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Fire in the Ice

Vol. 8, Iss. 1 Methane Hydrate Newsletter

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Safe Drilling in Gas-Hydrate Prone Sediments: Findings from the 2005 Drilling Campaign of the Gulf of Mexico Gas Hydrates Joint Industry Project (JIP)

By Richard Birchwood, Sheila Noeth (DCS Geomechanics Group, Schlumberger), & Emrys Jones (Chevron)

In 2005, the DOE-Chevron Gas Hydates JIP conducted a drilling, logging, and coring expedition designed to address concerns related to the safe drilling of deepwater oil and gas wells through gas-hydrate bearing strata.

Figure 1: The Chevron-led Gas Hydrate JIP's 2005 Expedition aboard the semi-submersible Uncle John investigated safety issues for drilling through gas hydrate-prone fine-grained sediments.

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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 two sites selected provided opportunities to test different geological settings for the fine-grained sediments typical of those found throughout the Gulf. Wellbore stability modeling, as calibrated by the JIP drilling results, indicate that gas hydrates as they commonly occur in the fine-grained sediments of the Gulf of Mexico can pose hazards to drilling, but these hazards can be effectively managed.

As for any other hydrocarbon, good drilling practices that promote wellbore stability are essential for safe and cost effective exploitation of gas hydrates reserves. The use of properly weighted drilling mud, washout mitigation procedures, adequate hole cleaning, and identification of shallow hazards, are standard measures taken by industry when drilling in environments typical of those in which gas hydrates can be found. However many unique drilling hazards have been associated with gas hydrates. These include:

(a) Loss of well control due to the influx of gas generated by drilling-induced dissociation,

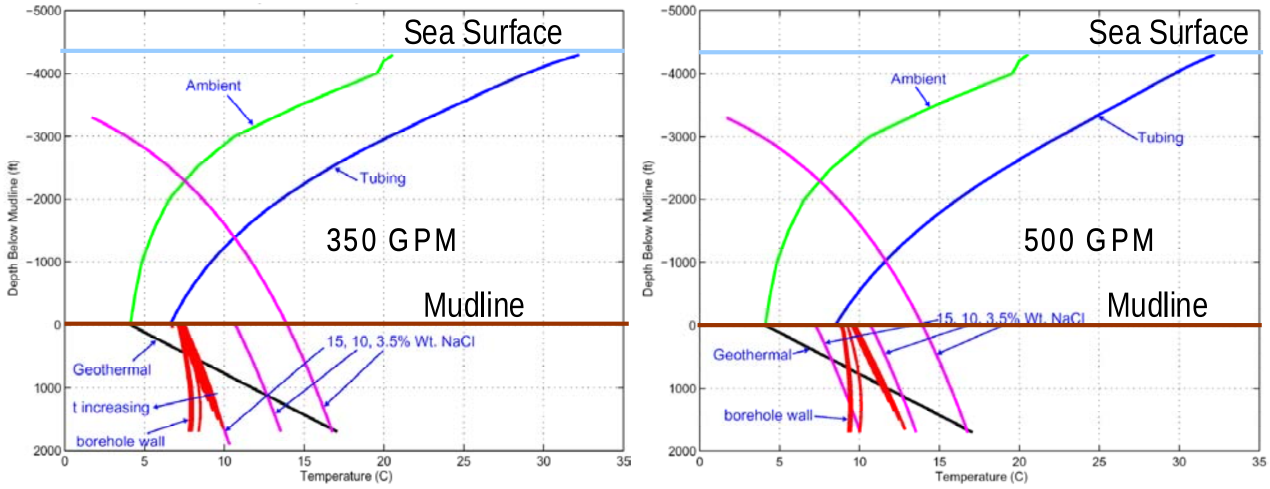
(b) Borehole failure caused by the loss of formation competence accompanying dissociation, and

(c) Loss of well control when drilling into overpressured gas below the hydrate stability zone.

While these hazards may exist, recent experience suggests that they can be addressed through proper planning aimed at preventing gas hydrate dissociation and avoiding gas kicks due to an influx of free gas. In support of the 2005 Gulf of Mexico drilling campaign of the Chevron Joint Industry Participation Project (JIP) co-sponsored by the U.S. Department of Energy (Figure 1), extensive pre-drill planning was undertaken to determine the locations of overpressured zones and the conditions under which gas hydrates would dissociate during drilling. Temperature simulations indicated that controlling the circulation rate was key to minimizing the thermal disturbance to the formation caused by drilling.

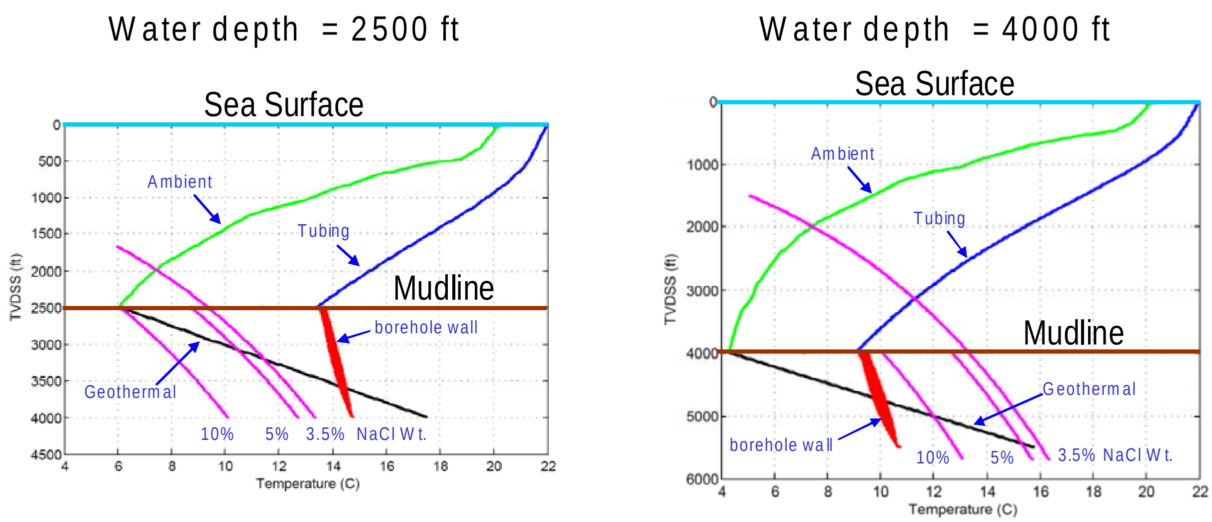
Figure 2(a) shows the results of drilling with a rate of penetration (ROP) of 100 ft/hr while maintaining a constant circulation rate of 350 gal/min. The water depth used in the simulations was 4300 ft; which was typical of the JIP drill sites. For the standard seawater salinity of 3.5% NaCl by weight, the temperature at the borehole wall is much less than the methane hydrate dissociation temperature, so there is little risk of dissociation. Figure 2(b) shows that increasing the circulation rate to 500 gal/min exacerbates dissociation for two reasons. First, as the circulation rate increases, the residence time of the fluid in the ocean section of the drillpipe decreases, resulting in a reduction of heat dissipated to the ocean. Second, higher flow rates lead to increased viscous heating within the drillpipe, particularly around the convergent zone at the bit nozzle.

Based on these results, a low circulation rate was maintained during the drilling campaign. Post-drill modeling and analysis of LWD temperatures suggested that boreholes remained sufficiently cool to prevent the methane hydrate from dissociating. This occurred despite the fact that unchilled seawater without chemical additives to inhibit dissociation was used as the drilling fluid. However, simulations also suggest that special treatment of drilling fluid may be necessary in certain cases. Figure 3 contrasts the thermal regime in 2500 ft of water with that in 4000 ft of water. In the former case, the gas hydrate stability zone extends some 700 ft below the mudline and a circulation rate as low as 350 gal/min is insufficient to prevent the borehole wall temperature from significantly exceeding the methane hydrate dissociation temperature (Figure 3a). In such cases, it may be necessary to pre-treat the drilling fluid.



(a) (b)

Figure 2: Temperatures associated with drilling at ROP of 100 ft/hr for 17 hours and then circulating for 2 hours. Water depth is 4300 ft. Temperatures in ocean (green), tubing (blue), virgin sediment (black) and at borehole wall (red) shown along with methane hydrate phase stability boundaries (magenta) computed at various sodium chloride concentrations. Borehole wall temperature profiles, which are shown at different times, curve sharply to the left during circulation. (a) Circulation rate of 350 gal/min. (b) Circulation rate of 500 gal/min.



