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Fire in the Ice

Spring/Summer 2007 Methane Hydrate Newsletter

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China's First Gas Hydrate Expedition Successful

By Haiqi Zhang (CGS), Shengxiong Yang (GMGS), Nengyou Wu (GMGS), Peter Schultheiss (Geotek Ltd.) and GMGS-1 Science Team

A deep water gas hydrate investigation has been successfully completed for the Guangzhou Marine Geological Survey (GMGS), China Geological Survey (CGS) and the Ministry of Land and Resources of P. R. China. Drilling expedition GMGS-1 was carried out between April 21st and June 12th 2007 in the Shenhu Area (north slope of South China Sea) from the drill ship SRV *Bavenit*. Fugro and Geotek provided a range of specialized services including drilling, wire-line logging, in-situ temperature measurement, pore water sampling, and pressurized and non-pressurized coring. Onboard analysis of non-pressure cores included infra-red core imaging, MSCL-S core logging and pore water geochemical analysis. Pressure cores were logged under pressure in the MSCL-P and X-ray images were obtained before the cores were depressurized to quantify the gas hydrate content and measure the gas composition using gas chromatography.

Eight sites were drilled in water depths of up to 1500 m, with testing and sampling to 250 metres below the seabed. A comprehensive program of borehole logging, coring, sampling and onboard analysis was conducted at five sites. Analysis of the data revealed the presence of thick (ranging from 10 to more than 25 meters) sediment layers rich in gas hydrate located just above the Base of Gas Hydrate Stability Zone (BGHSZ) at three of the sites. The gas hydrate was found in a disseminated form within the fine-grained foram-rich clay sediments in concentrations ranging from 20 to more than 40 percent of pore volume. The gas released from the hydrate was found to be more than 99% methane. Further analysis of the data and samples, including frozen gas-hydrate-bearing sediments preserved for further analysis onshore, will be undertaken in the coming months. Further details on Expedition GMGS-1 will be presented in an upcoming issue of *Fire in the Ice*.

The Research Vessel Bavenit (Photo Courtesy of Fugro)

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This newsletter now reaches more than 750 scientists and other individuals interested in hydrates in sixteen countries. If you would like to submit an article about the progress of your methane hydrates research project, please contact Karl Lang at 301-670-6390 ext. 129 (karl.lang@netl.doe.gov)

Characterization and Quantification of the Methane Hydrate Resource Potential Associated with the Barrow Gas Fields

by Tom Walsh and Peter Stokes, Petrotechnical Resources of Alaska (PRA)

Researchers on Alaska's North Slope are working to establish conclusive evidence for methane hydrate-sourced production from a conventional gas reservoir, with the goal of ultimately testing this potential via a dedicated well. The project is a collaborative effort among the Department of Energy's National Energy Technology Laboratory (NETL), the North Slope Borough, Arctic Slope Consulting Group, Petrotechnical Resources of Alaska, and the University of Alaska-Fairbanks. Findings from this project will contribute significantly to industry's understanding of the role of gas hydrate in the recharging of a producing gas field and how depressurization of gas hydrates via production of underlying free gas can be utilized as a method for commercial development. Equally important, this project will provide substantial economic benefits to the North Slope Borough, including lower energy costs through an expansion of recoverable gas reserves. The effort has advanced through its initial phase, and the results have been encouraging.

North Slope Borough

Barrow, AK, located on the northernmost point of land in the United States, is a cold and remote village bordered by the Chukchi Sea to the west and the Beaufort Sea to the north and east (Figure 1). However, Barrow's nearly 4,500 residents are warmer now than they were before the development of three large gas fields, discovered by U.S. Navy-sponsored exploration drilling back in the late 1940s. The three are South Barrow, East Barrow, and Walakpa (Figure 2). In 1984, ownership of the gas fields, along with the subsurface oil and gas estate, was transferred from the U.S. government to the North Slope Borough, of which Barrow is the seat of government. There are about 20 wells spread across the three fields (Figure 3). This puts the North Slope Borough, and specifically Barrow, in a very enviable position among remote

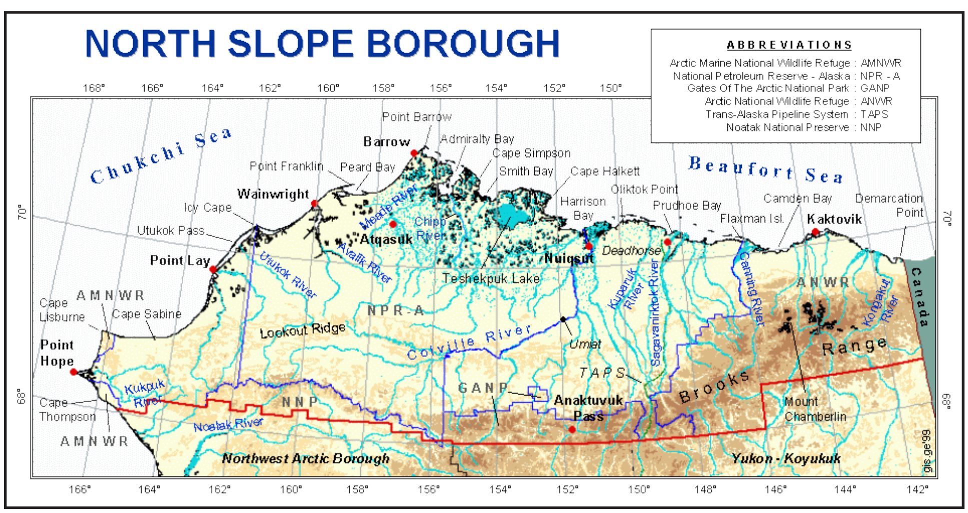


Figure 1. Map illustrating the boundary of the North Slope Borough, with its seat of government, Barrow, at the northernmost point.

Alaskan villages. The proven gas reserves in these three fields exceed 250 billion standard cubic feet of natural gas, equivalent to well over 100 years of gas supply for heating and electrical power generation at Barrow's current consumption rates. Most remote villages in Alaska must barge, or in extreme cases, fly in heating oil for heating and lighting houses and buildings, at great expense. Many coastal and inland villages within the vast (89,000 square miles) North Slope Borough use heating oil as their primary fuel source, and borough leaders would like to see other borough villages benefit from the use of local natural gas, or the expansion of infrastructure to deliver natural gas and/or electricity to other borough villages.

Methane Hydrates in the Alaskan Arctic

Confirmation of the presence of methane hydrate beneath the permafrost in Arctic Alaska was provided by the drilling of the Northwest Eileen No. 2 well in the Prudhoe Bay Unit in 1972, from which a core containing methane hydrate was recovered and analyzed. Since that discovery, significant effort has been made to understand and characterize the methane hydrate resource on the North Slope. Occurrence of methane hydrate on Alaska's North Slope has long been considered a drilling hazard. As hydrate-filled sands beneath the permafrost are penetrated on the way to deeper, oil-producing zones, formations on the boundaries of the hydrate stability zone can be inadvertently warmed by circulation of drilling fluid, causing hydrate dissociation and wellbore instability. Impacts include gas kicks at the surface, loss of circulation, and even wellbore or casing collapse.

