the ENERGY lab

Fire in the Ice

2015 Vol. 15, Issue 2 Methane Hydrate Newsletter

NETL

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CONTACT

Ray Boswell
Technology Manager—Natural Gas Technologies, Strategic Center for Natural Gas and Oil

412-386-7614
ray.boswell@netl.doe.gov

U.S. DEPARTMENT OF ENERGY

Preliminary Results of China's Third Gas Hydrate Drilling Expedition: A Critical Step From Discovery to Development in the South China Sea

YANG Shengxiong[1], ZHANG Ming[1], LIANG Jinqiang[1], LU Jingan[1], ZHANG Zijian[2], Melanie HOLLAND[3], Peter SCHULTHEISS[3], FU Shaoying[1], SHA Zhibin[1], and the GMGS3 Science Team

[1] Guangzhou Marine Geological Survey, Guangzhou, China
[2] Fugro, Houston, USA
[3] Geotek Ltd, Daventry, UK

On September 1, 2015, China's Geological Survey/Guangzhou Marine Geological Survey (CMG/GMGS) completed their third gas hydrate drilling expedition (GMGS3) in the South China Sea. Drilling, logging, coring, sampling, and shipboard testing were carried out safely, efficiently, and on schedule. A comprehensive set of data and samples reveals extensive gas hydrate occurrences in different geological conditions in the Shenhu area, characterized by variable gas hydrate saturations, coexistence of Type I and II gas hydrates, and a buried gas hydrate system that is active or recently active.

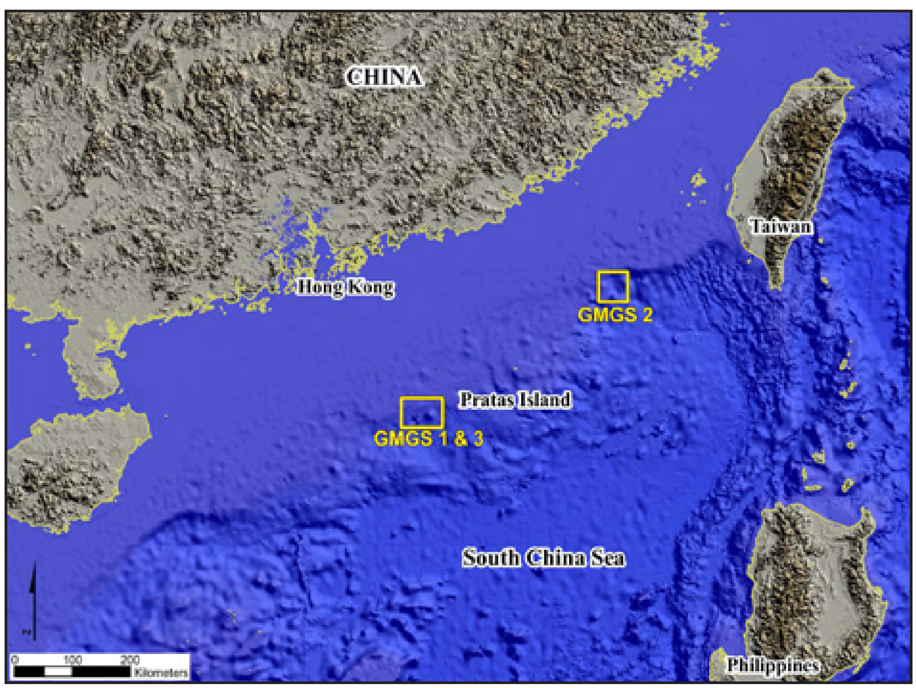

Figure 1. Locations of GMGS1, GMGS2, and GMGS3 in the South China Sea.

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321
541-967-5892

420 L. Street, Suite 305
Anchorage, AK 99501
907-271-3618

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

13131 Dairy Ashford, Suite 225
Sugar Land, TX 77478
281-494-2516

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This newsletter now reaches more than 1400 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 724-554-3680 or karl.lang@contr.netl.doe.gov

Overview of China's Offshore Gas Hydrate Drilling Expeditions

CGS/GMGS launched its first gas hydrate drilling expedition, GMGS1, in the Shenhu area in 2007 (Figure 1). Gas hydrates were recovered from Fugro pressure cores during the expedition, confirming the presence of gas hydrates in the South China Sea. CGS/GMGS conducted its second gas hydrate drilling expedition, GMGS2, in the eastern part of the Pearl River Mouth Basin in 2013, to further investigate the resource potential of gas hydrates in the South China Sea. This time, the results were more promising; a number of visible gas hydrates were recovered in fine-grained and coarse-grained clastic and carbonate sediments.

With improved recognition and knowledge from newly acquired geophysical and geochemical data in the Shenhu area, CGS/GMGS conducted the third gas hydrate drilling expedition in this area, with the intention of using GMGS3 results to identify and evaluate gas hydrate reservoirs for future development.

Operations and Methods

The 88-day GMGS3 expedition consisted of three legs: two logging-while-drilling (LWD) legs followed by a third coring leg. The expedition was performed using the Fugro Voyager, equipped with an R100 drill rig. A total of 19 sites were drilled for LWD operations, at depths from ~885 to ~1530 meters below seafloor (mbsf). The penetrated thicknesses ranged from 170 m to 360 m, with an average of 235 m. Of the 19 sites, 4 were drilled in the coring leg to obtain in-situ measurements and sediment samples for laboratory analyses (Figure 2). The Schlumberger LWD tools used in Legs I and II include GeoVISION, NeoScope, SonicScope (SonicVision), and ProVision tools which provide logs of gamma ray, resistivity, density, and neutron data, as well as resistivity image and compressional and shear-wave velocities.

Four non-pressurized and pressurized coring systems were used, including FHPC (Fugro Hydraulic Piston Corer), FMCB (Fugro Marine Core Barrel), PTCB (Pressure Corer Tool Ballvalve), and FPC (Fugro Pressure Corer), to provide fast, reliable, maximum recovery of sediments with and without hydrate during Leg III. Pore pressure dissipation tests were performed using the Piezo Cone Penetrometer (PCPT), and temperature tests were performed using a Temperature Cone Penetrometer (TCPT). In addition, an Autoclave Degassing System (ADS) was used to estimate hydrate saturation of the pressure cores. Shipboard geochemical testing and Multi-sensor Standard Core Logging (MSCL) geophysical measurements were carried out by GeoTek, Ltd.

Preliminary Findings

Gas hydrates were inferred to occur at nearly all drilled sites from elevated LWD resistivity and velocity values. Quantitative degassing analyses and freshening of pore water confirm that gas hydrates are present in all Leg III boreholes. Hydrate saturation was estimated from LWD resistivity and velocity values at each site, and based on gas volumes (after degassing) and pore water chloride anomalies at coring

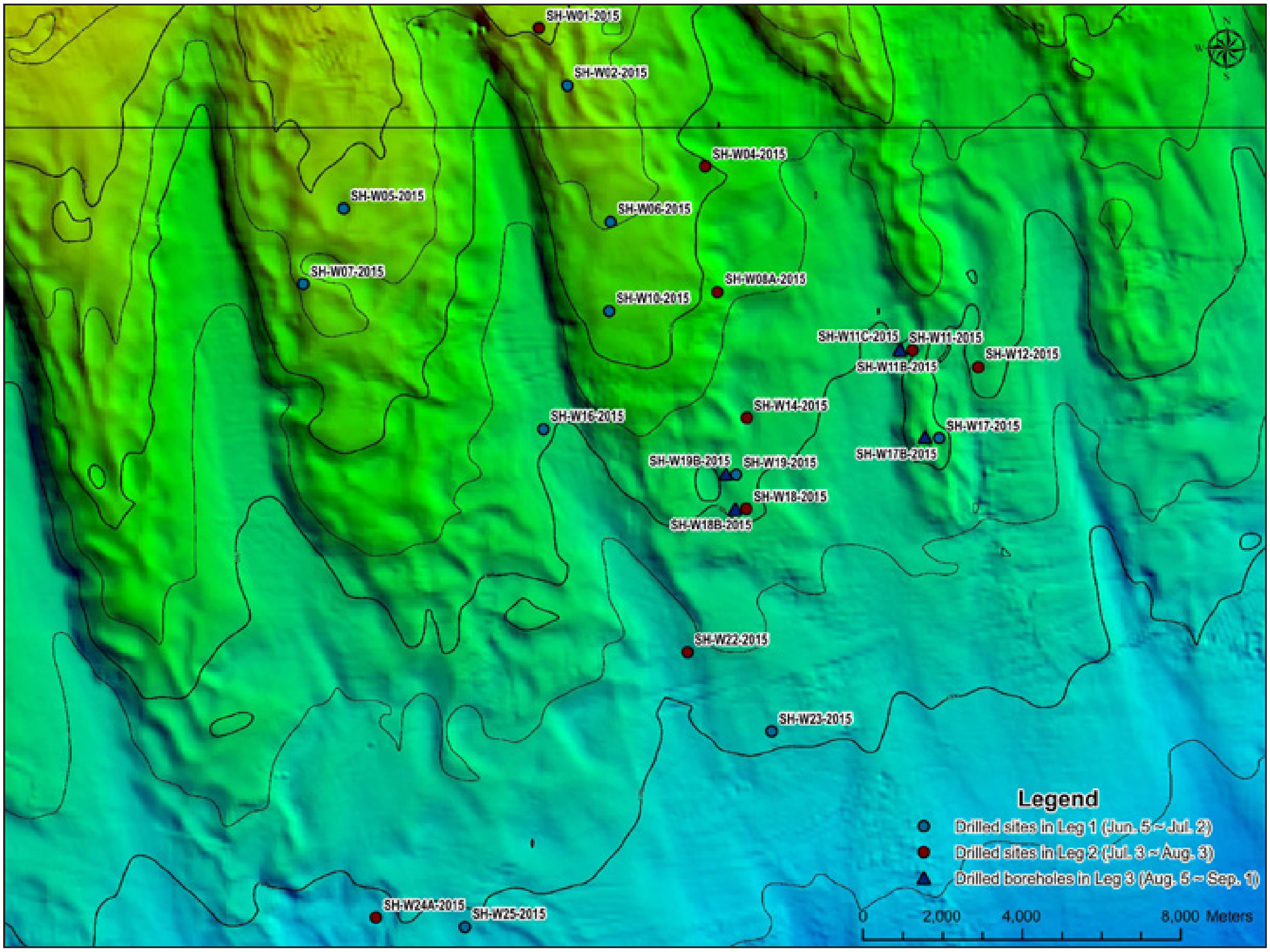


Figure 2. Locations of drilled sites and boreholes in the GMGS3 expedition.

and sampling sites. Hydrate saturation estimates from resistivity and velocity logs are generally in good agreement with estimates based on degassing and pore water freshening (Figure 4). Initial interpretation of drilling results is that low saturation hydrate-bearing sediments occur over a large area, whereas high saturation hydrate-bearing sediments only occur at some specific locations, including the Leg III sampling sites (Figures 2 and 4).

