

Fire in the Ice

Vol. 11, Issue 2 Methane Hydrate Newsletter



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GLOBAL RESOURCE POTENTIAL OF GAS HYDRATE – A NEW CALCULATION

By Arthur H. Johnson (Hydrate Energy International)

Published estimates of global gas hydrate abundance from the past thirty years point to a truly vast natural gas hydrate potential. These estimates include hydrate in low-grade (shale) deposits as well as in high-grade (sand) deposits, and are misleading as to actual economic potential. As noted in recent Max *et al.* (2006) and Collett *et al.* (2009) publications, high-grade gas hydrate deposits are best viewed as an extension of the conventional petroleum system, and a petroleum systems approach is essential for a valid assessment of hydrate resource potential.

Hydrate Energy International (HEI), as part of the Global Energy Assessment being conducted by the International Institute for Applied Systems Analysis (IIASA), recently released the results (Figure 1) of a new evaluation of gas hydrate resource potential utilizing a petroleum systems approach. The

Calculated Gas In-Place in Hydrate-Bearing Sands

Total Median = 43,311 tcf

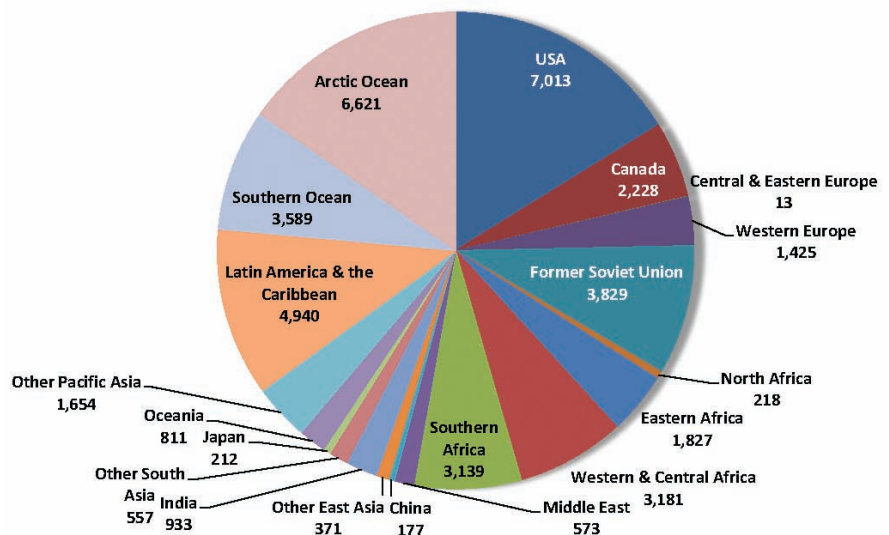


Figure 1: Calculated gas in-place in hydrate-bearing sands (median, tcf).

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evaluation resulted in calculations that support the probability of a large volume of hydrate being present in sand reservoirs in polar and deepwater sediments.

Previous Global Gas Hydrate Assessments

Most of the world's gas hydrate is removed from consideration as an energy resource when factors such as the combination of lithology and the methane flux required for deposits of concentrated hydrate in producible reservoirs are considered (Figure 2). High concentrations of hydrate may be present in marine and arctic sediments, leading to the possibility of exceptionally large volumes of natural gas occurring in porous, permeable reservoirs.

Hydrate resource estimates that have used the petroleum systems approach with a valid methodology cover specific locations or regions, and include:

- 6,717 Tcf of gas in-place in sand reservoirs in the Gulf of Mexico (Frye 2008),
- 85.4 Tcf of gas technically recoverable from hydrate-bearing sand reservoirs in the Alaskan North Slope (Collett *et al.*, 2008), and
- 40 Tcf of gas in-place for a limited area of the Nankai Trough, with 20 Tcf of that volume assessed to occur in sand-rich reservoirs (Fujii *et al.*, 2007).

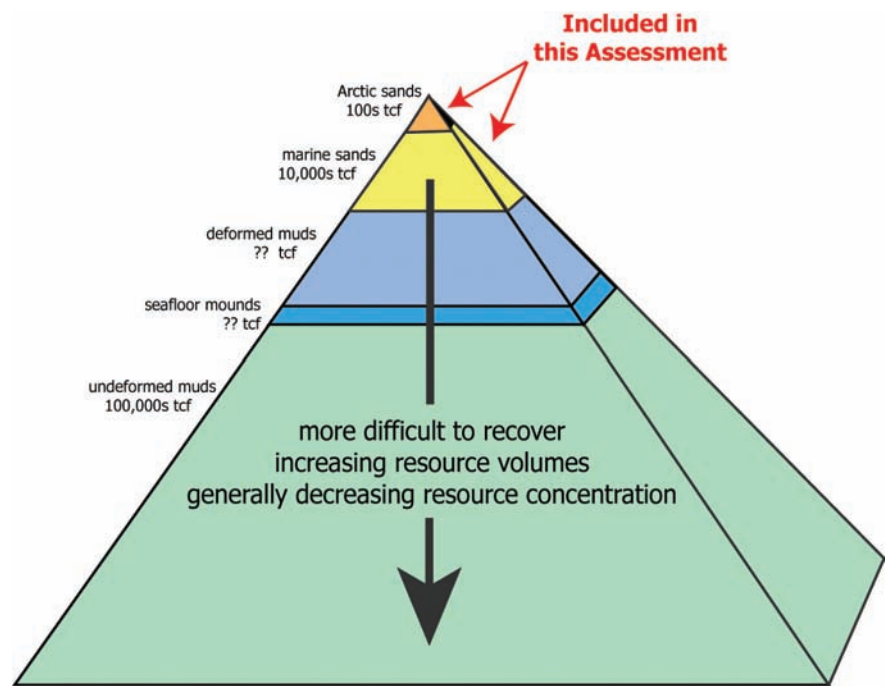


Figure 2: Modified gas hydrate resource pyramid (Adapted from Boswell and Collett, 2006).

- **New Global Gas Hydrate Assessment**

- As part of the Global Energy Assessment being conducted by IASA, HEI assessed every continental margin worldwide, incorporating geological models of likely sand distribution with prior interpretations of the occurrence of gas hydrate stability conditions. Under the guidelines of the IASA, the results are reported for the 18 Regions defined by the United Nations. In addition, separate resource assessments were conducted for the Arctic Ocean without regard for national boundaries, and for the Southern Ocean (from the coast of Antarctica north to 60 degrees south latitude).

- High-grade gas hydrate deposits are located where pressure-temperature conditions for hydrate formation occur with appropriate reservoir lithology and adequate gas input. Other than a few locations, such as those noted above, these parameters have not been adequately quantified at the shallow depths where gas hydrate may be present, even in areas with extensive conventional oil and gas drilling. Most of the marine gas hydrate systems that have been studied to date are fine-grained, with very poor reservoir potential. Since 2007, a general consensus has been growing for the need to adopt a petroleum systems approach that includes assessment of all of the parameters required for high-grade deposits.

Methane Hydrate Stability Zone Thickness

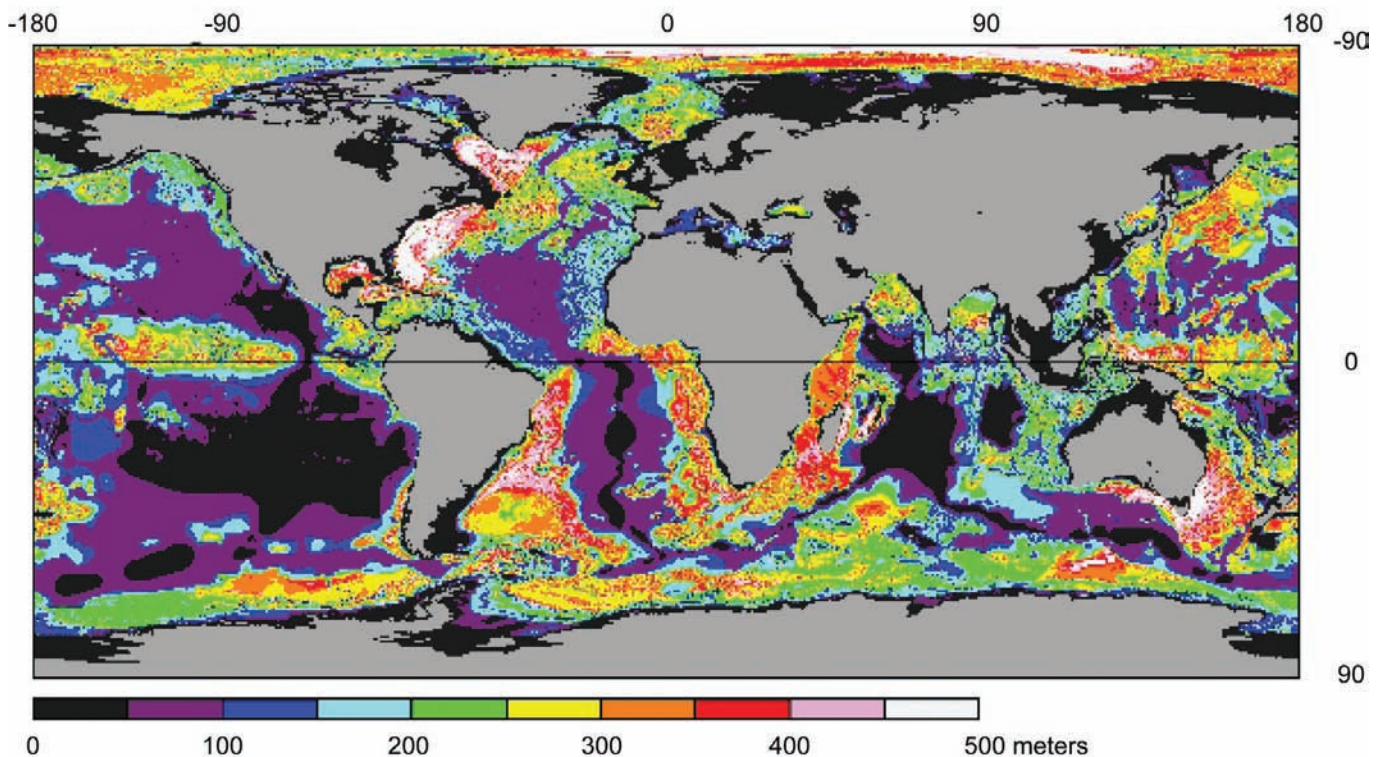


Figure 3: Estimated thickness of gas hydrate stability zone (Wood and Jung, 2008).

