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Fire in the Ice

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EVALUATION OF GEOHAZARDS OF *IN SITU* GAS HYDRATES RELATED TO OIL AND GAS OPERATIONS

By Jonny Rutqvist and George Moridis, Lawrence Berkeley National Laboratory (LBNL)

A key issue in the evaluation of gas hydrates are the geohazards that they pose. In this report, we describe numerical simulation studies conducted at LBNL to assess these hazards associated with the production of oil and gas through, and the potential production of gas from, hydrate-bearing sediments (HBS). Such hazards must be fully addressed and understood before gas production from hydrate deposits can be developed in earnest.

The geohazard associated with producing oil and gas from conventional reservoirs is the potential destabilization of gas hydrates in shallow sediments due to thermal stress imposed by heated well-bores (Peters *et al*., 2008; Rutqvist and Moridis, 2009). Figure 1 presents one example of a fully coupled thermo-dynamic and geomechanical simulation of such a

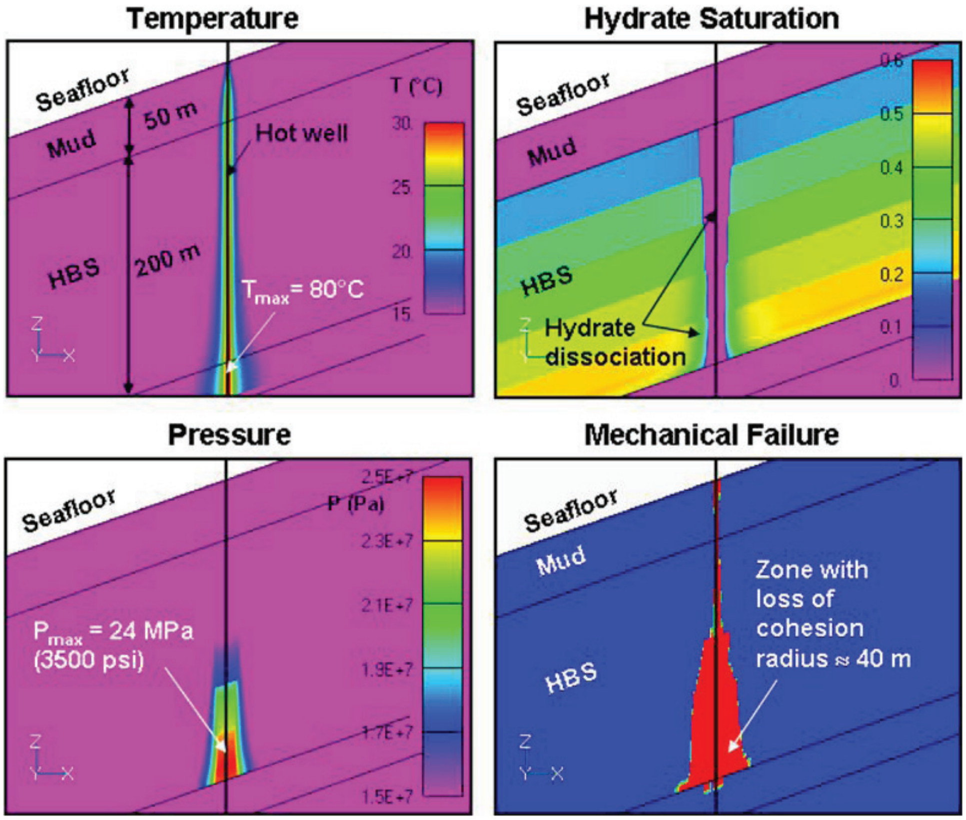

Figure 1: Simulation results of coupled thermo-dynamic and geomechanical changes around a hot production well intersecting an HBS near a sloping seafloor after 30 years of production and heating (Rutqvist and Moridis, 2010).

scenario near a sloping seafloor (Rutqvist and Moridis, 2010). In this case the hydrate dissociation and associated gas release causes significant pressure increase that eventually overcomes the mechanical confining stresses leading to a complete loss of cohesive strength. After 30 years, this zone of failure has extended to about a 40 meter radius and may jeopardize the support and stability of the well assembly near the seafloor. As such, careful evaluation of well placement within HBS is critical.

The primary geohazards associated with production of gas from HBS derive from the geomechanical response of HBS to intended dissociation, including potential well-bore instability, casing deformation, and ground subsidence. These hazards are common to all oil and gas operations, but are more acute in potential gas hydrate development as those deposits that are suitable targets for production often involve poorly consolidated sediments that are usually characterized by limited shear strength.

The dissociation of solid hydrates (a strong cementing agent) during gas production can degrade the structural strength of the HBS, which is further exacerbated by the evolution of the expanding gas zone, pore-fill volume changes, progressive transfer of loads from the hydrate to the sediments, and subsidence. The problem is at its highest intensity in the vicinity of the wellbore where the largest changes are concentrated, and is further complicated by production-induced changes in the reservoir pressure and temperature. These can significantly alter the local stress and strain fields, with direct consequence on the wellbore stability, the flow and fluid properties of the system, the potential for co-production of solid particles, and consequently on continuing gas production.

A newly developed numerical simulator at the Berkeley Lab has enabled numerical studies on well stability and geomechanical performance during gas production from HBS (Rutqvist and Moridis, 2009). The simulator was developed based on linking the Berkeley Lab's TOUGH+HYDRATE simulator, which describes the system hydraulic, thermal, and thermodynamic behavior in geological media containing gas hydrates, with the FLAC^{3D} geomechanical simulator (Itasca Consulting Group Inc., 2009). The simulator has recently been applied for scientific and engineering analyses of hydrate stability, including well bore and reservoir instability during depressurization-based production from known oceanic and permafrost related hydrate deposits (Rutqvist and Moridis, 2009; 2010; Rutqvist *et al*., 2009). Input data for these studies were based on data from the gas-hydrate bearing Frio sand deposit in Alaminos Canyon Block 818 of the Gulf of Mexico and from two known hydrate-bearing permafrost deposits: the Mallik (Northwest Territories, Canada) deposit and Mount Elbert (Alaska, USA).

Our current modeling results show that geomechanical responses during depressurization-based gas production in both oceanic and permafrost related hydrate deposits are driven by the reservoir-wide pressure depletion, ΔP, which is in turn controlled by the production rate and pressure decline at the wellbore. The depressurization of the reservoir causes vertical compaction and stress changes, which are proportional to the magnitude of pressure decline, ΔP, and depend on the geomechanical properties of the HBS and surrounding sediments. In general, the magnitude of subsidence will be much larger in the case of oceanic hydrate bearing sediments because of the much larger magnitude of the pressure decline, ΔP, than in the case of a permafrost hydrate deposit. In the case of depressurization-based production modeled for the Alaminos Canyon block 818 (Rutqvist and Moridis, 2009), the pressure declined approximately 30 MPa and resulted in subsidence on the order of several meters. Much of the compaction may take place in the compacted mud or shale layers located above and below the produced HBS and may be as large as 10%.

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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 Jennifer Presley at 281-494-2560.

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In the case of the production from permafrost deposits at Mallik and Mt. Elbert, the pressure decline was limited to a few MPa, which resulted in subsidence of only a few cm and a compaction strain of less than 1% (Rutqvist *et al*., 2009). In the case of production in permafrost settings, the subsidence is also mitigated by the presence of a relatively stiff permafrost overburden.

Depressurization-induced stress changes and associated strain will also strongly affect well stability and load on the well casing (Rutqvist *et al.,* 2008). In the case of a vertical production well, the pressure depletion will generally unload the formation uniformly in a plane normal to the axis of the well and therefore the load on the well casing will decrease. In the case of a horizontal production well, vertical compaction of the formation acting against the upper part of the well completion will likely cause shear failure in the formation in that area. Such shearing results in breaking of bonds between particles, which can lead to production of solids (e.g. sand grains) and creation of cavities around the wellbore perforations. The current analysis indicates that for both vertical and horizontal wells, it will be difficult to avoid shear failure in the formation around perforated production intervals of the wells. Thus, appropriate engineering measures, such as sand screens, need to be applied to prevent solids production.

