U.S. Department of Energy • Office of Fossil Energy • National Energy Technology Laboratory

Fire in the Ice

Vol. 8, Iss. 2 Methane Hydrate Newsletter

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MMS Releases Preliminary Results of Gulf of Mexico In-Place Natural Gas Hydrate Assessment

By M. Frye (MMS), J. Grace (Earth Science Associates), J. Hunt (MMS), G. Kaufman (MIT), J. Schuenemeyer (Southwest Statistical Consulting), and B. Shedd (MMS)

The U.S. Minerals Management Service (MMS) has recently released the results of a systematic geological and statistical assessment of in-place gas hydrate resources in the Gulf of Mexico (GOM). This assessment incorporates the latest science with regard to the geological and geochemical controls on gas hydrate occurrence, and provides a mean volume of 607 trillion cubic meters (TCM) or 21,444 trillion cubic feet (TCF) of methane in-place in hydrate form (Figure 1). In addition, the assessment has determined that a mean of 190 TCM (6,710 TCF) of this resource occurs as relatively high-concentration accumulations within sand reservoirs, with the remainder occurring within clay-dominated sediments. The full MMS assessment report is available at: http://www.mms.gov/revaldiv/GasHydrateAssessment.htm.

Ongoing Project Designed to Assess Gas Hydrate Resource

The MMS is a U. S. Department of the Interior bureau charged with managing the nation's natural gas, oil, and other mineral resources on 1.76 billion acres of the U.S. Outer Continental Shelf (OCS). Recently, the MMS launched an effort to assess the natural gas hydrate resource potential across the entire OCS, including the Alaskan, Atlantic, Gulf of Mexico, and Pacific margins. The goal of this ongoing project is to deliver, in succession, estimates of in-place, technically-recoverable, and economically-recoverable gas hydrate resources.

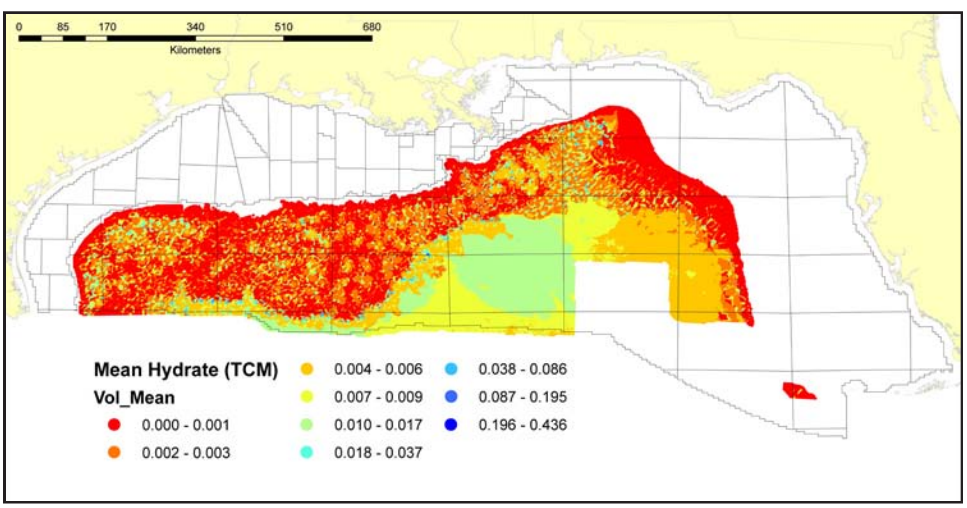

Figure 1: Map of in-place gas hydrate resources. Values are trillion cubic meters per cell.

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

This newsletter now reaches more than 1000 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)

The model framework and methodology for an in-place analysis were first developed for the GOM (Figure 2). The GOM was chosen for many reasons, including our rich understanding of the petroleum system and the abundance of geological and geophysical data available to us, all of which are attributable to the maturity of the GOM as a conventional oil and gas province. The total endowment of conventional oil and natural gas resources in the U.S. GOM is estimated to exceed 150 billion barrels of oil equivalent.

Unlike MMS conventional oil and gas assessments on the OCS, which are performed using a geologic play-based approach, the MMS gas hydrate assessment model was developed using a mass balance approach. The analysis is applied to each model cell, providing a level of spatial resolution that supports detailed mapping. The mass balance approach is transparent and allows extreme variable disaggregation. Therefore, as new or improved information becomes available for the various input parameters, the system can be easily updated.

The GOM study area exceeds 450,000 km^2 and is divided into a grid of 202,079 cells, each measuring 2.32 km^2. The initial study was limited to those areas in the GOM that are covered with either 2-D or 3-D seismic data. Cell size was selected to optimize the spatial resolution of the results with respect to the density of the input parameters, while providing an acceptable level computational speed and a manageable results database.

In an effort to capture the many uncertainties associated with the geologic framework and the petroleum systems analysis of the GOM, and their collective affect on the location and volume of undiscovered resources, a stochastic modeling approach was adopted. Specifically, uncertainties include the presence and quality of source rocks, reservoir rocks, and traps; the timing of hydrocarbon generation, migration, and entrapment; and the location, number, and size of accumulations. In this particular assessment, many of these uncertainties typically associated with conventional oil and gas resources are magnified when applied to an unconventional, poorly understood gas hydrate resource base. When necessary and feasible, each of these factors – including the volume of gas hydrate derived from them – is expressed as a range of values with an associated probability of occurrence.

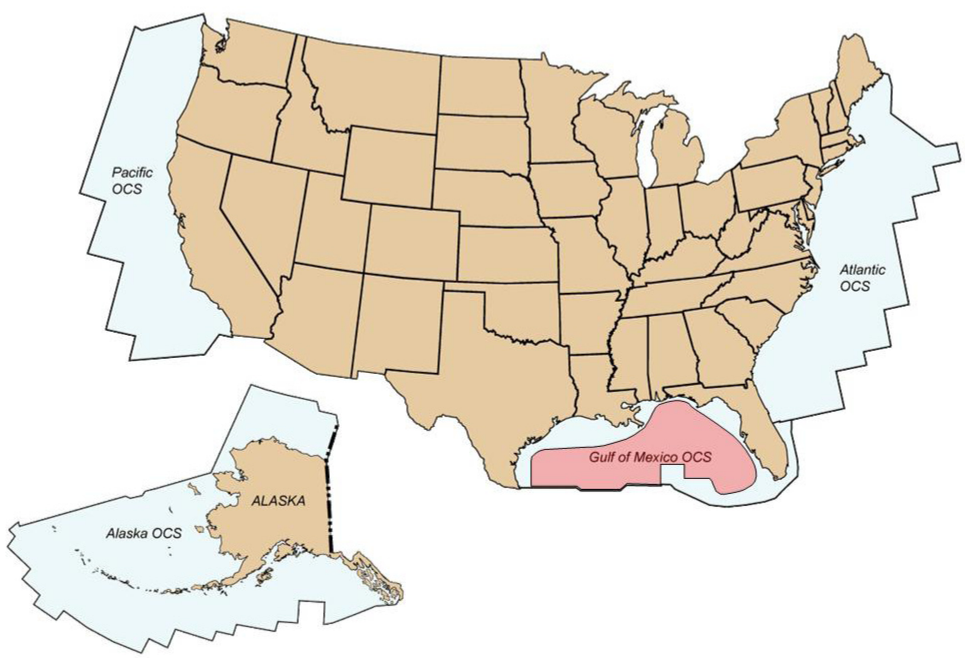

Figure 2: Gulf of Mexico study area highlighted in red.

Model Inputs

The functional form and probability distribution associated with each input parameter is determined in part by the amount of empirical evidence available. For example, the value of total organic carbon for each cell is "Monte Carloed" using a distribution based on nearly 700 measurements, under the assumption that the data available is representative of the GOM as a whole. A more desirable approach, and one we have taken when the data allows, is to map the input variables on a cellular-level using conventional seismic data. This approach provides a framework that represents the complex depositional and tectonostratigraphic history of the GOM basin. Four primary spatially-referenced datasets were developed using this approach:

- Bathymetry
- Depth to basement
- Sand component
- Surficial seismic anomalies

Model Structure

The software application through which the analysis is performed is composed of four modules (Figure 3). Models and sub-models in each module represent biological, chemical, or physical processes.