North Slope operators have not only learned to deal with the challenges posed by the presence of methane hydrate but have turned the corner and are now seriously looking at ways to develop this potentially huge energy resource. Anadarko Petroleum Corp. drilled a dedicated methane hydrate test well near Prudhoe Bay field in 2003, and although they did not encounter methane hydrate in the well, they were able to demonstrate novel drilling

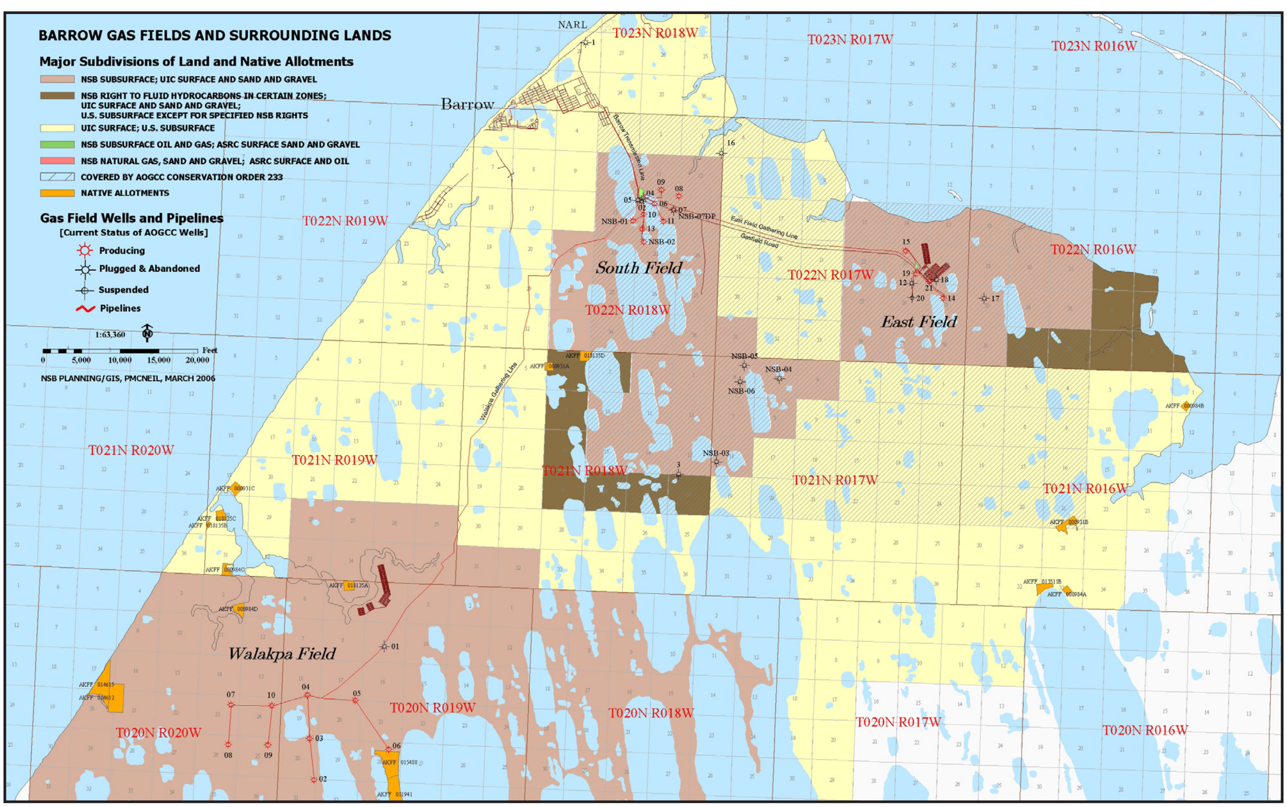


Figure 2. Map showing location of three gas fields relative to the town of Barrow.

technologies that protect the tundra environment in permafrost regions (see related article in Spring 2003 issue of FITI). BP Exploration (Alaska) Inc., along with NETL and the U.S. Geological Survey, completed a detailed characterization of several methane hydrate prospects in the Milne Point oil field area and just this year drilled and cored methane hydrate in the Mt. Elbert Prospect in Milne Point Unit (see Winter 2007 issue of FITI).

Barrow Methane Hydrate Research Project Objectives

The depletion mechanism for the Barrow gas fields is primarily gas expansion. However, there are potential contributions from an edge water drive and, more importantly, recharge from a gas hydrate accumulation updip of the free gas pool. While understanding the details of the drive mechanism is critical to field management and will impact future development plans for the Barrow fields, the opportunity to characterize and quantify a postulated methane hydrate accumulation in the Barrow area is closely aligned with the National Methane Hydrate Research Program objectives.

The objectives of the study are to integrate relevant hydrate research results with current knowledge of the Barrow fields to characterize and quantify the hydrate resource potential associated with the South and East Barrow and Walakpa gas fields. If the presence of a significant methane hydrate accumulation is verified, the producing gas fields in Barrow will provide an excellent opportunity to test the potential for production of methane hydrates through depressurization of the free gas zone at the free gas/hydrate interface.

Phase 1A Activities Completed

Phase 1A of the project has been focused on integrating prior research and current knowledge of the Barrow gas fields to fine-tune project objectives and deliverables. This phase is complete, and the methane hydrate stability model supports the existence of hydrates in potentially all three reservoirs.

Figure 3. Well housing and methanol tank (methanol injection is used to mitigate hydrate formation in the production string) at the East Barrow No. 14 well.

Figure 4. Team members Praveen Singh, a graduate student at the University of Alaska-Fairbanks (UAF), and Pete Stokes, manager of petroleum engineering with Petrotechnical Resources of Alaska, discuss hydrate phase behavior apparatus at the UAF Petroleum Development Laboratory.

New gas samples from all three fields were collected and analyzed for comparison to previous data. The results of the gas and formation water compositional analysis carried out by the project partners were integrated with recent and previously documented geopressure and geothermal gradient information to model the extent of the local methane hydrate stability zone. Modeling results indicated that all three fields have a hydrate stability zone that either intersects the known free gas reservoir or is near enough to indicate a high likelihood of hydrates above the free gas accumulations. A recommendation to proceed to Phase 1B has been supported by the Technical Review Committee. The results of Phase 1A work can be found online under the North Slope Borough project description listed in the Methane Hydrates section of the NETL website.

Phase 1B Activities

With hydrate stability established in Phase 1A, Phase 1B will determine whether there is hydrate of sufficient thickness and reservoir quality updip of the free gas accumulations to support production. This will require an integrated review of all seismic, well, and production history data, building on previous studies of the field data. Of particular interest is the characterization of the updip pinchout of reservoir sands.

Assuming the results of the hydrate stability modeling and reservoir limits review are encouraging, a detailed reservoir characterization will be undertaken to support simulation of hydrate production methodologies and planning for a potential dedicated hydrate test well. A goal of reservoir simulation modeling will be to quantify the impact of hydrate dissociation on recharge of the producing gas fields. This work will aid in understanding the effectiveness of secondary production via depressurization of the associated free gas interval.

Based on the static and dynamic reservoir modeling, the optimum location of a dedicated hydrate well for sampling and production testing will be proposed. The well will be designed to fit the geologic, reservoir, and operational specifics required in the Barrow gas fields but will also leverage and expand on the findings of the Anadarko and Milne Point wells.

Risks and Challenges

The presence of methane hydrate is dependent on the presence of several key components, including abundant methane gas and formation water to form the hydrate and the appropriate temperature and pressure conditions to support methane hydrate stability. Concurrent existence of all of the necessary components is critical, and there are documented cases for the central North Slope in which free gas is present within a methane hydrate stability zone. The presence of methane gas, formation water, and an appropriate temperature/pressure regime has been established in the Barrow gas field area, but there remains a risk that hydrates have not formed.