Figure 2 shows an example of the evolution of geomechanical changes around a vertical well associated with a potential long-term test of gas production from a hydrate deposit on the Alaska North Slope. The

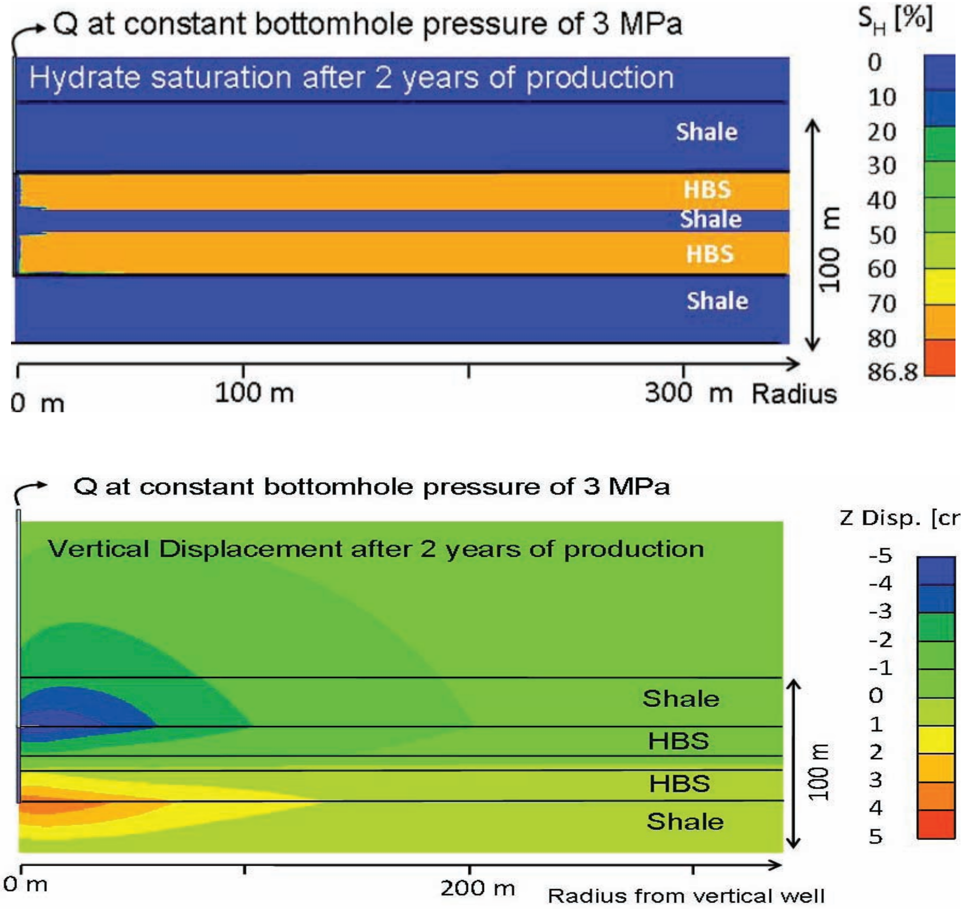

Figure 2: Calculated hydrate saturation and vertical displacement after 18 months simulated gas production simulating a potential long-term test of gas production from a hydrate deposit at the PBU-L106 site in North Slope, Alaska.

simulation models an 18-month field test of depressurization-based production from a single vertical well (constant pressure P_w = 3 MPa). The results indicate about 5 cm compaction of the 45 m thick reservoir interval, which corresponds to a vertical strain of only about 0.2% ground surface subsidence, indicating little danger for the production well and no significant interference with nearby wells and facilities. The results also indicate limited shear failure in the formation around the well perforation, although appropriate sand screens to further mitigate sand production is recommended.

In summary, it is clear that geohazards associated with HBS require close attention and location-specific analysis. These issues are most significant in the case of oceanic HBS, where modeled stress changes and vertical compaction can be substantial. The potential effect of non-uniform reservoir geomechanical properties and discontinuities (faults) that might be reactivated during production has not been assessed in the current analysis, but may be important as such features may cause large differential reservoir compaction and subsidence that might severely affect seafloor structures and horizontal wells. Further work is also required to better understand the impacts on the integrity of overlying reservoir seals. Moreover, for poorly consolidated and highly porous sand, formation failure may also occur in the form of pore-collapse in which the mean effective stress increases so much that inelastic grains slippage and rearrangement occurs. Oceanic hydrate bearing sediments may be at the highest effective stress in their geological life, which means that their pre-consolidation pressure (or collapse stress) would likely be exceeded during depressurization-based gas production. During pore-collapse, porosity and permeability may undergo more substantial irreversible changes. Such processes and their affect on the gas production from the HBS will be the subject of future studies.

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AN OPPORTUNITY TO ASSESS THE BEHAVIOR OF METHANE RELEASED IN THE DEEP OCEAN

By David Valentine, University of California – Santa Barbara

On April 22, 2010 the sinking of the *Deepwater Horizon* and the failure of the underlying safety devices created the largest point source of oil ever observed in the deep ocean. Information soon surfaced that significant amounts of methane were being released. While devastating, this situation provides a unique opportunity to understand the behavior of methane and other hydrocarbon gases released into the deep ocean. Although the methane release in the Gulf of Mexico was not related to *in situ* gas hydrates, this event does provide a high-rate end member to compliment ongoing University of California – Santa Barbara (UCSB) studies that are designed to help inform the fate of, and environmental impacts of, potential methane release from deepwater sea-floors.

To explore these issues, UCSB scientists supported by DOE's Methane Hydrate program participated on an NSF-sponsored expedition aboard the R/V *Cape Hatteras* from June 11 to June 21, 2010, to the *Deepwater Horizon* spill site. This was done in collaboration with scientists from Texas A&M University. During the cruise, our team investigated the distribution of methane throughout the water column, quantified the rates at which microbes were consuming the methane, and performed experiments to identify the responsible organisms using a stable isotope labeling approach. Initial results found methane to be concentrated at discrete depth intervals typically below 900 m water depth, with peak concentrations reaching 100,000 times the background level for the region. Depth intervals of elevated methane also displayed reduced levels of oxygen, typically ranging from 5-35% reduction below background levels. Ongoing measurements will aid in assessing whether methane oxidation contributes significantly to the observed oxygen loss. For more info on the broader project of which the sampling described in the article is a part, click here.

Water column sampling (CTD) devices are deployed off the R/V Cape Hatteras in Mississippi Canyon block 252 during the June 11-21 expedition. In the background, gas from the damaged Deepwater Horizon wellhead is burned by the drillship Discoverer Enterprise in a process known as flaring.

CORE-SCALE HETEROGENEITY OF HYDRATE DISTRIBUTION AND ITS IMPACT ON GAS PRODUCTION

By Yongkoo Seol and Evgeniy Myshakin, National Energy Technology Laboratory; Timothy J. Kneafsey, Lawrence Berkeley National Laboratory

Production of natural gas from hydrate-bearing sediments requires that the hydrate dissociate, and that the gas coalesce and migrate through the sediments to a production well. Visual and x-ray computed tomography observations of heterogeneity and hydrate distribution from appropriately collected and preserved cores provides direct insight into the reservoir heterogeneity at that scale, and how the dissociation, gas coalescence, and gas migration processes can occur. These observations complement field imaging techniques and provide higher resolution images to help form and refine the conceptual model for the reservoir. X-ray CT observations of dissociation and gas production from properly preserved cores can be particularly enlightening as the main processes of concern (dissociation, gas coalescence, gas migration, and to some extent sediment mechanical changes) can be observed. This article presents an overview of recent developments in applications of X-ray CT observation, and presents a new result that highlights the significance of heterogeneity in hydrate saturation distributions on potential gas production.

