Princeton Earth Physics Project, a program for placing seismometers in high schools and middle schools around the country as tools for teaching geology, physics, and computer networking.

Dr. Anne Trehu studies collisional plate boundaries, like the Cascadia subduction zone off the coast of Oregon. "Much of my research over the past 2 decades has been on understanding processes at plate boundaries by imaging subsurface structure on a crustal scale," explains Anne. "I got started in earth science research as a junior (BA in Geosciences, summa cum laude, 1975, Princeton University) doing a paper on a topic suggested by Prof. W. Jason Morgan. Jason has great insights into how the earth works and his enthusiasm for exploring and testing those insights was contagious. He has a wonderful knack for encouraging all his students, even undergrads, to believe they can contribute something new and important."

Since 1986, Dr. Trehu has been collaborating with the USGS and several other institutions to acquire a network of 2-D and 3-D seismic images of the crust and upper mantle of the western North American continental margin. The objective is a better understanding of the interactions along plate boundaries that control geologic evolution and seismic hazards in the region. Anne has conducted seismic experiments across the San Andreas fault system in central and northern California, the Cascadia subduction zone in central Oregon, and the Queen Charlotte fault in southeast Alaska and British Columbia.

"I first became fascinated by gas hydrates when hearing Bill Dillon talk about gas hydrates on the Blake Ridge while I was working as a post-doc with the USGS in Woods Hole, MA (PhD in Marine Geophysics, 1982, MIT-Woods Hole Oceanographic Institute Joint Program)," recounts Trehu. "But it was not until the seismic signature of gas hydrates popped up in several data sets collected for crustal work that gas hydrates became a central focus of my research."

The presence of gas hydrates on the Oregon continental margin has been known for several decades. Dr. Trehu is part of a multidisciplinary and multi-institutional group that has identified a major gas hydrate system in the accretionary complex of the Cascadia subduction zone and was co-chief of Leg 204 of the Ocean Drilling Program (ODP) in 2002, the first ODP Leg dedicated to studying gas hydrates along an active margin.

Since 1996, COAS faculty, in collaboration with colleagues at GEOMAR and elsewhere, have been involved in the geochemical characterization of local sediments and interstitial fluids, and extensive structural and tectonic mapping of Hydrate Ridge, located ~80 km west of Newport, Oregon. Anne and the geophysics group have participated in several cruises to observe and study the subsurface plumbing associated with the presence of hydrates and free gas.

"ODP Leg 204 and the site survey work done in preparation for it resulted in the first comprehensive view of the distribution and dynamics of gas hydrates in accretionary complexes," adds Trehu. "By dedicating a whole Leg to sampling a wide range of settings within a well-imaged structural system, we now have a much better understanding of how much hydrate is there, the factors leading to large heterogeneity in gas hydrate distribution and the processes that form concentrated hydrate deposits." Analysis of data from Leg 204 in collaboration with other members of the Shipboard Science Party remains underway.

Anne particularly enjoys the multidisciplinary flavor of gas hydrate research. "I'm very lucky to be able to work with such a great group of colleagues at OSU, like Marta Torres (sediment geochemistry), Joel Johnson (marine geology), and Bob Collier (water column geochemistry); each of whom are working on different, yet complementary, aspects of the gas hydrate problem. I also enjoy the camaraderie of extended field work, whether it be two months at sea on the *JOIDES Resolution* or several weeks doing a crustal imaging experiment out of a barn in a small Northern California town."