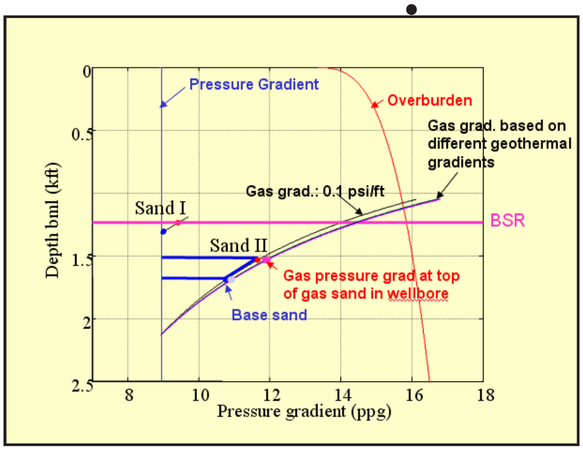
(a) (b)

Figure 3: Temperatures associated with drilling at ROP of 80 ft/hr for 19 hours. Circulation rate is 350 gal/min. Temperatures in ocean (green), tubing (blue), virgin sediment (black) and at borehole wall (red) shown along with methane hydrate phase stability boundaries (magenta) computed at various sodium chloride concentrations. Borehole wall temperature profiles are shown at different times and shift to the right with time. (a) Water depth of 2500 ft. (b) Water depth of 4000 ft.

During pre-drill planning, a dipping gas-bearing sand was discovered just below the BSR at the Keathley Canyon drillsite. The pore pressure at the base of the sand was estimated to be around 11 ppg. Extrapolation along the gas gradient indicated that the pore pressure was close to 12 pounds per gallon (ppg) at the proposed well intersection (Figure 4). A decision was made to avoid drilling into this potentially dangerously overpressured zone.

Problems were encountered at the Atwater Valley location but these were not gas hydrate related. Figure 5(a) shows several logs from the Atwater Valley 14 #1 well. A pre-drill wellbore stability model was used to predict the safe mudweight window for drilling (between the shear failure envelope and the fracture gradient). However the actual equivalent circulating density (ECD) that developed during drilling exceeded the fracture gradient. Consistent with the model, a pair of conjugate hydraulic fractures was observed on the image log (Figure 5b). The high ECD may have been the result of shallow water influxes or creep. The problems caused by the high ECD were managed through the use of weighted sweeps.

Figure 4: Predicted pressure in two sands below the BSR at Keathley Canyon. Pressure at well intersection in Sand I just underneath the BSR is 9.42ppg. Pressure at well intersection in Sand II is 11.66 ppg. Note the slightly higher equivalent mudweight for Sand II if gas densities based on geothermal gradients are used instead of a constant gas gradient of 0.1 psi/ft.



Washouts also occurred at connections (Figure 5b). This problem could be mitigated by minimizing the exposure of the formation to bit nozzle jets during short trips at connections. Taken collectively, these examples serve to illustrate the fact that non-hydrate related problems can cause greater difficulty than those due to gas hydrates.

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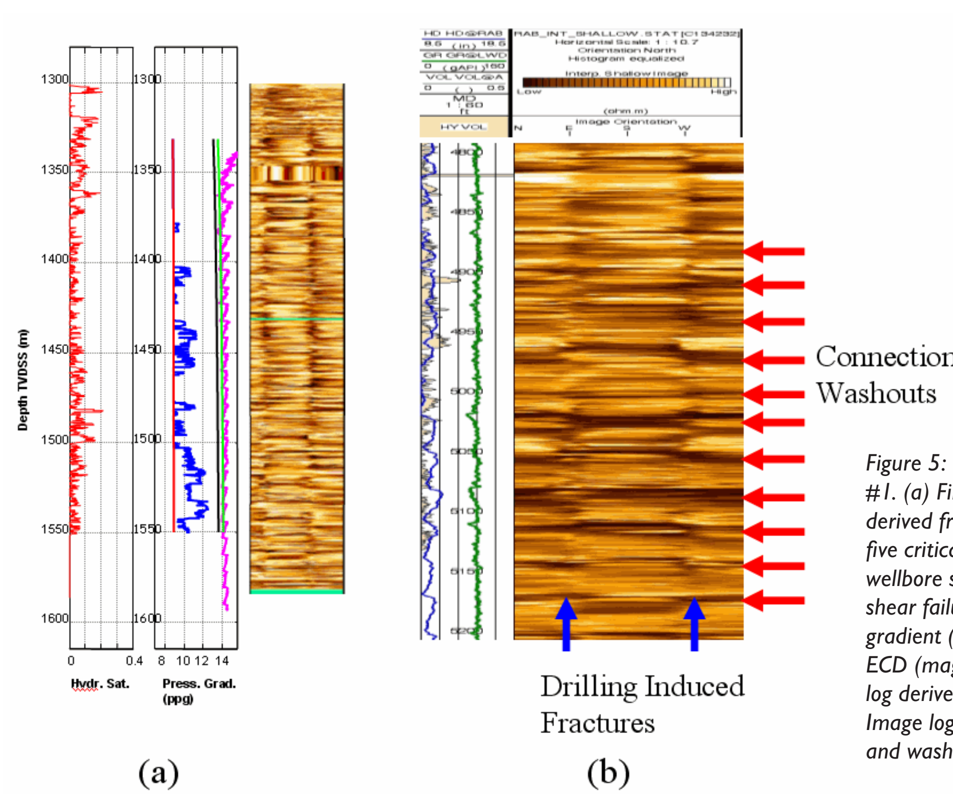

Figure 5: Logs from the well Atwater Valley 14 #1. (a) First track shows hydrate saturation derived from resistivity. Second track shows five critical mudweights associated with wellbore stability, i.e., pore pressure (red), shear failure envelope (blue), fracture gradient (black), overburden (green), and ECD (magenta). Third track contains image log derived from resistivity at the bit tool. (b) Image log showing drilling induced fractures and washouts.

Climate Change and the Global Carbon Cycle: Perspectives and Opportunities

By C. Ruppel and J.W. Pohlman U.S. Geological Survey, Woods Hole, MA*
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The relevance of methane hydrates research to broader societal themes is often framed in terms of methane's role in the global carbon cycle and its potential contribution to future climate change. To date, investigations of these fundamental issues have remained largely disconnected from applied studies focused on locating natural gas hydrate deposits, developing production technologies, and analyzing and mitigating hydrate-related geohazards. The 2005 reauthorization of the 2000 Methane Hydrate Research and Development Act provides broad latitude for better integration of applied and basic research related to methane hydrates, the carbon cycle, and climate change through its direction "to assess and to mitigate the environmental impact of hydrate degassing." This mandate includes sponsoring research that evaluates whether methane hydrate degassing triggered by either natural or anthropogenic perturbations will (1) contribute to global climate change and (2) release significant quantities of currently sequestered carbon to the ocean-atmosphere system. This article provides an overview of progress and challenges in these areas and sets the stage for future research on related issues under the auspices of the Methane Hydrate Act.

The amount of carbon sequestered in methane hydrates in marine and permafrost sediments is vast, yet uncertain, with estimates ranging from 500 to 10,000 Gt. This quantity represents 5 to 53%, respectively, of all of Earth's organic carbon not deeply buried or disseminated in the rock record. Collectively, natural gas hydrate deposits can be represented within the global carbon cycle as a capacitor (Figure 1), a dynamic reservoir that releases and takes up carbon in response to hydrologic, geologic, and global climate