X-ray CT Observations

X-ray CT images (Figure 1) show natural heterogeneities in terms of geologic material textures and hydrate distribution where the hydrate is present in the low density veins. The observation shows the interconnectedness of hydrate and high porosity (possibly higher permeability) regions, which are likely to be the location where gas coalescence and migration will occur and may become gas flow pathways upon hydrate dissociation.

Synthesizing methane hydrate-bearing sediments in the laboratory is necessary due to the limited availability of natural hydrate-bearing samples. Creating samples closely simulating natural hydrate distribution patterns is important when properties measured using the lab-synthesized samples are to be used for predictions of natural hydrate-bearing sediment behavior. Figure 2 shows four laboratory hydrate formation events in a silica sand core formed at 8° C and 8.27 MPa. Each formation event is preceded by a differing time gap between the previous dissociation and subsequent formation. The hydrate distribution pattern is not repetitive, and continuously evolves over the week-long series of tests in response to changes in capillary pressure induced by the changing pore geometry in the dynamic system.

Image Conversion for Heterogeneity Map

X-ray CT observations of laboratory gas production tests on methane hydrate-bearing sediment have been utilized to quantitatively examine fluid flow behavior upon depressurization and hydrate dissociation within the sediment. Results from numerical simulations, which used the CT observation as input conditions, have been compared to experiment observations. Direct incorporation of CT images into numerical simulations requires immense computation capacity, due to the fine resolution (512 x 512) of the CT images. Reduced resolution may be entirely sufficient for looking into flow behavior through porous media of interest. An automated tool has been developed for incorporating X-ray CT image data directly into the mesh used for numerical simulations (Figure 3). The tool reduces the total pixel numbers of original CT images by setting a larger grid dimension and averaged pixel values within the grid to assign values into the larger corresponding grid elements. The extent of down-scaling was adjusted so that in each grid element, properties were homogeneous, while the entire model domain preserved the intrinsic heterogeneous nature of the original 3-D image. The resulting model has a smaller number of elements that can be readily handled and still capture the heterogeneous nature of fluid flows occurring in the model domain.

Core-scale Simulations with Heterogeneity

We used the numerical simulation code TOUGH+HYDRATE to predict gas production from a core-scale, cylindrical sample containing methane hydrate in otherwise water-saturated sand. The simulations utilized the heterogeneous porosity and saturations derived from the X-ray CT experiment. Figure 4 shows gas production rates and cumulative volumes of gas produced for the idealized homogeneous and more realistic heterogeneous cases. Introduction of heterogeneity increases the rate of gas produced by an order of magnitude over that calculated in the homogeneous case. This is a direct consequence of the heterogeneous pore network resulting in varying hydraulic properties of the hydrate-bearing media, which allow the mobile phase to flow through high permeability channels faster than in the homogeneous case.

This approach can also be used to improve the characterization of pressurized core samples collected from natural hydrate deposits. Besides understanding the hydrate-sediment interactions and unique hydrate accumulation habits in specific types of sediments, the technique is capable of providing conditioning data necessary to develop a geostatistical model for porosity and phase saturation realizations for a hydrate-bearing accumulation with known lithology. This would enable the

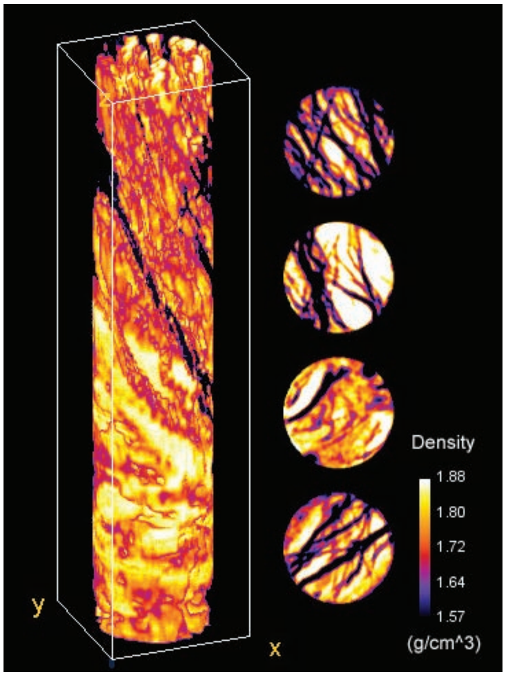


Figure 1: X-ray CT images of a natural hydrate-bearing sample collected from Site NGHP-01-21 in the Krishna-Godavari Basin showing hydrate-bearing veins in the clay-rich sediments.