Potential Benefits

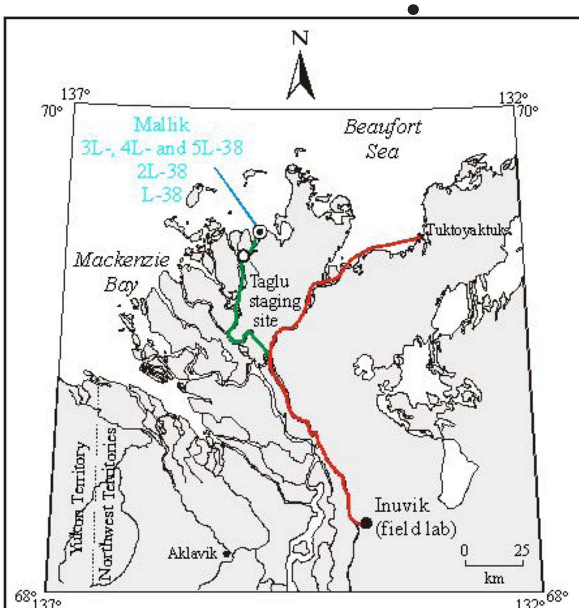
If the presence of a significant methane hydrate accumulation is verified, the producing gas fields in Barrow will provide an excellent opportunity to test the potential of production of methane hydrates through depressurization of the free gas zone at the free gas/hydrate interface. Beyond adding an important source of data to global research efforts regarding the potential for methane hydrates to supplement conventional production in arctic regions, the results of this study have the potential to greatly benefit the community of Barrow and similar communities across the North Slope by expanding the energy resources available for heating and electricity.

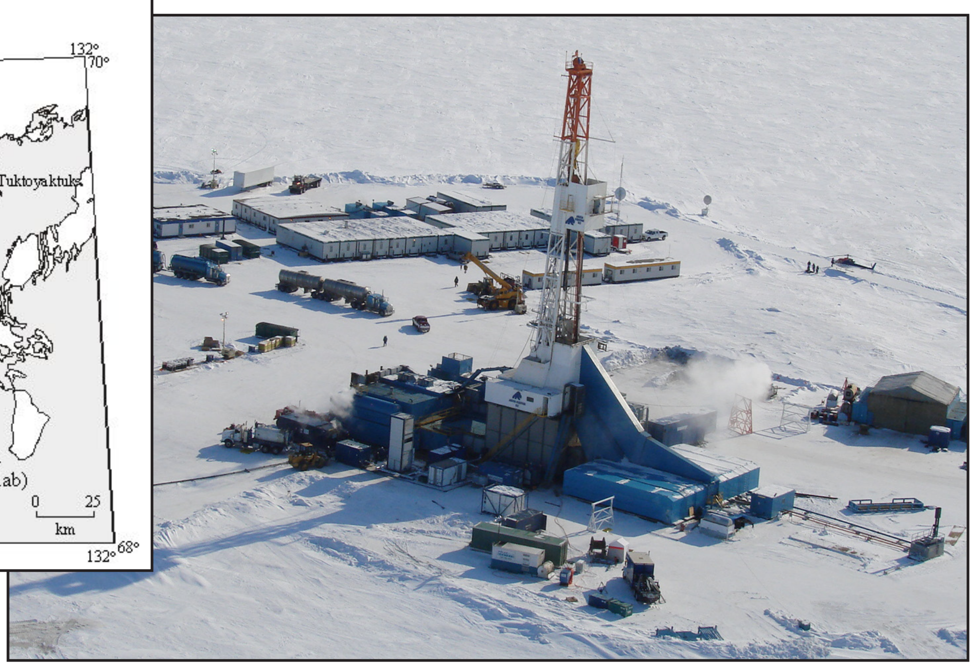
COMMUNITY UPDATE ON THE 2006-2008 JOGMEC/NRCAN/AURORA MALLIK GAS HYDRATE PRODUCTION RESEARCH PROGRAM, NORTHWEST TERRITORIES, CANADA

by S. Dallimore, Natural Resources Canada and 2006-08 Mallik team

In the Canadian Arctic, gas hydrates occur in association with thick permafrost occurrences and have been found in the vicinity of the Mackenzie Delta, in shallow water areas of the Beaufort Sea and in the Arctic Islands. Research related to Canadian gas hydrates has been led by the Earth Sciences and Energy Policy Sectors of Natural Resources Canada (NRCan), where scientists in the Geological Survey of Canada have for the past five years carried out a national research program to assess scientific and resource issues of pertinence to Canadians. Some of the most concentrated hydrate deposits have been described at the Mallik site located north of Inuvik, Northwest Territories (see map), where several international programs have been carried out in the past. The Mallik 2002 Research Well program included participation by Natural Resources Canada, Japan Oil, Gas National Corporation, GeoForschungsZentrum Potsdam, the U.S. Geological Survey, U.S. Department of Energy, Indian Ministry of Petroleum and Natural Gas/Gas Authority India and the BP-Cheveron Joint Venture. Research and development highlights included the collection of pristine gas hydrate core samples, state-of-the-art well logs and data from short term pressure drawdown and thermal production testing.

The current 2006-08 JOGMEC/NRCan Mallik gas hydrate production research program is being conducted to evaluate the natural properties and distribution of gas hydrates at Mallik, and to measure and monitor long term production behaviour. The Japan Oil, Gas and Metals National Corporation (JOGMEC) and NRCan are funding the program and leading the research and development studies. Aurora College/Aurora Research Institute, located





The Mallik drillsite (photo courtesy of JOGMEC/NRCan/Aurora) in Inuvik and Fort Smith, Northwest Territories, is acting as the operator for the field program (http://www.nwtresearch.com).

Winter 2007 Operations

The primary objective of the winter 2007 field activities was to undertake physical installations to allow for long term production testing of several gas hydrate intervals during the winter of 2007/2008. A drilling rig, a service rig and support facilities were mobilized by ice road from Invuik to the Mallik site in January 2007 to allow re-entry and completion operations on two wells. Aurora/JOGMEC/NRCan Mallik 2L-38 was re-entered on February 23rd, 2007 (see photograph). This 1150m deep well was originally drilled as a gas hydrate R&D well in 1998. The open hole section of the well bore was re-occupied and a 311.15mm (12 1/4") new hole section was advanced from 1150m to 1310m (RKB). To establish formation properties prior to testing, the open hole section (including the gas hydrate bearing intervals from 890-1100m) were logged with 5 separate logging runs. A 244.5mm (9 5/8") production casing was installed to 1288m to enable production testing in this well and also re-injection of produced water into a lower injection zone. To monitor formation response to testing, five externally mounted geophysical sensors designed under contract for JOGMEC were successfully installed outside of the casing and a cased hole logging program was conducted to allow repeat time series logging.

While operations were underway in Mallik 2L-38, Nabors Service Rig 414 carried out re-entry operations on Aurora/JOGMEC/NRCan Mallik 3L-38. This well, which was originally drilled in 2002 as part of the Mallik 2002 Research Well program, was deepened from 1188m to 1275m. Open hole and cased hole logging operations were carried out to characterize the geology below the gas hydrate bearing intervals and to establish candidate horizons for water injection planned during the 2007/08 production testing. Mallik 3L-38 was completed with 73mm tubing and subsequently injection tested.