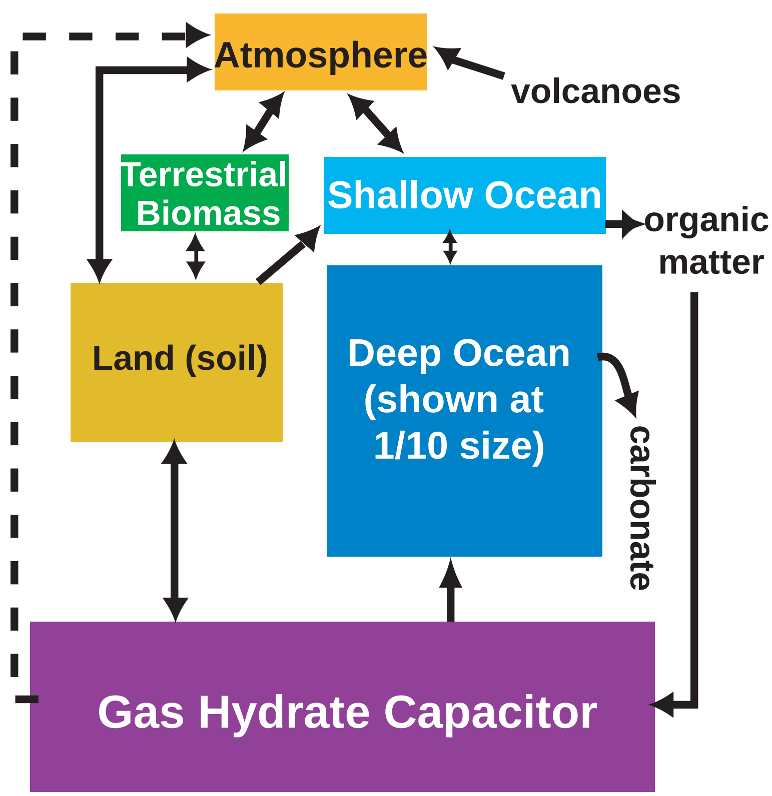

Figure 1: Schematic illustrating the global carbon cycle, excluding carbon trapped in fossil fuels and carbonate deposits and within the deep biosphere. Carbon reservoirs, except the deep ocean, are shown at the appropriate size relative to the atmosphere (765 Gt). The deep ocean would be ~50 times as large as the atmosphere if shown at the proper size. The gas hydrate reservoir is here portrayed as having 5000 Gt of carbon, which is ten times larger than the lower estimated bound and half the upper bound. Modified from Dickens (2003).

change processes acting on a range of time scales. At present, degassing of the gas hydrate reservoir is estimated to account for only 1 to 2% of annual global methane emissions. Under some global warming or hydrate production scenarios, the amount of methane released from methane hydrate deposits would increase. Methane is twenty times more potent than CO_2 as a greenhouse gas; however, methane is typically oxidized to CO_2, which is viewed as the key culprit in atmospheric warming, within about a decade. The volume and rate of present or future methane hydrate degassing are clearly potentially important, but as yet poorly constrained, variables in understanding carbon cycling and climate change.

Glaciation events lead to net recharge of the hydrate capacitor, with colder ocean and air temperatures encouraging greater sequestration of methane in permafrost and marine sediments (Figure 2a). At the same time, some loss to the capacitor probably occurs at the upper limit of marine hydrate stability, where depressurization associated with glacial period sea level lowstands can produce dissociation of the entire thickness of the gas hydrate zone in water depths of several hundred meters. During the last glacial period, submarine slides developed primarily during such sea level lowstands, which often coincided with abrupt increases in marine deposition of ice-rafted debris (Heinrich events). Compared to the vast expanse of continental margin sediments that could potentially have contained gas hydrate and experienced net recharge of the hydrate capacitor during the glaciation, the area that may have experienced degassing through slide movement or simple depressurization was probably relatively limited.

During Earth warming, temperature perturbations can cause release of methane from the capacitor through dissociation or dissolution of methane hydrates. In many cases, but not all, this methane may be emitted to the ocean-atmosphere system (Figure 2b). In permafrost zones, destabilization of methane hydrates has the potential to release methane that is rapidly conveyed to the atmosphere. In marine settings, eustatic sea level rise

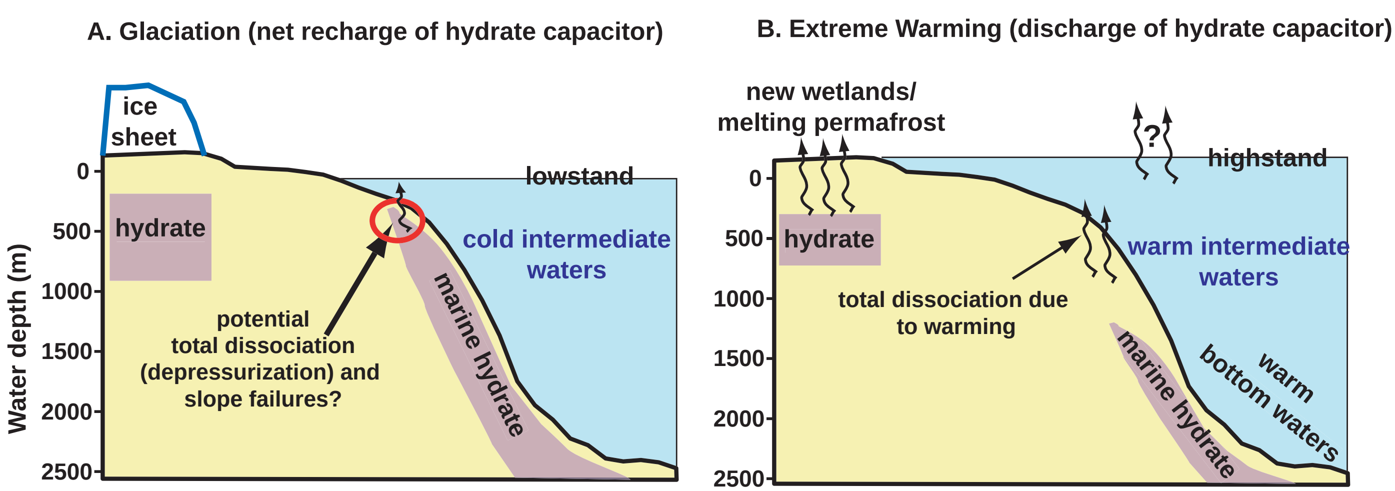

Figure 2: Schematic illustrating the possible impact of global climate change events on permafrost and marine gas hydrate reservoirs with (a) glaciation and (b) profound global warming. Minor thinning of deepwater marine methane hydrate deposits due to depressurization is not shown, and the relationship between terrestrial ice cover and permafrost-type methane hydrates is purely schematic. Part (b) illustrates global warming more profound than a typical interglacial period, where deepwater gas hydrate deposits, as well as those in permafrost zones, have thinned appreciably. Atmospheric methane could increase due to degassing of the gas hydrate reservoir and emissions from increased expanses of wetlands, particularly in areas of melting permafrost

partially offsets the destabilizing effect that ocean warming exercises on the hydrate reservoir. This pressure effect has the greatest impact on the hydrate reservoir at shallow water depths. During episodes of pronounced global warming, the outcome is certainly net degassing of at least some portion of the marine hydrate reservoir, but consequences during the more moderate warming associated with interglacials are more controversial. Open questions include the amount of methane that reaches the sediment-water or land-air interface from dissociating hydrate deposits at great depths and the proportion of methane emitted at the seafloor that eventually reaches the atmosphere. In marine settings, a critical issue is the role of microbially-mediated oxidation processes in the consumption of methane in both the shallow sedimentary section and the water column.

Much of the existing research that connects methane hydrate destabilization to episodes of global climate change focuses on events in the distant geologic past. Late Neoproterozoic (~600 Ma) cap carbonate deposits preserved in China have negative carbon isotopic signatures that have been linked to massive release of biogenic methane during degassing of gas hydrate deposits. During the Paleocene-Eocene Thermal Maximum (PETM) at ~55 Ma, foram tests also recorded a profoundly negative carbon isotopic excursion, as well as oxygen isotope fluctuations consistent with warming of the deep oceans for a period exceeding 150,000 years.

Determining whether methane hydrate degassing leads or lags the periods of most rapid global warming has proved difficult, but the high resolution climate records available for late Quaternary (roughly the last 800,000 years) hold promise. During the late Quaternary, repeated global warming events coincided with increased atmospheric methane. Kennett and others have postulated that warming of intermediate ocean waters on orbital to millennial time scales triggered rapid and massive degassing of the marine methane hydrate reservoir that, in turn, enhanced methane flux to the atmosphere and accelerated atmospheric warming. This “clathrate gun” hypothesis remains controversial for several reasons. For example, the deuterium to hydrogen ratios from methane trapped in ice cores during these warm periods are inconsistent with the injection of hydrate-derived methane into the atmosphere. In addition, non-hydrate methane sources (e.g., wetlands, Arctic lakes) cannot be fully ruled out as the source of the increased atmospheric methane during warming periods. Finally, the timing of submarine slope failures supports the clathrate gun hypothesis only for orbital, not millennial, time scales.

The dozens of numerical modeling studies examining links between methane hydrates and global climate change events have normally adopted a lag approach in which changes in temperature and pressure are deterministically ascribed and the corresponding evolution of a hydrate reservoir within homogeneous sediments monitored. Such studies provide first-order constraints on the rate of potential methane release from degassing hydrates and have demonstrated the viability of hypotheses that require degassing of a significant portion of the present-day hydrate reservoir to explain past excursions in the isotopic record. Other modeling has ignored the details of the degassing and focused instead on the atmospheric warming triggered by increased methane emissions from the methane hydrate reservoir. To date, no study has closely linked methane hydrate reservoir dynamics to ocean and atmospheric circulation models, the only feasible approach for realistically assessing the coupling between hydrate degassing and numerous short- and long-term oceanic and atmospheric processes.