The charge module contains a generation model and a migration model. A single Monte Carlo trial of the generation model produces the amount of biogenic methane produced in each cell at that trial. The migration model aggregates generation into hydrodynamic catchment basins and then spatially redistributes a fraction of the catchment's generated gas at that trial to each cell within it.

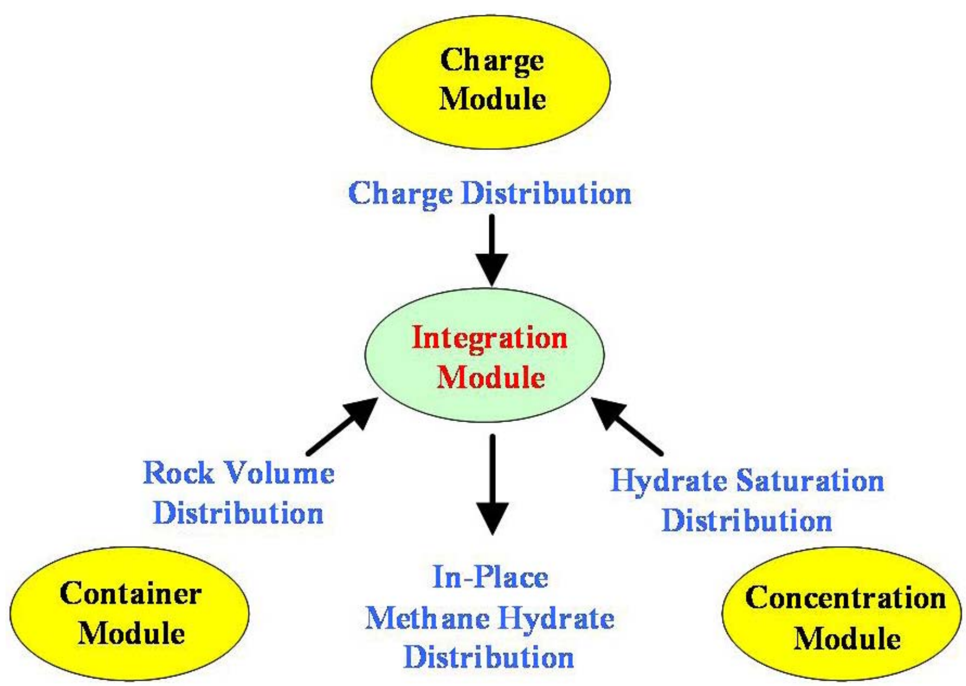

Figure 3: MMS assessment model architecture.

The container module employs a two step process to provide a value of the study area's rock volume that is a candidate for formation of natural gas hydrates. First, we model the gross hydrate stability zone (HSZ), which covers that volume of rock in which pressure, temperature and salinity conditions permit the formation of hydrates, if available pore space and sufficient hydrocarbon charge are present. Second, we remove a layer of the HSZ, starting at the seafloor and extending downward, where the saturation of gas in ambient waters is presumed to be below 100 percent. The gross HSZ, minus the undersaturated zone, yields the net HSZ.

The concentration module calculates the volume of hydrate per unit of bulk rock volume in the net HSZ. It includes models of rock porosity, based on depth and lithology, and of the fraction of void space that can be saturated by methane hydrates, based on lithology.

The integration module compares the charge module's output to the volume of candidate void space generated by the container and concentration module. The smaller of the two volumes is retained and recorded for each Monte Carlo trial. Executing the model over 1,000 trials yields a distribution of in-place methane hydrates in each cell. In-place volumes are converted to and reported at standard temperature and pressure (STP).

Results

The volume of undiscovered in-place gas hydrate is expressed as a cumulative probability distribution, where a specified volume or more of resources corresponds to a probability of occurrence. The total volume of biogenically-generated in-place gas hydrate on the GOM OCS is projected to range from 314 trillion m^3 (TCM) to 974 TCM (95% to 5%), with a mean of 607 TCM (Figure 4). As in most stochastic resource assessments, and certainly in one where a new methodology has been developed and deployed, the reader is encouraged to place considerable interpretative weight on the entire range of possible outcomes.

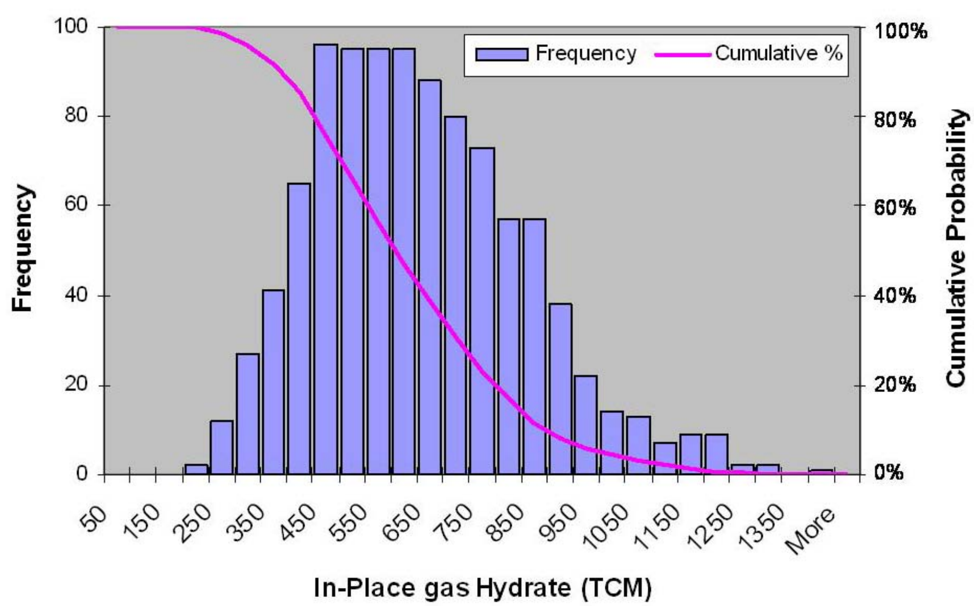

Figure 4: Distribution of in-place results for the GOM (trillion cubic meters).

The areal distribution of the in-place volume is heavily influenced by the geometry of the input data sets. For instance, large areas with limited hydrate accumulation are present across the salt mini-basin province that comprises much of the upper slope (see Figure 1). These areas often coincide with very shallow allochthonous salt features that occupy the bulk of, and sometimes the entire, hydrate stability zone. Also, areas that offer a thick sedimentary section, such as the deep mini-basins and much of the abyssal plain, provide an abundant supply of biogenic gas and often contain rich in-place volumes.

Many subjective decisions and interpretations of physical processes shaped the final volume distribution. Most noticeably, because gas generated in the upper slope is subject to distribution based on stratal dip, rich hydrate accumulations formed along the structurally positive margins of the mini-basins. Conversely, most gas generated in the abyssal plain remains in the cell of origin, yielding a relatively uniform distribution of in-place resources in this physiographic province.

The MMS in-place assessment model structure provides an opportunity to report resources by sedimentary host. At present, a non-stochastic approach is used to calculate the hydrate volume in sandstone reservoirs only. Mechanically, this is accomplished by determining the fractional measure of saturate-able void space in sands per cell, then applying this fraction to the mean volume captured in the in-place model run. Using this approach, the mean in-place resource in sandstone reservoirs equals 190 TCM (Figure 5). Updated releases of the MMS hydrate assessment will contain results from a stochastic technically recoverable model that will only consider sand-hosted resources as candidates for commercial production.