After completion of the physical installations at Mallik 2L-38 and Mallik 3L-38 a decision was taken to undertake a short pressure draw down production test to evaluate equipment performance and short term producibility of gas hydrate by this technique. Testing of a 12m gas hydrate interval from 1093-1105m, near the base of the gas hydrate stability zone, was begun on April 2nd. The results of this 60 hour test were encouraging, documenting robust gas flow rates. Important observations were also made in terms of produced water and the sediment response to production. The participants expect that the practical experience gained will prove to be invaluable for design of future operations.

Future 2007-2008 Operations

The JOGMEC/NRCan Mallik gas hydrate production research program is currently planning operations for the 2007-08 winter programs. At this time, it is anticipated that equipment will be mobilized by barge to a staging site approximately 17km from the Mallik site. Road construction will begin in November, 2007 with a goal of starting production activities in late December or early January, 2008. The primary focus will be to undertake longer duration testing of the Mallik 2L-38 well. Monitoring of the formation response to production will be made by repeated cased hole logging and measurements with other monitoring devices. The onsite operations will involve the re-entering of both 2L-38 and 3L-38. Pressure draw down testing will continue on the lower gas hydrate intervals tested in 2007 and then move to a shallower gas hydrate zone. Gas and produced water will be brought to the surface, measured and separated to allow for re-injection of produced water in Mallik 3L. At the conclusion of the production test, all wells will be abandoned and all equipment will be moved off location in April, 2008.

Seismic Detection of Natural Gas Hydrate in the Deepwater of Northern Gulf of Mexico

By Nader Dutta and Jianchun Dai, Schlumberger

In 2003, a Joint Industry Project in the deepwater Gulf of Mexico sponsored by the U.S. Department of Energy (DOE) and under the direction of the National Energy Technology Laboratory (NETL) began an effort to evaluate methods for predicting, quantifying and characterizing offshore gas hydrates. As part of this effort, Schlumberger was asked to develop a seismic-based technology for exploration of gas hydrates. Our approach was to incorporate the fundamentals of a petroleum system that has guided the development of exploration for conventional hydrocarbon resources. We focus on analyzing potential sources of natural gas, defining gas migration pathways in the shallow sediments, and characterizing the occurrence and distribution of shallow gas hydrate-bearing sediments. The methodology is mainly based on 3D surface seismic data. Because the northern Gulf of Mexico lacks quality well log data in the shallow, gas hydrate-bearing section, our methods for prediction, detection and quantification used analogue models based on geologic interpretation, seismic inversion and basic principles of rock physics. The result was a workflow we term the "five-step process" (Figure1). The following outlines this process with respect to our work with the DOE/Chevron JIP in the Keathley Canyon (KC) region of the Gulf of Mexico.

Step A: Seismic Reprocessing

The seismic data reprocessing was designed to improve resolution of geologic features in the strata within one second (two-way travel time) of the seafloor and to provide inversion-ready seismic data for elastic inversion. Key elements of the reprocessing include: re-sampling at 2 millisecond resolution, amplitude-preserving 3D Kirchhoff prestack time migration, and detailed velocity analysis using every seismic gather and every time sample and/or de-multiple. Amplitude preservation in this step is key so that later seismic inversion techniques can be used to extract meaningful estimates of P- and S-wave velocities (Vp and Vs) and bulk densities.

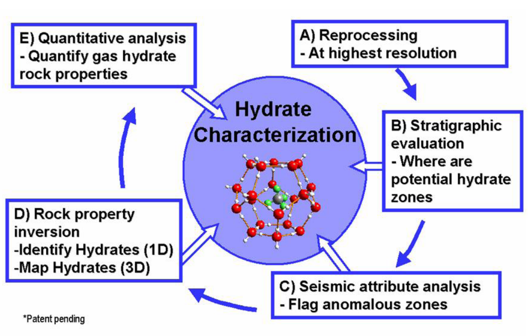


Figure 1: The five-step process for gas hydrates detection and estimation using seismic data.

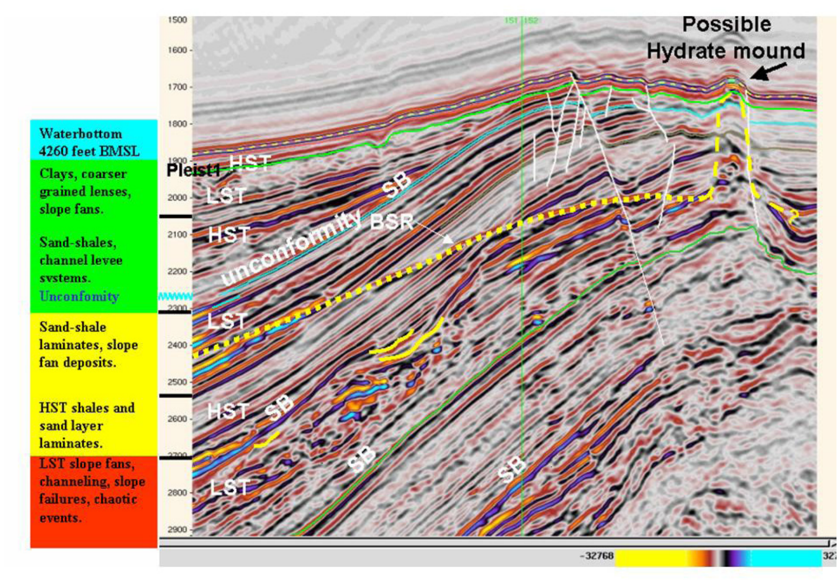


Figure 2: Seismic section with stratigraphic interpretation at KC. The BSR is indicated by the yellow dashed line (LST-low stand, HST-high stand, SB-sequence boundary).

Step B: Stratigraphic Evaluation

The seismic data are then evaluated for indicators of gas hydrate occurrence. Figure 2 shows data from Keathley Canyon in which a bottom-simulating reflector (BSR) is identifiable approximately 500 ms below the seafloor. The BSR is seen as both a discrete reflection cross-cutting regional geological strata and as an alignment of terminations of reflections (interpreted as gas-charged sands). The occurrence of BSR helps to define the base of the gas hydrate stability zone. In addition, the area also shows a surficial mound (Figure 2,) and below, evidence of free gas migration toward the seafloor through a system of faults. Such observations provide valuable regional context that greatly assists in the overall interpretation of gas hydrate occurrence in the locality.

Step C: Seismic Attribute Analysis

To add further value to the interpretation and stratigraphic evaluation process, we also evaluate numerous seismic attributes that may yield direct links to the occurrence of gas hydrate. These attributes can be frequency-based, amplitude-based, phase-based, and coherency-based. Among the large number of possible attributes, we have noticed that reflection strength is particularly useful as gas hydrate-bearing layers tend to have strong reflection due to higher elastic velocities. In addition, artificial illumination highlights surface features such as seafloor mounds. Seismic attribute analysis helps to further define possible gas hydrate related anomalies.

Step D: Rock Property Inversion

Prestack Full Waveform Inversion (PSWI) is applied at numerous locations to derive 1D high-resolution Vp, Vs, and density profiles. An example of PSWI generated prior to drilling is shown in the left panel of Figure 3. The correlation coefficient between the real and synthetic gathers is 0.91, suggesting a reliable inversion result. The right panel shows the inverted P- and S- impedance sections from hybrid inversion, which implements PSWI results into poststack inversion for accurate low-frequency compensation and amplitude calibration.