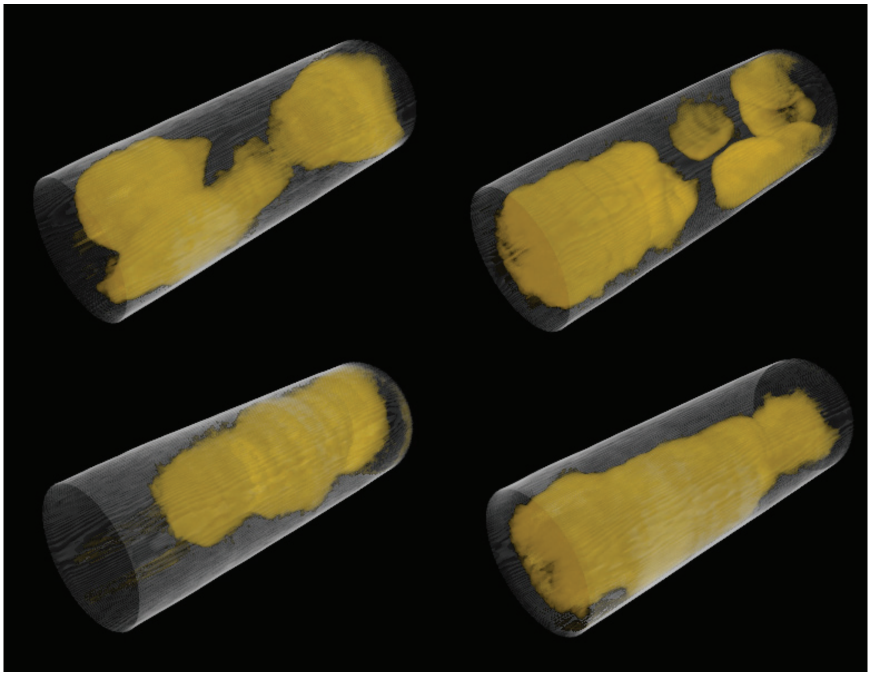


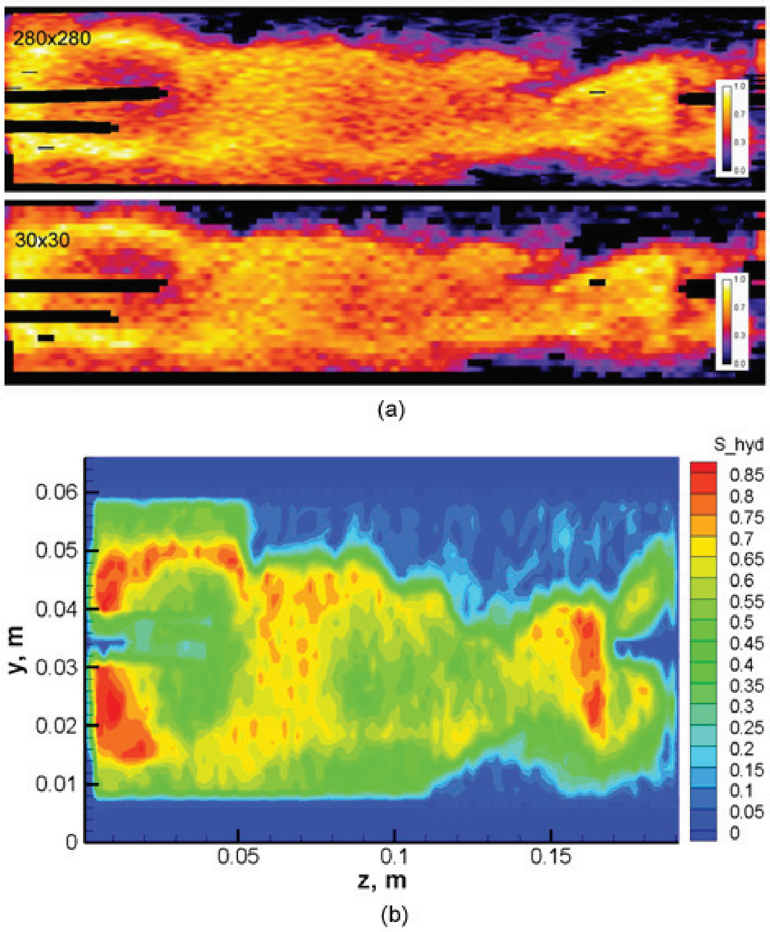
Figure 2: CT images showing distributions of methane hydrate (in yellow) synthesized at four separate events in a sand pack at 8° C and 8.27 MPa.

generation of 3-D heterogeneous porosity/saturation input for numerical simulations of reservoirs, and ultimately the delivery of more accurate predictions on gas production potentials and economic viability of a methane hydrate reservoir as an energy source.

Suggested Readings

Seol, Y., and T.J. Kneafsey, 2009. X-ray computed-tomography observations of water flow through anisotropic methane hydrate-bearing sand Journal of Petroleum Science and Engineering 66 (2009) 121–132

Kneafsey, T. J., Y. Seol, G. J. Moridis, L. Tomutsa, and B. M. Freifeld, 2009. Laboratory measurements on core-scale sediment and hydrate samples to predict reservoir behavior, in T. Collett, A. Johnson, C. Knapp, and R. Boswell, eds., Natural gas hydrates—Energy resource potential and associated geologic hazards: AAPG Memoir 89, p. 705–713.



(a)

(b)

Figure 3: Cross-section of laboratory-synthesized hydrate-bearing sample and the down-sampled image (a) and a numerical mesh that uses the initial hydrate saturation directly from the CT data (b)

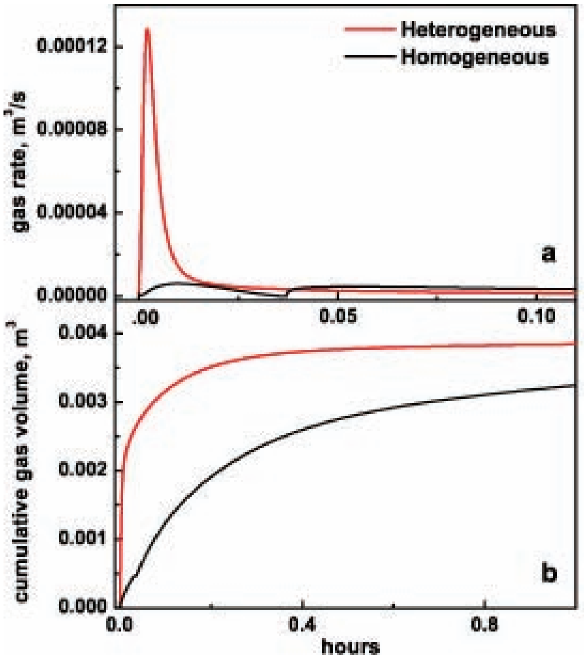


Figure 4: Rates of gas production (a) and cumulative volumes of gas (b) produced in homogeneous and heterogeneous cases.

RELATIVE GAS VOLUME RATIOS FOR FREE GAS AND GAS HYDRATE ACCUMULATIONS

By Ray Boswell, National Energy Technology Laboratory, Tim Collett, United States Geological Survey, Brian Anderson, National Energy Technology Laboratory / West Virginia University, and Carolyn Ruppel, United States Geological Survey

Gas hydrate is widely believed to represent a "compressed" or efficiently-packed form of natural gas, implying that gas hydrate is uniformly more energy dense than free gas accumulations at comparable depths. As first demonstrated by Barth (2005) for the deepwater Bering Sea, this is not necessarily the case. Here we explore this relationship for a range of gas hydrate settings that have been the focus of resource-related exploration and characterization.

The commonly cited "energy density" ratio for methane hydrate is 164:1, indicating that 164 unit volumes of methane at standard pressure (1 atm) and 0° C will be released from 1 unit volume of methane hydrate (assuming 96% of all cages are occupied by gas molecules). In the subsurface, this 164:1 ratio is largely independent of depth because gas hydrate is nearly incompressible at the pressures where gas hydrate is stable on Earth. However, the same is not true for conventional natural gas accumulations. In the case of methane vapor, the ratio of the volume of gas held at a given depth to the corresponding volume that would be released at the surface ranges greatly and is primarily governed by gas compression due to pressure, with additional complexities related to temperature.

The figure shows a comparison of the 164:1 methane density for gas hydrate with the changing energy density as a function of depth for "free"

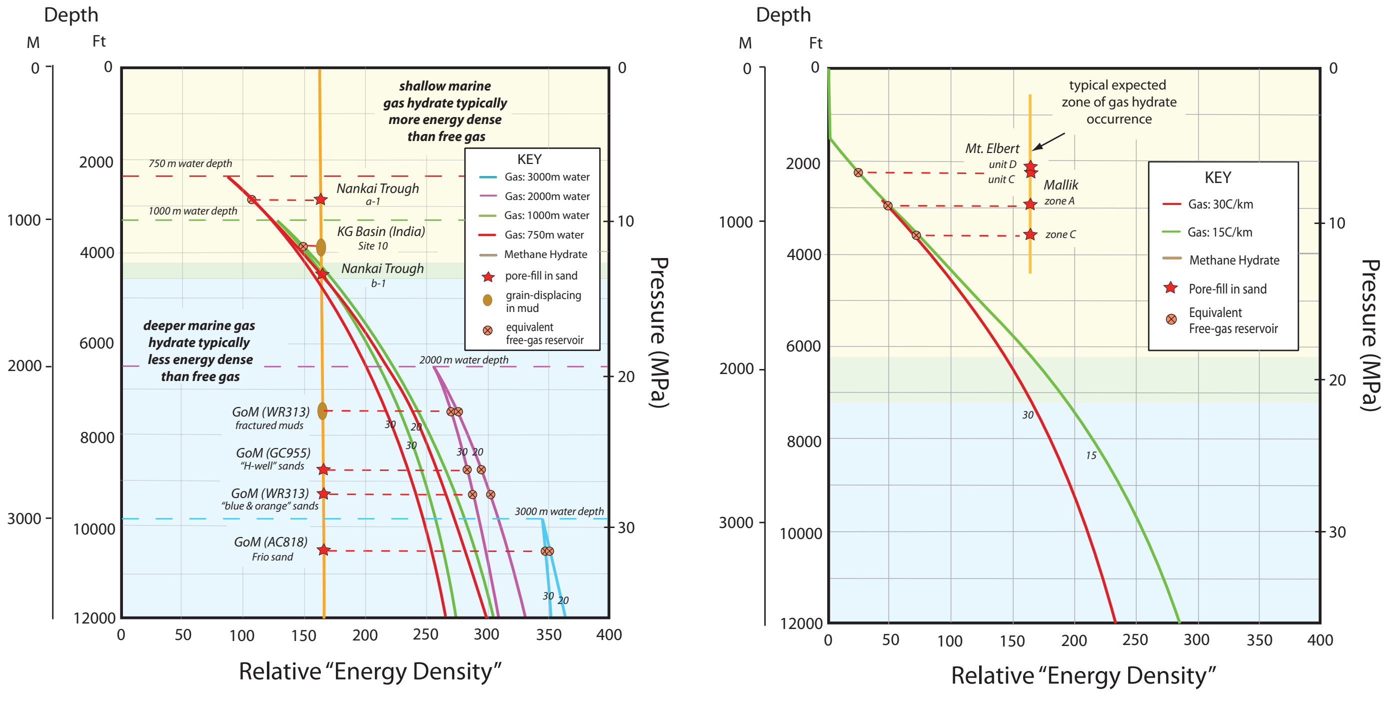


Figure 1: Comparison of energy density for free gas and gas hydrate deposits in marine (left) and permafrost (right) settings. "Relative Energy Density" refers to the ratio of gas held within a unit volume at surface conditions versus at depth. For gas hydrate, this ratio is ~1:164 and largely independent of depth. For gas, this ratio is 1:1 at the surface and increases with depth in response to pressure and temperature. Numbers plotted on the curves ("30", etc.) refer to thermal gradients in ° C/km.