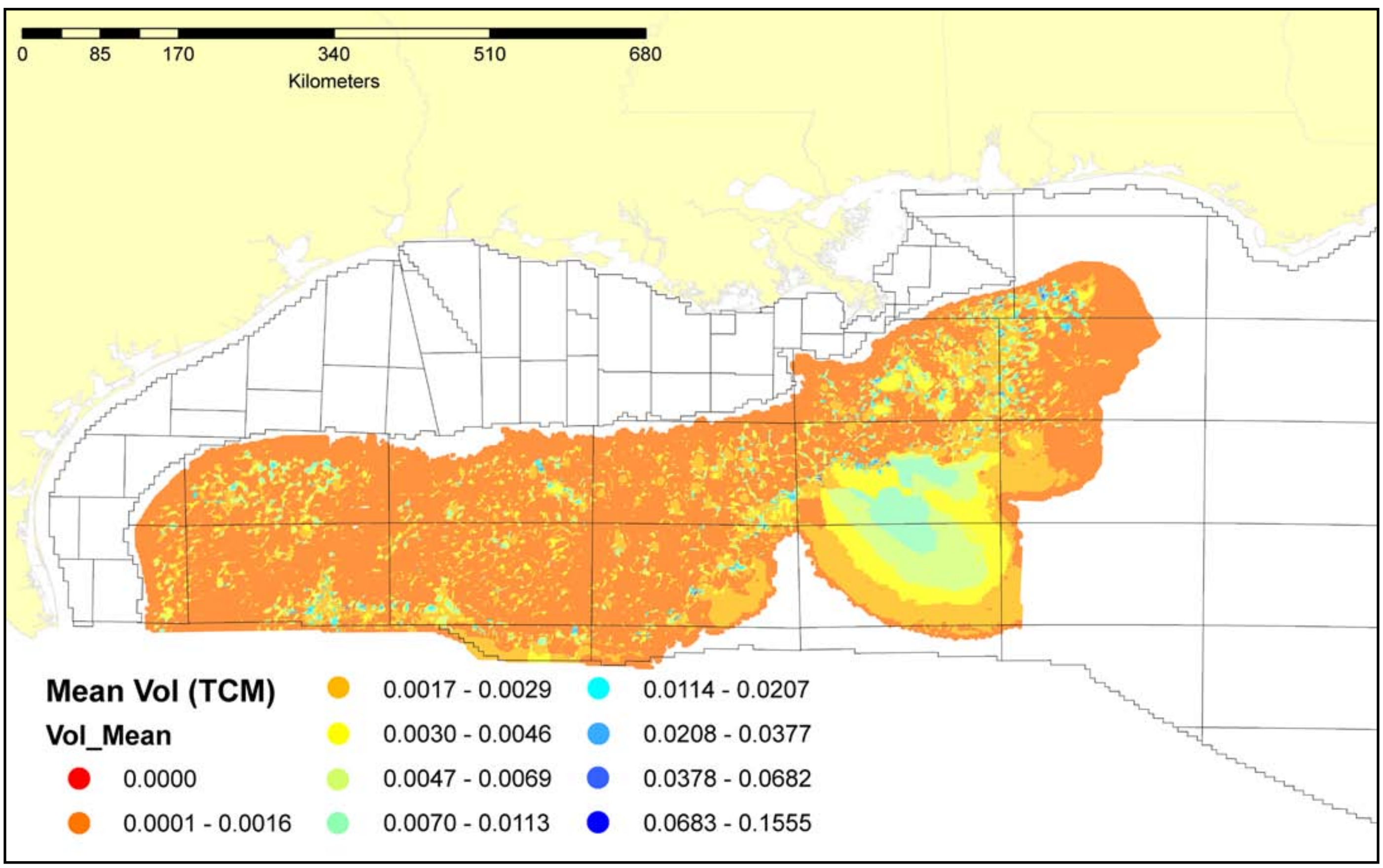

Figure 5: Map of in-place gas hydrate resources - sand only. Values are trillion cubic meters per cell.

Korean National Program Expedition Confirms Rich Gas Hydrate Deposits in the Ulleung Basin, East Sea

By Keun-Pil Park (KGHDO), Jang-Jun Bahk (KIGAM), Youngin Kwon (KIGAM), Gil Young Kim (KIGAM), Michael Riedel (McGill University), Melanie Holland (Geotek), Peter Schultheiss (Geotek), Kelly Rose (US DoE) and the UBGH-1 scientific party.

November 2007 marked the successful completion of South Korea's first large-scale gas hydrate exploration and drilling expedition in the East Sea: Ulleung Basin Gas Hydrate Expedition 1 (UBGH1), which successfully explored and recovered gas-hydrate-bearing sediments at three different locations in the Ulleung Basin. Expedition UBGH1 sailed 57 days in two legs aboard the multipurpose offshore support vessel *REM Etive*, which had been converted to a drilling ship by Fugro Seacore using the heave-compensated R100 portable drill rig (Figure 1). The Korea National Oil Corporation (KNOC) and Korea Gas Corporation (KOGAS) contracted Fugro to supply drilling, wireline logging, coring and associated services for Expedition UBGH1, while other companies including Schlumberger and Geotek provided Logging While Drilling (LWD) and core analysis services respectively. Technical decisions directing the scientific aspects of the work were made by the Korea Gas Hydrate R&D Organization and the Korea Institute of Geoscience and Mineral Resources (KIGAM).

Leg 1 of the expedition investigated five "type" locations in the Ulleung Basin (Figure 2), which were selected as representative of the basin based on pre-expedition 3-D seismic evaluations. Each of these sites was logged using the Schlumberger LWD suite of tools; in addition, 14 surface cores as well as many hours of camera surveys were collected using the *REM Etive's* remotely operated vehicles. The LWD data was used to select the three "type" locations most likely to contain gas hydrate for subsequent drilling and sampling on Leg 2. The second Leg lasted five weeks and entailed the drilling and coring of the three sites, where significant gas-hydrate-bearing reservoirs were documented up to 150 meters below the seafloor and at water depths between 1800 to 2100 meters.

Figure 1: The REM Etive *in dock at Busan, Korea, with the R100 drill rig amidships and laboratory containers aft.*

Shipboard Data and Samples Collected

During UBGH1 Leg 2, a total of 38 conventional cores were recovered and 15 successful pressure cores were taken (75% success rate). Conventional and pressure cores were recovered downhole using several wireline coring tools: i) a long piston corer (Fugro Hydraulic Piston Corer) which takes 7.5 meter cores; ii) a short hammer corer (Fugro Corer), which takes 3 meter cores; and iii) the Fugro Pressure Corer (Figure 3) and Fugro Rotary Pressure Corer which take 1 meter long cores at in situ pressures. One of the three sites also had wireline logs run with a suite of high precision slimline tools, including sensors for natural gamma, gamma density, neutron porosity, electrical resistivity, hole diameter and temperature.

Shipboard core analyses targeted the identification and quantification of gas hydrate within the sediment. Infrared thermal imaging was used to determine gas hydrate locations in all conventional cores; 18 samples containing gas hydrate were rapidly frozen in liquid nitrogen. The thermal data were used to identify samples for porewater analysis (for gas hydrate quantification; 249 samples) and gas analysis (for potential gas hydrate composition; 53 samples). Selected core sections were also split onboard for shipboard sedimentological description; 70 smear slides were described on board ship.