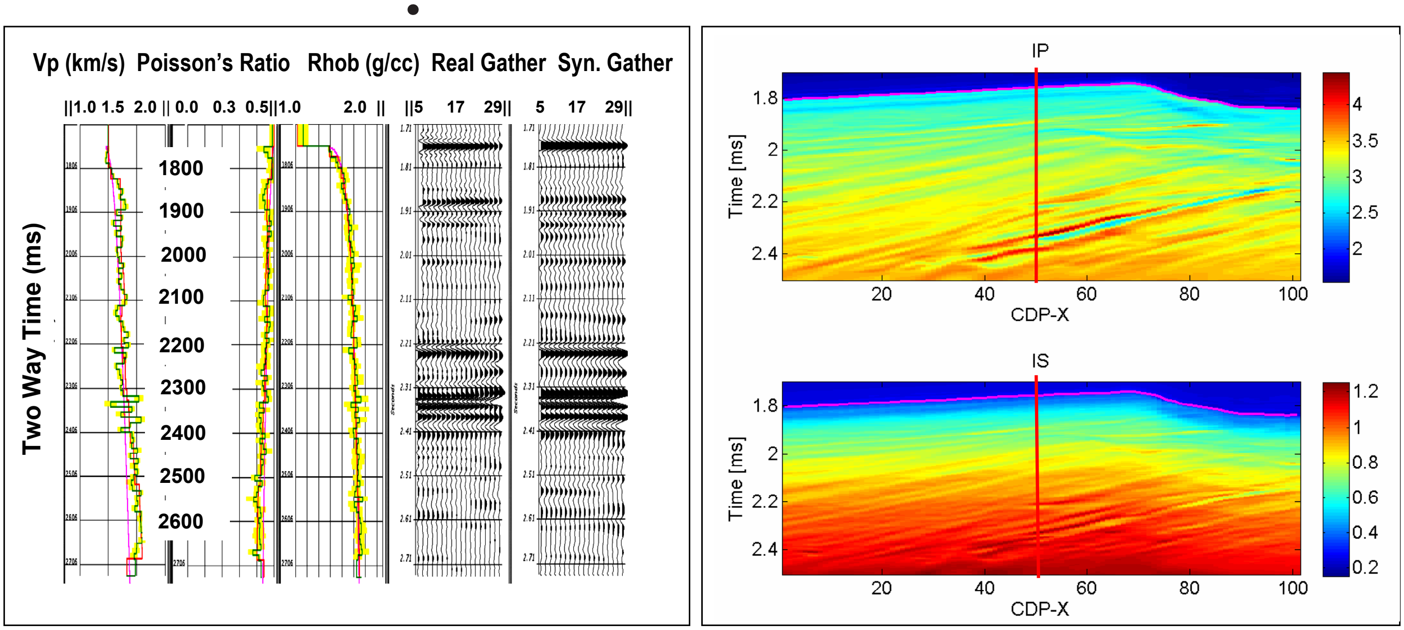


Figure 3: Left panel: An example of PSWI inversion at the pre-drill location indicated by the red lines in the right panel. The green curves in the left three columns are the inverted high-resolution P-wave, Poisson's ratio, and density profiles. The red curves are the corresponding input background values for the elastic parameters (low frequency model). The right two columns display the actual seismic angle gather and the synthetic angle gather after convergence during the iteration process. Right panel: The resulting P- (top) and S- (bottom) impedance derived from hybrid inversion.

Step E: Gas Hydrate Quantification

In lieu of well data to calibrate rock properties to gas hydrate content, a theoretical rock physics model is required to relate the concentration of gas hydrate (Sgh) from velocity/impedance information. We adopt the effective medium theory model that treats hydrates as load-bearing grains (part of matrix) for rock physics modeling, both for its simplicity and due to the fact that this model is consistent with gas hydrate drilling results in various regions. Separate estimates of Sgh are generated by comparing both P-wave and S-wave impedance (generated in Step D) against estimates of expected impedance at varying levels of gas hydrate saturation at each trace location. A final Sgh estimate is generated from a weighted average of the two estimates.

Results of Employing the Five-Step Process in the Keathley Canyon Area

Figure 4 shows the Sgh estimation generated for the Keathley Canyon area. Typical gas hydrate saturation estimates ranged from 0 to slightly over 20 percent of pore space. Hydrate saturations predicted from P- and S-impedance are consistent. The predicted gas hydrate events at the A and B horizons of Figure 4 were later confirmed by JIP drilling in 2005. Resistivity logging indicated elevated gas hydrate saturations at the two events that matched well with the pre-drill seismic prediction (see Figure 5). The log-based estimates have been scaled to mimic seismic resolution. The deviation between pre-drill seismic and log measurement in the shallowest section is difficult to evaluate and is likely due both to questionable log data (due to poor borehole conditions) and increased errors in the basic rock physics models in the extremely porous and unconsolidated shallow sediments.

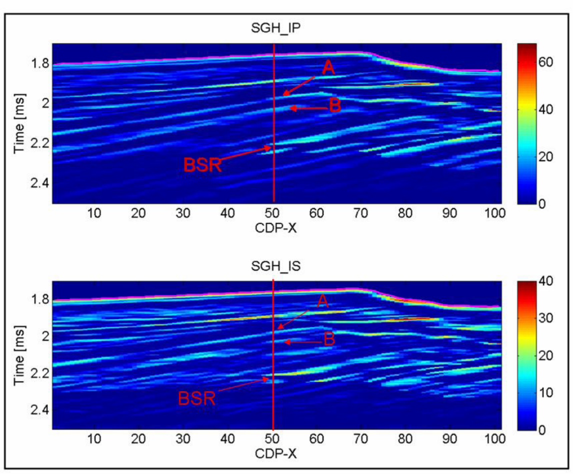
Overall, the comparison between seismic estimation and drilling results is quite encouraging. It shows that the seismic method can capture the general nature and vertical boundaries of gas hydrate anomalies even at modest concentration. We must caution, however, that there exist many uncertainties in the current seismic estimation method. Noise in the seismic data, ambiguities associated with the seismic inversion results, and inadequacies of the rock physics model and the parameters that dictate the predictability of hydrate saturation are just a few. It is crucial to calibrate the seismic estimation with available drilling information. However, despite all the uncertainties the proposed seismic method does provide crucial information for pre-drill gas hydrate analysis, and the selection of drilling locations. The method also has potential for large-scale gas hydrate resource estimation upon proper calibration.

SUGGESTED READING

Dai, J., Xu, H., Snyder, F., and Dutta, N., 2004. Detection and estimation of gas hydrates using rock physics and seismic inversion: Examples from the northern deepwater Gulf of Mexico, The Leading Edge, 23, p.60-66.

Mallick, S., and Dutta, N.C., 2002. Shallow water flow prediction using prestack inversion of conventional 3D seismic data and rock modeling, The Leading Edge, p.675-680

Figure 4: Gas hydrate saturations derived from P-impedance (top) and S-impedance (bottom). The red line indicates the pre-drill location. Hydrates at A and B, as well as the BSR, were confirmed by JIP drilling in 2006.