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Collett, T.S., Agena, W.F., Lee, M.W., Zyrianova, M.V., Bird, K.J., Charpentier, T.C., Houseknecht, D.W., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2008. *Assessment of gas hydrate resources on the North Slope, Alaska, 2008*: U.S. Geological Survey Fact Sheet 2008-3073, 4 p.

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Max, M.D., Johnson, A., & Dillon, W.P., 2006. *Economic Geology of Natural Gas Hydrate*. Springer, Berlin, Dordrecht, 341p.

Wood, W.T., and W.Y. Jung, 2008. Modeling the Extent of Earth's Marine Methane Hydrate Cryosphere, Proceedings of the 6th International Conference on Gas Hydrates (ICGH 2008), July 6-10, 2008, Vancouver, British Columbia, Canada, 8 p.

Three critical parameters were used for this study: the thickness of the hydrate stability zone, the probability of reservoir lithology within the hydrate stability zone, and the probability of adequate gas charge.

The thickness of the gas hydrate stability zone was determined with the use of data and reports obtained from the U.S. Naval Research Laboratory (NRL), and additional contribution of Warren Wood (NRL) in the success of the project is gratefully acknowledged. The NRL data was gridded by Wood and Jung at 2 minutes of latitude and 2 minutes of longitude to produce a global map (Figure 3). Calculation of the gas hydrate resource potential for each of the 20 Regions was determined by first segregating each region into separate sub-regions based on the local depositional setting. A range of values for the volume of sediment within the gas hydrate stability zone (corrected for sulfate reduction of methane near the seafloor) was calculated using the model developed by Wood and Jung for marine gas hydrate.

These volumes were multiplied by:

- a range of values of the percentage of sand within the hydrate stability zone,
- a range of values for the percentage of those sands that would be hydrate-bearing,
- a range of values for sandstone porosity, and
- a range of values for hydrate saturation of the pore space

This calculation provides an estimate of the gas in-place for the gas hydrate resource. Where detailed analyses have been conducted by previous researchers, those results have been integrated into the new evaluation. For Arctic sediments, the estimate was determined using the same petroleum systems approach or, where the parameters for a petroleum systems approach were not available, extrapolation of recent analyses such as Collett *et al.* (2008).

Results and Summary

The median estimates for gas-in-place in hydrate-bearing sands are summarized in Figure 1. The global volume of gas hydrate is enormous, and a significant portion of the total volume is expected to occur in reservoirs from which natural gas is technically recoverable. While the resulting resource estimates extend over several orders of magnitude, a narrower range of values will be obtainable in the future as additional data is collected.

Full results can be found in *Global Energy Assessment: Toward a Sustainable Future*, which will be published in late 2011 or early 2012 by Cambridge University Press.

DETECTING HYDRATES WITH PATCHY BSR: KRISHNA-GODAVARI BASIN, INDIA

By Priyank Jaiswal (Oklahoma State University)

In 2006, the Indian National Gas Hydrate Program conducted an extensive drilling/coring operation known as the NGHP-01 expedition (Collett *et al.*, 2006). It was executed to assess the hydrate potential of the Indian continental margin (see Collett *et al.*, FITI, Vol. 6, Iss. 3). One of the drill sites, NGHP-01-10 in the Krishna-Godavari basin, Indian east coast (Figure 1), recovered 128 m of continuous fractured hydrate-bearing sediments. The pore-volume hydrates saturation estimated from depressurization ranged from 17.6 to 25.4% making Site NGHP-01-10 one of the richest hydrate accumulations ever drilled. However, contrary to the conventional wisdom, Site NGHP-01-10 was not associated with a prominent, continuous Bottom Simulating Reflector (BSR) which is often a generic proxy for presence of

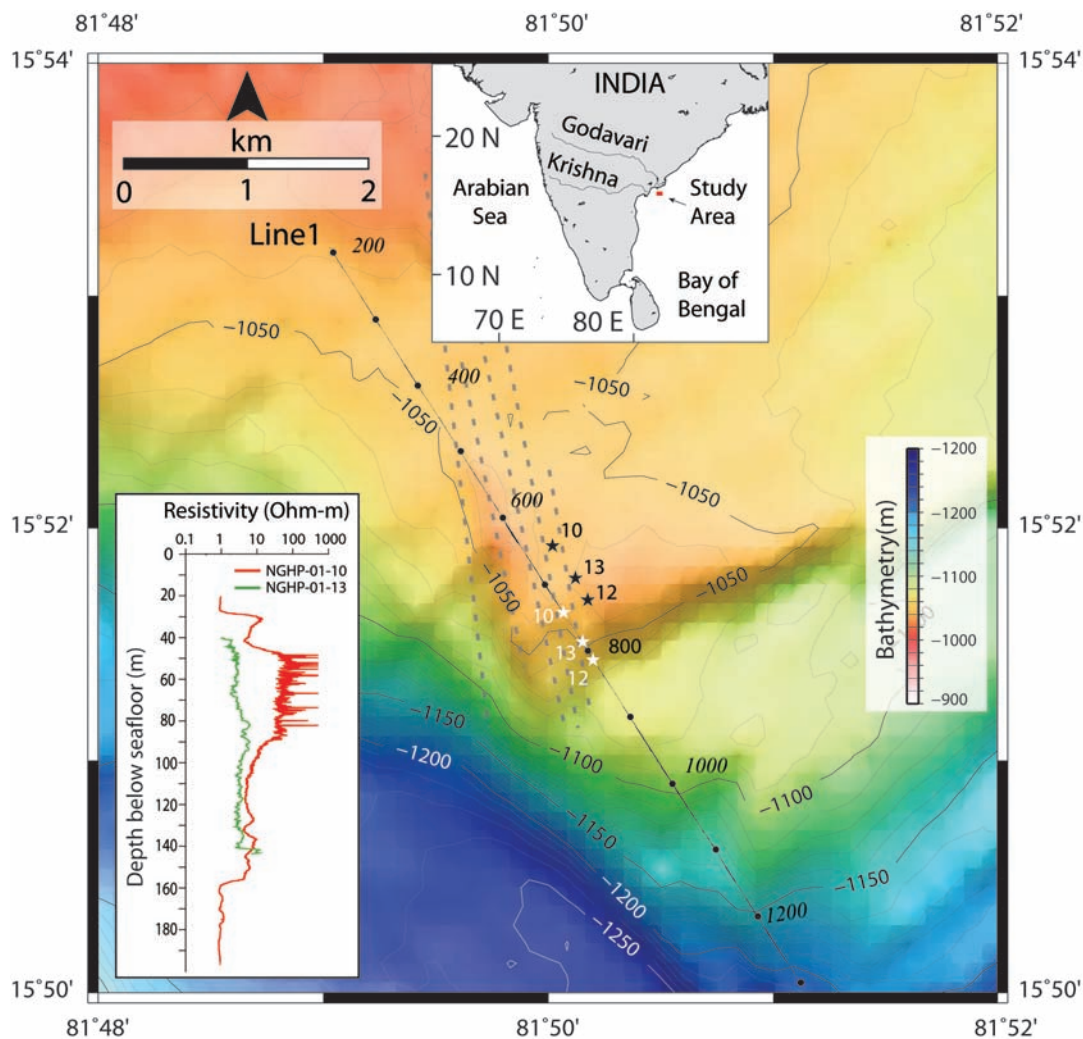


Figure 1: Location of Sites NGHP-01-10, 12, and 13 with their projections on the seismic line (Line 1) is shown with solid black and white stars respectively. Well projections are made along regional faults (Dewangan *et al.*, 2011) indicated in a dashed grey line. Location of the study area with respect to the Indian subcontinent is shown in the inset. Also shown in the inset is a comparison of the resistivity logs from Sites NGHP-01-10 and NGHP-01-12.