gas accumulations. In the figure on the left, free gas density calculated using the Peng-Robinson equation of state is shown for three water depths and for two representative geothermal gradients. Gas hydrate is shown as the nearly vertical line at a value of 164, with well-documented sub-seafloor gas hydrate accumulations indicated for reference. This figure shows that, assuming hydrostatic pressure gradients, gas hydrate and free gas accumulations have approximately equal "energy density" (energy content per unit volume) at a depth of ~4000 ft below sea-level. In other words, at that total depth relative to sea-level, a 100 ft-thick hydrate accumulation holds as much gas as a 100 ft-thick free gas accumulation, assuming that the two have the same reservoir properties and saturation. Above this depth, gas hydrate is more energy dense, and it becomes relatively more energy dense at shallower depths, ultimately being 164 times as energy dense as free gas at the surface if the hydrate is maintained at stable pressures. At depths of greater than ~4000 feet below sea level, free gas is more energy dense in the marine environment. At present, one of the deeper well-documented marine gas hydrate occurrence is within the Frio sand in Alaminos Canyon block 818. This deposit lies at the base of the gas hydrate stability zone approximately 1,500 feet below the seafloor in just over 9,000 feet of water (see Boswell *et al*., 2009). At this location, methane gas is not compressed within the gas hydrate structure relative to how it would reside in a free-gas reservoir under the same conditions; instead, the hydrate lattice actually works to keep the molecules farther apart than they would be in the free state, therefore lowering the energy density. If this deposit were to be shifted out of hydrate stability conditions without changing its pressure, the released gas would further compress by roughly a factor of two in response to the ambient pressure, thereby significantly reducing the overall potential volume expansion of the pore fluids (including both gas and water, see table). In contrast, gas hydrates at the *B-1* location in the Nankai trough (Kurihara *et al*., 2010) reside very close to the depth at which a gas hydrate and a comparable free-gas reservoir would have roughly equivalent energy densities. Other shallower gas hydrates, such as those in the Nankai *A-1* location or at Site 10 in the Krishna-Godavari basin (Collett *et al*., 2006) are characterized by gas hydrate energy densities that are significantly greater than a free-gas accumulation would be at that depth.

The figure on the right shows similar information for the two best characterized permafrost-associated accumulations, the Mount Elbert site (Alaska: Boswell *et al*., 2008) and the Mallik site (NW Canada: Dallimore *et al*., 2005). At these settings, STP conditions do not exist at the surface, depressing the energy density curves for free gas downward with relation to pressure. In addition, sediment temperatures are higher at shallower absolute depths relative to the surface than in the marine cases due to the lack of a thick overlying water column. As a result, temperatures will exceed those suitable for gas hydrate formation well above the "cross-over" point between free gas and gas hydrate energy density. Therefore, onshore permafrost-associated gas hydrate accumulations can always be considered more energy dense than an equivalent free gas accumulation at the same depth.

The gas volume ratio comparisons have important implications for understanding the potential impact of gas hydrate dissociation, whether natural or induced. Most critically, the nature of the geomechanical and hydraulic response of hydrate-bearing sediments to *in situ* gas hydrate dissociation will differ for shallow and deep reservoirs. In shallow marine and in permafrost settings, there will be significant volume expansion of the fluid (gas and water) accompanying dissociation, leading to pressure build-up and potential fracturing under thermally-induced dissociation conditions, unless there are clear pathways for fluid and gas release (Santamarina and Jang, 2009). As shown in the table, the hypothetical change in fluid volumes (assuming *in situ* conversion from gas hydrate to free gas and water at unchanging pressure) declines significantly with burial depth and pressure.

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Example location	Gas Hydrate Energy Density	Energy Density of Comparable Free Gas	Potential Volume Change in Fluids (Gas + Water)
Mount Elbert C	164	25	7.36 x
Mallik Zone A	164	70	3.14 x
Nankai Site A-1	164	105	2.36 x
Nankai Site B-1	164	164	1.80 x
WR313 Orange Sand	164	300	1.35 x
AC 818 Frio Sand	164	350	1.27 x

Table 1: Comparison of energy density (as defined above) between comparable gas hydrate and free gas reservoirs. Right hand column indicates potential volume change of pore fluids for in situ *conversion of gas hydrate to free gas and water at unchanging pressure.*

THE ROLE OF METHANE HYDRATES IN THE EARTH SYSTEM: `BURPS OF DEATH´ OR SEDUCTIVE IRRELEVANCE?

By David Archer, University of Chicago

This is the title of one of the many sessions on methane hydrates that will be presented at the Fall AGU meeting in San Francisco this December. Methane hydrates have been invoked as major players in climate and carbon cycle variations in the deep past, such as the Paleocene/Eocene thermal maximum (PETM) event 55 million years ago, and they loom large in the awareness of the public today with regard to their potential impact on future climate change. But, as reviewed in a new *Perspectives* piece in *Science* by Richard Kerr, the perception of methane hydrate ice often has too much fire in it.

The trouble with methane as the culprit in the PETM is that the fingerprints just don't match. The amount of carbon indicated by the carbon isotopic excursion, if it came from –60 $^{o}/_{oo}$ biogenic methane, wouldn't be enough to drive the warming, as indicated by the oxygen isotopes. One possibility is that the climate sensitivity of the Earth was much higher than it is now, but the Paleocene was an ice-free world, and the lack of an ice/albedo feedback would tend to make the climate less responsive to CO_2 then than today, not more sensitive. The easier explanation is that the carbon was less isotopically labeled, like –20 $^{o}/_{oo}$ organic matter, say from permafrost peats. The total carbon release would be higher, more neatly explaining the warming.

In the present-day, there is definitely methane escaping from lakes and from surface and shallow sub-sea sediments, particularly in the Arctic. From the lakes, the methane could be coming from decomposing organic matter rather than hydrates, but that makes little difference to the prognosis for a carbon cycle or methane feedback to anthropogenic climate change. And methane sources from the ocean are small (less than 20 Tg/y), essentially negligible in the face of much higher fluxes from natural and artificial wetlands and other sources (roughly 440 Tg/y). While permafrosts and hydrates have a huge potential to amplify the human impact on Earth's climate, they will probably do so slowly, over centuries, leading to an increase in the ongoing methane concentration of the atmosphere but not a game-changing factor-of-100 spike in atmospheric methane which would occur if all the methane in gas hydrate destabilized all at once.

To better understand the implications of methane hydrate for carbon cycling and global climate over various timescales, Bruce Buffett, Patrick McGuire and I are working on a two-dimensional model of the deep sedimentary methane cycle, on the basin size scale, to use as another tool to understand the stability of the hydrate reservoir. The SpongeBOB model integrates the transport of solid and fluids with geochemical reactions of the deep biosphere within a growing continental margin sediment complex. There are critical unknowns in the system that our attempt to reverse-engineer it will reveal, such as a necessity for gas migration in the very deep sediment column, and the sensitivity of methane production to temperature and carbon age.