Our preliminary results confirm that deep thermogenic gas has migrated upward to form gas hydrate in shallow sediments below the base of the methane hydrate stability zone. This concept has also been proposed by others. During pre-drilling site selection, our scientific team inferred the gas chimney of site SH-W17-2015 interpreted from 3D seismic could be associated with the nearby Liwan deepwater gas field, ~10 km to the east. By using in-situ tests, the base of methane hydrate stability zone was accurately calculated at the site. Elevated LWD resistivity and velocity below the base of the methane hydrate stability zone indicate the presence of gas hydrate. Moreover, geochemical analysis of gas composition, showing significant concentrations of ethane and propane,

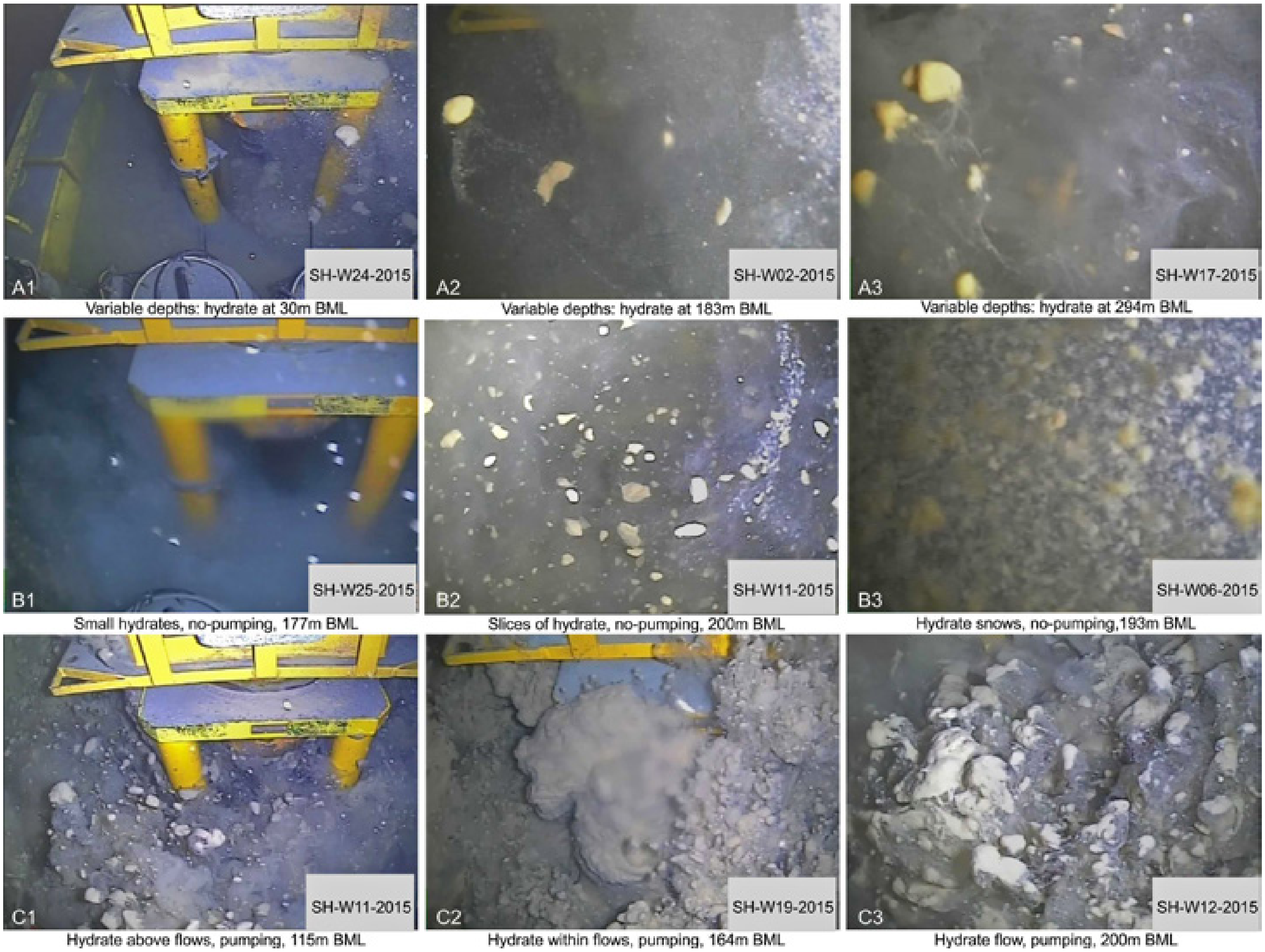


Figure 3. Gas hydrates were observed round the seabed frame at different penetrating depths (A1-A3), displaying different morphologies and amounts when no-pumping (B1-B3) and pumping (C1-C3).

indicate a thermogenic source (Figure 5). These results provide new insights to assess the regional gas hydrate resource in the Shenhu Sea.

Future Work

This expedition demonstrated the potential for gas hydrate resources in the Shenhu Sea area. Sand- and clay-rich gas hydrate reservoirs were tentatively identified from seismic, LWD logs, and coring results. The geological, geophysical, and engineering information obtained from the expedition allow us to analyze hydrate-bearing sediments for reservoir characterization. Our scientific team is currently integrating and analyzing all of these data. More in-depth results of the expedition will be published as they become available. In the future, we plan to undertake more field and desktop studies to further evaluate the production potential of the Shenhu Sea and adjacent areas.

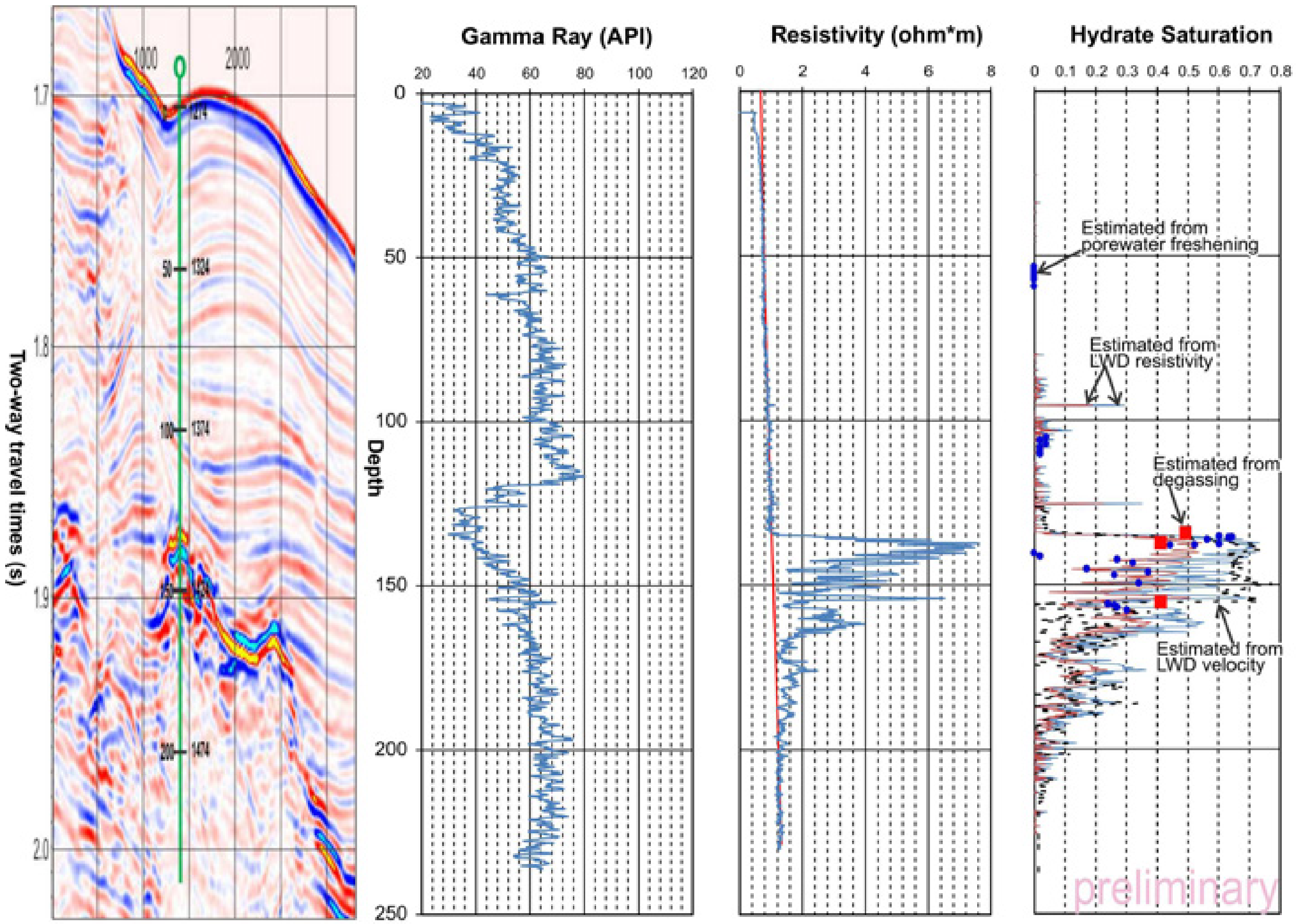


Figure 4. Seismic profile, LWD data, and estimated hydrate saturation from resistivity, velocity, pore water freshening, and degassing at site SH-W19-2015 and SH-W19B-2015.