Many critical research questions related to present-day and future global climate and carbon cycling fall clearly within the mandate of national research programs on methane hydrates. NETL itself currently supports several predictive modeling studies related to hydrate reservoir degassing as well as research on the microbial oxidation of methane in ocean water, an important factor limiting the efficiency of methane transfer from the seafloor to the atmosphere. In the coming years, the research community will be poised to make fundamental contributions on a range of pressing issues: What is the global integrated flux of methane from permafrost and marine gas hydrates? Are high gas flux sites quantitatively the most important contributors to methane emissions? How will production strategies for methane hydrates alter methane emissions? Could novel techniques be devised to fingerprint methane and carbon trapped in methane hydrate deposits so as to better trace their paths once they are mobilized in the ocean and atmosphere? Under which geologic, physical, and thermodynamic conditions is gas derived from dissociating methane hydrates most likely to cross the land-air or sediment-ocean interface instead of forming anew as methane hydrate? Research on these and related questions will advance our understanding of the role of methane hydrates in past and future climate change and the effect of climate change on the hydrates component of the global carbon cycle.

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Unique Tools Sample Sediment Pore Water near Seafloor Hydrate Mounds in the Gulf of Mexico

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The Gulf of Mexico Gas Hydrates Research Consortium, with funding from DOE, the Minerals Management Service, and the National Oceanic and Atmospheric Administration, has established a seafloor monitoring station at 1 kilometer (km) water depth at Mississippi Canyon Block 118 (MC 118). The station is designed to quantify temporal variations in gas hydrate and free gas reservoirs and thus assess hydrate stability. While stability fields of gas hydrates are generally defined by pressure and temperature, in this article we address a third parameter that is seldom investigated: the concentration of dissolved methane in fluids bathing the hydrate. Questions infrequently asked are "Is the concentration of dissolved methane in the pore waters surrounding the hydrate sufficient to indicate thermodynamic stability? Are the hydrates at equilibrium with methane in the pore fluids bathing them, or are they shedding methane to surrounding sediments at high rates?" These questions were sparked by observations of exposed hydrates outcropping on the seafloor at MC-118 (e.g., the now famous "dragon's head" gas hydrate spar illustrated in Figure 1). We were also intrigued by the results of a yearlong, time-lapse photography series of a hydrate mound carried out by Ian MacDonald of Texas A&M University. The series of photographs recorded fish coming and going and nearby microbial mats changing color, however, the morphology, size and shape of the exposed hydrate mound remained unaltered.

In order to determine the influence of methane concentration in nearby fluids on hydrate stability, we need to be able to measure the pore-water dissolved methane concentration in the fluids bathing a gas hydrate deposit. Sampling such fluids is no small feat, as at 1 km water depth, any gas in the pore fluids will expand 100-fold during ascent to the surface (or, if held at a constant volume, the fluid pressure in the sample container will increase 100 fold). To measure *in situ* dissolved methane concentrations, we required something different from the

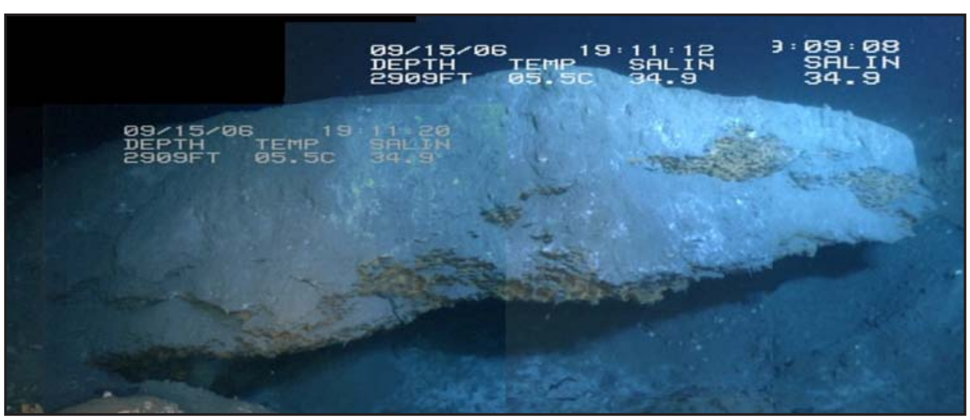

Figure 1: Composite photo of large hydrate outcrop, located near core 25 on Figure 3a, with sediment drape and ice worms (photo courtesy of Paul Mitchell, University of Mississippi).

pressured core sampler developed by Dickens and others, a device that yields the sum of dissolved and gas bubble methane in addition to that derived from decomposing gas hydrates. The need for *in situ* dissolved methane concentration data led us to develop a pressurized, *in situ* pore-water sampler.

We first adapted an older pore water suction sampling device originally intended for collection of non-pressurized samples of dissolved ions, in order to measure dissolved gases. The original device had a 50 centimeter (cm) long sampling tip with 10 ports configured at differing distances along its length. We replaced the sample chambers with reinforced stainless steel cylinders and configured high pressure valves on either side of the chambers (Figure 2). Initial tests of the device were quite successful. Pre-adaptation, dissolved gas pore water profiles measured by the device were low and spiky, demonstrating significant dissolved gas losses during sampler ascent (Figure 3), while post-adaptation profiles were smooth and concave upward, reaching concentrations as great as 15 milli-moles/L (mM). However, the device was too heavy and cumbersome for submersible use and emplacement using remotely operated vehicles (ROVs) was out of the question.

We further modified the device by decoupling the sampling reservoirs from the harpoon style sampler, which resulted in a sleek, light-weight and highly mobile sampling device (Figure 4a and 4b). The reconfiguration resulted in less weight being put on the submersible and ROV robot arms, improved the seal in the sediments, enabled the device to be used by smaller ROVs and permitted more precise positioning in unique environments (e.g., the mussel bed in Figure 4b).

As we explored the seafloor surrounding the gas hydrates found in outcrops at other hydrate locations (e.g., Northern Cascadia Margin), we became increasingly interested in the drape of sediments overlying the hydrate deposits. Was this drape gas charged? We hypothesized that it should be saturated with methane if the hydrates were at equilibrium with respect to

Figure 2: The first pore-water probe with high pressure stainless steel sample chambers and on/off valves. The 50-cm probe tip is visible below the lab cart. Inserting the probe into the sediment required the entire device to be manipulated on the seafloor.

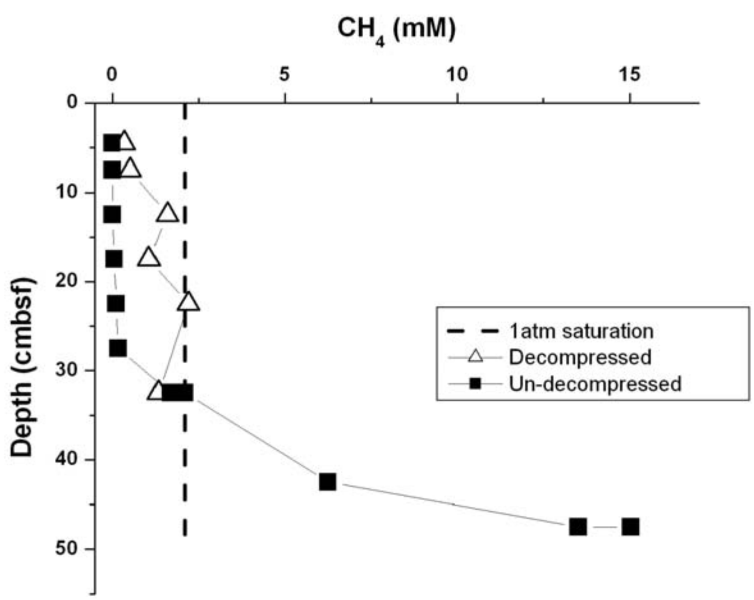

Figure 3: Methane concentrations at 1-atm saturation (dotted line), are compared to data from the original pre-adaptation instrument (where samples were allowed to decompress) and from the adapted instrument outfitted with high-pressure sample chambers and valves (un-decompressed samples). Figure adapted from Lapham, 2007 dissertation.

dissolved pore water methane concentration. This led to a third adaptation to our pore-water probe design: a series of interchangeable sampling heads to achieve maximum flexibility. This redesign included a feature that permitted the probe depth to be adjusted to obtain horizontal gradients extending away from a hydrate deposit in addition to vertical gradients above a deposit (Figure 5). With the new device, we were able to sample pore water within 3 cm of the hydrate surface, where we expected to observe dissolved methane concentrations approaching the saturation value of approximately 70 mM.