A sediment transport scheme in the model sorts the sediment and deposits it across the continental margin, tuned to reproduce the progressing clinoform character of sediment accumulation. Fluid flow is induced by the accumulating mass of sediment. We show results from an accelerated simulation that took 1 million years, gearing up for final an accelerated simulation that took 1 million years, gearing up for final production runs that will span 200 million years and take 200 times longer to run. The Darcy flow (Figure 1) is upward relative to individual sediment grains, but relative to the sediment-water surface the "total flow" (Figure 2) in most places is downward, reflecting burial of porewater by sediment accumulation, except in the region inshore of the sediment depocenter, where sediment accumulation is decreasing through time due to lack of accommodation space, giving time for the pore water to drain. One-dimensional models of hydrate formation find the fluid flow relative to the sediment-water interface to be a primary controlling factor in hydrate accumulation.

Organic carbon concentrations in surface sediments in the model are based on measurements from the Mid-Atlantic bight, but once buried, the rate of conversion to methane and DIC is not very well constrained. Respiration rates increase with warmer temperature, up to a maximum of 50° C or so. This factor alone would tend to produce methane fairly deeply in the sediment (Figure 3). The reactivity of organic carbon in nature has also been observed to scale inversely with the age of the carbon, in that fresher stuff reacts more quickly. When we also include this scaling in our model respiration rates, the predicted depth of methanogenesis in the sediment column gets much shallower (Figure 4). One constraint on organic carbon age may be the radioactive element iodine-129, produced by cosmic rays in the atmosphere and decaying with a half-life of 17 million years. Radioiodine is incorporated into organic matter at close to the atmospheric ratio, but it decays before the iodine is released to the pore water when the organic matter decomposes. The abundance of radioiodine in pore waters may reveal the age of the decomposing carbon (Figure 5).

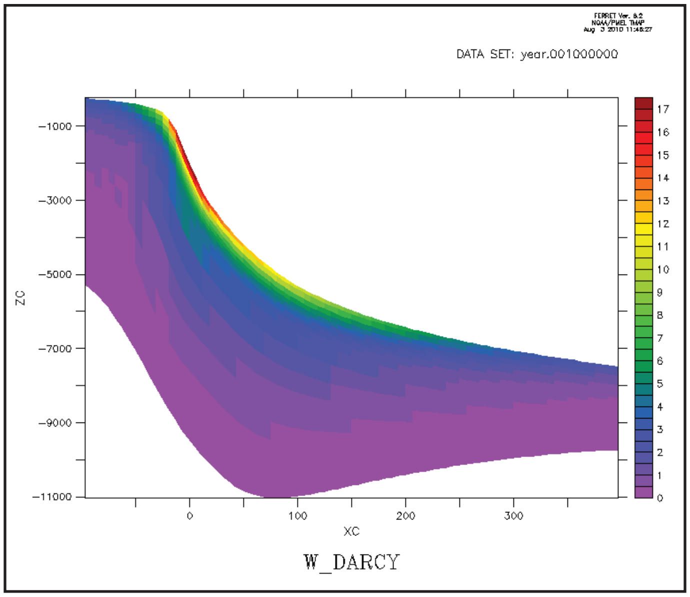


Figure 1: Vertical fluid flow relative to sediment grains (Darcy flow), in millimeters per year.

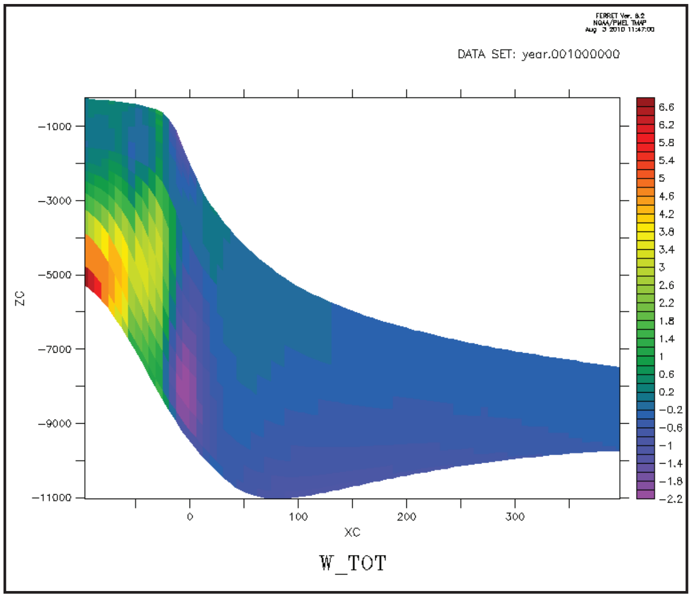


Figure 2: Vertical fluid flow relative to the sediment-water interface, including the effect of pore fluid burial by sediment accumulation, in millimeters per year.

When we dial these processes in sufficiently to grow a continental margin that looks like the Atlantic margin of the United States (a well-studied and simple first case), we will be in a position to "clobber" the resulting solution with a warming ocean as an upper boundary condition, in the hopes that the processes required in the model to reproduce the present-day can be used to predict the future; the extent and, perhaps more reliably, the timing of a future large-scale methane release to the ocean.

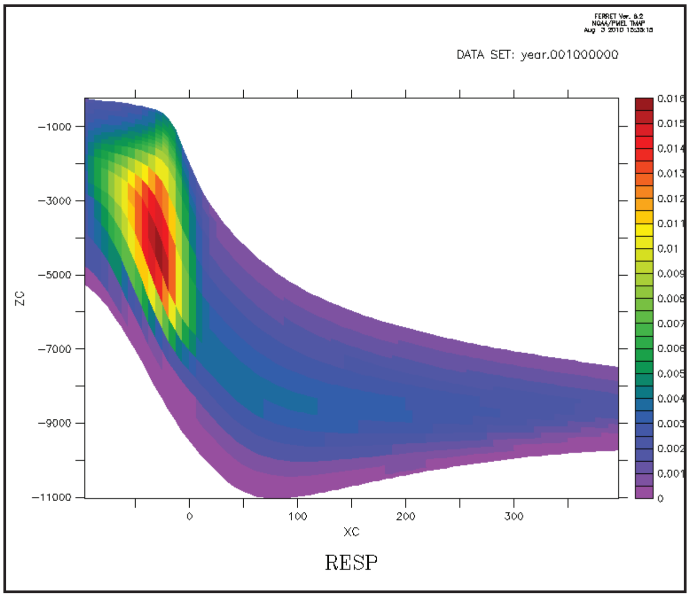


Figure 3: Respiration rate in the sediment column according to temperature scaling only.

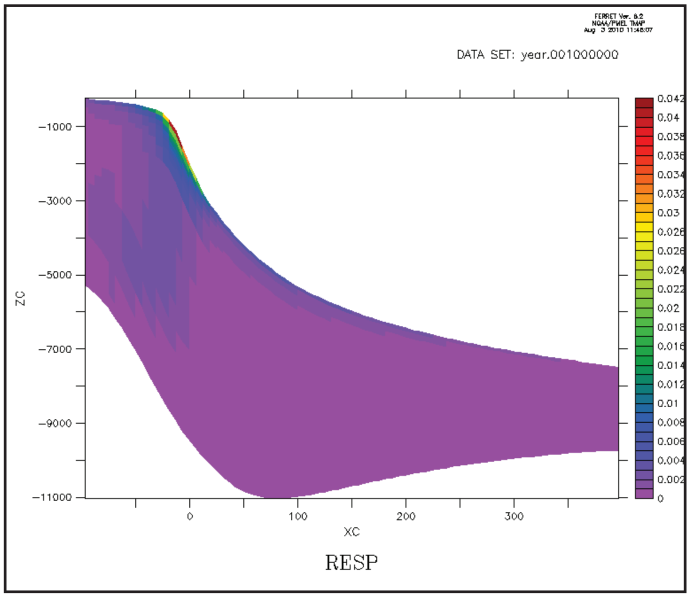


Figure 4: Respiration rate in the sediment column using both temperature and organic carbon age scaling.