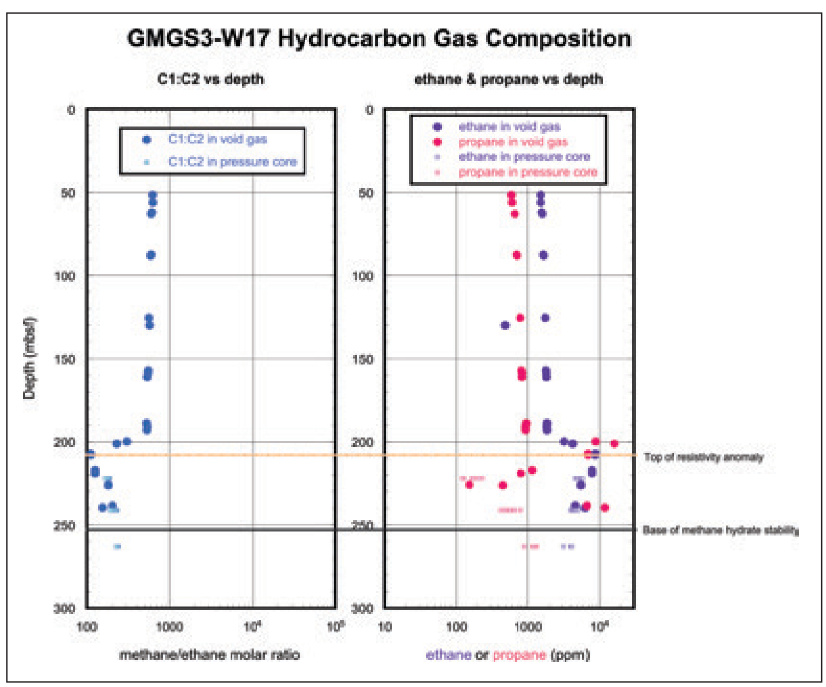


Figure 5. Site SH-W17-2015 hydrocarbon gas composition.

Gas Hydrate Occurrences in the Black Sea – New Observations from the German SUGAR Project

M. Haeckel[1], J. Bialas[1], I. Klaucke[1], K. Wallmann[1], G. Bohrmann[2], K. Schwalenberg[3], and SUGAR participants

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany
[2] MARUM, University of Bremen, Germany
[3] Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany

Methane seepage, mud volcanism, and gas hydrates are very common in the Black Sea (Figure 1). In this large anoxic sea, methane expelled at cold vents causes methane-enriched bottom waters (up to ~11 µM), while hydrogen sulfide produced by microbial sulfate reduction in the water column below ~150 m leads to elevated sulfide levels (up to ~300 µM). As a consequence, surface sediments show rapidly decreasing sulfate concentrations towards the zone of anaerobic oxidation of methane (AOM) at depths of 3-5 m below seafloor (mbsf), compared to background concentrations.

Extrapolating the corresponding diffusive CH_4 flux yields an estimated depth of 30-50 mbsf as the expected depth at which gas hydrates should occur on the slopes and deep basins of the Black Sea. At active seep sites,

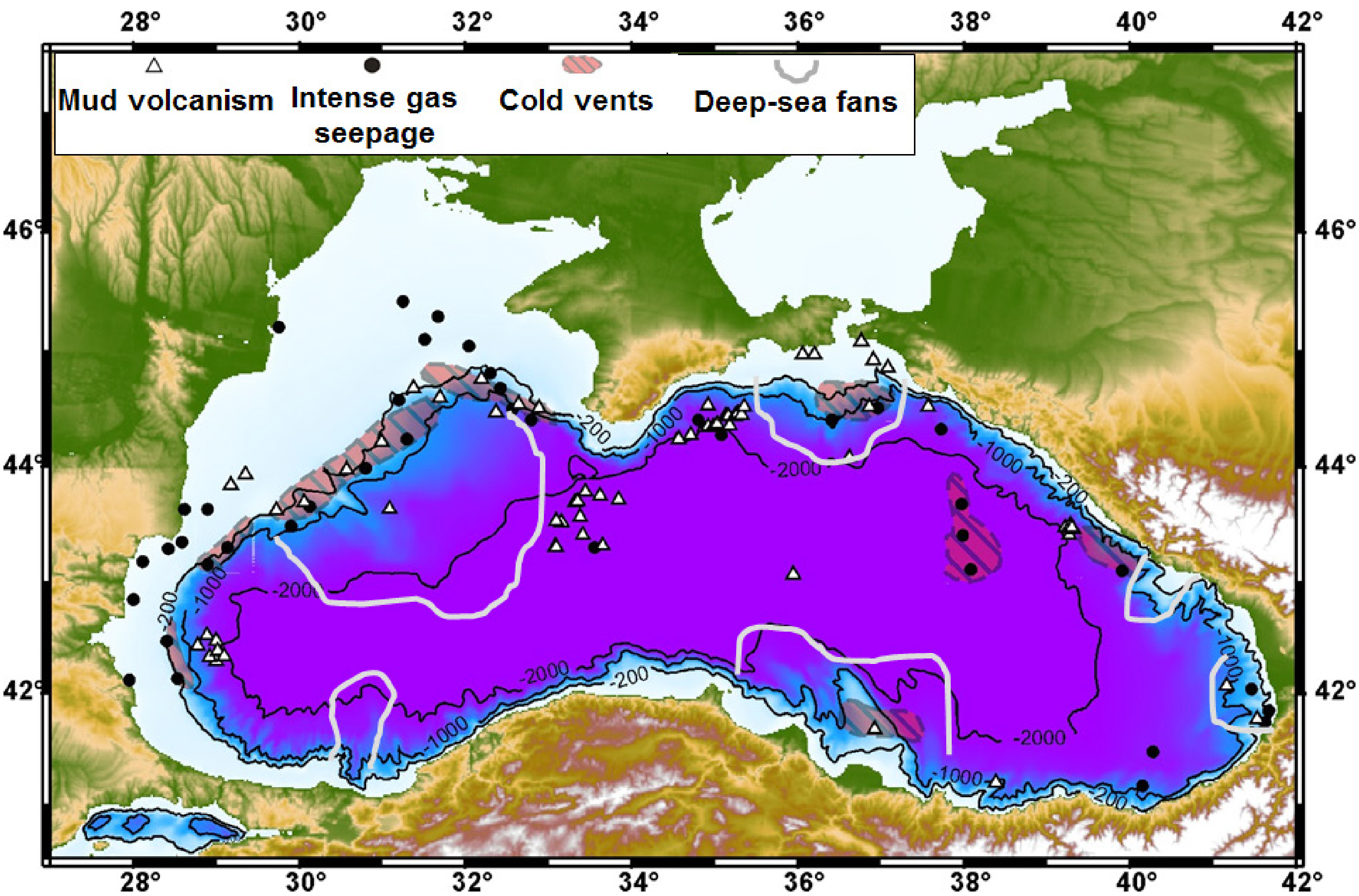


Figure 1. Map of the Black Sea indicating ubiquitous gas seepage, including cold vents and mud volcanoes. Major deep-sea fans are also shown (clockwise from upper left: Danube-Dnjepr, Sea of Azov, Bsipi, Rioni-Tschorochi, Kizilirmak-Yesilirmak, Sakarya). Modified from Schmale et al. (2011).

the AOM zone and the occurrence of gas hydrates are shifted further toward the seafloor.

Due to the warm bottom water temperatures (~9 °C) and low salinity (~22.3) in the Black Sea, gas hydrates become thermodynamically stable at water depths greater than ~720 m. Because the low salinity of 3 to 5 of the past limnic stages of the Black Sea still prevails in the sediments from 20 to 350 mbsf (see articles by Degens and Ross; and Soulet and others), the gas hydrate stability zone (GHSZ) may extend slightly upslope to a water depth of ~665 m (Figure 2). Depending on the local heat flow (27-35 °C/km) and the water depth, structure 1 CH_4 hydrates are generally stable down to 250-400 mbsf.