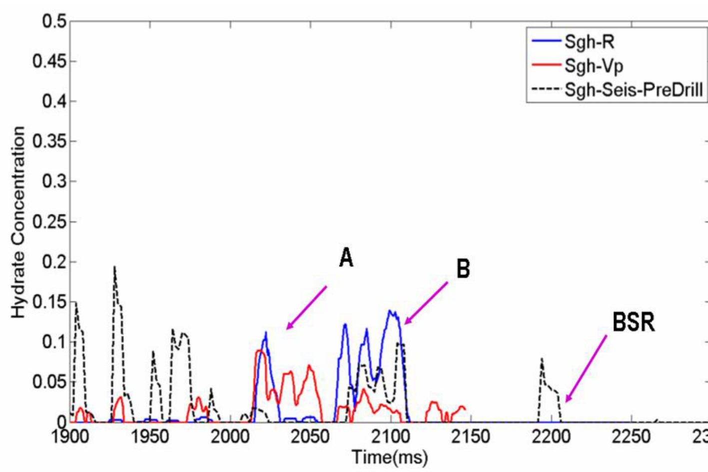


Figure 5: Comparison of Sgh estimated from well log and the pre-drill seismic prediction from PSWI. The blue (Sgh-R) and red (Sgh-Vp) curves are the Sgh estimations in seismic scale from resistivity and P-wave velocity, respectively. The black dots (Sgh-Seis-PreDrill) are the result of pre-drill prediction.

Exploration Priorities for Marine Gas Hydrate Resources

Ray Boswell (U.S. DOE/NETL), Robert Kleinberg (Schlumberger), Tim Collett (USGS), and Matt Frye (MMS)

A primary goal of the U.S. national gas hydrates R&D program is the determination of the future energy supply potential of marine gas hydrates. An earlier article in this newsletter (Boswell and Collett, Fall 2006) described a conceptual gas hydrates "resource pyramid" which portrayed the nature of distinct gas hydrate resource plays, their estimated relative abundance in terms of in-place resources, and their relative position with respect to the nature of the technological challenge that may be required to enable future production. This follow-on article focuses on the marine resources that form the bulk of the gas hydrate resource pyramid, (Fig. 1) and recommends specific R&D priorities for marine gas hydrate exploration.

At present, four different marine gas hydrate play types are known: 1) sand-dominated reservoirs; 2) clay-dominated fractured reservoirs, 3) massive gas hydrate formations exposed on the sea-floor; and 4) low-concentration disseminated deposits encased in largely impermeable clays. The first two of these play types warrant further exploration and production R&D efforts as both provide the bulk permeability that appears to be necessary for the high gas hydrate concentrations. Both are consistent with environmentally sound, well-based extraction techniques. Furthermore, these two play types may often be very closely related and found in combination. In appraising these two, the most pressing need is to better understand the abundance, on a regional basis, not only of in-place gas, but more importantly, of potential recoverable resources. Obtaining this understanding will continue to be the core focus of the U.S. national R&D program.

A New Approach to Marine Gas Hydrate Exploration

Assuming sufficient resource abundance, future commercial production from either sand bodies or fractured clay-dominated sediments will require the ability to reliably prospect for rich gas hydrate accumulations through remote sensing. Over the past two decades, the selection of drill sites for gas hydrate exploration has been driven primarily by: 1) investigation of presumed proxies for gas hydrate occurrence, most notably the bottom simulating reflectors apparent in seismic surveys, but also surficial features that are indicative of current or recent high fluxes of methane through

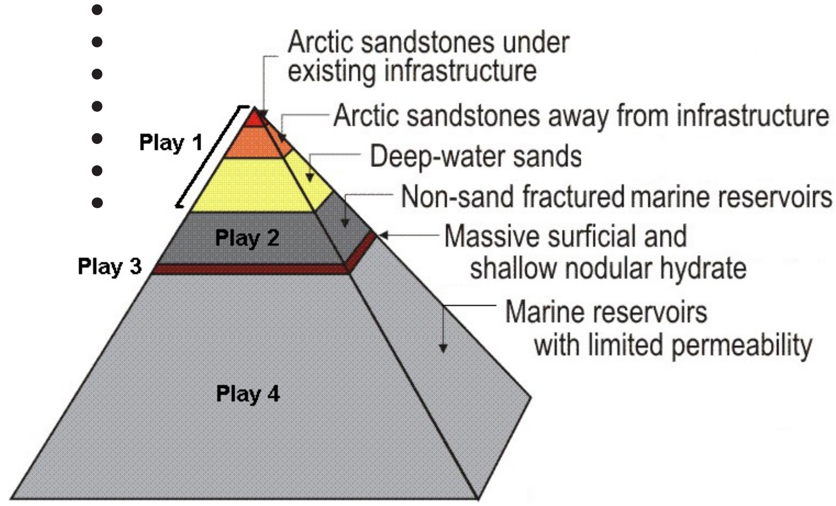


Figure 1: Four gas hydrate play types within the gas hydrates resource pyramid

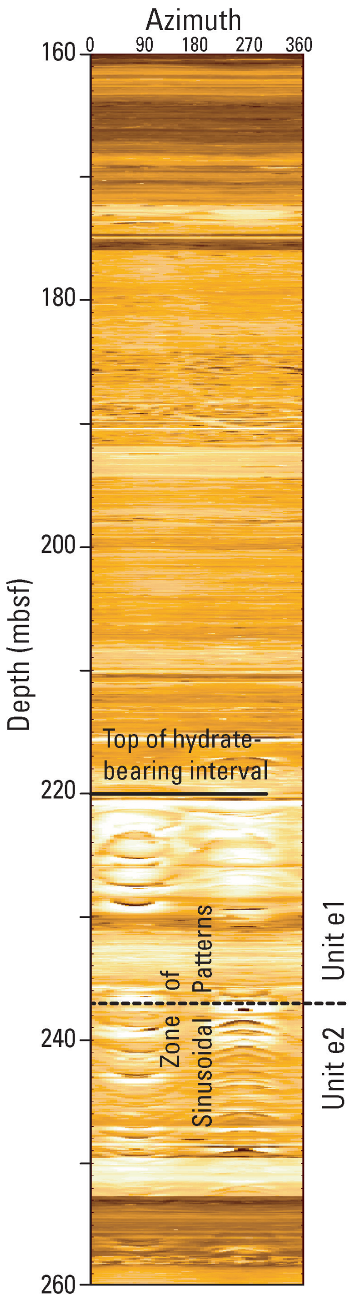


Figure 2: A 360⁰ borehole resistivity image of gas hydrate-bearing fractured fine-grained sediment from the Keathley Canyon well drilled by the Chevron JIP in 2005. The sinusoidal patterns in the interval below 220 mbsf are consistent with steeply-deeping, hydrate-filled fracture surfaces. From Hutchinson et al – upcoming JIP Science results volume.

shallow sediments; or 2) scientific concerns such as the desire for closely-spaced drill holes in transects across a region or feature of academic interest. The first approach has, at several sites, been shown to be a poor indicator of potentially producible accumulations. The second approach has different drivers, and cannot be expected to result in discovery of such deposits.

To improve the reliability of marine gas hydrate exploration, the U.S national R&D effort is actively pursuing a new approach; the development of technologies for the direct detection of gas hydrate reservoirs or other indicators diagnostic of concentrated gas hydrate accumulations. This is a fundamental shift from the past reliance on indirect indicators of gas hydrate to the direct appraisal of the gas hydrate occurrence and richness. The potential for direct detection and characterization in the marine environment has recently been demonstrated by work within the DOE/Chevron Gulf of Mexico Joint Industry Project (JIP) (see article by Dutta, this issue). The ability to successfully prospect in the Arctic has also recently been documented (FITI, Winter 2007).