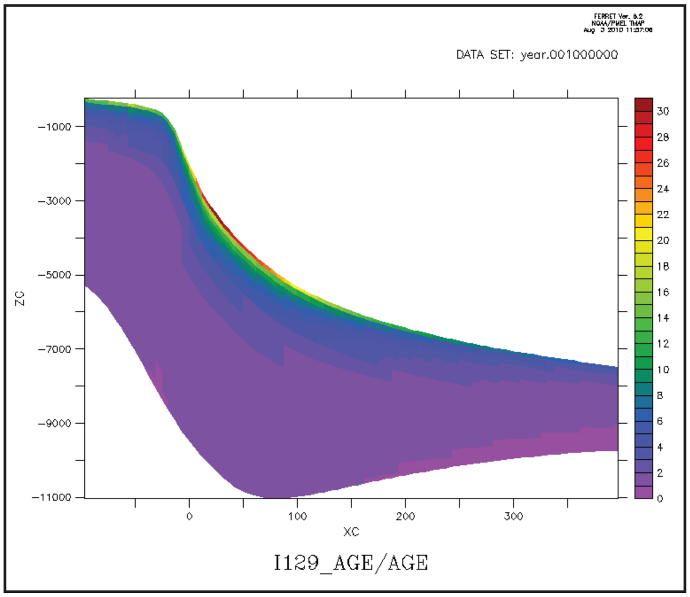


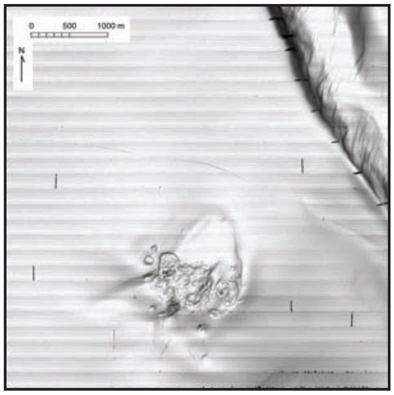
Figure 5: Ratio of I-129 age in the porewater to the deposition age of the solid sediment.

ANNOUNCING AN INTER-LABORATORY COMPARISON PROJECT TARGETING PHYSICAL PROPERTY MEASUREMENTS

In the laboratory, specimen preparation, sample-handling and measurement procedures all impact the physical properties of hydrate-bearing sediments. For samples brought to the laboratory from the field, laboratory effects can compound the physical property alterations that occur during sample recovery from *in situ* conditions. To better understand laboratory-induced effects, an Inter-laboratory Comparison Project (ILCP) has been launched among more than a dozen research institutions worldwide. The ILCP has been modeled after the successful International Methane Hydrate Reservoir Simulator Code Comparison study, click here. Initially, the ILCP will address acoustic wave velocity measurements, focusing on a series of five tests to determine measurement uncertainties. Wave velocity measurements will be made on dry sand, water-saturated sand, partially water-saturated sand, ice-bearing sand, and hydrate-bearing sand. To reduce sediment-related uncertainties, the ILCP is distributing F110 sand from a single batch to each of the participants, and the sample fabrication, measurement pressures, temperatures and pore content are specified for each test.

Measurement results will be obtained separately by each research group, and then shared with all participants on January 1, 2011. The initial test results will be combined and analyzed by the ILCP, with results and conclusions to be presented at the International Conference on Gas Hydrate in July, 2011. The ILCP is open to interested researchers with access to suitable laboratory instrumentation. If you wish to join, please contact any of the project chairs:

- William Waite, U.S. Geological Survey: wwaite@usgs.gov
- Carolyn Koh, Colorado School of Mines: ckoh@Mines.edu
- J. Carlos Santamarina, Georgia Institute of Technology: carlos.santamarina@ce.gatech.edu



View of Mississippi Canyon block 118 showing the detail of Woolsey Mound

Underwater Feature Named in Mississippi Canyon 118

The U.S. Board on Geographic Names recently named an undersea feature located in Mississippi Canyon 118 as Woolsey Mound after the late Dr. James Robert (Bob) Woolsey. The feature located at 28°51'N, 088°29'W is in the Gulf of Mexico Hydrates Seafloor Observatory. Dr. Woolsey was the lead on all scientific interpretations at the site and was considered an expert on the feature.

Prior to his passing, Dr. Woolsey was a research professor at the University of Mississippi and also served as Director of the Mississippi Mineral Resources Institute, and the Center for Marine Resources and Environmental Technology. For more about Dr. Woolsey, please see the Spotlight in Research in the Fall 2008 issue of the *Fire in the Ice*.

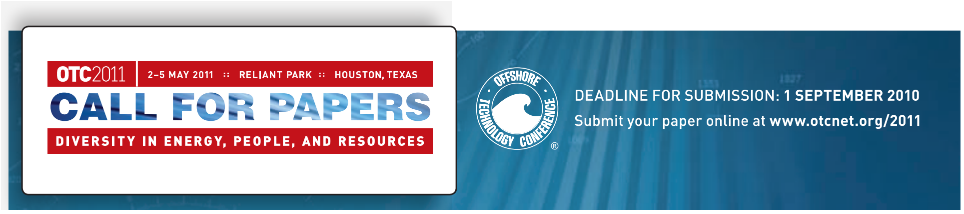
Laura Brothers

University of Maine Student Selected as the Newest Methane Hydrate Research Fellow

Laura Brothers, a PhD candidate at the University of Maine, was recently named as the recipient of a Methane Hydrate Research Fellowship.

Following completion of her PhD in August 2010, Laura will be advised by Carolyn Ruppel and stationed at the US Geological Survey Woods Hole Sciences Center. There she will research permafrost degradation and potential hydrate dissociation in nearshore Beaufort Sea. Through the reprocessing and integration of existing industry geophysical datasets she aspires to delineate the seaward extent and, potentially, the thickness of subsea permafrost in the nearshore Beaufort Sea and thereby identify the likely location of the shallow offshore hydrate degassing front.

Laura graduated from Bryn Mawr College in 2001 with a degree in Sociology and a minor in Geology. She completed her bachelors in Geology a year later at West Virginia University. She combined her societal and scientific interest in a dual masters program for Marine Policy and Oceanography at the University of Maine. Her integrated thesis focused on sediment transport in a heavily engineered embayment. After completing her Masters' program in 2006 she continued on for a PhD in Earth Sciences and studied nearshore shallow gas and seep feature dynamics in previously glaciated embayments.