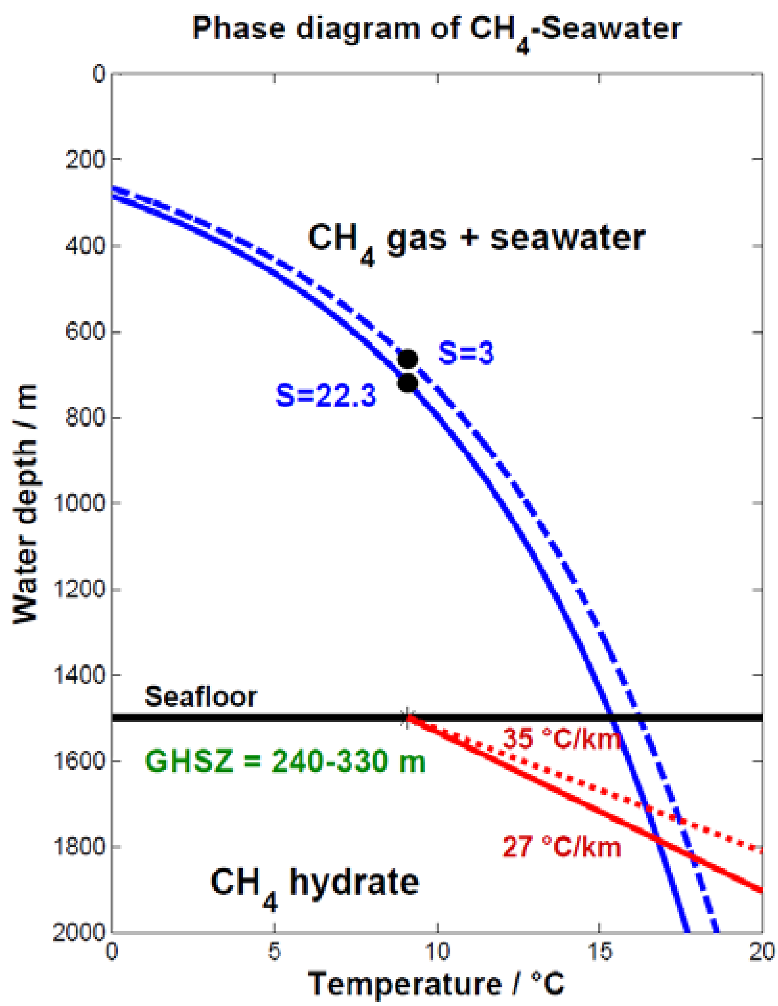
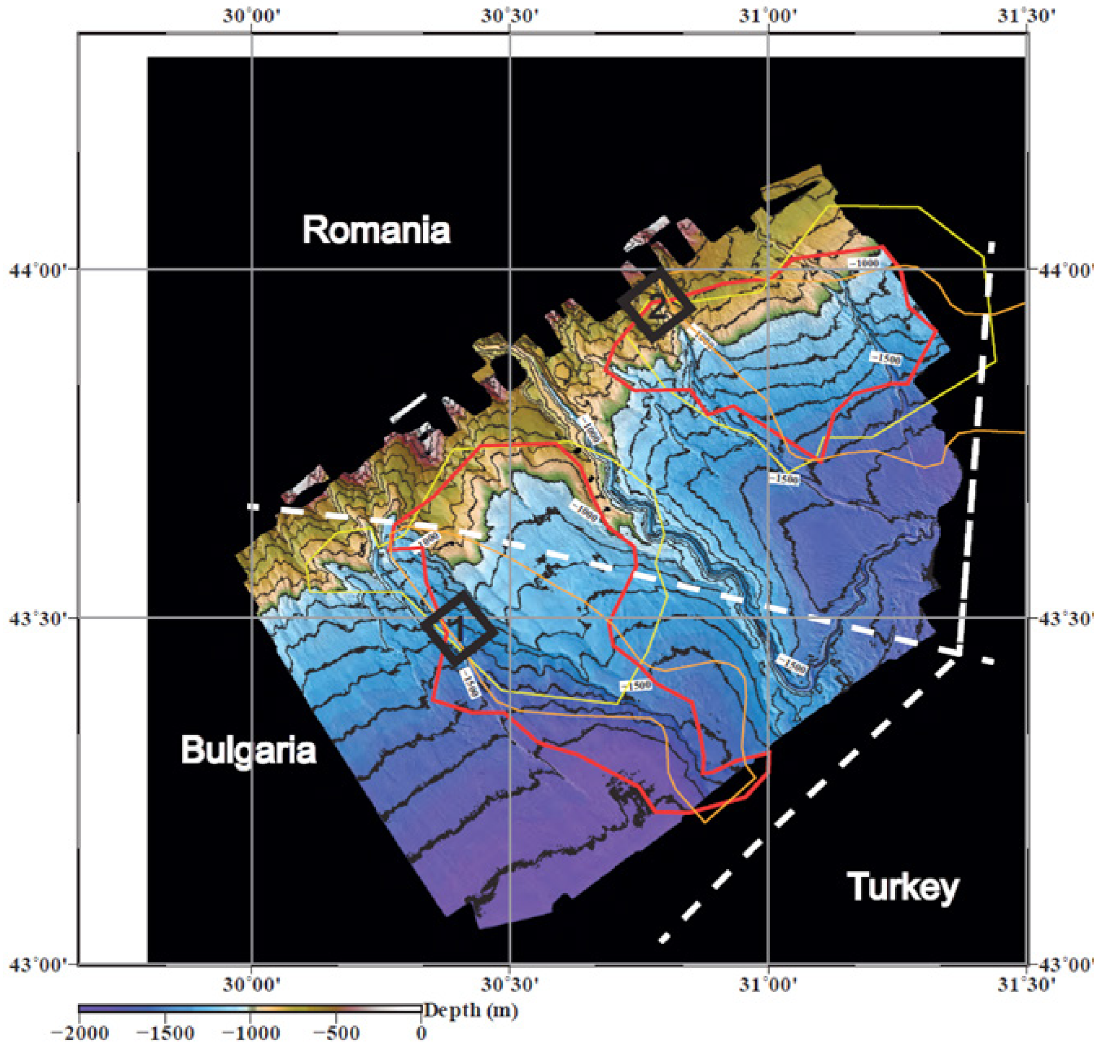


Figure 2. Thermodynamic stability of Structure 1 methane hydrates under typical environmental conditions prevailing in the Black Sea.

More than 15 years of seep research in the Black Sea conducted by the European marine science community makes it one of the best studied gas hydrate provinces in the world. Reservoir-quality gas hydrate accumulations are expected in permeable sandy-silty deposits, such as turbidites and channel-levee-systems of the large paleo-river systems around the Black Sea. The most prominent one is the paleo-Danube river system in the western Black Sea, located in the economic zones of Bulgaria and Romania (Figure 3).

Figure 3. Map of the Paleo-Danube channel-levee system. The colored polygons outline the BSRs mapped by different studies (red: MSM34; orange: Popescu et al., 2007; yellow: Baristeas, 2006). Black rectangles mark Areas 1 and 2.



From December 2013 to February 2014 scientists from the German SUGAR (Submarine Gas Hydrate Reservoirs) project, in collaboration with colleagues from IMST-Seislab in Turkey, IFREMER in France, and IOBAS in Bulgaria, began investigations of the gas hydrate accumulations in this area, deploying geophysical, geochemical, and geotechnical equipment from *R/V Maria S. Merian* (cruises MSM 34 and 35).

A continuous BSR is prominent in two areas, southwest and northeast of the central Viteaz canyon (Figure 3), as identified in the acquired high-resolution 2D seismic data. Additional 3D P-cable seismic cubes together with ocean bottom seismometer (OBS), and controlled-source electromagnetic (CSEM) data were collected in two selected working areas (rectangles indicate Areas 1 and 2 in Figure 3).

Area 1 is marked by a stack of up to 5 BSRs below the levees, and inverted reflection events with increased amplitudes in buried channels that are interpreted as indications for gas migration and hydrate formation within the GHSZ. Gas migration is believed to move laterally along the buried permeable channel fills and levees, because no vertical pathways, such as fractures, seismic pipes, or chimneys, are present. In addition, no active seep sites were detected in hydro-acoustic surveys in the entire southwestern BSR area, and geochemical analyses did not reveal enhanced methane fluxes towards the seafloor in this area. Together, these observations suggest a sealed gas hydrate deposit beneath this area. First analysis of the CSEM data reveal very high electrical resistivities (> 10 Ωm), which are partly explained by low porewater salinity but may also indicate high gas hydrate saturations within the upper 300 mbsf.

In contrast, active gas expulsion from several spots on the seafloor was observed in Area 2. The gas flares are associated with a slump feature

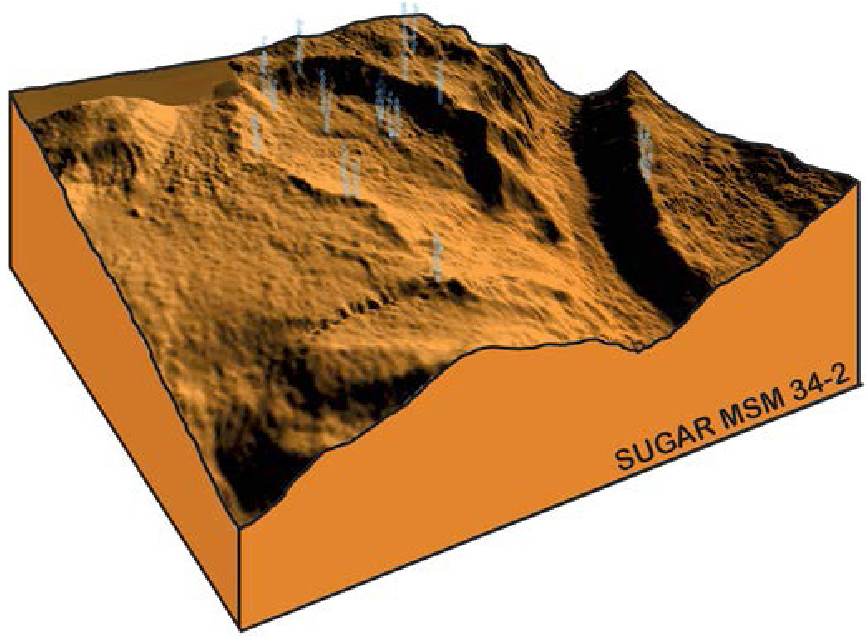


Figure 4. 3D view of the bathymetric map of the slope failure in Area 2. Gas seeps are imaged in water depths of 580-750 m by their hydro-acoustic reflections ("gas flares" shown in light blue) in the multibeam data.

(Figure 4), which is underlain by a BSR event with an unexpected strong upward bending shape. Geochemical analyses indicate the emission of biogenic gas with up to ten-fold increased AOM rates in the area of the slope failure.

Follow-up work in both areas is taking place currently, in Phase III of the SUGAR project. This phase includes characterizing the identified gas hydrate reservoir, addressing relevant environmental challenges, and developing appropriate production scenarios and monitoring strategies. A drilling campaign with the mobile rig MeBo200 is anticipated to take place in 2017. Further joint European gas hydrate activities will be organized within the framework of the recently launched COST Action MIGRATE.

Acknowledgments

The authors wish to express their gratitude to the master and crew of *R/V Maria S. Merian* for their excellent support during the cruises. Thank you also to all the colleagues who contributed their efforts before, during and after the cruises. The work was financed by the German Federal Ministry for Economy and the Ministry for Education and Research through the SUGAR project (grant nos. 03G0819A, 03SX320A, 03SX320Z, 03G0856A) and by the EU project MIDAS (grant no. 603418).

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Methane Hydrate Dynamics on the Northern US Atlantic Margin

Carolyn Ruppel[1], Jared Kluesner[2], John Pohlman[1], Daniel Brothers[2], Frederick Colwell[3], Stefan Krause[4], and Tina Treude[5]

[1]US Geological Survey, Woods Hole, MA
[2]US Geological Survey, Santa Cruz, CA
[3]Oregon State University, Corvallis, OR
[4]GEOMAR, Kiel, Germany
[5]University of California-Los Angeles, Los Angeles, CA.

Most gas hydrate studies on the US Atlantic margin (USAM) have focused on the southern sector, which includes the Blake Ridge and Cape Fear areas. However, recent assessments by the Bureau of Ocean Energy Management (BOEM; FITI, Vol. 13, Iss. 1) imply that the greatest resource potential for USAM methane hydrates is in deep water (>1500 m) sediments farther north. In recent years, more than 570 methane seeps have been discovered on the USAM upper continental slope (<1500 m below sea level or mbsl) and outer shelf between Cape Hatteras and Georges Bank (Figure 1), partially overlapping the area with the highest gas hydrate resource potential. On both the energy and climate fronts, this region is primed for more in-depth investigation as a gas hydrate province.