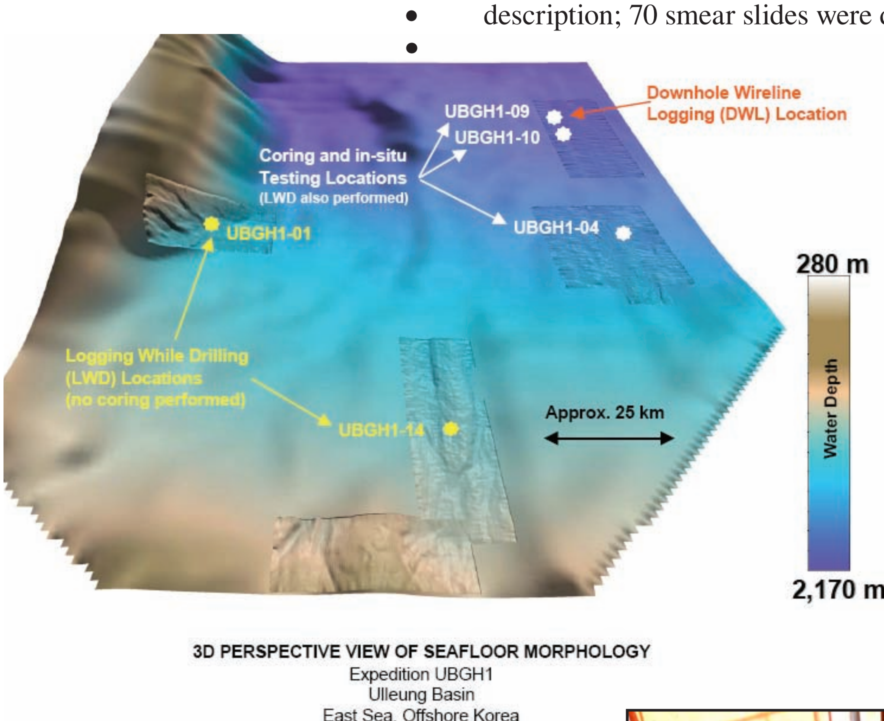

Figure 2: Study sites in the Ulleung Basin, a back-arc basin off the east coast of South Korea.

Figure 3: Drill floor on board REM Etive*, with the FPC being loaded into the drillstring prior to lowering and coring.*

Figure 4: An X-ray of a pressure core collected on Expedition UBGH1 showing gas hydrate in veins and layers. Gas hydrate was present at all three locations.

All pressure cores were analyzed under in situ pressure using the Geotek MSCL-P (Pressure Multi-Sensor Core Logger) to rapidly identify gas hydrate and measure gas hydrate-sediment properties under pressure. Gas hydrate may be visible in X-ray images (Figure 4) or gamma density profiles as low-density structures, or identified by high acoustic velocities. After MSCL-P analysis, seven of the pressure cores were stored for further analysis on shore; the remaining eight cores were subjected to controlled depressurization experiments to quantify the methane concentration and thus the gas hydrate saturation within the core. Once depressurized, pressure cores were sampled for porewater analysis to determine porewater freshening from gas hydrate dissociation.

Preliminary Findings

The sediments from the three locations drilled and cored during UBGH1 were all deposited in sea-level controlled slope/basin environments; the finer sediments were a mix of terrigenous and pelagic materials, with coarser materials deposited by debris flows or turbidity currents. The dominant sediments were siliceous and calcareous clays, however coarser-grained sand and silt beds, centimeters to meters thick, were also present (Figure 5). Gas hydrate was detected at all three sites in both the clay matrix, as veins and layers, and as pore-filling material within the silty/sandy layers (Figure 6). At one site, a 130-meter-thick gas-hydrate-bearing sedimentary interval of interbedded sands and clays was penetrated, which is one of the thickest gas-hydrate-bearing intervals to be documented worldwide. Another 100-meter-thick gas-hydrate-bearing interval was also discovered at another location. Methane was the predominant gas within core voids as well as in gas hydrate at all three sites; ethane was 0.3% or less of most gas samples (maximum

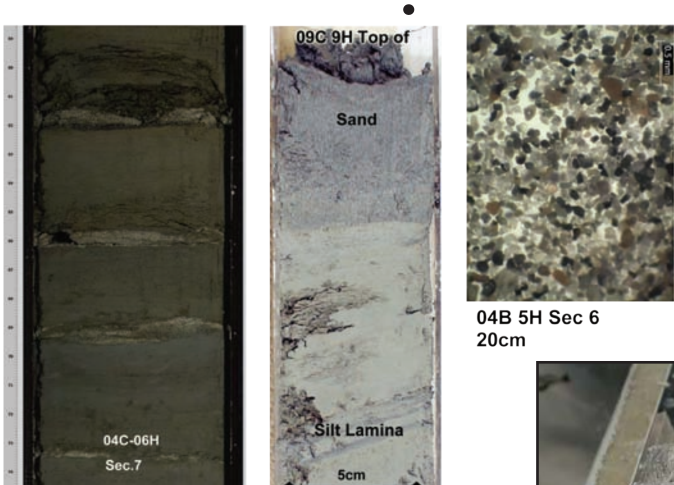

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Figure 5: Images of interbedded silts and sands in a clay matrix, along with photomicrograph of coarse fraction. The coarser-grained materials were mostly composed of quartz, but foraminifera and volcanic glass shards were also present.

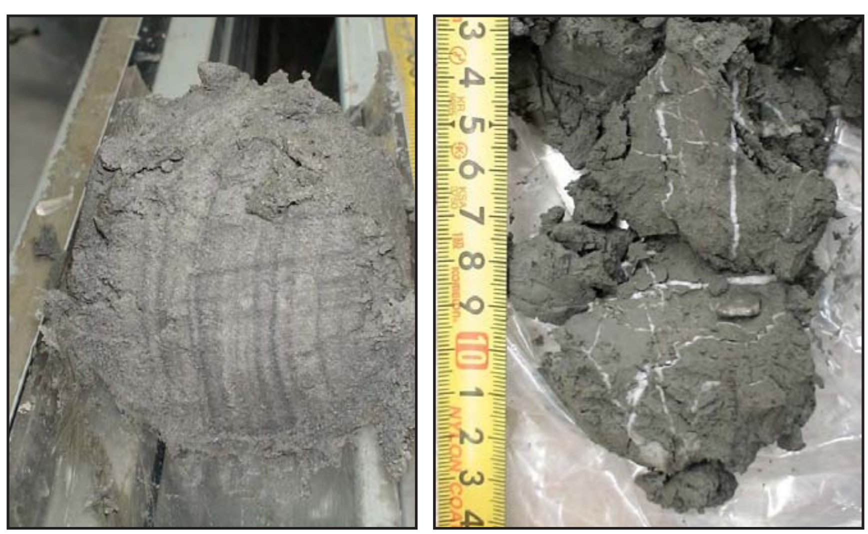

Figure 6: Gas hydrate present in clay material as veins, displacing sedimentary grains, and as a pore-filling matrix within sandy layers.

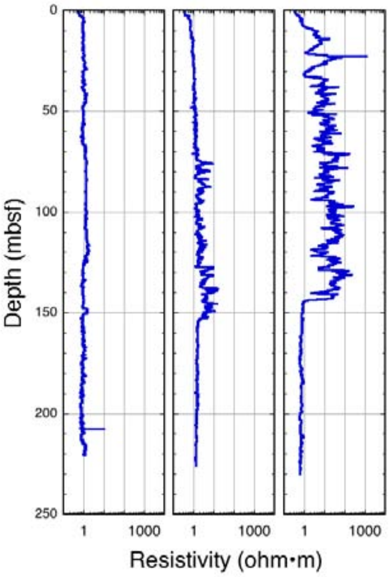

Figure 7: LWD electrical resistivity from the three "type" locations drilled, showing resistivity profiles differing by orders of magnitude. Gas hydrate was present at all three locations

ethane concentration 1%, in hydrate-bound gas). Quantification of gas hydrate from porewater freshening analysis showed that gas-hydrate-bearing sand layers contained an average of 30% gas hydrate by pore volume. The highest gas hydrate saturation from analysis of pressure cores, which average over a one-meter interval, was 23% gas hydrate by pore volume. While the overall magnitude of the electrical resistivity logs (Figure 7) correlated loosely with the overall average gas hydrate saturation for the different sites, there was no obvious quantitative relationship between the two data sets.

Implications and next steps

The five "type" locations drilled in the Ulleung Basin (three of which were cored) will now allow extrapolation of gas hydrate probability to other sites in the Ulleung Basin that have seismic data. The thick gas hydrate accumulation discovered at one of the locations is similar in many ways to that found in the Krishna-Godavari Basin on Indian National Gas Hydrate Program Expedition 1, with many grain-displacing gas hydrate veins in clay, but there are also similarities to the preferential distribution of hydrate in sands found in the interbedded sands and clays drilled on Integrated Ocean Drilling Program Expedition 311 at the Cascadia Margin.