Sand-dominated Plays

Gas hydrates enclosed in reservoir-quality sands are best known from the Arctic. However, there are several documented cases of marine sands with high gas hydrate saturations. Examples include the Nankai trough discovery, and hydrate shows at the Ocean Drilling Program (ODP) Leg 204 and Integrated Ocean Drilling Program (IODP) Expedition 311 sites off the Pacific coast of North America. These results suggest that one of the primary controls on the degree of gas hydrate saturation is reservoir lithology. Currently, work within the JIP is focused on a highly-saturated, marine gas hydrate bearing sandstone reservoir (Fig. 2) located in Alaminos Canyon Block 818 (Smith *et al*, FITI, Winter, 2006). Furthermore, work by the Minerals Management Service (MMS), including integration of the MMS's ongoing marine gas hydrate resource assessment within the JIP, has shown that reservoir-quality sands are much more common in the shallow sediments of the gas hydrate stability zone than previously thought.

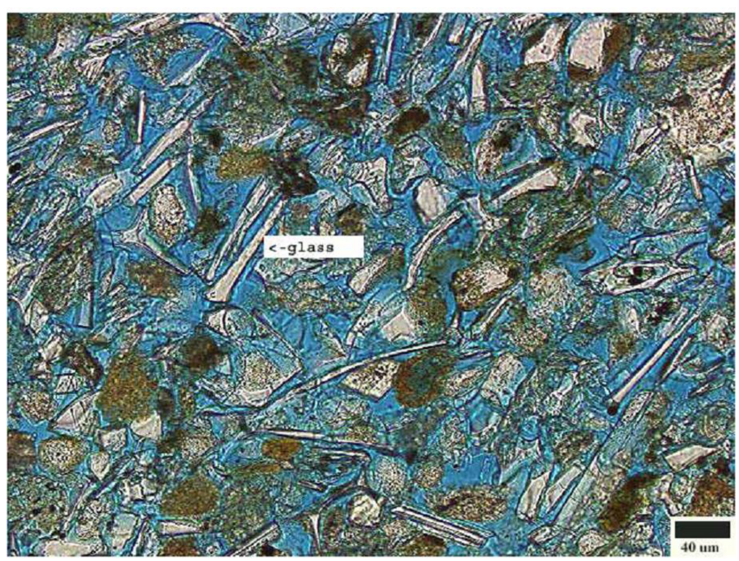


Figure 3: A side-wall core photomicrograph of porous and permeable marine sand from Alaminos Canyon block 818. This immature volcaniclastic sand contained >60% gas hydrate in situ based on log evaluation (photo courtesy of Chevron).

Fractured Clay-dominated Plays

The majority of marine gas hydrate systems that have been studied to date are fine-grained, clay-dominated systems and associated surficial/near-surface seep-related massive gas hydrate deposits. Until recently, it was widely believed that subsurface gas hydrate saturations in fine-grained lithologies were generally restricted to very low values (~10 percent). However, the 2005 exploration well drilled at Keathley Canyon by the JIP uncovered elevated saturations in fine sediments with numerous steeply dipping fractures (Fig. 3). More spectacularly, the 2006 National Gas Hydrate Program (NGHP) Expedition 01 offshore India (FITI, Fall 2006) found a 130-m thick zone of extensively deformed clay sediment with gas hydrate saturations commonly exceeding 70 percent (Fig. 4). These findings have broadened the model for high gas hydrate concentrations to include fractured clay-dominated systems in which gas hydrate is concentrated in vertical and subvertical gas conduits. The conduits may open as a result of gas overpressure below the gas hydrate stability zone, or they may be pre-existing tectonically-created features. Very likely, both modes are to be found in nature.

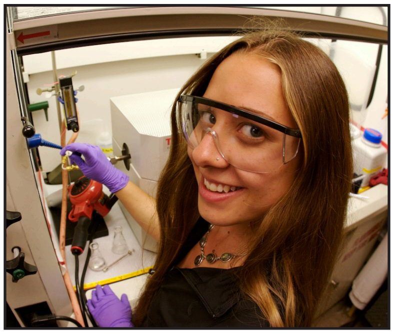
Figure 4: An example longitudinal X-ray image of a one-meter-long pressure core obtained from offshore India containing gas-hydrate bearing fractured clay-dominated sediments. Gas hydrate (lightest shading) occurs primarily as thin, high-angle features filling apparent fractures (photo courtesy of NGHP Expedition 01).

Combination Plays

Given the nature of marine sediments, it is likely that both sand-dominated and clay-dominated fractured reservoir systems will often occur in close association. For example, some potentially significant marine gas hydrate accumulations may occur in relatively permeable horizontal or subhorizontal sand bodies that are charged and maintained by gas migration through a system of vertical to subvertical fractures. There is as yet very little information concerning the continuity and lateral extent of such reservoirs.

Near Term R&D Priorities

The U.S. national R&D program recognizes the need to pursue scientific knowledge and technology development related to high-potential marine gas hydrate plays. Sand, fractured clay, and combination plays are targets for emerging seismic and electromagnetic exploration technologies and the development of unconventional production techniques. Because conventional marine exploration and production technologies favor the sand-dominant play, investigation of sand plays has a higher near-term priority in the program. However, this prioritization will depend on improved information on the relative abundance of accumulations of each type. Are high-saturation accumulations such as that seen in Alaminos Canyon 818 or in the fractured clay-rich system offshore India only the first of what will be many documented examples of common features, or are they relatively rare examples? Going forward, the program will continue to probe this issue; both within the U.S. program and through collaboration with international gas hydrate research efforts.



First NETL-NAS Methane Hydrate Fellowship Awarded to Monica Heintz

Solving geological engineering problems and studying microbial communities that oxidize methane in the ocean would seem to most people to be totally different scientific endeavors. But when Monica Heintz's curiosity about the interface between the biological and mineral worlds steered her from the Colorado Rocky Mountains to the Pacific Ocean, she found that many of the skills she had gained as an undergraduate at the Colorado School of Mines could be applied in modeling how naturally elevated methane concentrations in the ocean change due to currents, dilution, and most importantly, consumption by microbes that rely on methane as a carbon and energy source. Methane is a powerful greenhouse gas, with about 20 times the radiative capacity of carbon dioxide. The oxidation of methane in the water column is one of the least characterized processes of the global carbon cycle, and yet a significant portion of methane released from marine sediments is consumed before it can reach the atmosphere.

Monica was recently selected as the first recipient of a new Methane Hydrate Research Fellowship awarded by the U. S. Department of Energy in a program directed by the National Energy Technology Laboratory (NETL) and managed by the National Academies of Sciences (NAS). Ms. Heintz will concentrate on identifying the microorganisms responsible for methane oxidation in the marine water column and will investigate the ways in which this "biological filter" controls how much of the methane released from the seafloor, either from hydrates or seeps, eventually reaches the atmosphere.

Monica's interest in science started early. "I really can't remember a time when I didn't want to be a scientist," she says. "In my childhood years, I remember working on science fair-type projects in the garage with grandfather—an electrical engineer. When I went to CSM I was determined to be a physicist, until an introductory earth science course drew me into the geological engineering program. Then, when I made the decision to go on to graduate school I realized I could focus on practically any problem I wanted." Ms. Heintz chose to begin by studying microbial communities associated with marine hydrothermal systems under the leadership of U.C. Santa Barbara professors Rachel Haymon and Dave Valentine, soon after a visit to the campus. "The people there were terrific, I loved southern California, and two months after starting graduate school I was on a ship, at the Galapagos Spreading Center, collecting samples from plumes of hydrothermal fluid emanating from the mid-ocean ridge with the goal of identifying members of the microbial community that harvest energy from the chemicals in hydrothermal fluids." She is currently working toward a PhD in Earth Science as part of Dr. Valentine's biogeochemistry group.