Seafloor Methane Seeps and Gas Hydrates

Scientists have identified methane seeps on the northern USAM using water-column backscatter data collected with multibeam sonar on the National Oceanic and Atmospheric Administration (NOAA)'s ship Okeanos

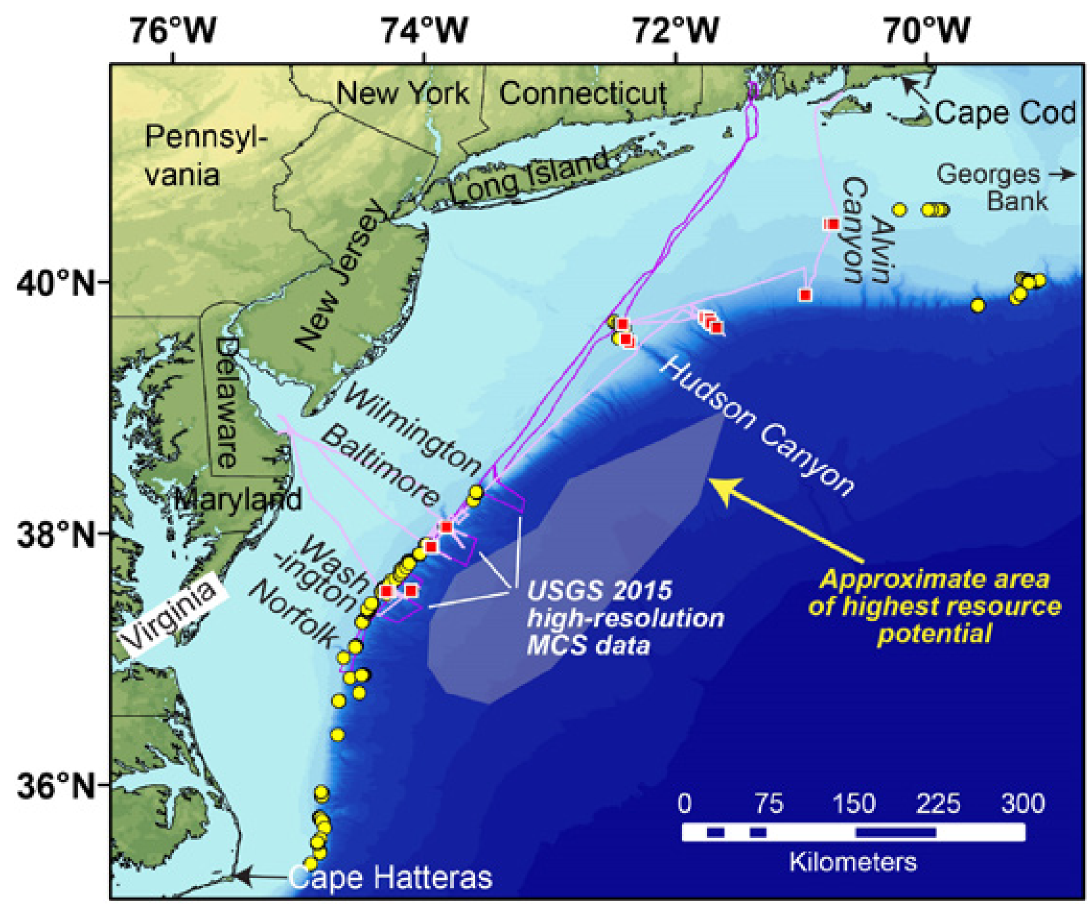

Figure 1. The northern US Atlantic margin with the ~570 seeps described by Skarke et al. (2014) shown as yellow circles. The purple and pink paths are the shiptracks for the April 2015 R/V Endeavor *and the September 2015* R/V Sharp *cruises, respectively. Red symbols denote piston or multicore samples, and italicized names refer to key shelf-breaking canyons. Most of the new MCS lines lie in the area between Wilmington Canyon and Norfolk Canyon, a sector that hosts more than 240 upper slope methane seeps.*

Explorer between 2011 and 2013. The results and a seep database were reported in 2014 in Nature Geoscience (see Skarke and others article, listed under Further Reading). Backscatter data reveal water-column gas plumes that can be traced downward into seafloor seeps, as verified during dives by NOAA's remotely operated vehicles.

As part of the seeps study, 240 upper slope seeps were identified from Washington to Wilmington Canyon, at depths between 180 (nominal shelf-break) and 600 mbsl. This depth range brackets the updip limit of gas hydrate stability (505 to 550 mbsl). Warming of intermediate ocean waters over several decades may be driving dissociation that feeds contemporary seepage at some of these sites. There is also evidence for ephemeral seeps that are active at timescales of days to months and may recur at the same location for thousands of years.

Approximately 40 seeps identified in the 2014 database occur at >1000 mbsl, well within the gas hydrate stability zone. In contrast to southern USAM deepwater seeps (e.g., Blake Ridge), which are fed by gas hydrate dissociation in sediments overlying salt diapirs, the deepwater seeps in the northern USAM leak methane from underlying fractured rock.

Recent Cruises

In April 2015, the USGS acquired approximately 500 km of high-resolution multichannel seismic (MCS) data (Figure 2) and coincident sea-air methane flux measurements over upper slope sites from just south of Norfolk Canyon to Wilmington Canyon aboard the *R/V Endeavor*. The surveys included dip lines between the shelf-break and ~2000 m water depth and strike lines collected parallel to the margin. The seismic source was a sparker that produced up to ~400 m sub-seafloor penetration at a nominal vertical resolution of ~2.6 m. In high-resolution sparker data, the base of gas hydrate stability typically does not manifest as a strong, negative-polarity bottom-simulating reflector (BSR), rendering sparker data more difficult to interpret than airgun data.

USGS researchers, led by J. Kluesner, are using seismic attribute analyses to better identify the gas hydrate-free gas transition and fluid-migration pathways in the high-resolution sparker data. In 2014, the USGS applied this approach to high-resolution MCS dip lines that were collected north of Hudson Canyon and across the New Jersey margin. In the attribute analyses, shallow, coarse-grained strata characterized by high reflectivity and high frequencies were interpreted as hosting gas hydrate. The continuation of one of these layers to depths shallower than the current updip limit of gas hydrate stability implies ongoing dissociation at this location, possibly in response to decadal warming of ocean temperatures. For the 2015 MCS data, frequency-based attribute analysis has produced good agreement between the inferred top of gas and the theoretical depth to the base of gas hydrate stability.

In September 2015, USGS researchers Ruppel and Pohlman, co-principal investigator Colwell, and collaborator Krause, representing Treude, conducted a 13-day sampling program on the *R/V Sharp* to study upper slope gas hydrate dynamics along some of the MCS lines (Figure 3).

The USGS piston coring system recovered nearly 100 m of sediment in 19 cores between Norfolk and Alvin Canyons. Thermistors attached to the corer measured sediment thermal gradients, expanding the region's limited heat flow database. A mini-multicorer equipped with a real-time video system was deployed to acquire undisturbed, 30-cm-long sediment

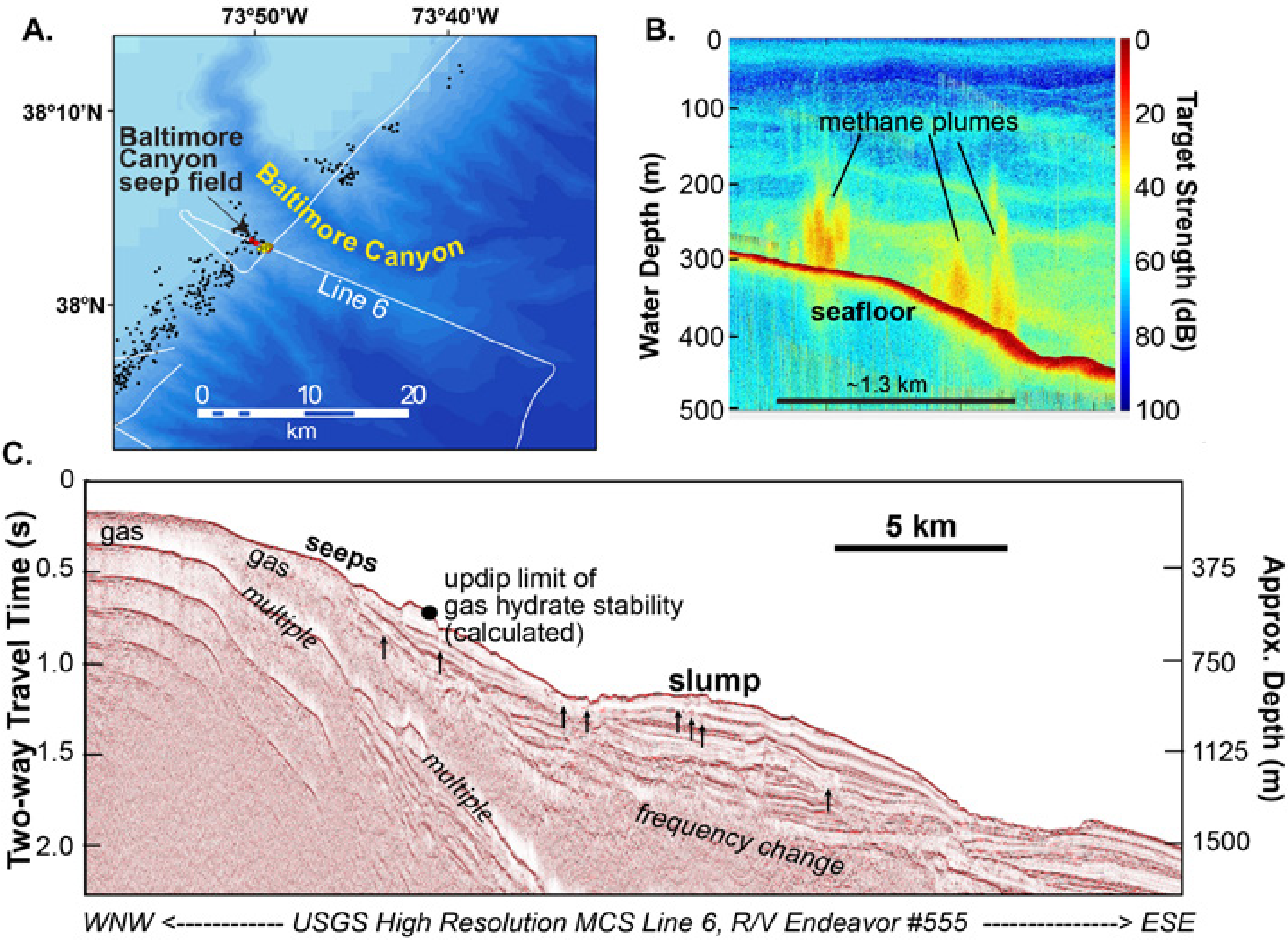

Figure 2. The Baltimore Canyon seep field lies on a promontory south of the canyon's axis and hosts extensive chemosynthetic communities explored by BOEM, NOAA, NSF, and USGS cruises from 2012-2015.