- hydrates. The site had a rather a patchy and discontinuous BSR. A simple
- BSR-guided site selection would thus have overlooked Site NGHP-01-10.
- This raises an important question – are there other seismic proxies for
- hydrates besides a BSR? We use a full waveform inversion method to show
- that a high-resolution P-wave velocity (V_p) model can be a reliable proxy
- for hydrates. Seismic data for the waveform inversion is 2-D and from the
- vicinity (~250 m away) of Site NGHP-01-10.
- **Waveform Inversion**
- The main goal of waveform inversion is to replicate the observed field
- seismic data; the velocity model is an automatic byproduct of the
- process. We implement waveform inversion in the frequency domain

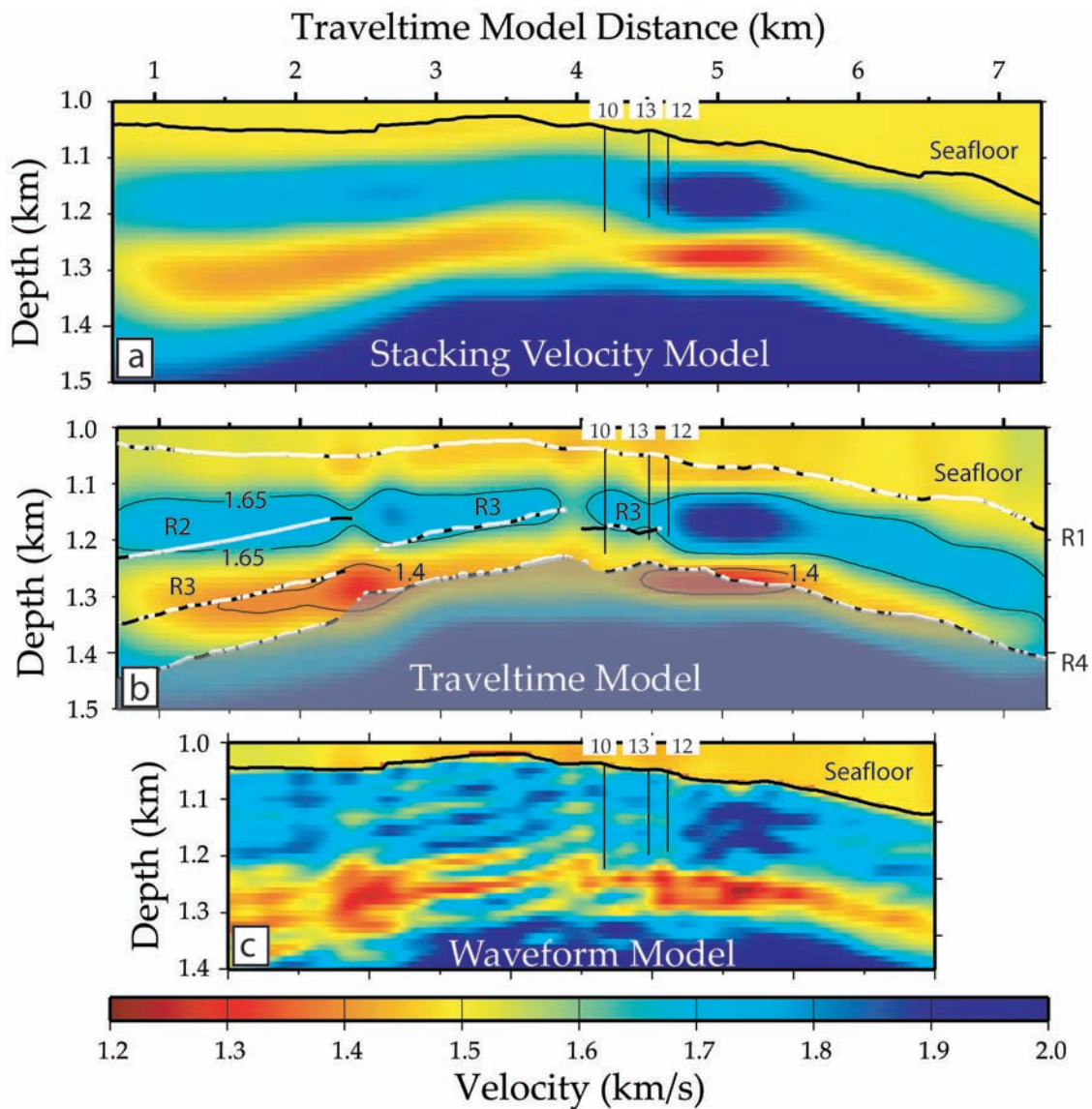


Figure 2: Velocity model evolution: a) Model from stacking velocity analysis, b) Model from a composite traveltimes inversion – depth migration method (Jaiswal and Zelt, 2008), and c) Model from waveform inversion. The sea floor is labeled and the trajectory of Sites NGHP-01-10, 12, and 13 are overlain. Horizons R1 – R4 are used in modeling. Velocity greater than 1.65 km/s and less than 1.4 km/s respectively indicate hydrates and free gas.

- (Pratt, 1999), i.e., instead of reproducing the individual wiggles in a seismic trace we try to reproduce the amplitude spectrum. The implementation is multi-scale, i.e., the lower end of the frequency spectrum which corresponds to the larger scale features of the subsurface is first reproduced and followed by the higher end which corresponds to the finer details of the geology. The multi-scale approach, only possible in the frequency domain, mitigates the inherent non-linearity of the waveform inverse problem. In practice, the waveform inversion begins with a smooth, large-scale velocity approximation of the subsurface, also known as the starting velocity model, and improves it iteratively through a local descent method.

- **Initial Model for Waveform Inversion**

- We estimate the starting model for waveform inversion using a coupled traveltimes inversion - depth migration method. The traveltimes inversion, similar to the waveform inversion, is aimed at reproducing the arrival times of reflection seismic events. The geometry of reflectors required by traveltimes inversion is determined by depth migration which in turn uses the velocity model estimated by traveltimes inversion. A cyclic implementation of inversion and migration is continued until a common structural solution is obtained (Jaiswal and Zelt, 2008). In this application we begin the traveltimes inversion using a stacking velocity model (Figure 2a) and use reflection traveltimes from four horizons from within and outside the hydrate stability zone (R1 – R4; Figure 2b). The BSR is not used to keep the modeling objective. In three cycles the method converges to yield a final velocity model and a final depth image.

- **Multiscale Imaging**

- Waveform inversion began with a determination of the source signature using the starting model and the scaled real data. Following this, 8-16 Hz data were successively inverted in 1 Hz frequency bandwidths in five steps. In each step, three frequencies spaced 0.2 Hz apart were inverted simultaneously. The updated model from each step was used as the starting model for the next step. Prior to updating the model in each step, the source signature was recalculated using the updated model from the previous step. Iterations were continued in each step until the reduction in the objective function's value was less than 0.1%. Successive incorporation of higher frequencies in each step appears to have yielded a higher wavenumber solution of the velocity model. In the end we considered the velocity inversion model from inversion of frequencies up to 16 Hz as final (Figure 2c). A comparison of the sonic log from Site NGHP-01-10 with the velocity profile from the waveform model at the projected location of Site NGHP-01-10 on the seismic line (Figure 3) suggests that the waveform inversion is realistic and accurate.

- **Interpretation**

- The depth image suggests presence of faults at Site NGHP-01-10 and in the vicinity (Figure 4a). Faults play a dual role: a) they form flow channels for fluids containing dissolved methane from the deeper subsurface and

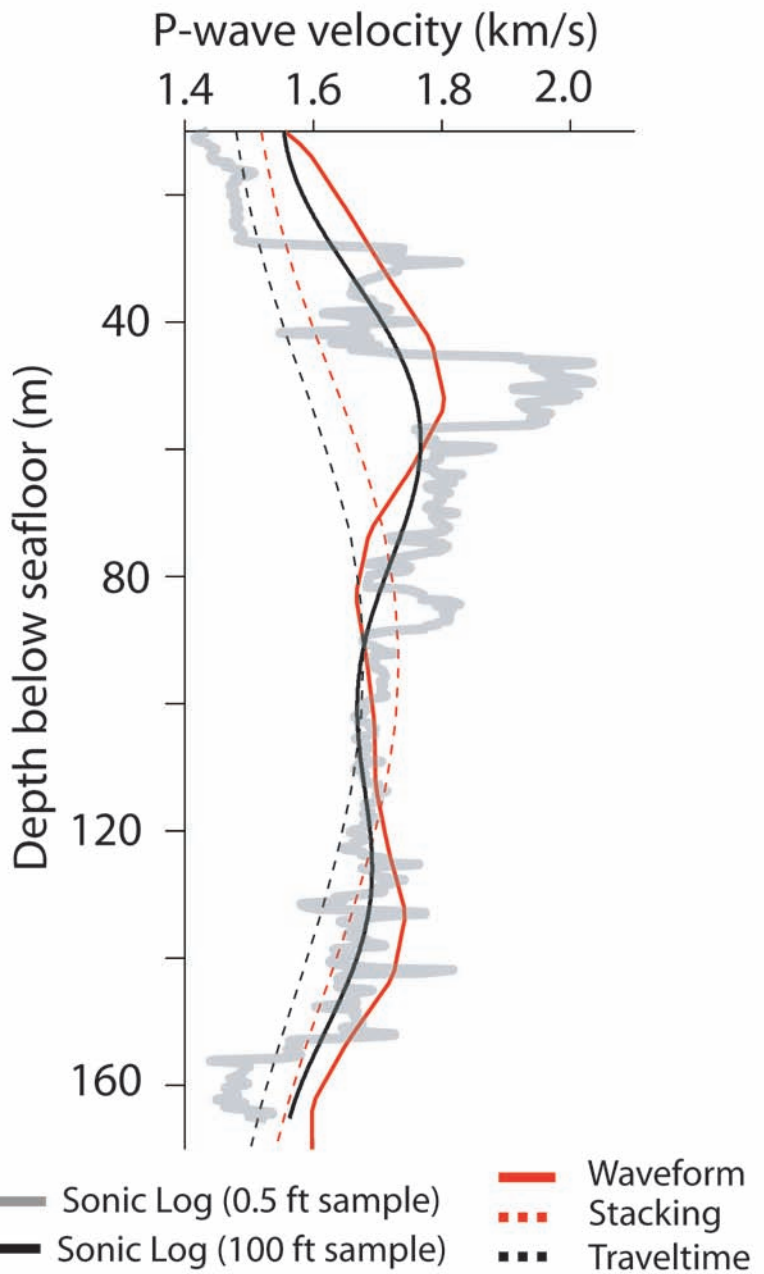


Figure 3: Velocity comparison for Site NGHP-01-10. LWD Sonic log is shown in thick gray line. The dashed red and black lines respectively represent velocity profiles from the stacking (Figure 2a) and the inversion-migration (Figure 2b) models at the projected location of the Site NHGP-01-10 (Figure 1). Resampled log from 0.5 ft to grid size of the waveform inversion model is shown in solid black line. Velocity profile from the waveform inversion model (Figure 2c) is shown in a solid red line.