The results, however, proved quite contrary to our hypothesis. Despite the capability of the device to capture and retain dissolved gases at pressures of up to 100 atmospheres, we never observed dissolved methane concentrations above 15 mM, and generally concentrations were far lower. The below-saturation methane concentrations in pore-water surrounding hydrate deposits and their apparent temporal stability indicate that other factors may be playing an important role in maintaining hydrate equilibrium (e.g., the presence of a protective microbial slime coating).

Incorporating what we had learned from the development of the previously described pore-water samplers and adapting instruments developed by Jannasch, Kastner, and others, we developed an instrument for the determination of temporally variable in situ methane concentrations at the MC 118 seafloor monitoring station. The Pore-Fluid Array (PFA) is designed to obtain a continuous temporal record of in situ gas and ion concentrations and isotopes in pore-fluids near hydrate deposits (Figure 6). The device is a weighted, gravity emplaced seafloor sediment probe that contains filtered probe ports along the shaft that are interfaced to a pore-fluid sampling instrument package via small diameter tubing and a low dead-volume connector. An important feature of the PFA is that the pumps and sample collection package can be periodically replaced by an ROV without

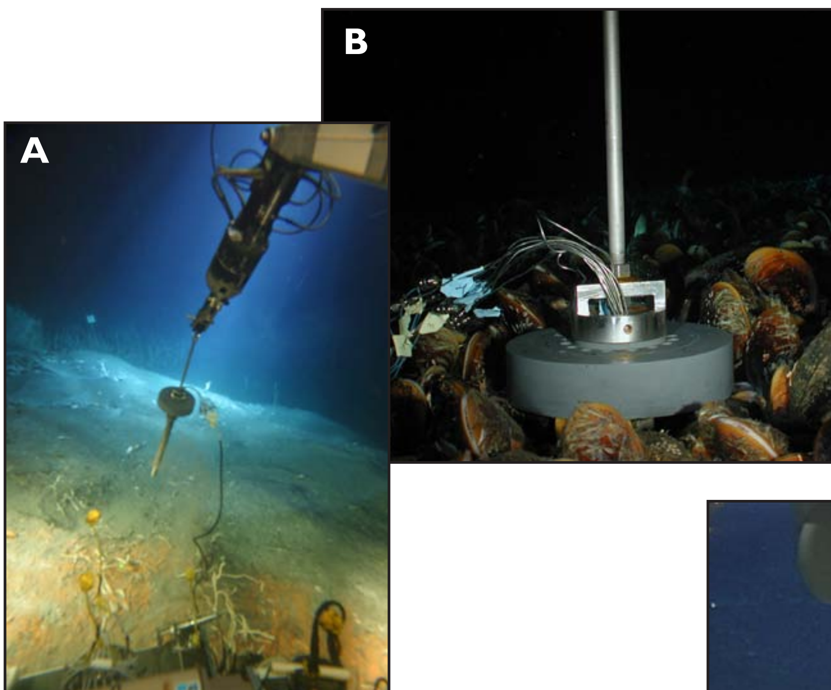

Figure 4: A second generation adaptation showing the decoupled probe tip (A) being manipulated by a submersible robot arm and (B) inserted into sediments beneath a mussel bed.

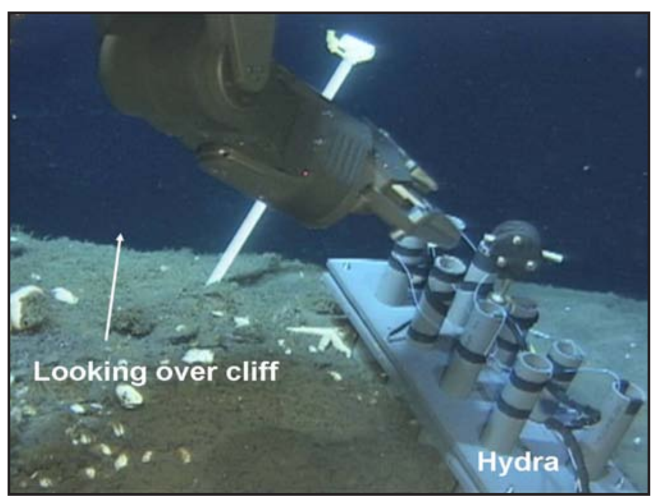

Figure 5: The third generation of the pore fluid sampler involved a probe tip adaptation that permitted the measurement of horizontal pore fluid gradients. Here, the device is deployed within 15 cm of sediment overlying exposed hydrate.

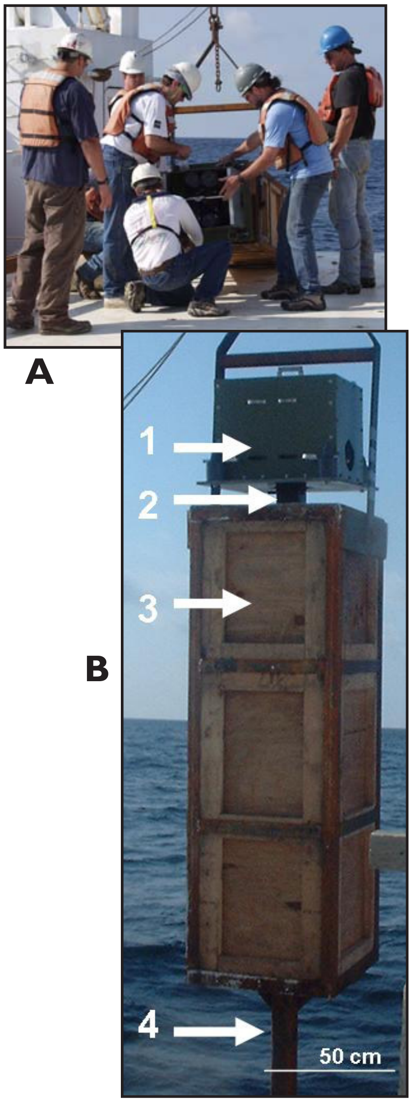

Figure 6: The pore-fluid array (PFA): A) preparation for deployment at MC 118 and B) The PFA suspended off the back of the ship (1 = sampler box, 2 = low dead-volume connector, 3=cement weight, and 4 = probe tip which extends 10 meters).

removing the probe shaft from the sediments, thus minimizing disruption of sample collection between visits.

The current PFA instrument package is comprised of four OsmoSamplers (developed by Hans Jannasch at Monterey Bay Aquarium Research Institute) and a high pressure valve. The OsmoSamplers use osmotic pumps to pull pore-fluids into lengthy, small diameter, gas-tight, copper tubing coils. The OsmoSamplers are ideal for deep-sea deployments because they require no power, have no moving parts, and require little maintenance. In order to obtain an in situ sample, the sample coils are plumbed into a high-pressure valve that, when closed on the seafloor, prevents samples from degassing upon ascent through the water column. Preliminary results from the PFA reveal elevated methane concentrations within 1.2 meters below the seafloor as compared to overlying seawater (Figure 7). The results also show a sudden, sharp increase in recorded methane concentration in the overlying water column that coincided with a magnitude 6.0 earthquake concentrated 260 miles southwest of Tampa, Florida, on September 10, 2006, during the final days of a deployment.

The development of seafloor probes and the PFA for measurements of in situ dissolved methane and other gas concentrations in the deep sea environment will help us develop a better understanding of the factors controlling hydrate stability. These instruments also can help to lay the foundation for a continuous seafloor hydrate monitoring station where changes in these geochemical parameters can be observed in concert with variations in dynamic geophysical processes such as salt diapir tectonics.

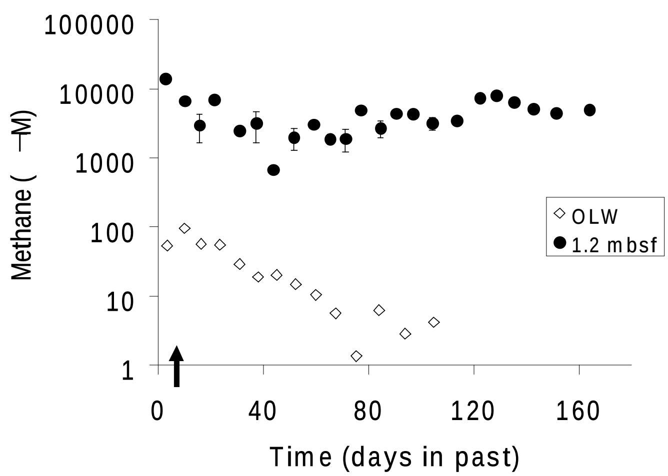

Figure 7: Methane concentrations over time for overlying water (OLW) and 1.2 meters below seafloor (mbsf). Arrow signifies the timing of a 6.0 earthquake. Figure adapted from Lapham, unpublished data.