(A) The 14 seeps shown as yellow circles were found in multibeam backscatter analyses (Skarke et al., 2014). The yellow circles denote seeps found using the USGS EK60 in April 2015, and at least 7 of these were previously-unrecognized sites. Black dots mark pockmarks mapped by the USGS in Brothers et al. (2014).

(B) Target strength calculated using M. Veloso's Flarehunter scripts based on EK60 data collected across the Baltimore Canyon seep field on the upslope portion of MCS Line 6.

(C) Migrated MCS data on Line 6, with key features marked. Arrows show some of the locations where gas migration is detected. The frequency change is one of the features being exploited to track the distribution of gas and gas hydrate in these MCS data.

samples for microbiological, biogeochemical, and oxidation rate studies, especially near seafloor chemosynthetic communities at seep sites.

Fourteen Conductivity-Temperature-Depth (CTD) deployments retrieved water samples for dissolved methane measurements and for microbiological studies. Unlike some CTDs compiled in global databases, the CTDs on this cruise were run to full ocean depth, yielding a true bottom water temperature reading to constrain gas hydrate stability calculations.

The USGS also used a modified cavity ringdown spectrometer to measure stable carbon isotopic compositions of methane and CO_2 in the water column and in pore water samples retrieved aboard the ship. During nighttime operations, the USGS deployed a towed Chirp seismic instrument to acquire high-resolution images of the shallow sedimentary section to guide the choice of coring sites. The September 2015 data are still being processed, but key observations include low concentrations of methane in the recovered cores and dramatic warming of bottom water temperatures in a seep field located just at the updip limit of gas hydrate stability.

During both the April and September cruises, the USGS acquired continuous water column imagery using a Simrad EK60 transceiver and a 38 kHz split-beam transducer. The EK60/EK80 system is a fishery instrument that geoscientists use for bubble plume studies. While the wide cone of ensonification produced by multibeam sonars can readily detect gas plumes, fisheries echosounders provide quantitative information about bubble size and concentration in a narrower cone.

The USGS used the EK60 to discover new upper slope and deepwater seeps and to survey previously-identified upper slope seep fields that were in some cases found to be no longer emitting methane. Plumes associated with deepwater seeps were more persistent in time and could be traced hundreds of meters above the seafloor, ending near the top of the methane hydrate stability zone in the water column.

Future Work

Future work on the northern USAM will focus on acquiring data to establish whether gas hydrate dissociation is supplying methane to upper slope seeps; and determining the timing of methane emissions relative to major climate events over the past 20,000 years. The rate at which the upper edge of gas hydrate stability adjusts to ocean warming remains unknown and could be constrained by a combination of data acquisition and numerical modeling. Currently, the distribution of gas hydrate on the continental slope of the USAM is unknown, and mapping this distribution should be a priority for both climate and energy studies.

Acknowledgments

This work was supported in part by USGS-DOE interagency agreements DE-FE000291, DE-FE0005806, and DE-FE0023495. R. Colwell's participation was supported by a subaward from DE-FE0010180. Operational and technical staff from the USGS Woods Hole and Santa Cruz Coastal and Marine Science centers were critical to the success of the shipboard programs, as were the crews of the *R/V Endeavor* and *R/V Sharp*. G. Hatcher originated the real-time seafloor video system used in September 2015. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Figure 3. Sampling activities carried out in September 2015 aboard the R/V Sharp. *(Left) USGS operational personnel preparing to put the piston corer over the side. (Center) Deploying the mini-multicorer, which was equipped with USGS-built real-time video system. (Right) F. Colwell and S. Krause sampling the CTD.*

Gas Hydrate, Carbonate Crusts, and Chemosynthetic Organisms on a Vestnesa Ridge Pockmark—Preliminary Findings

*Giuliana Panieri[1], Daniel J. Fornari[2], Pavel Serov[1], Emmelie K. L. Åström[1], Andreia Plaza-Faverola[1], Jürgen Mienert[1], Marta E. Torres[3], and the CAGE scientific team**

[1] CAGE - Centre for Arctic Gas Hydrate, Environment and Climate
[2] Woods Hole Oceanographic Institution
[3] Oregon State University

** The CAGE scientific team includes: William G. Ambrose Jr., Michael L. Carroll, Stefan Bünz, Sophie Joanna George, Carolyn Graves, Friederike Gründger, WeiLi Hong, Gregory J. Kurras, Giacomo Osti, Alexey Portnov, Andrea Schneider, Anna Silyakova, Mette M. Svenning.*

During the CAGE15-2 cruise in May, 2015, we deployed a towed system equipped with a high-resolution, digital still camera and multi-core capabilities to study the Vestnesa Ridge, offshore West Svalbard, at approximately 79° N latitude. We observed a pervasive, thin hydrate pavement, carbonate crusts, and bacterial mats on surface sediments of two Vestnesa Ridge pockmarks. Our discovery of these hydrate-associated features informs our understanding of gas hydrate dynamics and methane release in the Arctic Ocean, and how these processes may impact carbon budgets and cycles, ocean acidification, and benthic community survival

Vestnesa Gas Hydrate Ridge

Vestnesa Ridge is a NW-SE trending elongate feature, approximately 100 km long and 100 m high, comprised largely of drifted sediment. It is located in the Fram Strait, north of the Molloy Transform Fault, in water depths of ~1200 m (Figure 1). It is characterized by intensive seabed faulting and rifting, and by prominent 400 to 600 m-wide pockmarks that lie above acoustic blanking zones. The acoustic blanking zones are thought to correspond to regions of active gas migration.

The two features described here are active gas release systems, based on repeat mapping of hydro-acoustic flares that extend upward and nearly reach the sea surface (Figure 1b). Gas analyses indicate both biogenic and thermogenic hydrocarbon sources, with migration pathways likely controlled by reactivated fracture networks.

Methods

The towed system is based on the Woods Hole Oceanographic Institution (WHOI) MISO (Multidisciplinary Instrumentation in Support of Oceanography) TowCam deep-sea imaging system, which is equipped with a deep-sea digital camera and a real-time Conductivity, Temperature, Depth (CTD) instrument that provides both altimetry and depth data (http://www.whoi.edu/main/instruments/miso). The system has the ability to transmit images from the camera and CTD in real time so that operational and sampling decisions can be made onboard the ship.

The UiT multicorer system (integrated TowCam and Multicorer; TC-MC) allowed for collection of six 60 cm-long, visually-guided cores. Selection of areas where the instrument was deployed along the six survey lines shown in Figure 1a was determined using multibeam bathymetry and hydro-acoustic data.