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b) fault gauges are high-permeability zones that are preferred by hydrate for nucleation and growth over the low-permeability clay dominated background. At the same time, focused fluid flow through faults could perturb the temperature and salinity conditions at the base of the hydrate stability zone making an otherwise continuous BSR become patchy and discontinuous. Hydrate formation at Site NGHP-01-10 and the vicinity are most likely dominated by focused fluid flow and not a vertical steady-state diffusion mechanism (Bhatnagar *et al.*, 2007). As a result the BSR has no relation with the overlying hydrates at Site NHGP-01-10. However, a close match of the velocity profile from the waveform inversion with the sonic log (Figure 3) suggests that V_p is a good proxy for presence of hydrates.

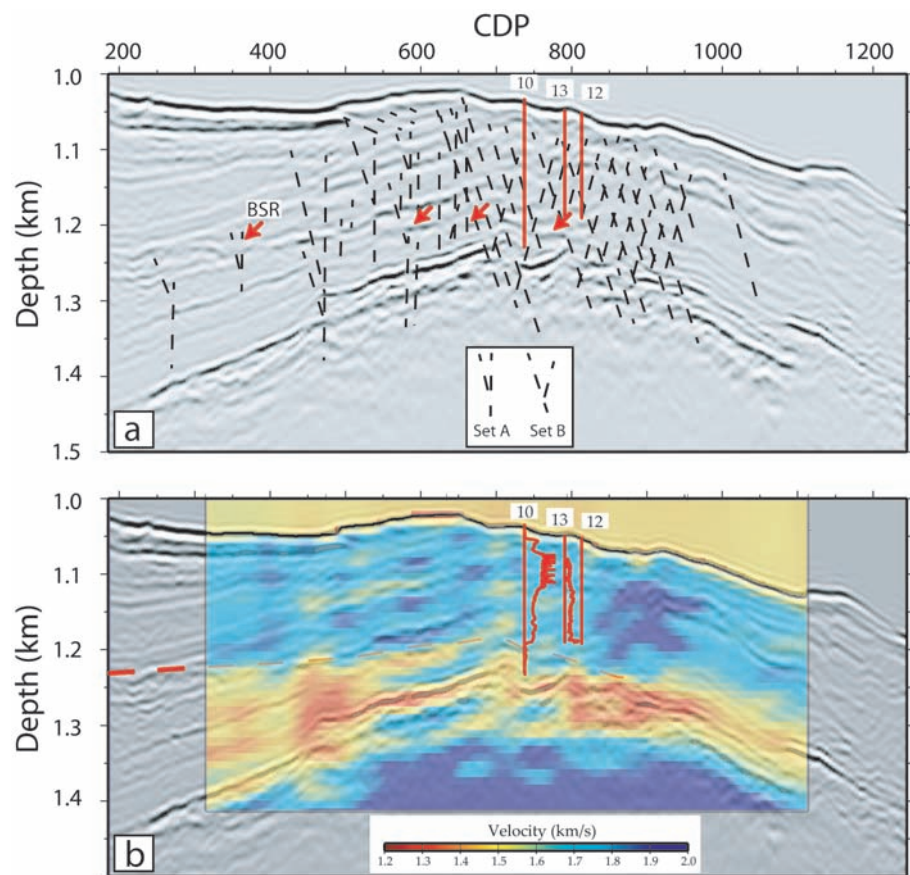


Figure 4: Composite interpretation. a) Depth-migrated image with the inversion-migration velocity (Figure 2b). Two main set of faults can be interpreted. The BSR is indicated in solid red arrows. The BSR becomes patchy in fault dominated parts of the line. b) Waveform model (Figure 2c) overlay shows high (<1.65 km/s) velocity zones within the hydrate stability zone above the patchy BSR. A comparison with the sonic from Site NGHP-01-10 (Figure 3) suggests that the high velocity patches indicate hydrate-bearing sediments.

ELECTRICAL PROPERTIES OF METHANE HYDRATE + SEDIMENT MIXTURES

By Wyatt L. Du Frane (Lawrence Livermore National Laboratory), Laura A. Stern (US Geological Survey), Karen A. Weitemeyer (Scripps Institution of Oceanography), Steven Constable (Scripps Institution of Oceanography), and Jeffery J. Roberts (Lawrence Livermore National Laboratory)

As part of our DOE-funded proposal to characterize gas hydrate in the Gulf of Mexico using marine electromagnetic methods, a collaboration between SIO, LLNL, and USGS with the goal of measuring the electrical properties of lab-created methane (CH_4) hydrate and sediment mixtures was formed. We examined samples with known characteristics to better relate electrical properties measured in the field to specific gas hydrate concentration and distribution patterns. Here we discuss first-ever electrical conductivity (σ) measurements on unmixed CH_4 hydrate (Du Frane *et al.*, 2011): $6 \times 10^{-5} \text{ S/m}$ at 5°C , which is ~ 5 orders of magnitude lower than seawater. This difference allows electromagnetic (EM) techniques to distinguish highly resistive gas hydrate deposits from conductive water saturated sediments in EM field surveys. More recently, we performed measurements on CH_4 hydrate mixed with sediment and we also discuss those initial findings here. Our results on samples free of liquid water are important for predicting conductivity of sediments with pores highly saturated with gas hydrate, and are an essential starting point for comprehensive mixing models.

Background

Seismic methods have traditionally been used to map the spatial distribution of gas hydrate deposits. A bottom simulating reflector (BSR) indicates the lower limit of the stability field, typically marking the gas hydrate to free gas boundary, but provides little information about the

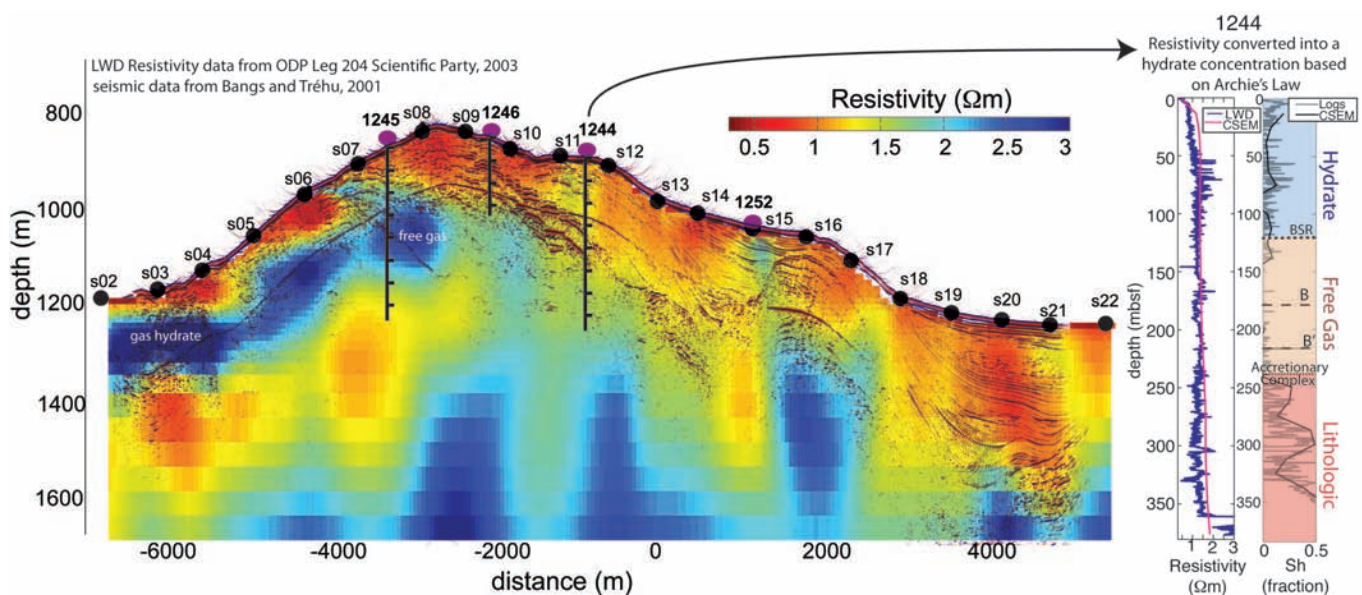


Figure 1: Comparisons of inverted CSEM resistivity data to well log and seismic data at Hydrate Ridge showing the potential of CSEM as a complementary geophysical method for gas hydrate assessment.

- occurrence of gas hydrate above it. Seismic blanking zones indicate
- hydrate or gas only at shallow depths below the seafloor. Besides acoustic
- properties, electrical properties can also be used to detect gas hydrate,
- which has high electrical resistance (σ^{-1}) that provides a suitable target for
- marine controlled source electromagnetic (CSEM) surveys.
-
- CSEM sounding measures the amplitude and phase of EM energy through
- the seafloor at one or more frequencies; this data can be inverted to
- resistivity. Pilot CSEM studies at Hydrate Ridge (2004; see Figure 1)
- and the Gulf of Mexico (2008) indicate that CSEM is highly sensitive to
- concentration and geometric distribution of gas hydrate; however, to
- make quantitative estimates of hydrate volume requires knowledge of the
- conductivity of gas hydrates in combination with petrophysical mixing
- relations established from theory and experiment. There have been
- few studies on the electrical properties of sediment/gas hydrate/water
- mixtures. Liquid water bearing samples help to resolve mixing laws, but
- lack characterization and are dominated by water with no quantitative
- information on the conductivity of gas hydrate phase. It is well known that

gas hydrates are resistive, but exactly how resistive are they?