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Call for Abstracts: 2010 AGU Fall Meeting in San Francisco, California

The 2010 Annual Meeting of the American Geological Union will be held 13-17 December, 2010, in San Francisco, California. The meeting will feature in hydrates in both poster and oral sessions, including:

- Scientific Session B48: Geochemical Signals of Early Diagenesis,
- Scientific Session B53: The Role of Methane Hydrates In the Earth System: “Burps Of Death” Or Seductive Irrelevance?
- Scientific Session NG20: Multi-Phase Flow: An Interdisciplinary Challenge
- Scientific Session NS03: Biogeophysics: Towards Modeling of Geophysical Signatures of Microbial Processes in the Earth
- Scientific Session OS13: Fluid Flow and Gas Hydrates in Continental Margins
- Scientific Session T03: Polar Heat Flow

Abstract submission for these sessions is now open and will close on 2 September, 2010. Instructions for submitting an abstract can be found at http://www.agu.org/meetings/fm10/program/abstract_submissions.php

Call for Abstracts: 2011 AAPG/SEPM Annual Meeting in Houston, Texas

The 2011 Annual Meeting of the American Association of Petroleum Geologists and Society for Sedimentary Geology will be held 10-13 April, 2011, in Houston, Texas. The meeting will include both poster and oral sessions on a wide variety of topics with hydrates being featured under “Theme 4: Challenged Resource Frontiers.” This session will cover multidisciplinary aspects related to the characterization, assessment, and understanding of gas and oil resources from less-than-conventional reservoir systems in both the U.S. and the international arena. Abstract submission for this session is now open and will close on 23 September, 2010. Instructions for submitting an abstract can be found at http://www.aapg.org/Houston2011/

Gas hydrates session at the CURIPC 2010 – Calgary Canada

The Canadian Society for Unconventional Gas (CSUG) and the Society of Petroleum Engineers (SPE) are co-sponsoring the first Canadian Unconventional Resources and International Petroleum Conference (CURIPC), 19-21 October, 2010 in Calgary, Alberta, Canada. This conference will include a session on the research and development of gas hydrates as a potential clean energy resource for the future. This session will highlight the state-of-the-art of gas hydrates science and engineering in Canada and around the world, and will consider a wide range of issues related to the exploration and future commercial production of gas hydrates. Details of the conference, including sub-categories of interest within the gas hydrate session, can be found at http://www.spe.org/events/curipc/2010/.

Gulf of Mexico Hydrates Research Consortium Fall Meeting Scheduled

The fall meeting of the Mississippi Mineral Resources Institute/Center for Marine Resources and Environmental Technology (MMRI/CMRET) Gulf of Mexico Hydrates Research Consortium will be held on the 26-27 October, 2010 at the E. F. Yerby Center on the campus of the University of Mississippi. Meeting topics will include project updates, reports on recent deployments at Mississippi Canyon block 118 (MC 118), cruise planning for 2011, and discuss proposals and prospective oil spill work at MC 118. Meeting participants that have received project funding or participated in a recent cruise funded by the Consortium are asked to come prepared to report their findings. For additional information contact Carol Lutken, Interim Director of MMRI/CMRET, at cbl@olemiss.edu.

International Symposium on Methane Hydrate Resources: From Mallik to the Nankai Trough

Japan Oil, Gas and Metals National Corporation (JOGMEC) and Natural Resources Canada (NRCan) will host the International Symposium on Methane Hydrate Resources: From Mallik to the Nankai Trough on 15-17 November, 2010 in Tokyo, Japan. The primary goal of the symposium will be to provide an overview of recent research achievements by Japan to characterize methane hydrates in the Nankai Trough area, and by Canada and Japan to quantify the production response of permafrost hydrates of the Mackenzie Delta. National presentations by other leading gas hydrate programs will also be presented, providing a venue for discussions about future international research and development priorities. In this conference, oral and poster presentations will present a summary of the recent achievements and accomplishments of the MH21 Research Consortium and Japan-Canada Joint Study of the Mallik site. For more information on poster submissions and to register, please visit http://www.mh21japan.gr.jp/english/

The 7th ICGH

The United Kingdom organising committee welcomes colleagues from across the globe to Edinburgh, Scotland, for the 7th International Conference on Gas Hydrates. Held every three years, ICGH is a very special event in that it encompasses all aspects of hydrate research; from fundamental physical properties, applied flow assurance, to global climate change, ICGH caters equally to both academia and industry.

E I
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Venue

Scotland; the land of mountains, misty glens and ancient castles, is steeped in history. ICGH7 will be held in Scotland's capital city, Edinburgh, home of the Famous Edinburgh Festival, at the International Conference Centre (EICC). Located in the heart of the city beneath the ramparts of Edinburgh Castle, the modern, purpose built EICC is an ideal venue for this prestigious and popular event.

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENTAL RESEARCH COUNCIL

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Conference Programme

Abstracts welcomed on all aspects of gas hydrates, including:

Gas Hydrate Fundamentals
Phase equilibria, kinetics, physical & thermodynamic properties, modelling, molecular dynamics

Energy & Novel Technologies
Gas separation & storage, CO_2 capture & sequestration, natural hydrate gas production, desalinisation, refrigeration...

Natural Gas Hydrates
Origins & distribution, geochemistry, fluid flow, mud volcanoes & gas seeps, biology, ecology, geophysics, seafloor stability, drilling & production hazards

Extraterrestrial gas hydrates
Planetary bodies & comets

Special Sessions:

Hydrates & Climate Change
Role of gas hydrates in past and future climate change

Hydrates & Flow Assurance
Equilibria, thermodynamics, LDHIs, cold flow, prediction, monitoring, remediation

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GRAHAM WESTBROOK

Professor of Geophysics
University of Birmingham

When he is not busy teaching, writing, or performing research, Graham and his wife can be found in the company of their eighteen-year old black and white cat or playing tennis "not particularly well, but it helps keep me fit."

GRAHAM WESTBROOK

Graham Westbrook's interest in geophysics first became aroused when he was training as an officer in the Royal Navy aboard the survey ship *HMS Hecla*. There he met Martin Bott, Professor of Geophysics at the University of Durham, who was gathering seismic data off southwest England for crustal scale refraction experiments.

After leaving the navy to attend the University of London to obtain his Bachelor of Science in Geology, Graham worked for his PhD at the University of Durham, with Martin Bott as his supervisor, on the structure of the crust and upper mantle of the Lesser Antilles island arc and the accretionary complex along its eastern margin.

Graham is currently Professor of Geophysics at the University of Birmingham in the UK, and is also a visiting professor at the National Oceanography Centre in Southampton and a longtime collaborator with researchers at Ifremer in France. Prior to his current position, he taught and researched at the universities of Durham and Keele, and he has also spent time at Lamont-Doherty Earth Observatory, University of California at Santa Cruz, and l'Institut Universitaire Européen de la Mer in France.

His interest in gas hydrate came about when, "in the late 1980s, I started using the depth of the BSR to estimate heat flow from accretionary wedges at convergent plate boundaries," notes Westbrook. "My participation in ODP Leg 146, as co-chief with Bobb Carson in 1992, intensified my interest in hydrates." It was during this leg that, "we initiated, in an *ad hoc* way, the routine measurement of core temperature as an indicator of the presence of hydrate. On the core deck of the *JOIDES Resolution*, Miriam Kastner remarked on how cold the sample she was holding felt. This prompted me to measure the variation of temperature in the core that had just been retrieved, using a lab thermometer," says Graham. "Subsequently, Jean-Paul Foucher calculated the cooling that could be expected from hydrate dissociation and Juichiro Ashi took core-temperature measurements for the rest of the drilling leg. This eventually led, after development by others, to the infrared thermal scanning of cores."

He recalls that among his more unusual activities was the unorthodox deployment of an array of ocean-bottom seismometers by lowering them on a cable, using acoustic navigation, to improve the precision of positioning, which enabled the high-resolution 3D seismic tomographic definition of a large hydrate accumulation offshore Norway, in 2006. He comments, however, that "the discovery of plumes of methane gas bubbles coming from the seabed at the margin of the gas hydrate stability zone offshore Svalbard in the Arctic two years ago was almost outshone as an experience by my first full view of the Aurora Borealis in all its glory, with glowing curtains of light hanging in the night sky."

For Graham, one of the most stimulating aspects of hydrate research is, "its multi-disciplinary nature and the opportunities that it offers for learning from fellow researchers with different scientific backgrounds and skills," he says. "It is particularly satisfying when new combinations of techniques yield discoveries that, while thought possible, were not certain to be achieved."

As to key questions facing hydrate researchers, Graham believes that, "From the point of view of hydrate's relevance to climate change, it is important to know how widely distributed hydrate is in the margins of the Arctic ocean, where it is most sensitive to global warming. More generally, there is much that we need to learn about how gas migrates though the hydrate stability zone."