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Comparison of drilling results to pre-drill estimates of gas hydrate occurrence: "Mount Elbert" test site, Alaska North Slope

By Tanya Inks (Interpretation Services, Inc.), Myung Lee (USGS), Warren Agena (USGS), Tim Collett (USGS), and Ray Boswell (DOE-NETL)

In February, 2007, the U.S. DOE, BP Exploration (Alaska), and the U.S. Geological Survey teamed to conduct a gas hydrates drilling, coring, and testing program at the "Mount Elbert" site on the Alaska North Slope (see Winter 2007 FITI). This article describes the pre-drill geophysical characterization of the target zones at the Mount Elbert site, and compares those predictions with the drilling results. We believe these results demonstrate the soundness of the geophysical techniques employed while indicating areas for further improvement of the methodology.

The seismic prospecting that resulted in the selection of the Mount Elbert test site utilized 3-D seismic data for the Milne Point area of the larger Prudhoe Bay production region. Analysis of the data revealed a number of anomalous seismic events within the section between the base of the ice-bearing permafrost and the estimated base of the gas hydrate stability zones. Overall, fourteen seismic anomalies consistent with significant intervals of anomalously high acoustic velocities suggesting gas hydrate occurrence were delineated (Figure 1). The seismic data were correlated to the existing well data to link each event to regional reservoir sand horizons. None of these anomalies had been penetrated by earlier drilling. In fact, no wells in the Milne Point area had encountered more than 20 feet of total gas hydrate.

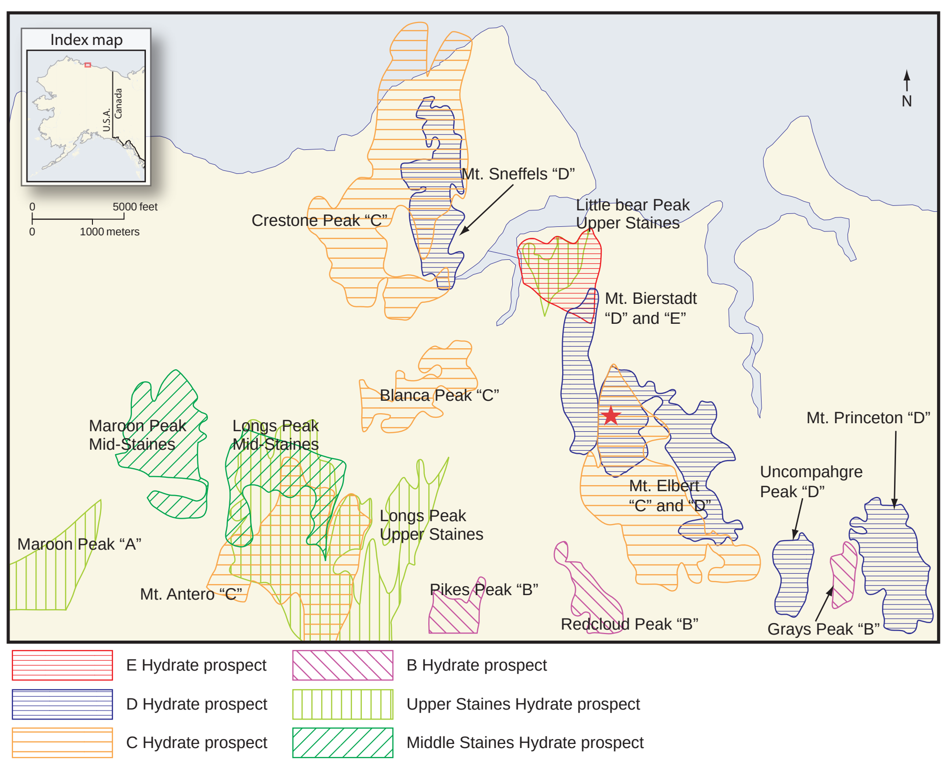


Figure 1: Gas hydrate prospects in the Milne Point area. The Mount Elbert site is marked with a star.

For each anomaly, we produced estimates of reservoir thickness and gas hydrate saturation. Reservoir porosity and other key parameters were derived from surrounding well data. A uniform dominant frequency of 55 hertz and a single wavelet deconvolution were used for the entire 3-D volume. Our evaluation of the 14 prospects clearly identified the Mount Elbert location as the best target for additional field data acquisition. The location included the presence of two thick, highly-saturated target zones at the level of two regional reservoir-quality sands (the "C" and "D" sands). In addition, the seismic responses at both horizons are very clearly delineated by bounding faults, with highest gas hydrate saturation and thickest reservoir fill in the structurally highest locations. This clear organization of the seismic response in a manner consistent with the local geology provided additional confidence in the interpretation.

Pre-drill prediction of gas hydrate saturation was determined by thin bed modeling in which the measured amplitude and peak-to-trough time separation were matched to values generated by varying gas hydrate saturation and thickness in our reservoir and seal model. Figure 2 illustrates the favorable comparison between our initial velocity and porosity estimates (as derived from nearby well data) and the drilling results. Because the impedance contrast between the seal and reservoir is minimum at about 35% gas hydrate saturation, minimum saturation estimated from the thin bed method is about 35%. Figure 3 provides an example of the pre-drill estimates for the accumulation in relation to the location of the Mount Elbert well.

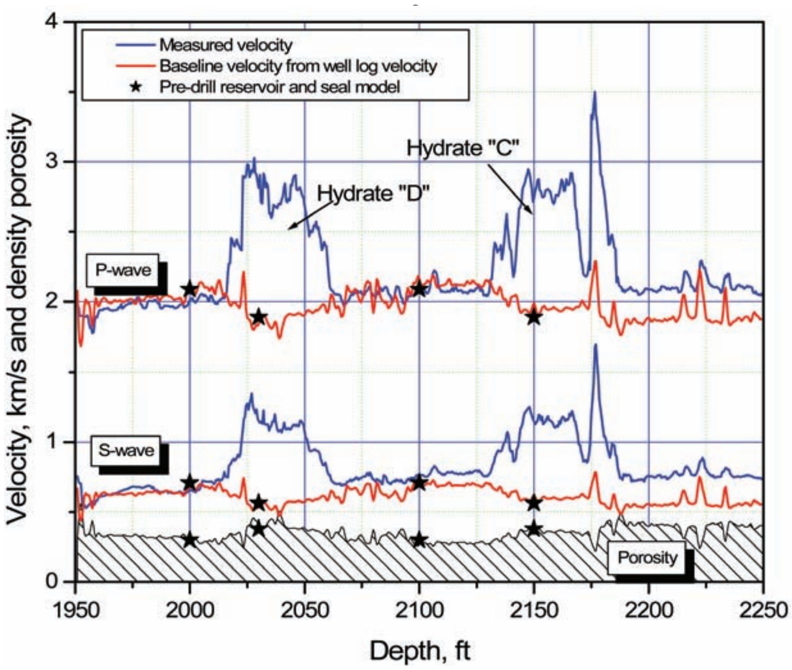


Figure 2: Comparison of pre-drill estimates of porosity and p-wave velocity (black stars –derived from nearby well data) with drilling results (lines).

Overall, the wireline log data obtained at the Mount Elbert well indicate that our pre-drill estimates for the "C" zone were reasonable, although somewhat optimistic (Figure 4). The "C" zone thickness estimate was 77% accurate (54 feet measured vs. 70 feet estimated); while the gas hydrate saturation estimate was 73% accurate (~65% measured vs. 89% estimated). Our predictions were even more successful for the "D" zone: 100% accurate for thickness (46 feet measured vs. 46 feet predicted), and 96%

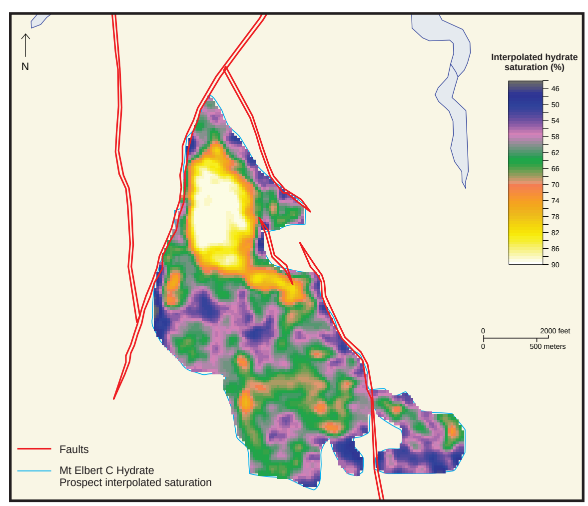


Figure 3: Example of pre-drill prediction of gas hydate saturation for Mount Elbert "C" prospect.

accurate for gas hydrate saturation (~65% measured vs. 68% predicted). Note that gas hydrate saturation in each zone varied significantly, largely in response to reservoir quality; the measured values given above are estimates of the average value throughout the gas hydrate bearing interval.