Monica's research under the Methane Hydrate Research Fellowship will ramp up this summer when she participates in a July research cruise in the Santa Barbara and Santa Monica Basins, offshore southern California. The goal of the cruise is to balance the methane budget for the major seep fields in the area. Monica will be collecting samples to screen for methanotropic microbes and will be using radioactively-tagged methane to determine how quickly they oxidize methane in the water column. She will apply results from the work on this cruise to investigate how much of the 40 metric tons per day of methane seeping from the seafloor at the shallower Coal Oil Point seep just off the Santa Barbara coast might be oxidized by bacteria before it escapes into the atmosphere. In this effort, she will be working with Dr. Susan Mau, a post-doctoral researcher in Dr. Valentine's group.

Gulf of Mexico JIP to Hold Open Workshop

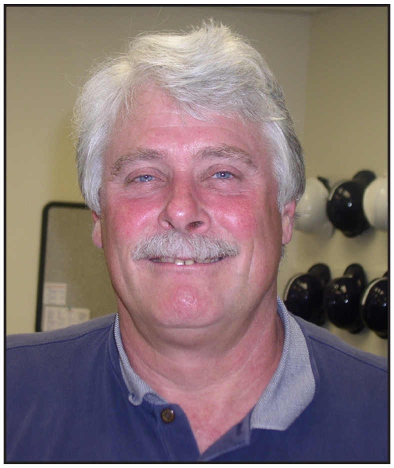
The DOE-Chevron Gulf of Mexico Gas Hydrates Joint Industry Project will hold an open meeting on July 26, 2007 from 8:00 AM to 5:00 PM at the Schlumberger-WesternGeco offices in Houston, Texas. The JIP has developed a plan for conducting logging-while-drilling and other data collection activities designed to characterize the nature of gas hydrate occurrence within sand-dominated reservoirs in the Gulf. Prior JIP workshops identified the confirmed accumulation in Alaminos Canyon Block 818 (AC818) as the primary site for a potential field expedition in the Gulf of Mexico in the spring of 2008. The goal of this workshop is to have an open discussion among all interested parties on the nature of the drilling, logging and other data collection activities to be undertaken at AC818, and the prioritization of additional potential drill sites within the Gulf of Mexico that may be added to the JIP expedition should budgets be sufficient. At present, likely elements of the agenda, in addition to discussion of the optimal activities at the AC818 location, include an overview of potential field sites in Alaminos Canyon Block 857 and a review of well sites based on the ongoing Gulf of Mexico gas hydrates resource assessment being conducted by the Minerals Management Service. If you would like to present a recommendation for a drill site in the Gulf to test potential gas-hydrate bearing sand reservoirs, please contact Emrys Jones ejones@chevron.com or Mike Smith michael.smith@mms.gov before July 23. Please be prepared to present seismic, well log, or other data that provides evidence of hydrates located in sandy sediments at your suggested locations. The information will be used for the meeting attendee's review and discussion and with your permission will be made public.

SPE Forum Targets Unconsolidated Reservoirs

An SPE Forum will be held August 26-31 in Kananaskis, Alberta, Canada, that will focus on the technical challenges of producing hydrocarbons from unconsolidated formations. Topics will include integrating soft rock geomechanics with production modeling, and interpreting reservoir monitoring data in unconsolidated reservoirs. While methane hydrate reservoirs will not be a primary topic, this forum will address several of the key technological challenges that face engineers attempting to produce from gas hydrate reservoirs. Check out http://www.spe.org/spe-app/spe/meetings/FCN1/2007/index.htm for more details.

SEG Annual Conference to Kick-Off with Unconventional Resources Forum

At the Society of Exploration Geophysicist's Annual Conference in San Antonio, to be held on September 23-28, the topic of the opening day SEG Forum will be "Unconventional Resources." This year's Forum, which begins at 9:30 AM on Monday the 24th, will include representatives from a major multinational, a large independent, a service company, and a governmental agency. If you are attending the SEG Meeting this year, don't miss this opening event.



WILLIAM SHEDD

Geophysicist, Minerals Management Service
William.Shedd@mms.gov

When not studying hydrates Bill enjoys a wide range of outdoor activities with his family – camping, sailing, swimming, and bicycling. He is an avid partaker of the food, music, and culture of New Orleans, and like many of his fellow New Orleanians, continues to be an enthusiastic participant in both Mardi Gras and the New Orleans Jazz Festival, despite the temporary setbacks brought by hurricanes.

MMS Geophysicist Helps Set the Stage for Hydrate Production

In one way, the methane that will some day be produced from gas hydrates in the Gulf of Mexico is no different than the trillions of cubic feet of conventional natural gas that have already been produced from those waters—companies wishing to find and produce it will need to acquire a lease to do so. And that requires the Interior Department to make an assessment of the lease's resource value before the bidding starts. Developing this pre-sale assessment on a lease-by-lease basis for the conventional natural gas resource is difficult enough, but accounting for the value of methane hydrate—a resource that has never been commercially produced offshore—has required the Interior Department's Mineral Management Service (MMS) to essentially start from scratch. Bill Shedd, who is playing a key part in that effort at the MMS, has found the challenge stimulating.

"When the MMS was initially charged with assessing natural gas from hydrates as a resource, I helped develop the ongoing hydrate assessment methodology. I have also been involved in the geophysical and geological mapping and the generation of the grids we are using to model hydrate volumes in the Gulf of Mexico and the Atlantic OCS," says Bill. "Perhaps the most interesting and exciting phase of the work I've done in the Gulf of Mexico has been to map potential hydrocarbon seep sites on the seafloor … and thus the potential hydrate exposures … and then participate in the submersible dives with Dr. Harry Roberts of Louisiana State University to verify those mapping efforts."

Shedd has viewed the Gulf of Mexico from both sides of the lease sale auction block. After receiving his B.A. in Geology from the University of Rochester in 1973, Bill continued graduate work at Louisiana State University until 1977 when he went to work as a geologist for Shell Oil Company in New Orleans. Like many explorationists during the boom years of the late 70s and early 80s, he went on to work for an independent, launched his own company with three associates in 1989 and ultimately became a consultant. Then, in 1997 he joined the MMS as a geophysicist in the Resource Evaluation Office's Geology and Geophysics Section doing lease sale bid evaluations. In 2002 Shedd became part of a group mapping water bottom amplitude anomalies, which he had determined were caused by oil and gas seeps.

"It has been very rewarding to work in a frontier area like the hydrates play with many of the foremost scientists in the field," adds Bill. "I've interfaced with geologists, geophysicists, engineers, geochemists, biologists and statisticians … and they've all convinced me how little we really know about hydrates and how much more work needs to be done."

Shedd believes some of the most significant questions in need of answers relate to understanding how methane hydrate accumulations can be characterized with an eye towards their ultimate potential for production. For example: Does the gas migrate into the reservoir rock along faults that we can map? Does the hydrate form in the middle of an interstitial pore space and grow outward towards the pore throats, allowing for higher concentrations, or vice versa? Can hydrates be "melted" economically in the deep water OCS? Can the gas be delivered at high enough pressure to share pipeline space with conventional gas production or will dedicated low pressure lines need to be laid?

"The leasing process forces us to think about the ultimate value of the methane hydrate resource, and this requires that we make some reasonable assumptions about how it is distributed and how it might be produced. We have to use the best information we have in hand and apply an assessment methodology that can be modified as the quality of information improves with time," adds Shedd. "It's exciting to play a part in helping this new resource emerge."