Post-expedition studies are ongoing and include continued interpretation and evaluation of the numerous datasets collected while at sea, detailed sedimentological description of split-core sections and analyses of sediment sub-samples, testing of frozen gas-hydrate-bearing sediments, and analysis of gas and porewater samples collected shipboard. The postcruise analysis of the pressure cores was recently completed (to be the subject of a future article in *Fire in the Ice*), though one core remains stored under pressure for future analysis.

Members of the UBGH1 Korean scientific party with a sample of massive gas hydrate.

Analysis of Pressure Test data from the "Mount Elbert" Gas Hydates Well

By the International Gas Hydrate Code Comparison Group

Background

Since 2006, an international code comparison group (CCG) has collaborated in an effort to apply the leading gas hydrate numerical simulators to a series of idealized problems of increasing complexity. The CCG (see sidebar for participating scientists and codes) has completed work on the initial five problems, which moved from simple 1-D heat and mass transfer problems through a complex 3-D simulation of gas hydrate dissociation in an idealized reservoir (see *Fire in the Ice*, Winter, 2007). Given the lack of real-world data on gas hydrate producibility, this effort provided the best opportunity for model verification and calibration, and has resulted in meaningful improvements to the codes employed by all the members of the CCG.

Field Test Data

In February, 2007, DOE-NETL, the USGS, and BP Exploration (Alaska), Inc., conducted an extensive research program at the "Mount Elbert" well site in the Milne Point region on the Alaska North Slope (see *Fire in the Ice*, Winter 2007 and sidebar for participating scientists). As part of this program, a series of experiments were conducted with Schlumberger's Modular Dynamic Tester (MDT) tool to explore the petrophysical properties of a highly gas hydrate saturated sandstone reservoir (Figure 1). Four zones were tested. In each zone a 1 meter section of wellbore was sealed off and testing proceeded through a series of stages. Each stage consisted of a period in which fluids were pumped from the formation (thereby reducing formation pressure), and a second period in which the pump was stopped and the pressure response observed. Gas and water samples were collected during selected flow periods and a fluid analyzer on the MDT tool enabled the identification (but not volumetric measurement) of gas and water as it entered the tool. Lastly, the team was able to emplace a small programmable sensor on the outside of the tool in order to monitor temperature changes during the operations.

Figure 1: The crew of the Doyon 14 rigging up the Modular Dynamic Tester at the Mount Elbert test site, February, 2007

The only prior systematic tests of formation pressure response of a gas hydrate reservoir were conducted during the Mallik research program in 2002. A unique aspect of the Mount Elbert program was the fact that these experiments were conducted in the open hole, removing many complexities related to the nature and effect of casing perforations. In addition, the individual Mount Elbert tests were of much longer duration, with the test lengths ranging from 6 to nearly 12 hours. Notably, these four tests produced consistent formation responses to depressurization.

To provide an additional data set, the CCG agreed to attempt to history match the data from the "C-2" test as the 6th problem of their collaborative effort.

The Mount Elbert C-2 MDT Test

The C-2 MDT test was one of four tests conducted and was marked by three primary experimental phases (Figure 2). Initially, the reservoir was pumped for 15.5 minutes in a manner that did not reduce formation pressure below that which would cause hydrate dissociation. Upon shut-in, the reservoir pressure built back up in a manner consistent with a "porous media" response. This initial phase is significant in that it confirmed the ability of a highly-saturated gas hydrate reservoir to flow formation water in response to depressurization. Such flow is critical to the ability to depressurize gas hydrate reservoirs that are not in direct communication with subjacent free gas or free water zones. All members of the CCG team were able to history match this first data set with little difficulty. Furthermore, all team members reported estimates of formation permeability within a narrow range (from 0.12 to 0.17 md - slightly higher than that estimated from the Mallik tests and slightly greater than that typically used as an upper limit defining a tight gas reservoir, 0.1 md).

The second experimental phase of the C-2 test included another 15.7 minute flow, this time with pressure drop sufficient to initiate hydrate dissociation. Upon shut-in, the pressure response was observed to be much slower, or muted. A third phase involved a 116.9 minute flow during which a fluid (gas and/or water) was extracted, followed by more than four hours of shut-in. Pressure response in this phase was even more restricted than in phase 2. In addition, both the 2nd and 3rd shut-ins showed an unexpected "kink" within the early stages of the pressure build-up. Both phenomena, the muted responses after shut-in following hydrate

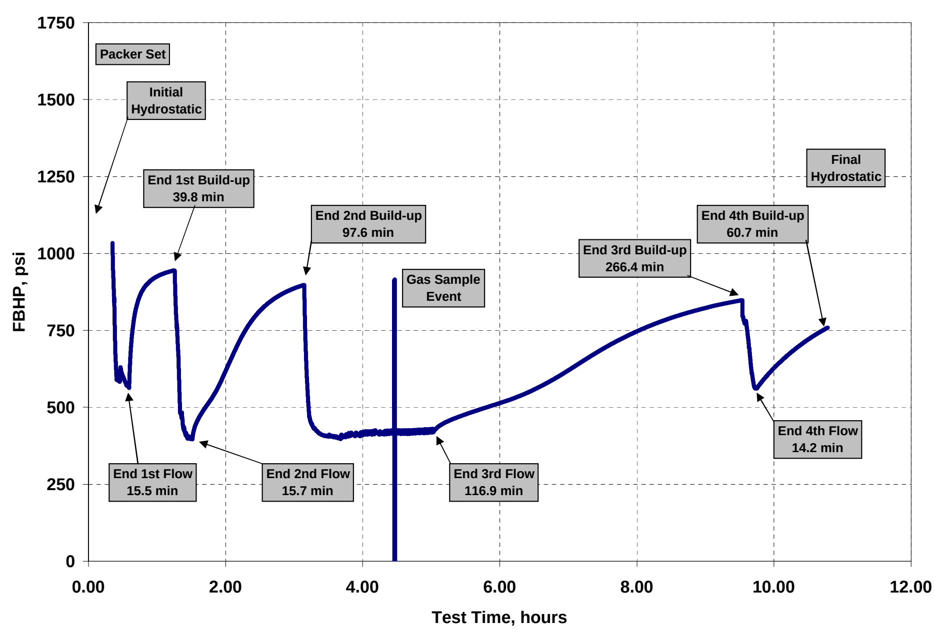

Figure 2: Pressure data obtained during the C-2 Test

dissociation and the "kink," were repeated in other MDT tests and are clearly manifestations of some as yet poorly understood process.

History matching of phases 2 and 3 proved more difficult, at least in part due to data limitations. One of the limitations of the MDT tool is that it does not record the water and/or gas volumes making up the produced fluid. However, it was surmised that the volumes were likely very small, and that as a result the effects of fluid storage and segregation, as well as compression of gas in the annular space around the MDT tool, could not be ignored in attempting to interpret the observed data. Unfortunately, none of the participating codes were equipped with the necessary mathematics to explicitly include these effects (which are normally negligible under typical reservoir modeling scenarios).

Figure 3 shows the results of the history match for three selected models (MH21-Hydrate, STARS, STOMP-Hydrate). Each of the modelers was able to produce good matches of the pressure history, but could not do so while maintaining a reasonable match to the estimated (but very poorly known) produced gas and water volumes.

Next Steps

The analysis of the MDT data at the Mount Elbert site indicates a significant advancement in the understanding of the petrophysical response of gas hydrate bearing sandstones. Over the next several months, each participant in the CCG will conduct simulations of three end-member geological settings (varying primarily in initial temperature) for gas hydrate on the Alaska North Slope. The results of this modeling will be used by DOE and its research partners in the design of future, longer-term production tests. However, it is important to note that the modeling parameters used to match the MDT data are not fully understood, and may be compromised by the inability of the each of the models to explicitly incorporate well-bore storage issues. Further investigation of that potential effect is now underway through an experimental effort at the Colorado School of Mines, and the results of that study will be incorporated as they become available. The results of the initial five problems considered by the CCG group, as well as the findings of the MDT analyses, will be presented at the upcoming International Conference on Gas Hydrates (ICGH-2008) meeting in Vancouver, Canada, in June 2008.