We believe that the success of these predictions is largely the result of the accurate initial estimation of porosities and P-wave velocities for both the sandstone reservoirs and the bounding finer-grained units. This accuracy was possible due to the proximity of quality well data. This approach, therefore, would be much more difficult to apply in a "frontier" area. In addition, we believe that future prospecting for gas hydrate reservoirs on the North Slope could be further improved by separately reprocessing the seismic data for each prospect with close attention to the phase of the wavelet and dominant frequency at the reservoir horizon. In addition, predictions would likely be improved if we analyze the observed amplitude by considering both maximum and minimum saturations expected for a given prospect. Another factor is the heterogeneity in the C zone, which contains an unexpected, low-porosity and high-velocity zone at the base of the unit.

The drilling at Mount Elbert demonstrates the potential for the reliable prediction of the occurrence, thickness, and saturation of gas hydrates on the Alaska North Slope through the integration of geological and geophysical analyses. These findings provide increased confidence in our ability to assess gas hydrate resource volumes on a regional scale. In addition, by identifying an occurrence of 94 feet of total gas hydrate section in an area where previous drilling had encountered no more than a total of 20 feet, we have shown that prospecting for discrete, highly concentrated gas hydrate deposits – a key component of any future gas hydrate exploration and production efforts—is clearly feasible.

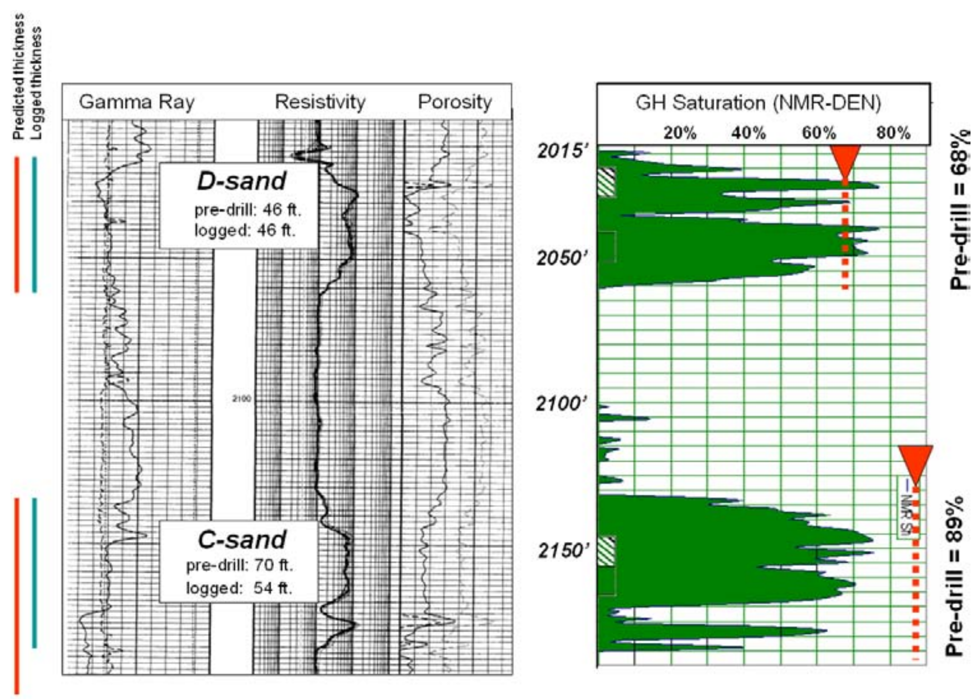


Figure 4: Log data and derived gas hydrate saturation from the Mount Elbert well, showing comparison to pre-drill estimates.

DOE-NETL Methane Hydrate Program Plans Release of Research Funding Opportunity

The Department of Energy (DOE), National Energy Technology Laboratory (NETL) intends to release a funding opportunity announcement (FOA) by early February 2008 focused on soliciting research that will support ongoing efforts to determine the potential of methane hydrates as a future energy source. The funding opportunity will seek proposals that will: 1) evaluate opportunities for production testing in Alaska; 2) develop production systems for high-saturation subsurface sandstone reservoirs; and 3) develop new tools for detecting and characterizing hydrates via remote sensing applications, particularly deep marine electro-magnetics (EM), in association with new or ongoing field projects. DOE is also anticipating an additional request for projects probing the links between gas hydrates and global climate/global carbon cycling at a later date. Formal release of the FOA will be announced via the DOE-NETL business / solicitation website at http://www.netl.doe.gov/business/solicitations/index.html.

Hydrates To Be Well Represented at Offshore Technology Conference this May

The 2008 Offshore Technology Conference to be held May 5-8, 2008 at Houston’s Reliant Center, will feature three sessions (21 individual papers) on natural gas hydrates. The first session on Wednesday afternoon (May 7th) focuses on laboratory studies for hydrate property determination. Researchers from Japan, Australia, the U.K. and the U.S. will present results ranging from techniques for estimating permeability of hydrate-bearing sediments to the kinetics of integrating hydrate methane recovery with carbon dioxide sequestration. A second session on Thursday morning will highlight hydrate production strategies. Here, a number of papers will feature the results of simulations of production from various classes of hydrate deposits. The third session, held on Thursday afternoon, targets production-related geomechanical and geophysical processes. These seven papers discuss properties of retrieved core sediments, laboratory studies of hydrate-bearing sediment behavior during fracturing or production, and the feasibility of using geophysics to monitor gas hydrate production. Information related to the overall technical program and registration is available at http://www.otcnet.org/2008/index.html/.

Triennial Hydrates Conference Set for Vancouver in 2008

The 6th International Conference on Gas Hydrates (ICGH 2008) will take place in Vancouver, British Columbia, Canada on July 6-10, 2008. ICGH 2008 is the latest in a series of conferences held every three years since 1993. The conference aims to bring together the entire gas hydrates research community; academic researchers, industrial practitioners, government scientists and policy makers are all welcome.

Themes for the 2008 conference include: Energy and Resources, Environmental Considerations, Geohazards, Oil and Gas Operations, Novel Technologies, and Fundamental Science and Engineering. Please visit the conference website http://www.icgh.org/ for more details.

Third Award Made Under Methane Hydrate Fellowship Program

Dr. Laura Lapham was selected from among a group of highly-qualified applicants to pursue post-doctoral investigations of factors that control hydrate stability in continental slope environments. Gas hydrate stability is dependent upon pressure, temperature, and surrounding methane concentrations. But although pressure and temperature conditions are often directly measured, *in situ* methane concentrations are rarely the focus of direct measurements. Laura's research will focus on measuring methane concentrations to determine how they control hydrate stability.

While conducting her Ph.D. work, Laura was struck by seafloor observations and other investigators' findings that outcropping hydrate persisted year after year in spite of being bathed in overlying ocean water that is typically under-saturated with respect to methane. Under such conditions, thermodynamic models predict that the hydrate should dissociate. Therefore, for her fellowship project, Lapham intends to address the questions: 1) "Is the concentration of dissolved methane in the pore waters surrounding a hydrate deposit sufficient to indicate thermodynamic stability? 2) Are the hydrates at equilibrium with methane in the pore fluids bathing them, or are they shedding methane to surrounding sediments at high rates? 3) What role does microbial methane oxidation play in hydrate stability?"

To answer these questions, Laura intends to develop two novel seafloor pore-fluid sampling devices that will allow the measurement of *in situ* methane concentrations and $\delta^{13}C\text{-}CH_4$ values adjacent to and at discreet distances away from shallow buried marine gas hydrates (see article on page 9). Laura will also conduct laboratory experiments to test these instruments and measure dissolution rates prior to field deployments. Both laboratory and field results can then be compared with theoretical predictive models to improve our knowledge of gas hydrate stability and dissolution.