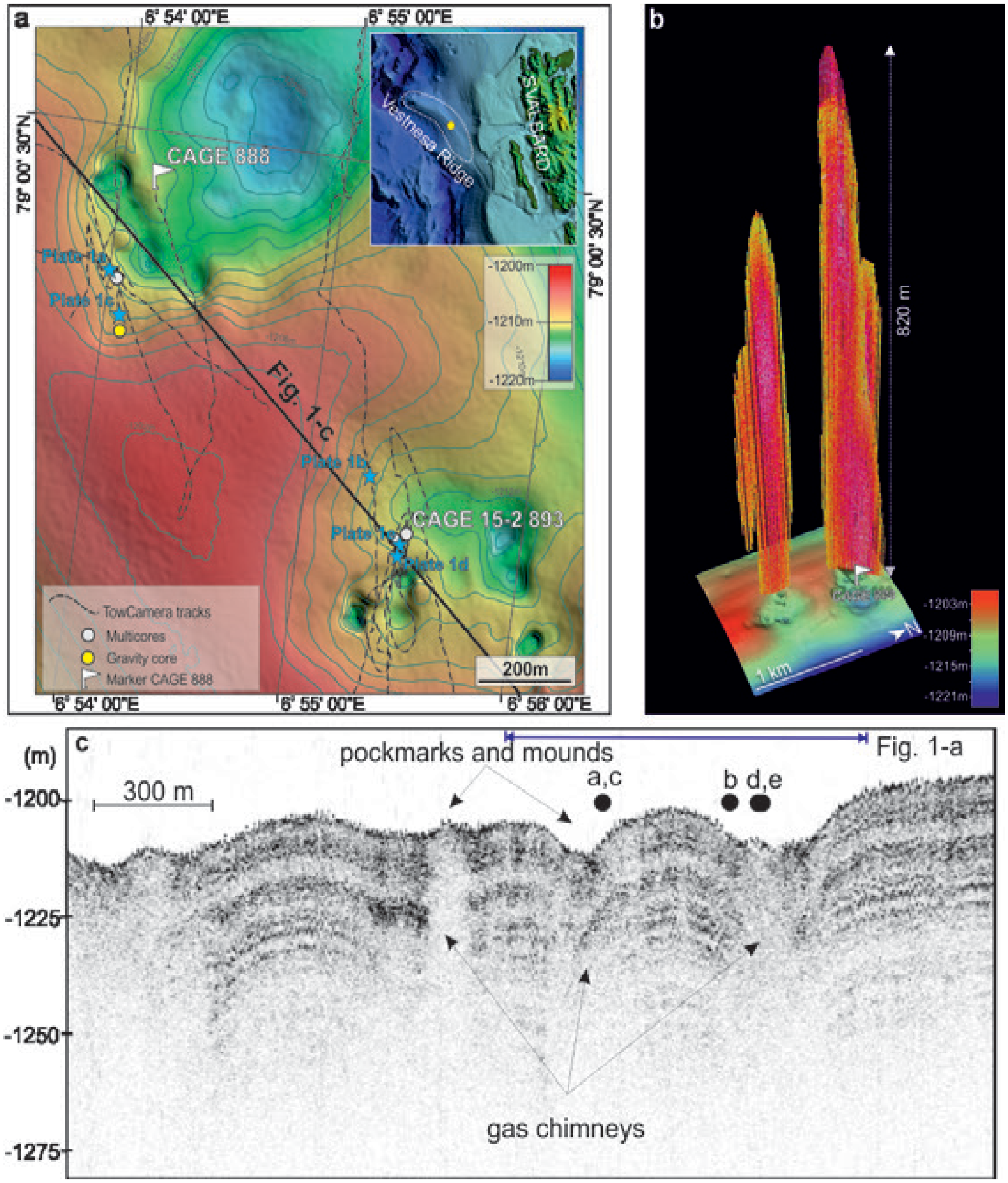

Figure 1.
(a) Regional multibeam bathymetric map with transect ending at site CAGE888, showing the location of marker "CAGE 888", the TowCam-Multicorer surveys and CAGE 15-2 893 MC sample that contained gas hydrate. (b) Single-beam echosounder showing acoustic flares resulting from rising gas bubbles from subseafloor hydrate deposits. Marker CAGE 888 is indicated below the northern flare. (c) Chirp subbottom acoustic profile showing gas chimneys associated with seafloor mounds and pockmarks. The black dots indicate the projection of images a-d in Plate 1 along the profile.

Highlights

Acoustic flares indicative of active gas release are aligned along the eastern edge of the Vestnesa Ridge, where 4D seismic data indicate rising gas within the sediment. Several camera surveys showed that the seafloor outside the pockmark area is soft, muddy sediment and is extensively bioturbated by fauna consisting primarily of ophiurioids and polychaete tubes (Plate 1a).

Within the pockmark, gas seeps are highly localized, and small patches of bacterial mats 3 to 4 meters in diameter occur. Individual white bacterial mats are ~20 cm in length (Plate 1b), typically surrounded by black sediment, which in the TC-MC cores contained abundant iron sulfide minerals.

Large carbonate blocks (Plate 1c) and outcrops are common in the seep areas and range from 10 cm to more than 2 m in length; in some cases they rise up to 3 m above the seafloor. The blocks are colonized by abundant epifauna, because they provide a hard bottom substrate for sessile benthic organisms and a shelter for mobile megafauna.

Cracks in the seafloor expose a thin crust (approximately 2-3 cm thick) of surface sediment cemented by gas hydrate layers (Plate 1d). This pavement is prevalent in seep areas and is colonized by dense mats of tube-dwelling polychaetes (Plate 1b), as confirmed by benthic sampling. Multicore samples from these areas also reveal the presence of abundant frenulating tubeworms, belonging to the family Siboglinidae, which are known to live in association with chemosynthetic bacteria.

Analyses of the uppermost sediment where gas hydrates were observed in the pockmark on Vestnesa Ridge yield a methane concentration of 5 mM (millimolar). Saturation with respect to gas hydrate is 59.7 mM.

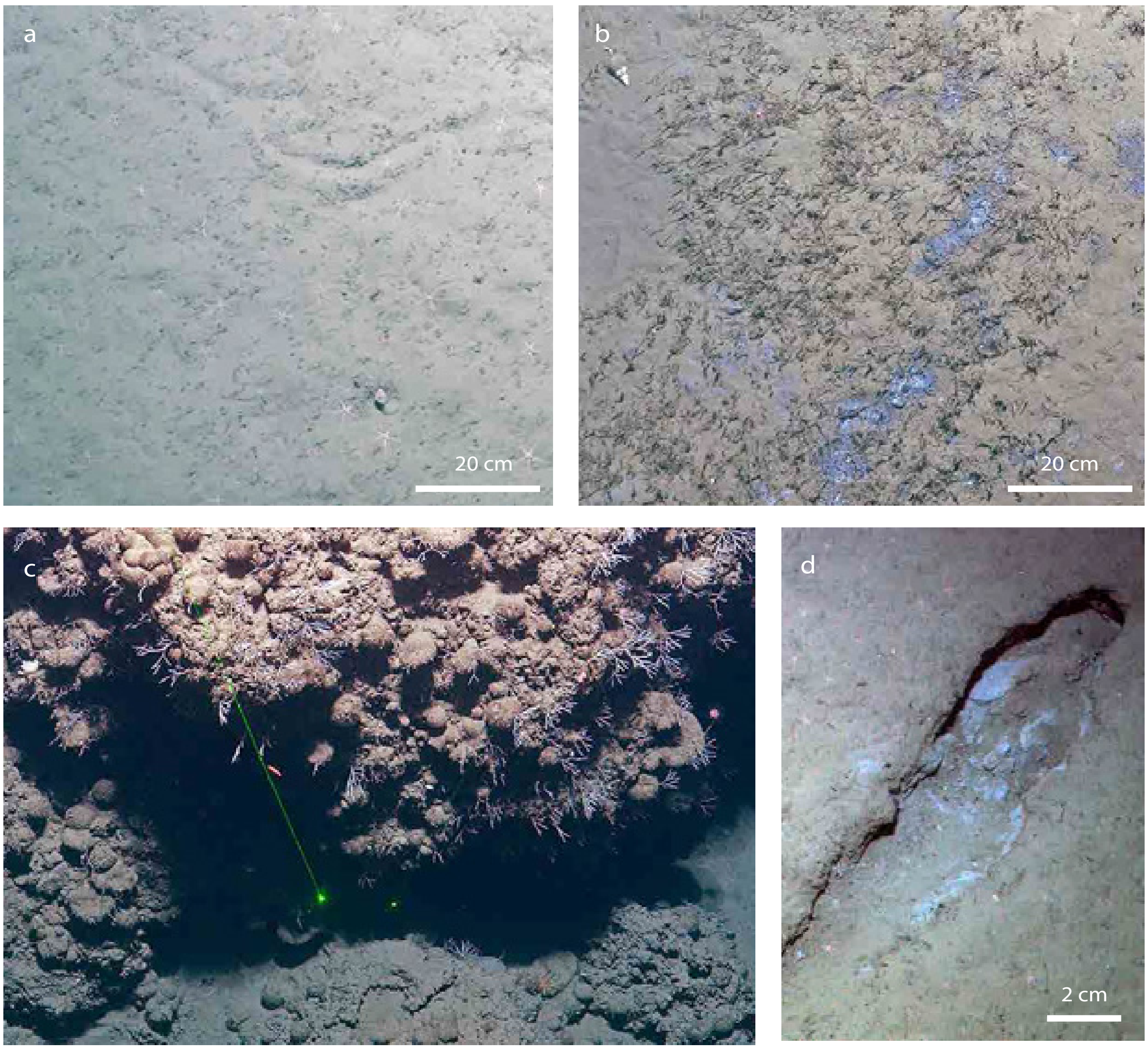

Plate 1. Images acquired using the WHOI-MISO Ocean Imaging System 16 MP deep-sea still camera on the TowCam-Multicorer system. (a) Soft sediment, mud bottom, with large number of Ophiurioids. A track of a mollusk is obvious crossing the center of the image. Individual polychaete tubes protrude ca. 3-5 cm long above the bottom. (b) White bacterial mat in patches throughout the image highlighted against the iron sulfide bearing black sediment; high density of polychaete tubes protrude ca 1-2 cm above the sediment surface. (c) Large carbonate concretions provide a hard substrate for epifaunal invertebrates (e.g., erect bryozoans and spherical sponges) and structure for mobile fauna. Green laser dots spaced 20 cm apart (these are present in all images and provide the ability to scale features in all images. (d) Thin pavement at the seafloor exposed by cracks in the indurated hydrate crust and thought to be sediment cemented by fine gas hydrate layers.

Methane values below saturation reflect extensive degassing of the core as evidenced by intense bubbling observed for ~30 minutes after the recovery of the TC-MC system in all of the 5 cores recovered from this site. Marker "CAGE 888" was deployed at this location to allow for future time-series investigations of gas seeps at this site using seafloor observatories

Discussion and Conclusions

Seepage at the CAGE 888 pockmark is highly localized, indicating focused flow of methane. This observation is consistent with seismic data (Figure 1c) that indicate discrete, fine scale (<10 m) fracture conduits that likely serve as migration pathways beneath the seeps. These zones are commonly capped by strong seafloor reflections, possibly indicating the presence of authigenic carbonate.

In other well-known areas where gas hydrate occurs at the seafloor—for example on Hydrate Ridge off the coast of Oregon and in the Gulf of Mexico--large colonies of lamellibrachia and vesicomyidae bivalves are known to occur. In contrast, camera surveys and benthic sampling in the Vestnesa pockmark area reveal a seafloor with small-scale heterogeneity, rich and diverse microbiological communities, and small tubeworm assemblages—but without the expected colonies of chemosynthetic mega-fauna associations. This observation is consistent with other active gas seeps and plume areas along the western Svalbard margin and in the Barents Sea.

The occurrence of gas hydrate at Vestnesa Ridge--particularly in the near-surface sediments described here, but also as previously documented at ~2 m below seafloor—attests to the presence and abundant supply of methane to the seafloor. This methane flux, and the associated hydrogen sulfide generated by anaerobic oxidation of methane sustain the bacterial communities observed in our TC-MC system surveys. The question remains as to why, at present, there are no communities of large chemosymbiotic associated taxa in this area. Instead, seeps here are associated with discrete patches of bacterial mats and small tubeworm assemblages.

Our discovery of gas hydrate pavements within the Vestnesa pockmarks, and the association with methane plumes in the water column, leads us to suspect that additional near-surface hydrate deposits are present elsewhere along the margins of the Arctic basin. Much of the Arctic margin is within the gas hydrate stability regime and is characterized by acoustic flares and other seismic evidence of upward gas migration.

Further research is needed to test for the presence of gas hydrates elsewhere along the margins of the Arctic basin. This is required to address concerns about gas hydrate stability in the region and the potential for methane release, and associated acidification of the ocean.