Making Gas Hydrate

Hydrate was synthesized using a temperature cycling technique developed at USGS to fully-react H_2O ice and pressurized CH_4 (15-30 MPa) into polycrystalline CH_4 hydrate (Stern *et al.*, 2004). We developed a pressure cell to synthesize CH_4 hydrate while measuring in situ electrical conductivity (Figure 2). Starting samples were comprised of granular ice that was either free of sediment, mixed with quartz sand (OK#1), or mixed with silica glass beads. Mixtures were made in varying proportions with 100-10vol% ice and 0-90vol% sand or beads. Comparative measurements were performed on some samples after dissociation of hydrate to ice by venting CH_4 .

After full reaction to hydrate and subsequent testing, sample characteristics and phase distribution were assessed by cryogenic scanning electron microscopy (cryo-SEM; Figure 3) using techniques and instrumentation first described in *Fire in the Ice Vol. 2, Issue 2*.

Electrical Conductivity

Impedance spectra (20 Hz to 2 MHz) were collected throughout each run and used to calculate conductivity while excluding systemic contributions. Conductivity had typical exponential dependence on temperature:

$$\sigma(T) = \sigma_0 * e^{-E_a/RT}$$

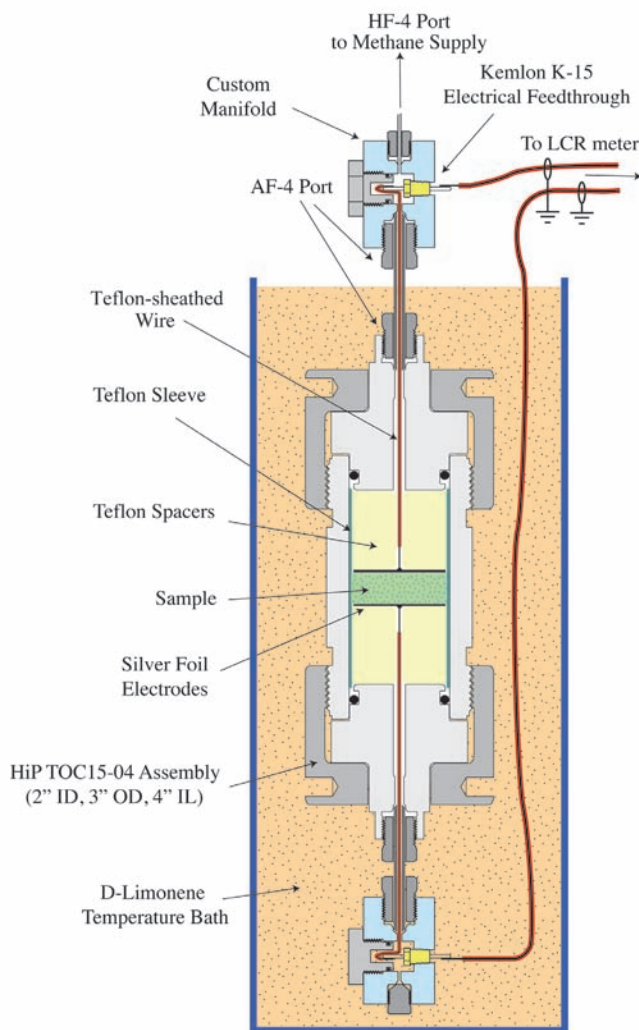


Figure 2: Pressure vessel used to synthesize CH_4 hydrate and measure conductivity.

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where σ_0 is a pre-exponential constant, E_a is activation energy, R is the gas constant, and T is temperature. Plotting $\log(\sigma)$ versus $10^3/T(K)$ gives slopes that are proportional to E_a which characterizes the temperature dependence (Figure 4).

Conductivity measurements of unmixed CH_4 hydrate (i.e. no sediment, shown in blue) ranged between 10^{-5} to 10^{-4} S/m. After the unmixed hydrate was dissociated, we measured conductivity of unmixed ice which was $\sim 400\%$ higher, with $\sim 50\%$ higher activation energy. The conductivity of CH_4 hydrate is much less than seawater ($\sim 10^{-1}$ to 10^1 S/m) and much greater than quartz ($< 10^{-18}$ S/m).

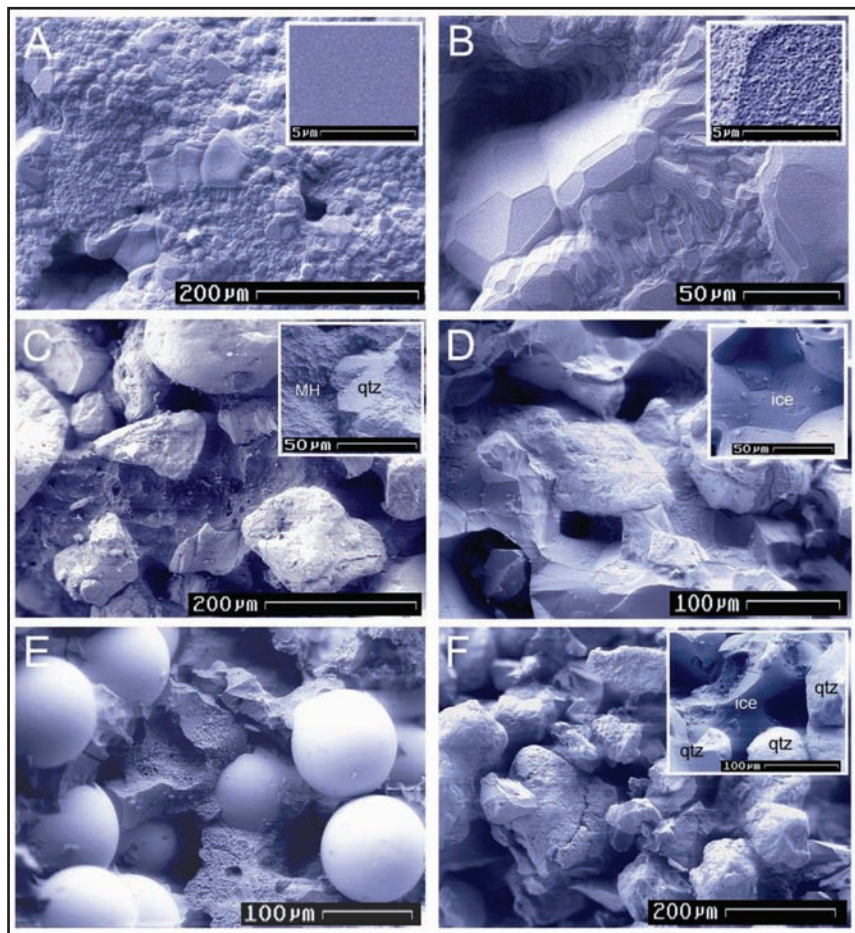


Figure 3: Cryo-SEM images of hydrate-sediment mixtures. A and B show single-phase (unmixed), polycrystalline CH_4 hydrate with 20% porosity. Hydrate grains typically range 10-80 microns in diameter and are fully dense as-grown (A, inset) but develop surface pitting with time in the high-vacuum SEM column (B, inset). C shows a 50:50vol% hydrate:sand sample and D shows a 50:50vol% ice:sand sample. Significant annealing of the ice grains accompanies dissociation at our test conditions (compare D and C insets), but there is no significant migration of sand, thus enabling comparison of measurements before and after dissociation. E shows a 50:50vol% hydrate:beads sample. SEM shows uniform distribution of phases in all three samples (C, D, and E) as well as similarities in the nature of the grain contacts, helping establish a basis for comparison of conductivity measurements. F shows a 10:90vol% ice:sand sample, with some of the connecting ice expanded in the inset.

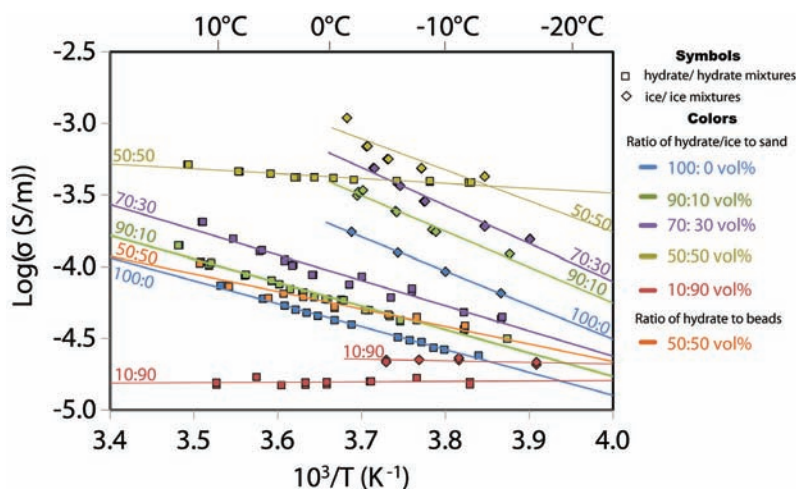


Figure 4: Electrical conductivity measurements versus inverse temperature for CH_4 hydrate and CH_4 hydrate-sediment mixtures.

To evaluate the effects of sediments we measured the conductivity of CH_4 hydrate mixed with either quartz sand or glass beads. We immediately noticed that hydrate samples containing quartz sand had higher conductivity than samples without sand, which is counterintuitive because the quartz sand by itself is highly resistive. Increased sand concentrations, up to 50 vol%, resulted in increased conductivity and decreased E_a (green, purple, yellow). Sand had similar affect on samples with dissociated ice. However the sample with 10:90 vol% hydrate: sand had much lower conductivity. Lower conductivity likely resulted from poorly connected hydrate, whereas sand connectivity had a smaller effect on conductivity. This indicates that the majority of electrical current conducts through the hydrate/ice rather than the sand.

Fine particles on the weathered surfaces of the sand likely increased the concentrations of impurities and charge carriers in the surfaces of hydrate/ice grains, which lead to increased surface conductivity. To evaluate this mechanism further we measured a sample with 50:50 vol% hydrate: beads (shown in orange). The synthetic glass beads are significantly more uniform and of higher purity than the natural quartz sand, and hence we observed a less pronounced surface conductivity contribution.