Laura will be working in collaboration with Dr. Jeff Chanton (Florida State University), Dr. Rudy Rogers (Mississippi State University), Dr. Tim Short (SRI International), and the Gulf of Mexico Hydrates Research Consortium.

Well Log Data From BP-DOE-USGS "Mount Elbert" Test Available

Digital well log data acquired at the February 2007 gas hydrates test well at Milne Point, Alaska are now available. Data include Gamma ray, neutron porosity, density porosity, three-dimensional high resolution resistivity, acoustics including compressional- and shear-wave data, nuclear magnetic resonance, neutron spectroscopy, OBMI Electrical Imaging, and electromagnetic potential logs. A full listing of the available data, as well as instructions on obtaining the data, is available on the NETL gas hydrates website at http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/maincontent.htm.

NRC to Begin Assessment of Methane Hydrate R&D Program

As called for under the Energy Policy Act of 2005, the Department of Energy will engage the National Research Council (NRC) to conduct a study of the progress made under the methane hydrate R&D program. The study will review in detail the research conducted by DOE and partners from 2005 through 2007, review the process under which R&D has been conducted, and evaluate future R&D needs. Recommendations will be made concerning the potential for hydrates to contribute to domestic natural gas supply by 2025, any need for changes to the current program, the coordination of interagency, academic, and industrial research, and the progress in graduate education and training related to methane hydrates. An ad hoc committee of approximately 10 members, including an expert from outside the United States, will meet at least four times during the study period to gather information and analyze input. In addition to external testimony heard during open session meetings, the committee will rely on published literature, technical reports, previous NRC work, and other sources of information to address the study charge. The work will most likely begin in March or April 2008 with the final report due to Congress by September 30, 2009.

Gulf of Mexico Hydrates Research Consortium Annual Meeting Set for February

The annual meeting of the Gulf of Mexico Hydrates Research Consortium will be held in Oxford, Mississippi, on Tuesday and Wednesday, the 26th and 27th of February, 2008. The meeting will run from 8:30 to 4:30 on Tuesday, and 8:30 to 2:00 on Wednesday. The first day will include presentations and discussion of the updated model of the mound at MC118 by the team of post-docs working on the geochemical and seismic reflection data. Wednesday will consist mostly of planning for the spring cruises, deployments and recoveries, and for data treatment. Plans for the April and May/June cruise should be fairly firm by the close of this meeting. Contact Carol Lutken, Associate Director for Research Programs at the Center for Marine Resources and Environmental Technology at 662-915-7320 if you have questions regarding this event.

IGC-33 Abstracts Deadline February 29th

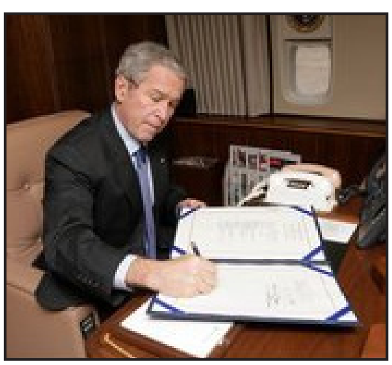
Three gas hydrate sessions have been organized for the International Geological Congress (IGC) to be held in Oslo, Norway on August 6-15, 2008. The deadline for abstracts is February 29. The sessions are: Gas hydrates in oceanic and permafrost environments (GAH-01); Causes and consequences of dissociation of gas hydrates (GAH-02); and Exploration and assessment of gas hydrates (GAH-03). Visit http://www.33igc.org/coco/ to learn more.

Call for Papers: Gas Hydrates Symposium at the American Chemical Society 2009 National Meeting

The 237th American Chemical Society National Meeting, to be held March 22-26, 2009 in Salt Lake City, Utah, will feature a Gas Hydrates Symposium with several sessions on natural gas hydrates. These include: gas hydrates in energy production, recovery and assessment; industrial applications of gas hydrates (flow assurance, energy storage and separation processes); and fundamental studies of gas hydrates (thermodynamics, kinetics). If you are interested in presenting a paper, contact symposium chairs Carolyn Koh or Dendy Sloan at the Colorado School of Mines Center for Hydrate Research (ckoh@mines.edu or esloan@mines.edu) before March 1, 2008.

Methane Hydrates Federal Advisory Committee Meeting Set for April 2008

A meeting of the Methane Hydrate Federal Advisory Committee has been scheduled for April 24-25 in La Jolla, California. The 14-member Advisory Committee provides advice to the Secretary of Energy and assists in developing recommendations and priorities for the Department of Energy's methane hydrate research and development program. For further information please contact Edith Allison, U.S. Department of Energy, Office of Oil and Natural Gas, Washington, DC. Phone: 202-586-1023.



2008 Spending Bill Includes Funding for Methane Hydrates Research

Congress passed an omnibus spending bill in late December that provides the U.S. Energy Department with $24.4 billion for fiscal 2008. Included in the bill was $15 million for NETL-managed gas hydrate research, an increase over the $12 million allocated for that area during 2007. In addition, the bill included Congressionally-directed spending of $1 million for the Gulf of Mexico hydrate consortium at the University of Mississippi.

GILLES GUERIN

Borehole Research Group

Lamont-Doherty Earth Observatory

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Gilles is a marathon runner and never goes on any trip, professional or personal, without his running shoes. He believes that he may hold the record for laps run around the helideck of the R/V *JOIDES Resolution*.

Logging Hydrates and Logging Miles

Engineering schools in France (called *Grandes Ecoles*) are supposed to train elite French students for management careers within large French companies, and this is the path followed by most of Gilles Guerin's classmates at the *Ecole Superieure d'Ingenieurs de Marseille*. But with dual Master's degrees in offshore engineering and ocean sciences (the latter from the University of Aix/Marseille), Gilles decided to sail in a different direction … literally. "When I was offered the opportunity to pursue research as a PhD student at Columbia University, working for the Borehole Research Group (BRG) at Lamont-Doherty Earth Observatory, I did not think twice," says Guerin. "The position offered the freedom and independence that in my mind define a researcher, and also the opportunity to sail around the globe as part of the Ocean Drilling Program."

Gilles is currently an associate research scientist with BRG, which is responsible for collecting downhole logging data for what is now the Integrated Ocean Drilling Program, and for maintaining the program's logging database. He sails on a regular basis as a logging scientist to acquire new data; generally on gas-hydrate related cruises aboard the R/V JOIDES Resolution. Back in the lab, he works on the data collected and assists with data processing and integration and provides support for logging operations on ongoing cruises. "Going to sea for months at a time to collect data, sometimes in challenging conditions, I would say is both the most rewarding and most challenging aspect of my work," says Gilles. "Living through logging operations that can last 24 hours or more, being part of a very close team, working together with the rig-floor crew to fix any unforeseen setback, and visualizing in real time the data as they are measured down the hole are the things that I miss whenever I haven't sailed for a long time."

Guerin's involvement with gas hydrate research started after ODP Leg 164 to Blake Ridge. "I did not sail on this leg, but I processed the sonic logging waveforms recorded by an experimental logging tool developed by my lab," says Gilles. "This gave me a chance to derive the first shear velocity profile in gas-hydrate bearing sediments." The work suggested the possible influence of gas hydrate on acoustic energy dissipation, which was later confirmed at the Mallik wells in Canada. It became one of the chapters in Guerin's PhD dissertation and cemented his continued interest in gas hydrate research. His current research focuses on understanding the pore scale mechanical interaction between gas hydrate and its host sediment.

Gilles credits his thesis advisors, Dave Goldberg, the director of BRG, and Roger Anderson, the founder of BRG, with motivating him to pursue hydrate-related research. Adds Guerin, "Both guided me in my studies, but also encouraged me to explore my own inclinations in choosing topics and methods of research. Tim Collett has also been a major influence, as he has trusted me as logging scientist on recent gas-hydrate related expeditions and this has allowed me to get involved with gas hydrate research programs beyond ODP/ IODP; for example, the Indian Government's National Gas Hydrate Program cruise in 2006."

Dr. Guerin believes that one of the most significant challenges facing gas hydrate researchers is the task of completely integrating the very diverse data sets that can be used to identify and characterize gas hydrate occurrences. "The integration and correlation between standard core measurement data, pore fluid chemistry, pressure core data, downhole logs and seismic data is still mostly qualitative and this makes it difficult to accurately measure gas hydrate distribution," says Gilles. "Estimates over all can be consistent among the different methods, but it remains difficult to extrapolate anything reliably beyond the borehole." Gilles and his team at BRG continue to focus on this and other gas hydrate research challenges.