Acknowledgments

This work was supported by the Research Council of Norway through CAGE, Center of Excellence for Arctic Gas Hydrate Environment and Climate project number 223259, and from the US Department of Energy, NETL Award DE-FE0013531. Dan Fornari was supported by WHOI's Investment in Science Fund and NSF grant OCE1154266. We thank Marshall Swartz of WHOI who assisted in the mobilization and testing of the TC-MC system for this work and Kevin Manganini for assistance in the mechanical design of the TC-MS system.

SUGGESTED READING

Berndt, C. et al. (2014), Temporal constraints on hydrate-controlled methane seepage off Svalbard, Science 343, 284–287.

Bünz, S., Polyanov, S., Vadakkepuliyambatta, S., Consolaro, C., Mienert, J. (2012), Active gas venting through hydrate-bearing sediments on the Vestnesa Ridge, offshore W-Svalbard. Mar. Geol. 332–334, 189-197.

Hustoft, S., Bünz, S., Mienert, J., Chand, S. (2009), Gas hydrate reservoir and active methane-venting province in sediments on 20 Ma young oceanic crust in the Fram Strait, offshore NW-Svalbard. Earth Planet. Sci. Lett. 284, 12-24.

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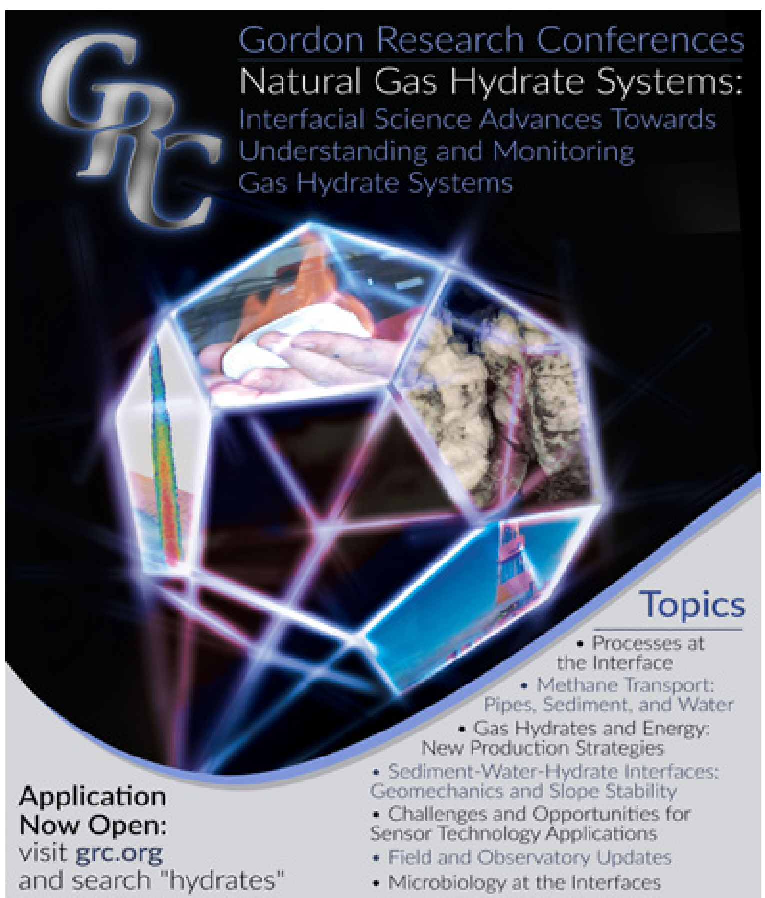
2016 Gordon Research Conference on Gas Hydrates

The 2016 Gordon Research Conference on Natural Gas Hydrate Systems will be held February 28-March 4th at the Hotel Galvez in Galveston, Texas. The conference will be chaired this year by Marta Torres (mtorres@coas.oregonstate.edu) of Oregon State University and Carolyn Koh (ckoh@mines.edu) of Colorado School of Mines. The overall theme of the 2016 conference is "Interfacial Science Advances Towards Understanding and Monitoring Gas Hydrate Systems." The focus will be on understanding interfacial attributes of clathrate hydrates, next-generation tools used to probe them, and recent advances in conventional and alternative energy, sensor and monitoring technologies, microbiology and system ecology, rock mechanics, slope stability, and climate issues. Individual topics for the 2016 conference include:

- Gas Hydrates and Energy: New Production Strategies
- Sediment-Water-Hydrate Interfaces: Geomechanics and Slope Stability
- Methane Transport: Pipes, Sediment, and Water



- Challenges and Opportunities for Sensor Technology Applications
- Field and Observatory Updates
- Microbiology at Interfaces
- Processes at the Interface

The aim of the conference is to link the latest advances in gas hydrate science to current issues of scientific, societal, and economic relevance. In addition to laboratory and numerical studies, the conference will include results of field studies of gas hydrate formation, accumulation, and destabilization in the Arctic, Gulf of Mexico, North Atlantic, eastern and western Pacific, and Indian Oceans.

Applications to participate in the meeting must be submitted by January 31st, 2016. Early submittal is advised, as the meeting may fill up before the deadline. To apply, visit grc.org and search "hydrates."

OOI-Node on Hydrate Ridge Mini-Workshop

Following the Gordon Research Conference on Gas Hydrates, Marta Torres of Oregon State University and Evan Solomon of the University of Washington will co-convene a mini-workshop on an Ocean Observatories Initiative (OOI) for advancing the scientific understanding of Hydrate Ridge, off the coast of Oregon. The 1.5 day workshop will be held March 4-5, 2016 at the Hotel Galvez immediately after the Gordon Research Conference. The goal of the workshop is to consolidate ideas for future science programs that optimize the use of the long-term, cabled ocean observatory on Hydrate Ridge. The steering committee for the workshop includes Nathan Bangs, Robert Collier, Michael Riedel, and Tina Treude.

To apply for the mini-workshop, please email Marta Torres at mtorres@coas.oregonstate.edu.

CAGE to Host 2016 Conference on Gas in Marine Sediments

The 13th International Conference on Gas in Marine Sediments will be held at the Center for Arctic Gas Hydrate Environment and Climate (CAGE) at the Arctic University of Norway, in Tromsø, Norway in September, 2016. This annual conference, last held in Taipei, Taiwan, brings together scientists and researchers from around the world and from a wide range of disciplines to discuss current issues associated with marine and lacustrine sediments containing natural gas. Up to 300 participants are expected to participate in the 2016 conference.

For more information and to submit a paper for inclusion in the conference, please contact Jürgen Mienert, the Director of CAGE, at jurgen.mienert@uit.no

Announcements

SBC Energy Institute Fact Book on Gas Hydrates

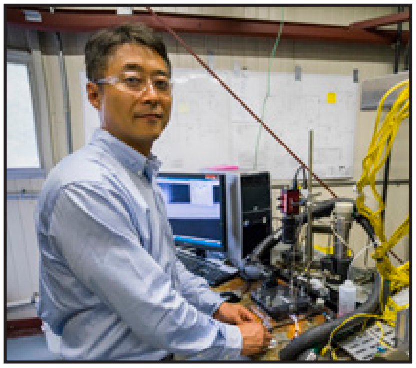
Schlumberger's SBC Energy Institute has released its new Gas Hydrates FactBook, a peer-reviewed summary of the current status of gas hydrate research, development, and demonstration (RD&D); gas hydrate exploration and production strategies; and environmental and safety challenges associated with the potential exploitation of this resource.

The purpose of the 97-page document is to "provide stakeholders with a balanced, unbiased assessment of gas hydrates and the tools to understand them properly." The FactBook is co-authored by Benoit Decourt, Sylvain Alias, and Romain Debarre, all of the non-profit SBC Energy Institute.

The FactBook includes helpful discussions of the history of gas hydrates development; currently favored production technologies and associated recovery rates; the need for longer duration production testing; environmental and safety issues related to gas-hydrate recovery and climate change; and the outlook for future production of gas from hydrates. It also includes a summary of exploratory drilling programs and production tests that have been conducted in Asia and North America.

The Gas Hydrates FactBook is available online and can be downloaded at: https://www.sbc.slb.com/SBCInstitute/Publications/GasHydrates.aspx

Spotlight on Research



YONGKOO SEOL

NETL Morgantown

Dr. Yongkoo Seol is a research scientist and team leader in the Predictive Geosciences group at NETL. Seol is engaged in laboratory studies designed to help characterize gas hydrates in nature, and he develops models to predict gas production from hydrate reservoirs.

Seol was born and raised in Jeonju, a small city 200 km south of Seoul, South Korea. As a boy, he enjoyed camping, swimming, and especially building things. He was an exceptionally good student in all areas of science, except biology, and he knew from a young age that he wanted to be an engineer or scientist.

Seol studied geology at Seoul National University and came to the U.S. in 1992 to pursue his PhD at Purdue University, followed by a post-doc at Ohio State. His father encouraged him to study abroad, and Seol enjoyed the freedom he was afforded to pursue a wide range of research topics with full support of his supervisors. He completed coursework across many disciplines, including hydrogeology, environmental chemistry, and organic chemistry. Seol appreciated the ability to study many different subjects while in graduate school; and he realizes now that this gave him flexibility later in life to collaborate on a broad spectrum of research projects.

Prior to working at NETL, Seol worked at Lawrence Berkeley National Lab, and it was there that he became interested in methane hydrate research. He was inspired by hydrate scientists Tim Kneafsey and George Moridis, who were deeply passionate about their work. The commitment to laboratory work was impressive, and the dedication to model building contagious. Seol remembers a conversation in which Kneafsey stated that he was so committed to his work that he would be happy to die there in the lab beside his samples. Today, Seol enjoys mentoring students and postdocs in the laboratory, sharing his passion with the next generation of scientists.

Outside of work, Seol enjoys home improvement projects, especially those that involve building and woodworking. In addition, he manages a Korean language school in Morgantown—founded originally for Korean and Korean-American children living in the U.S. Teachers, including Seol, work with children to help them maintain their Korean language skills and their connection to Korean relatives and culture. In recent years, it has become a popular place for students of all ages and cultures to learn Korean. Seol also plays the cello. He enjoys playing cello duets with his 13 year-old son, and he hopes, after retirement, to play in a small orchestra or string ensemble.