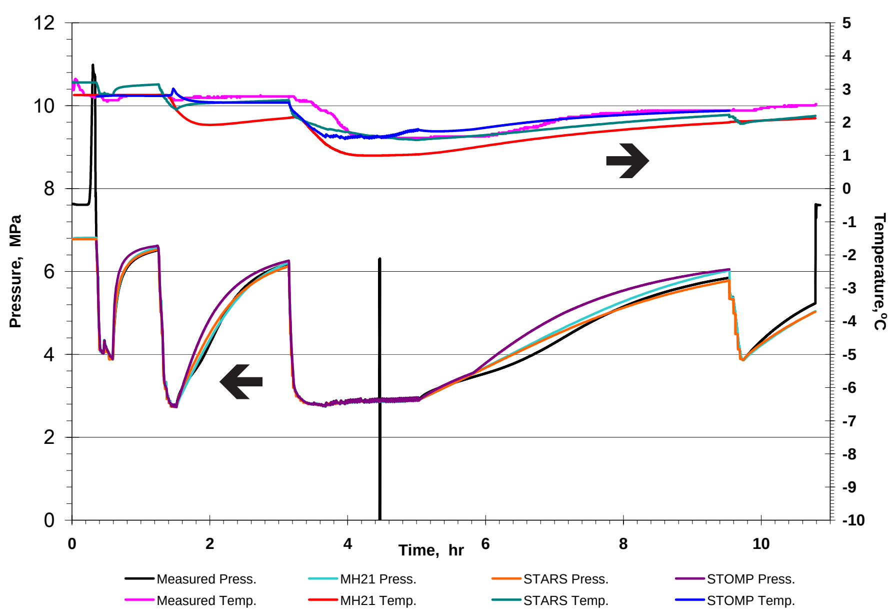

Figure 3: History match results for three selected models (MH21-Hydrate, STARS, STOMP-Hydrate) compared to measured temperature and pressure history

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Formation and Dissociation of Methane Hydrates in the Marine Environment

By Sabodh K. Garg and John W. Pritchett (Science Applications International Corporation)

Several semi-analytical models to describe the formation of methane hydrates in undersea marine sediments have been developed in recent years, but the utility of these existing models is limited by the simplifying assumptions that were required to solve the coupled system of mass and energy balance equations (see Xu and Ruppel, 1999; Davie and Buffett, 2001; and Liu and Flemings, 2006 and 2007, for example). To better represent the actual geological processes associated with hydrate formation and dissociation in the marine environment under a wide range of conditions, we have developed a one-dimensional (vertical) numerical computer model (see Garg *et al.*, 2008 for details). The model can be used to simulate many aspects of hydrate formation, decomposition, reformation, and distribution over time-scales of millenia:

- Burial history of deep marine sediments and associated phenomena (e.g. sediment compaction and consequent reduction in sediment porosity and permeability, fluid expulsion, time evolution of temperature and pressure, changes in effective stress, heat flux).
- In situ generation of biogenic methane from buried organic carbon, and methane dissolution in formation brine.
- Methane hydrate formation, decomposition, reformation, and re-distribution in response to changes in gas concentration, pressure, temperature and fluid salinity. Hydrate formation and decomposition are treated as equilibrium processes since kinetic phenomena are not expected to be important on geologic time-scales.
- The role of the sulfate reduction zone in suppressing hydrate formation.
- The possibility of a free-gas region beneath the hydrate stability zone ("HSZ").
- Multi-phase (i.e. liquid brine with dissolved brine, free gas, gas hydrate) flow through a deformable porous matrix. The model accounts for permeability changes caused by formation and decomposition of the gas hydrate.

Initial applications of the new model to study hydrate distributions at Blake Ridge (site 997) and Hydrate Ridge (site 1249) are described by Garg *et al.* (2008). Salient model results for these two sites are summarized in the next two paragraphs.

Our calculations for site 997 at Blake Ridge indicate that methane migration into the HSZ from a deep source (or a mixed methane source, i.e., both methane generation in situ and deep methane influx) is the most likely mechanism for the observed distribution of hydrate with depth at this site. If the upflowing fluid is liquid brine saturated with methane (no free gas), then the maximum computed free gas saturation beneath the HSZ is 2% to 3% or less - in line with saturation values derived from seismic observations (see *e.g.*, Holbrook *et al.*, 1996). If a higher free gas saturation is present beneath the HSZ as inferred from well logs (Collett and Ladd, 2000; Flemings *et al.*, 2003), the upflow must contain some free gas. Model results also indicate that the free gas saturation below the HSZ and the hydrate distribution near the bottom of the stability zone both depend strongly upon the critical gas saturation that is assumed. Unlike previous work (see *e.g.* Xu and Ruppel, 1999, Davie and Buffet, 2001, and Liu and Flemings, 2007), our model provides for a direct computation of the effective stress. The computed effective stress at the base of the HSZ is large and compressive even with a continuous free gas column (gas saturation about 10%) beneath the HSZ. Thus, for realistic values of capillary pressure, it is unlikely that the sediments at site 997 are critically stressed as has been suggested by some previous workers (Flemings *et al.*, 2003 and Hornbach *et al.*, 2004).

Liu and Flemings (2006) were the first to discuss the role of three-phase (hydrate, liquid and gas) equilibrium in free gas migration up to the sea floor at Hydrate Ridge site 1249. Later Liu and Flemings (2007) presented generic calculations based on observations at site 1249. Our calculations for site 1249 differ in several important respects from the work of Liu and Flemings (2007). We successfully reproduced the observed distributions of porosity and in situ chlorinity at site 1249. Unlike Liu and Flemings (2007), our model includes the heat of hydrate formation. Formation of hydrate at early times releases a large amount of heat, and results in a shoaling of the base of the HSZ. Later on, after most of the hydrate has formed, the HSZ deepens (Figure 1). The computed temperature profile within the HSZ is nonlinear (Figure 2); this model result should be testable with precise temperature measurements in boreholes. Finally, we note that the computed effective stress at the bottom of the HSZ is compressive but small in magnitude (Figure 2). It is thus possible that capillary effects at site 1249 may result in sufficiently high gas pressure to cause sediment failure.

To summarize, our numerical model can be used to investigate the distribution of methane hydrates in marine settings. The model can also be of help in assessing the impact of changes in ocean water depth and temperature on the stability of marine hydrates. For applications to gas chimneys and submarine landslides, the numerical model will need to be extended to two or three-dimensions.

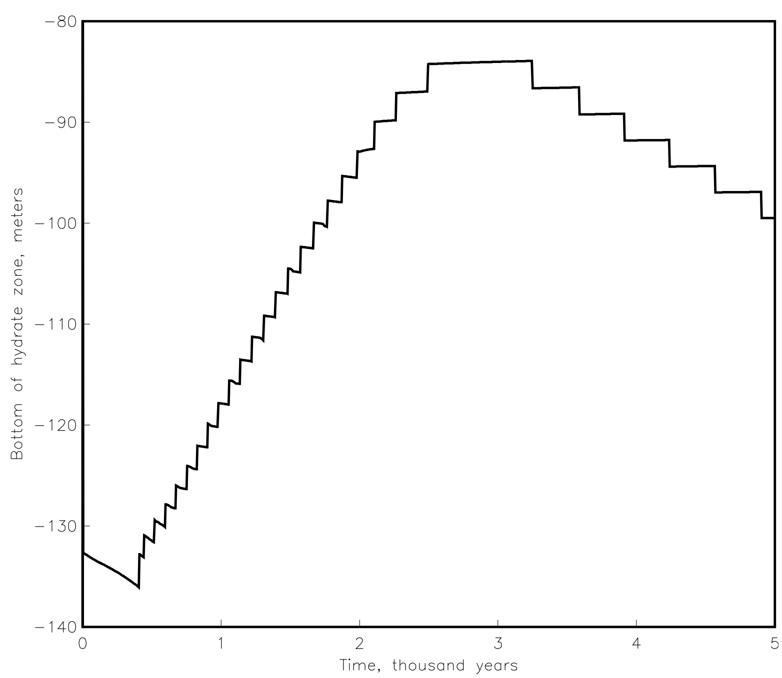

Figure 1: Location of the bottom of the hydrate stability zone (Hydrate Ridge site 1249). After an initial transient, the bottom shoals to a minimum depth of ~84 mbsf at t ≈3000 years, and subsequently deepens. The stair-step appearance is due to spatial discretization. Figure reproduced from Garg, et al. (2008).