Next Steps

Our measurements have been successful in determining the electrical conductivity of single-phase CH_4 hydrate and reveal general trends by comparison of various ice/sediment mixtures to hydrate/sediment mixtures. Such factors as chemical impurities, surface conductivity, sediment angularity, and porosity-permeability issues – just to name a few – still require greater investigation to fully understand their contributions and competing mechanisms. For more fundamental materials science perspective, we can examine defect structure of CH_4 hydrate using different electrode materials. Other specific directions of interest for future work involve measuring CO_2 hydrate (\pm sediment), where CSEM may play a role in monitoring CO_2 sequestration in storage sites such as at Snøhvit.

ACKNOWLEDGMENTS

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NEWFOUNDLAND AND LABRADOR GAS HYDRATES RESEARCH PROGRAM – A STEP IN THE RIGHT DIRECTION

By Julie Halliday (C-CORE & Memorial University)

The island of Newfoundland and the mainland portion of Canada known as Labrador collectively form the most easterly province in Canada, Newfoundland and Labrador (NL) (Figure 1). Surrounding the province is a broad, tectonically quiescent continental margin that extends over 500,000 km² from the Laurentian Channel in the south to the Labrador Sea in the north. Interconnected sedimentary basins are dispersed along the margin (DeSilva, 1999). Of these basins the Jeanne D'Arc has been the most prospective to date while portions of the Orphan and Flemish Pass Basins show considerable petroleum potential. With three oil and gas producing projects offshore and another on the way, the province is considered rich in conventional hydrocarbon resources (Department of Natural Resources (NL), 2009).

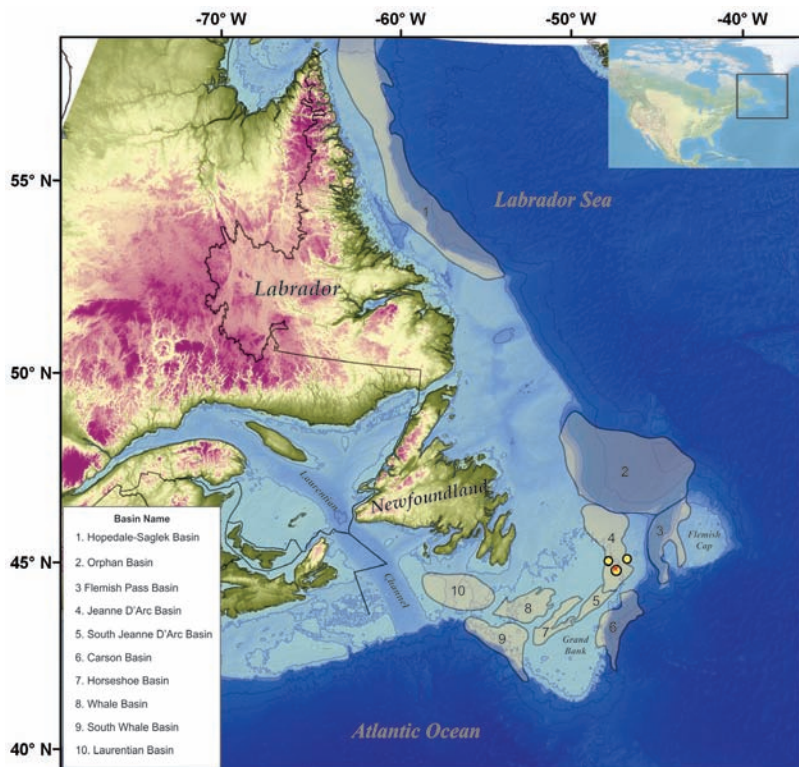


Figure 1: Distribution of sedimentary basins on the continental shelf around Newfoundland and Labrador. The location of Hibernia, Terra Nova and White Rose production facilities are shown (yellow dots) along with the location of the upcoming Hebron project (red star). Blue lines represent -100 m, -500 m, -1000 m, -2000 m, -3000 m and -4000 m bathymetric contours. Insets show the figure location within North America (upper right) and basin names (lower left).

Over the past two decades a significant amount of petroleum exploration has been undertaken in the province. Simultaneously, gas hydrate research had been intensifying around the globe, including on Canada's west and north coasts (Bellefleur *et al.*, 2006; Boswell and Collett, 2011; Buffett and Archer, 2004; Riedel, 2002). Despite the amount of existing data and infrastructure, gas hydrates research on the NL margin has been minimal. A small group of local researchers aspire to change that.

Previous Work on Gas Hydrates

Gas hydrates research has been limited to a few studies on Canada's east coast. Extent and thickness of the hydrate stability zone have been calculated and resulting gas hydrate volumes between $1.9-7.8 \times 10^{13} \text{ m}^3$ have been estimated (Majorowicz and Osadetz, 2001; 2003) (Figure 2). More recent work has been focused on identification and mapping of Bottom-Simulating Reflectors (BSR) on the Scotian and NL margins (LeBlanc *et al.*, 2007; Mosher, 2011; Shimeld *et al.*, 2004). Mosher, 2011 identified seven BSR regions located at depths of 250-450 m below the seafloor that total over 9000 km² (Figure 2). However to

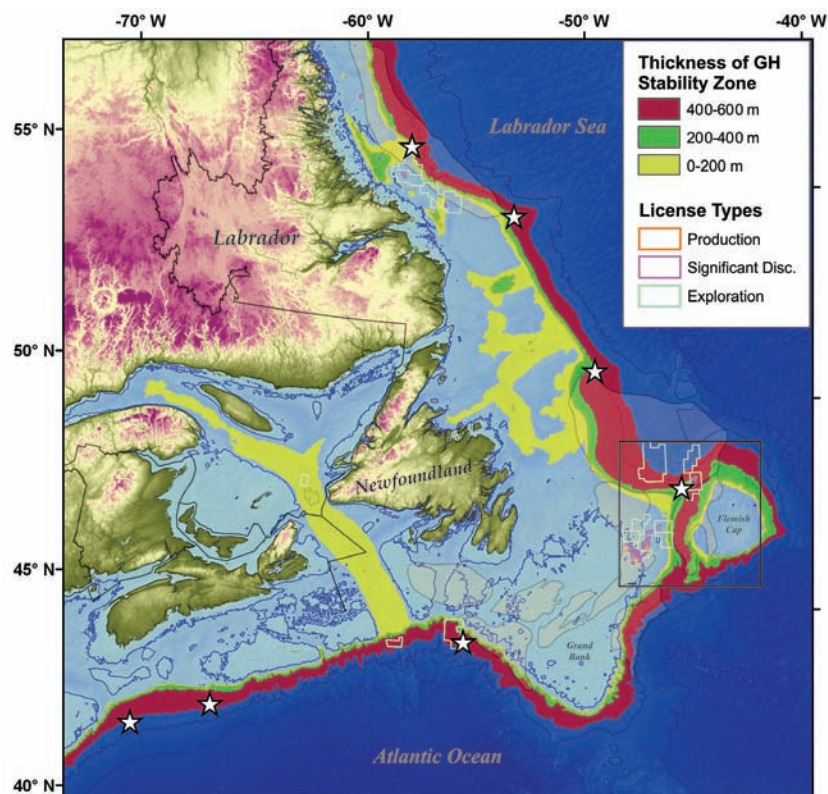


Figure 2: Calculated hydrate stability zone thickness after (Majorowicz and Osadetz, 2003) with the location of petroleum licenses. The approximate locations of BSR's observed by Mosher, 2011 are denoted by white stars. Black rectangle outlines the location of Figure 3. Sedimentary basin location denoted by tan-colored lenses (see Figure 1 for names). Blue lines represent -100 m, -1000 m, -2000 m, -3000 m and -4000 m bathymetric contours.

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date, no physical samples of gas hydrate have been recovered from the NL margin. Moreover, the role that gas hydrates could play in future production activity on the NL margin has not been assessed.

2010 C-CORE Workshop on Gas Hydrates as an Energy Resource for the Canadian East Coast

In 2010, C-CORE held a two-day workshop on gas hydrates in St. John's, NL. Objectives of the workshop were to educate the local community on gas hydrates and stimulate gas hydrate research in both the public and private sectors. Experts from academic, industry and government sectors were brought together to discuss gas hydrates in general and on Canada's east coast. The outcome of the workshop included a set of short- and long-term recommendations for gas hydrate research within the province of NL (C-CORE, 2010). Included in the short-term recommendations was characterization of the gas hydrate bearing sediments and assessment of gas hydrate resource and geohazard potential on the NL margin. Development of drilling and production techniques and identification of trial test sites were part of the long-term recommendations. It was also recognized that the required research and development of NL gas hydrates resource can only be accomplished from combined effort and partnership between academic, government and industry communities.