ADDITIONAL READING

Collett, T.S. and J. Ladd (2000), Detection of gas hydrate with downhole logs and assessment of gas hydrate concentrations (saturations) and gas volumes on the Blake Ridge with electrical resistivity logs, Proceedings ODP Scientific Results, Leg 164, 179-191.

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Flemings, P.B., X. Liu, and W.J. Winters (2003), Critical pressure and multiphase flow in Blake Ridge gas hydrates, Geology, 31(2), 1057-1060.

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Hornbach, M.J., D.M. Saffer, and W.S. Holbrook (2004), Critically pressured free-gas reservoirs below gas-hydrate provinces, Nature, Volume 427, 142-144.

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Liu, X., and P.B. Flemings (2007), Dynamic multiphase flow model of hydrate formation in marine sediments, Journal of Geophysical Research, Volume 112(B3), B03101, doi:10.1029/2005JB004227.

Trehu, A.M, et al. (2003), Proceedings Ocean Drilling Program Initial Reports, Volume 204, Ocean Drilling Program, College Station, Texas, doi:10.2973/odp.proc.ir.204.

Xu, W. and C. Ruppel (1999), Predicting the occurrence, distribution, and evolution of methane gas hydrate in porous marine sediments, Journal of Geophysical Research, Volume 104(B3), 5081-5095.

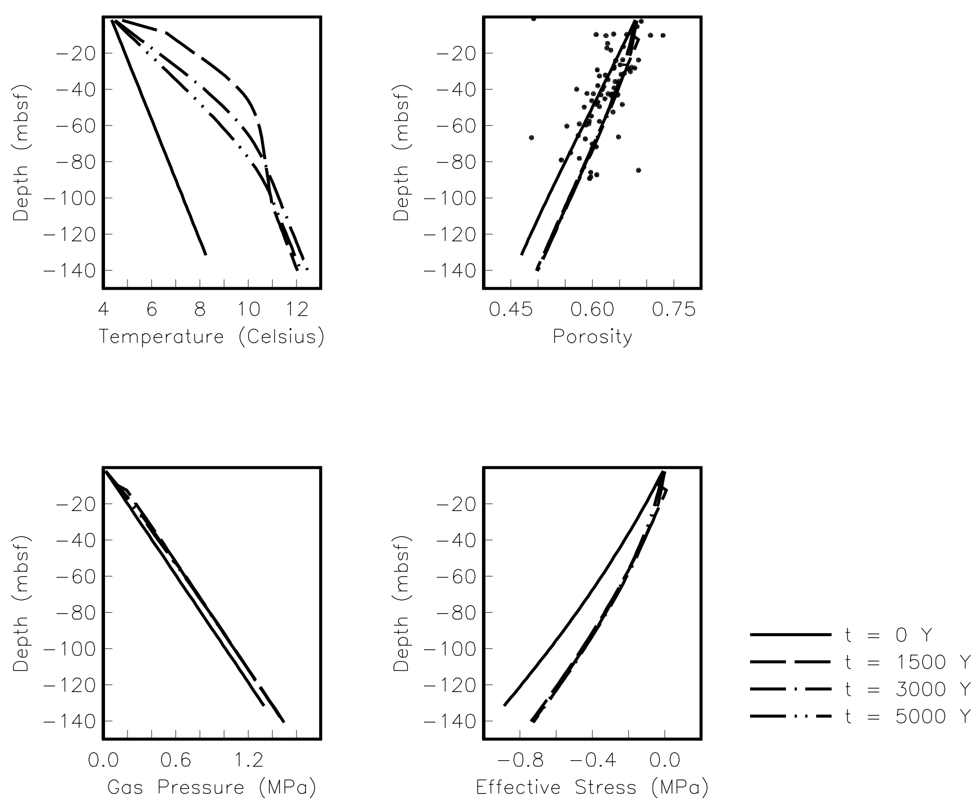


Figure 2: Temperature, porosity, gas pressure (= liquid pressure + capillary pressure) referenced to sea floor and effective stress (= vertical stress + gas pressure; negative in compression) distribution with depth at t = 0, 1500, 3000, and 5000 years (Hydrate Ridge site 1249). Solid dots in the porosity plot denote the measurements reported by Trehu et al. (2003). Figure reproduced from Garg, et al. (2008).

Methane Hydrates Advisory Committee Members Announced

The members of the Methane Hydrates Advisory Committee (MHAC) were approved by the Secretary of Energy on March 11th. Six members retired after having provided the Department of Energy with valuable insights and advice over the past several years. The members are:

Continuing Members:

Dr. Peter Brewer, Monterey Bay Aquarium Research Institute

Mr. Richard Charter, National OCS Coalition

Mr. Arthur Johnson, Hydrate Energy International

Dr. Miriam Kastner, Scripps Institute of Oceanography

Dr. Stephen Masutani, University of Hawaii

Dr. E. Dendy Sloan, Colorado School of Mines

Mr. Robert Swenson, Alaska Department of Natural Resources

Dr. Jean Whelan, Woods Hole Oceanographic Institute

New Members:

Dr. David Goldberg, Columbia University

Mr. Robert T. Miller, ConocoPhillips

Dr. Amos Nur, Stanford University

Dr. Craig Shipp, Shell International E&P Inc.

Dr. Anne Trehu, Oregon State University

Dr. Joseph Wilder, University of Akron

Retiring Members:

Dr. Nader Dutta, Schlumberger

Dr. Emrys Jones, Chevron

Ms. Kimberley Juenger, World Energy Systems

Dr. Devinder Mahajan, Brookhaven National Laboratory

Mr. Scott Wilson, Ryder Scott Co.

Dr. Robert Woolsey, University of Mississippi

The next meeting of the Methane Hydrate Advisory Committee Meeting will take place at the La Jolla Shores Hotel, La Jolla, California, on April 24–25, 2008. The agenda includes updates on the simulation code comparison, research targeting the methane hydrate role in global climate change, the MMS assessment of offshore methane hydrate resource, the Chevron JIP, the BP Arctic Project, plans for field tests, DOE projects, international activities, the National Research Council Assessment and the 2009 Report to Congress.

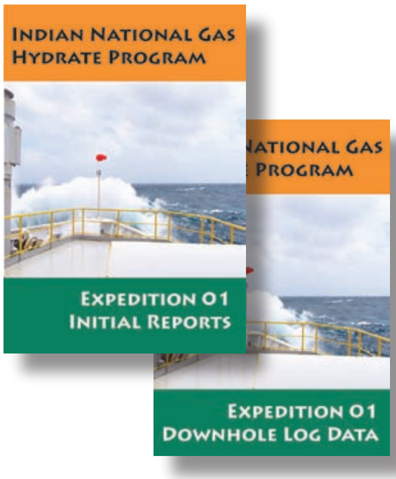
DOE Requests Proposals for Projects Exploring the links between Gas Hydrate, Carbon Cycling, and Global Climate Change

On or about March 2008 the U.S. Department of Energy/National Energy Technology Laboratory will issue an amendment to its existing Funding Opportunity Announcement (FOA) to request proposals for projects that will address gas hydrate's role in the natural environment. The primary intent of this solicitation is to fund efforts that will shed light on the role methane and gas hydrates play in global carbon cycling and in climate change, either in the geologic past, at the present, or in the future. Studies of interest could include, but are not necessarily limited to: quantification of the production, consumption, and flux of methane in oceanic (sediment and water column) and terrestrial (particularly arctic) environments, the influence of gas hydrate on methane mobility and the dynamic response of gas hydrate accumulations to changing geologic/environmental conditions, and integration of gas hydrate-relevant data and processes into ocean circulation, atmospheric, and climate models.