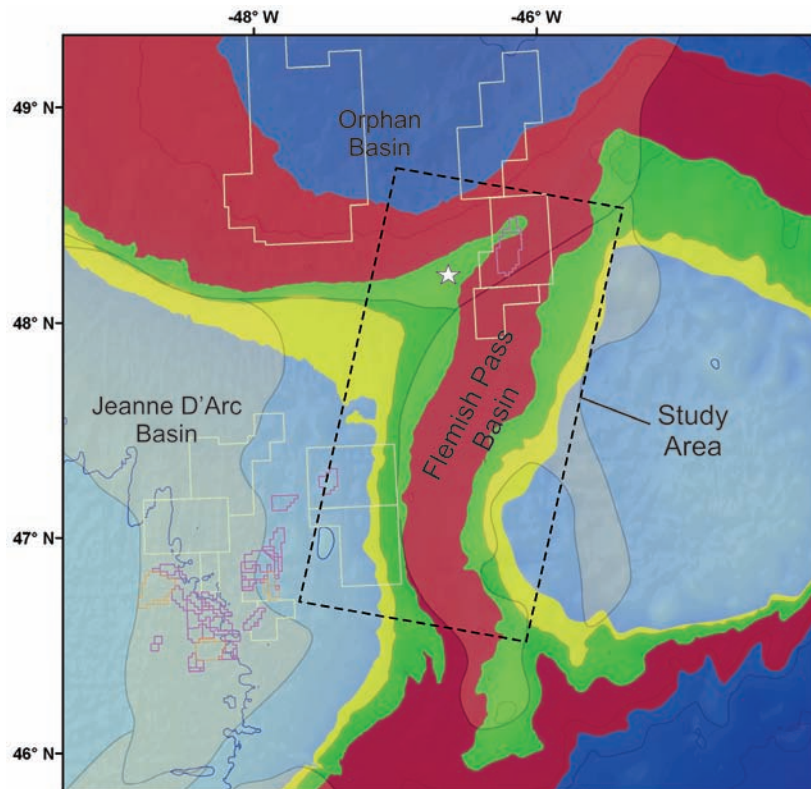


Figure 3: Dashed rectangle outlines the generalized location of the study area in Phase 1 of the NL Gas Hydrates Research Program. Outline of sedimentary basins shown by tan-colored lenses. Calculated stability zone thickness after (Majorowicz and Osadetz, 2003) and BSR observed by Mosher, 2011 (white star) are shown. See Figure 2 for location and legend.

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Current Research Program

Since the workshop steps have been taken to get a gas hydrates research program underway in NL. In September of this year contracts were finalized between C-CORE, industry and government partners providing funding for the first phase of NL provincial gas hydrates research program. The program builds on the 2010 workshop recommendation of a phased-research program to where Phase 1 would involve a desktop study utilizing existing data, both industry and public, to assess the hydrate potential on the NL margin. Subsequent phases would include dedicated fieldwork aimed at identifying future potential drill sites.

Commencement of the Phase 1 portion of the research program has been concurrent with the penning of this article. This initial research program is to span from now until 2014 and is focused on the Sackville Spur and Flemish Pass Basin areas (Figure 3). A significant discovery license is held here and Mizzen deepwater wells (1069-1153 m) have recently been drilled within the block (CNLOPB, 2011). The objective of Phase 1 is to identify and characterize the gas hydrate bearing sediments in this area from both resource and geohazard perspectives through examination of pre-existing industry and public data. It is envisaged that the outcome of Phase 1 of the NL gas hydrates program will lay the groundwork for future research phases with the ultimate goal of obtaining physical samples of gas hydrate from the NL margin.

GAS HYDRATE R&D IN CHINA: NEXT STAGES

By Shengxiong Yang, Chinese Geological Survey

Numerous studies on gas hydrate, occurring in both marine and permafrost settings, have been conducted by researchers in China for over ten years, with research activity increasing in the last five. In 2007, Expedition GMGS-1, sponsored by Guangzhou Marine Geological Survey, China Geological Survey and the Ministry of Land and Resources of P.R. China, recovered marine gas hydrate from three of five sites cored in the Shenhu area of the northern South China Sea (Figure 1A). These hydrate-bearing cores were the first ever recovered from the South China Sea (see [Zhang et al., FITI, Vol. 7, Iss. 3](#)).

Gas hydrates have also been recovered from the Qilian Mountain permafrost in the Qinghai province (Figure 1B), during scientific drilling that occurred in the winter of 2008 and summer of 2009. The project, sponsored by the Chinese Academy of Geological Sciences, China Geological Survey, Qinghai No. 105 Coal Geological Exploration Team, recovered white to grayish white ice-like gas hydrate in three of four holes drilled, with signs of potential gas hydrate presence (i.e. gas bubbling and water seepage on fresh core surfaces, low temperatures indicated by infrared camera, etc.) occurring at all four holes (see [Lu et al., FITI, Vol. 10, Iss. 1](#)).

Future gas hydrate research and investigation in China will focus on carrying out a broad portfolio of basic research on gas hydrate, both offshore and in the permafrost, to fully evaluate the nature and occurrence of gas hydrates. These studies will include understanding the sources of gas, the types of deposits formed, their mode of occurrence, the controls

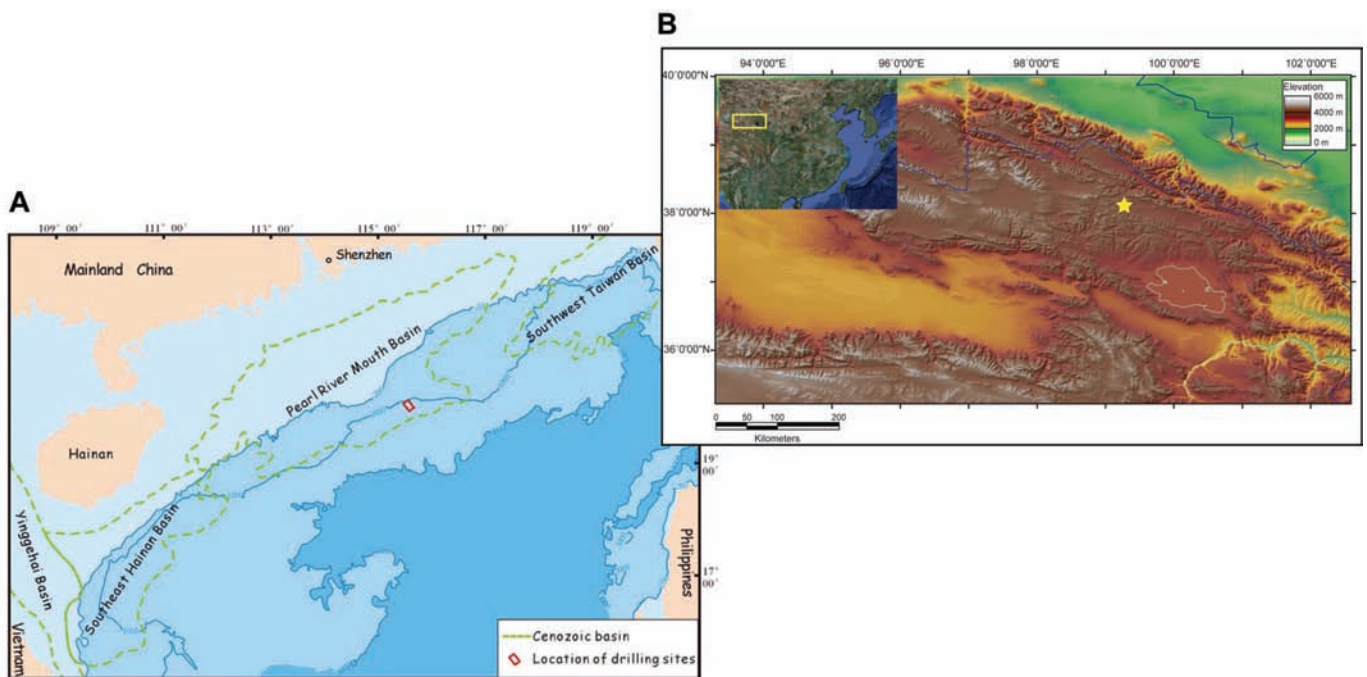


Figure 1: (A) Location of Expedition GMGS-1 sites (red box) in the Shenhu area of the South China Sea. (B) Topographic map of Qilian Mountain area, China with area of interest indicated (yellow star).

- on the formation and enrichment of deposits, their dynamic behavior
- with time, and others. China will pursue this program through the
- continued field investigation of gas hydrate in the South China Sea and in
- the permafrost with the goal of more accurate delineation of the nature
- and extent of occurrences and potential resources. The launch of China's
- new research vessel, the *R/V Haiyang Liu Hao* (Figure 2) in 2009, will allow
- researchers ready access to pursue their research program in the South
- China Sea.
- These programs will be supported by R&D programs to develop improved
- technologies for gas hydrate characterization and production, including
- high-resolution seismic techniques such as OBS, high-precision positioning
- of sampling techniques such as ROV, and techniques for methane
- extraction from gas hydrates based on findings from integrated programs
- of laboratory experimentation and numerical simulation. China will also
- work to develop technologies for the long-term observation of the gas
- hydrate occurrences at the seafloor to better understand the dynamic
- process of hydrate formation and decomposition. Going forward, China
- will place a strong emphasis on the establishment of environmental
- baselines in gas hydrate zones, enabling the preliminary prediction and
- assessment of potential environmental and geohazard implications of gas
- hydrate exploitation.



Figure 2: The R/V Haiyang Liu Hao

• Announcements



FLORIDA STATE UNIVERSITY STUDENT SELECTED AS NEWEST METHANE HYDRATE RESEARCH FELLOW

Rachel Wilson, a post-doctoral researcher at Florida State University (FSU), was recently selected as a recipient of a Methane Hydrate Research Fellowship.

Rachel will be working with Jeff Chanton at FSU to study controls on hydrate stability, specifically the dissolution of hydrate at interfaces with methane-limited water. While dissociation of hydrate is widely studied as a mechanism for hydrate instability, dissolution is relatively unexplored. Theoretical considerations predict that dissolution should be diffusion controlled; however, field observations of outcropping hydrate indicate that this is not always the case. Such formations, therefore, have been described as “meta-stable”, but the causation is not well-understood. Observations from JIP test wells have found evidence of gas hydrate-filled sands in contact with free water. Interfaces between gas hydrate-bearing sands and high free-water layers are sites of potential hydrate dissolution, hence instability.

Using laboratory experiments and an acrylic pressure chamber, Rachel will simulate these conditions and measure hydrate dissolution rates to determine if hydrate intercalated in sand layers exhibit “meta-stable” properties similar to observations of outcropping-type hydrate. These experiments will incorporate oils (thought to inhibit dissolution in natural systems) and mixed source gas compositions into hydrate and measure resulting dissolution rates in an effort to gain further insight into hydrate stability.

Rachel received a Bachelor of Science in Chemistry from Western Carolina University in 2004. In 2010, she received a Ph.D. in Chemical Oceanography from FSU with a thesis on chemical tracers and stable isotope modeling. Since completion of her degree, she has been studying the chemical and physical environment of hydrate outcrops in the Gulf of Mexico and Cascadia Margin via sediment cores and pore fluid sampling arrays.

Announcements



At our 2010 GRC Hydrates Meeting (held at Colby College, Maine), morning and evening oral sessions were interspersed with poster sessions, thoughtful discussions, and spirited soccer games.

APPLY NOW TO ATTEND THE 2ND GORDON RESEARCH CONFERENCE ON NATURAL GAS HYDRATE SYSTEMS MARCH 18 - 23, 2012, VENTURA, CALIFORNIA

This Gordon Research Conference (GRC) will emphasize the occurrences and processes that influence the dynamic systems of present day and paleo-hydrates. GRC conferences bring together academic, government, and industry researchers from around the world and from all career stages to a week-long retreat-style meeting. The GRC features longer-format talks, extended poster and discussion sessions, and no concurrent sessions. Informal social activities and unscheduled time, hallmarks of the GRC's interactive style, further promote the sharing of ideas.

Agenda Topics, Discussion Leaders, and Oral Presenters

Synoptic View	Ray Boswell <i>Erwin Suess & Keith Kvenvolden</i>
Hydrates in the Past	Gerald R. Dickens <i>Andy Ridgewell, Sabine Kasten, & Charlie Paull</i>
Hydrates in the Present	Marta Torres <i>Katey Walter & Gerhard Bohrmann</i>
Basic Physics of Hydrates	Hideki Minagawa, Joo Yong Lee, & Judith Schicks
Basic Chemistry of Hydrates	John Ripmeester <i>Ryo Ohmura & Mark Rodger</i>
Systems Models	Bruce Buffett <i>David Archer & Evan Solomon</i>
Hydrate Production	Masanori Kurihara <i>Kishore Mohanty & Tim Collett</i>
New Results	Miriam Kastner <i>Scott Dallimore & George Moridis</i>
Extraterrestrial Hydrates	Max Colemal <i>Christophe Sotin & Megan Elwood Madden</i>

We are accepting applications from researchers at all career stages, from all over the world, and from government, academic, and industry sectors. Partial financial support will be available to some participants to offset the costs of the all-inclusive (lodging and meals) registration fee.

Please apply to attend this meeting here: <http://www.grc.org/application.aspx?id=14538>

Regular updates to the meeting description and program will be made at <http://www.grc.org/programs.aspx?year=2012&program=naturalgas>.

• **Announcements**

• **METHANE HYDRATE PRODUCTION TECHNOLOGIES TO BE TESTED ON ALASKA'S NORTH SLOPE**

• The U.S. Department of Energy, the Japan Oil, Gas and Metals National Corporation, and ConocoPhillips will work together to test innovative technologies for producing methane gas from hydrate deposits on the Alaska North Slope.

• The collaborative testing will take place under the auspices of a Statement of Intent for Cooperation in Methane Hydrates signed in 2008 and extended in 2011 by DOE and Japan's Ministry of Economy, Trade, and Industry. The production tests are the next step in both U.S. and Japanese national efforts to evaluate the response of gas hydrate reservoirs to alternative gas hydrate production concepts. The tests will provide critical information to inform potential future extended-duration tests.

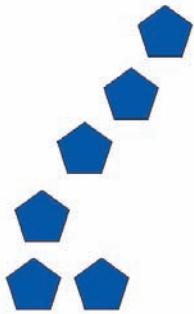
• The tests will utilize the "Iġnik Sikumi" (Iñupiaq for "fire in the ice") gas hydrate field trial well, a fully instrumented borehole that was installed in the Prudhoe Bay region by ConocoPhillips and the Office of Fossil Energy's National Energy Technology Laboratory earlier this year.

• The current test plans call for roughly 100 days of continuous operations from January to March 2012. Tests will include the initial field trial of a technology that involves injecting carbon dioxide (CO₂) into methane-hydrate-bearing sandstone formations, resulting in the swapping of CO₂ molecules for methane molecules in the solid-water hydrate lattice, the release of methane gas, and the permanent storage of CO₂ in the formation. This field experiment will be an extension of earlier successful tests of the technology conducted by ConocoPhillips and their research partners in a laboratory setting.

• Following the exchange tests, the team will conduct a one-month evaluation of an alternative methane-production method called depressurization. This process involves pumping fluids out of the borehole to reduce pressure in the well, which results in dissociation of methane hydrate into methane gas and liquid water. The method was successfully demonstrated during a one-week test conducted by Japan and Canada in northwestern Canada in 2008.

L&S Cryogenics recently completed fabrication of the CO₂ tank (in white) and the gas mixing skid (in blue) that will be used during the field test.





Fiery Ice from the Seas

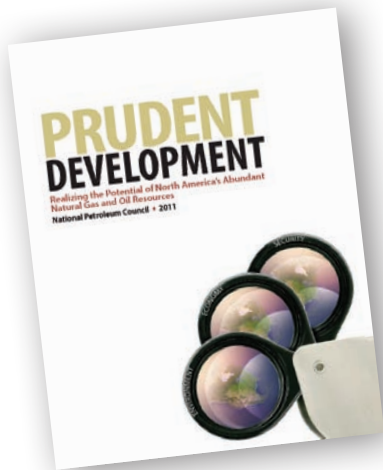
• Announcements

• 8TH INTERNATIONAL WORKSHOP ON METHANE HYDRATE R&D SCHEDULED FOR SPRING

• The Fiery Ice International Steering Committee is sponsoring the 8th International Workshop on Methane Hydrate Research & Development, to be held in Sapporo, Hokkaido, Japan on May 28 – June 1, 2012. Planned activities for the workshop include national R&D program reports, plenary lectures, and poster sessions. Numerous breakout sessions on specific R&D topics provided by the Fiery Ice International Steering Committee members are also scheduled. The deadline for submitting abstracts is February 29, 2012. Details and registration are available on the Workshop website at <http://www.2012fieryice.jp/>.

• METHANE HYDRATE R&D STATUS REVIEWED AS PART OF NPC GAS STUDY

• The National Petroleum Council's recent analysis: "Prudent Development - Realizing the Potential of North America's Abundant Natural Gas and Oil Resources" was released in September. Recently, the NPC has posted more than 50 separate focused topical papers that were prepared in conjunction with the study, including The paper #1-11: entitled "Gas hydrate: research status and potential as a future energy resource for the United States". This and other reports can be downloaded from www.npc.org.



• METHANE HYDRATE SESSION AT THE 2012 OCEAN SCIENCES MEETING

• *The Marine Gas Hydrate Deposits: Research, Monitoring Strategies and Present-Day Knowledge* session will be featured at the upcoming 2012 Ocean Sciences Meeting. Salt Lake City, Utah will play host to the more than 4,000 attendees expected to attend this joint international meeting to be held on February 20-24, 2011. Visit <http://www.sgmeet.com/osm2012/default.asp> for more information or to register to attend.



• Spotlight on Research



CHAR-SHINE LIU

Professor,
National Taiwan University
Institute of Oceanography

Outside of the classroom and lab, Char-Shine enjoys travelling and listening to music. "I also enjoy teaching, not only to teach students knowledge, but more importantly to teach them how to learn, how to face challenges and solve problems, and how to be a good person."

After completing his studies in geophysics at Taiwan's National Central University, Char-Shine Liu discovered the next chapter of his life in a book about the early days of the Deep Sea Drilling Program (DSDP). "I read 200,000,000 Years Beneath The Sea by Peter Briggs," he recalls. "I became excited by concepts of plate tectonics, the science, and the technologies involved in ocean drilling research." Eight years later Char-Shine would earn both his Masters of Science and a Ph. D. in geophysics from Scripps Institution of Oceanography at the University of California, San Diego, the home institution of DSDP. "I enjoyed learning marine seismic techniques while at sea investigating crustal structures and seafloor tectonic processes," says Liu.

He followed his marine seismic experience with a stint as a post-doctoral researcher for the Consortium for Continental Reflection Profiling (COCORP) project at Cornell University. The project pioneered the use of multichannel seismic reflection profiling of the continental lithosphere. After COCORP, Char-Shine worked in the oil industry for several years before coming across a vacancy announcement for a position with the Institute of Oceanography at the National Taiwan University. "They were looking for a capable person to run their MCS system on their new research vessel (R/V *Ocean Researcher 1*)," he says. "As my qualifications fit their requirements, I sent in my application and got the position." Twenty-four years later, Char-Shine is now a Professor at the Institute, teaching courses on geophysical exploration. He also continues to conduct research work using marine seismic reflection techniques.

Char-Shine's interest in gas hydrate was sparked during a research cruise off the coast of southern Taiwan in 1990. "I was working with U.S. scientists conducting marine geophysical surveys to study the arc-continent collision processes. Dr. Don Reed, one of my collaborators, told me that he found BSRs on the seismic profiles," says Liu. "It was the first suggestion of a gas hydrate presence offshore southern Taiwan." Additional seismic data collected in the following years showed that "gas hydrate might be widely distributed in the area. With Taiwan importing over 99% of her energy needs, I became more interested in gas hydrate research and its energy potential for my country."

The most stimulating aspect of hydrate research for Char-Shine is, "the building up of a strong geophysical investigation team, including the training of many young scientists, and the opportunity to develop and utilize many new techniques in gas hydrate research," he says.

Char-Shine believes the greatest challenge facing hydrate researchers is the furthering of our understanding of the "dynamic processes of gas hydrate in the natural environment."