We anticipate the closing date for proposals will be around May 1, 2008. Please watch the DOE/NETL website http://www.netl.doe.gov/business/solicitations/index.html for the formal announcement of the amended FOA.

The 2008 International Conference on Permafrost to be held June 29-July 3

The International Permafrost Association (IPA) will host the 2008 International Conference on Permafrost (ICOP) on the campus of the University of Alaska-Fairbanks from June 29 to July 3, 2008. The meeting is the 9th ICOP and marks the 25th anniversary of the formation of the IPA. The theme for the meeting is "Permafrost on a warming planet: impacts on ecosystems, infrastructure, and climate." Special efforts will be made to involve young researchers, educators and students of all ages, and native communities from all countries with an interest in permafrost science and engineering. The U.S. Permafrost Association (USPA), incorporated in Alaska as a not-for-profit organization, is the parent organization for the NICOP. Visit http://www.nicop.org for more information and to register.



India's National Gas Hydrate Program (NGHP) Releases Expedition 01 Scientific Data at International Conference

This past February, more than 300 gas hydrate scientists from around the world convened in New Dehli, India, to release and discuss the initial results of India's NGHP Expedition 01 (May-August, 2006). Expedition 01, which was led by India's Directorate General for Hydrocarbons and the U.S. Geological Survey, was the first gas hydrate research and exploration program conducted in India's offshore (See Fall 2006 FITI). The expedition conducted ocean drilling, coring, logging and analytical activities at 21 sites located both on the passive margins of the Indian peninsula and within the convergent tectonic setting of the Andaman Islands.

The three-day conference was highlighted by an addresses from India's Minister of Petroleum and Natural Gas, Shri Murli Deora (see photo), NGHP program leaders including Mr. V. K. Sibal, Dr. P. Kumar, and Mr. M. Lall, and Expedition 01 science lead Dr. Timothy Collett (USGS). Presentations were also provided by the leaders of international gas hydrate programs in India, Korea, Japan, U.S.A., Canada, and Taiwan, as well as by more than 50 contributing scientists on all aspects of the project. In summarizing the event, Directorate General of Hydrocarbons Director General and NGHP Program Coordinator V. K. Sibal said, "The global gas hydrate resources are estimated to be huge. Although the exploration and exploitation of gas hydrates pose significant challenges, the opportunities are unlimited. The combined wisdom of the scientific community from across the world could provide the answers and solutions to many of these challenges. The Indian gas hydrate program has been fortunate in having the benefits of a truly global

USGS Energy Program Coordinator Dr. Brenda Pierce, along with Minister Deora (far right) and DGH Director General V.K. Sibal (second from right) conferring at the NGHP International Conference on Gas Hydrates in New Dehli collaboration in the form of the first gas hydrate expedition in Indian waters. The results of the studies are not only encouraging, but also very exciting. I believe that the time to realize gas hydrate as a critical energy resource has come."

An additional highlight of the conference was the release of a compilation of project data that are now available on a two-DVD set. The Initial Reports DVD contains a 35-page program summary, a 95-page discussion of operational methods, and separate integrated reports on the scientific data acquired at each of the 21 sites visited. Each chapter outlines the initial finding with respect to the lithostratigraphy, pore water geochemistry, gas geochemistry, sediment physical properties, downhole logging and pressure coring operations. These data were collected under the guidance of project scientific lead, Dr. Timothy Collett and co-chiefs Drs. Michael Riedel (McGill University), Jim Cochran (Columbia University), Ray Boswell (U.S. DOE), Pushpendra Kumar (ONGC) and Arun Vasant Sathe (ONGC).

The two Downhole Log Data DVDs contain all the log data acquired at 12 logging-while-drilling holes and 13 wireline-logging holes, as well as comprehensive data processing notes and special log data displays and images. These data were collected and processed under the supervision of the Borehole Research Group at the Lamont-Doherty Earth Observatory of Columbia University.

NETL Seeks Hydrates Research Technology Manager

The National Energy Technology Laboratory is seeking a qualified professional to fill a position of General Engineer/Physical Scientist (GS-0801/1301-14/15) at the Strategic Center for Natural Gas and Oil (SCNGO) in Morgantown, WV. The incumbent serves as a Technology Manager for the Ultra-deepwater and Unconventional Natural Gas and Other Petroleum Resources (UDW) Research and Development (R&D) Program and the Methane Hydrates (Hydrates) R&D Program both of which are managed by the SCNGO at NETL. Interested parties should reference announcement NETL-08-21 when contacting Tamara Sisler at (304) 285-4271, Tamara.Sisler@netl.doe.gov for more details. The application process closes April 28, 2008.

MARTA E. TORRES

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Marta, who is both a mom and an oceanographer, considers herself lucky to have found a balance of career and family … in spite of the demands of field work. She hopes she has provided her son with a good model of a working woman pursuing her aspirations.

photo credit W. Crawford (IODP-TAMU)

Geochemist Values an Interdisciplinary Approach to Gas Hydrate Research

Marta Torres started her science journey as an undergraduate in chemistry at the University of Costa Rica, a country where both the Atlantic and the Pacific oceans are never too far away. She came to the U.S. in 1980 to study oceanography at Oregon State University. "At Oregon I was very fortunate to find in Erwin Suess an excellent advisor, mentor and friend," says Marta. "Dr. Suess fostered my interest in geochemistry and introduced me to issues related to submarine fluid flow." Upon completing her graduate education in 1988, she went to work as a staff scientist in the Ocean Drilling Program, and then took a research position at Geomar, in Kiel, Germany. In 1993 Marta returned to Oregon State University, where she has been part of the College of Oceanic and Atmospheric Sciences faculty ever since.

Throughout her career Torres has been primarily interested in the geochemical fluxes associated with fluid transport in convergent and transform margins, the rates of fluid migration, composition of the fluids, and the chemical-rock reactions along flow paths. "I have been fortunate in that I have been able to conduct my research using a variety of sophisticated tools, including a deep-sea drilling platform (the *JOIDES Resolution*), remotely operated vehicles (the ROPOS system of the Canadian Scientific Submersible Facility) and deep submergence vehicles (the *Alvin* and *Nautile*)," adds Marta. Her studies have been concentrated in the Eastern Pacific convergent margin, including the Cascadia, California, Peru and Chile margins. All of these locations host gas hydrate accumulations, since these deposits are commonly associated with areas of fluid transport at continental margins where natural gas originates from the decomposition of organic matter. More recently Torres has also participated in expeditions to study gas hydrates in the India Ocean and on the north slope of Alaska.

Dr. Torres' perspective on the current status of hydrate research is that while the research community has come a long way in understanding the fundamental properties of gas hydrates and the factors that control their formation and distribution in marine sediments, researchers have less understanding of the processes that affect gas hydrate dynamics in subsea environments that experience changes over a wide range of time scales. "To move forward, we need to take advantage of evolving technologies to study gas hydrates with observatory science," says Marta. "Observatories focused on gas hydrate bearing sites will provide the data needed for determining the factors influencing subsurface fluid flow and how this flow relates to stabilization and destabilization of gas hydrates and also for studying the effects of microbial activity on gas hydrate processes. These observatories will also allow us to gain a better understanding of the role of hydrates in the global carbon cycle, their potential as an energy resource, and the effects of gas hydrates on slope stability."

Marta feels that the oceanographic research she does in general, and specifically her work on gas hydrates, is particularly rewarding because of the highly interdisciplinary nature of the problem. She adds, "Unraveling the complex and dynamic processes at play is non trivial; this however leads to exciting and intellectually stimulating interactions with scientists from a wide range of disciplines. I have been lucky to be part of a team of researchers who are bright, insightful and share with me the joy of discovery, the thrill of adventure and the simple fun of being out in the field."