Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

MIS24-01 Room:101B Time:May 27 16:15-16:30

Types and distribution of gas chimneys: host structure of shallow gas hydrates

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Gas chimney is defined as a subsurface columnar structure of a few 100 m to a few km in longest diameter, characterized by well-developed acoustic blanking down to more than a km. Gas chimney is a major host structure of shallow gas hydrates in Japan Sea, often capped by hard ground as recognized by strong back-scatter image of a side scan sonar, indicating surface exposure of massive gas hydrate, carbonate concretions and bacterial mats and related chemosynthetic communities. Intensive acoustic surveys such as MBES and SBP confirmed 971 gas chimneys over 30,000 km2 areas during the reconnaissance survey in 2013-2014 .

Based on the occurrence and distribution pattern of gas chimneys, three morphological types have been identified in survey areas. Type A: Single, cylinder shaped chimney with about 200 to 400 m in diameter, randomly scattered on basin floors. Type A is common on the basin floor of the Oki trough, which is characterized by thick organic rich sediments. Gases are predominated by microbial methane. Type B: Composite, irregularly shaped blanking zone with horizontal area of about 500 m x 3,000 m, often occur in transition from slope to basin floors. Type C: Single to composite, cylinder shaped chimney with about 400 to 600 m in diameter, occurs on the crest zone of ridges and spurs along the faults. Type B has been identified by high-resolution AUV surveys on the slope area of the Oki trough, and is suspected to occur in the Tsushima basin and off Hidaka. Hydrate gases have not been collected and analyzed yet. Type C is characteristic in the Toyama (off Joetsu) and Mogami trough, which developed along the mobile belt of the eastern margin of Japan Sea. Inversion tectonics at around 5 to 2 Ma caused folding and reverse faulting to provide conduits for upward migration of deep seated thermogeni gases. Hydrate gases are either thermogenic or variable mixture of thermogenic and microbial. Distribution of the types and size of gas hydrate-bearing gas chimney structures provide fundamental constrains for the resource assessment of shallow gas hydrates.

Keywords: shallow gas hydrates, gas chimney, Oki trough

MIS24-02 Room:101B Time:May 27 16:30-16:45

FY2014 AUV survey in shallow methane hydrate fields in Japan Sea

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As a part of national project of shallow methane hydrate exploration, high-resolution acoustic survey (SK14 cruise) using an autonomous underwater vehicle (AUV) was performed in offshore areas of Oki, Joetsu, and Mogami Trough from May 10th through June 3rd in 2014. The survey was carried out basically in the same manner as that of SK13 cruise. We used AUV 'Deep1' and the mother vessel 'Shinkai-maru (329 t)' (both are from Fukada Salvage & Marine Works Co., Ltd.). The Deep1 is installed three acoustic observation equipment, a multi-beam echo sounder (MBES), a sub-bottom profiler (SBP) and a side-scan sonar (SSS), and its battery can make the vehicle perform over 20 hours dives. An ultra-short base line (USBL) system was taken for navigation. For the surveys, we applied normal mode taking line interval of 150 m and precise mode taking that of 10m. The vehicle keeps altitude above the seafloor at 50 m for the normal mode and 25 m for the precise mode. The targets of the survey were chosen from some topographical anomaly points, called mounds and pockmarks, which had been identified by the previously performed wide area surveys (7K13 and 7K14 cruises). The AUV were able to clarify detailed topography and shallow geologic structures in the mounds, pockmarks and the surroundings and grasped characteristic features and the variations of acoustic blanks, high reflection layers, seafloor high reflections and so on.

Keywords: Methane hydrate, AUV, multi-beam echo sounder, SBP, sub-bottom profile, side-scan sonar

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MIS24-03 Room:101B Time:May 27 16:45-17:00

Investigation of seafloor methane hydrates by marine controlled source electromagnetic method in offshore Joetsu areas

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We have conducted an investigation of seafloor methane hydrates by towing-type marine controlled source electromagnetic method in offshore Joetsu areas. The MCSEM system, owned by Scripps Institution of Oceanography, is composed of one transmitter and four receivers installed with 100m space, which are connected with a cable. The system was towed at the height of about 50m from the seafloor. The transmitter transmitted electrical current with the particular wave form containing various frequency components. The combinations of the transmitter and four receivers at each frequency have the information on sub-seafloor resistivity structure at different depths. The maximum depth of investigation was about 100m.The investigation was carried out for about three weeks, from the middle of August to the beginning of September, 2014. We used the survey ship, Shinnichmaru operated by Fukada Salvage & Marine Works construction Co., Ltd., and the operation of MCSEM system was mainly conducted by Ocean Floor Geophysics Inc. (OFG) Corporation.

The plane views and sections of apparent resistivity values show some resistive anomalies consistent with those of the sub-bottom profiling results. Moreover, three-dimensional inversion of MSCEM data was applied to illustrate more detailed sub-seafloor resistivity structure, and we compared the resultant structure with some features of submarine topography.

Keywords: seafloor methane hydrates, marine controlled source electromagnetic method, offshore Joetsu areas

MIS24-04 Room:101B Time:May 27 17:00-17:15

Exploration results of shallow gas hydrate by 2014 Logging While Drilling in Off-Joetsu and Mogami Trough, Japan Sea

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Research cruise GR14 of Greatship Ragini with Geoquip Marine GMTR 120 for LWD (Logging While Drilling) survey was conducted by Meiji University, in Off-Joetsu and Mogami Trough areas on the eastern margin of Japan Sea, during June 20th to July 17th, in 2014. The objective of the cruise is to explore the "gas chimney structure", which have been inferred from the acoustic blanking on the high resolution seismic profiles and from which methane gas hydrate have been sampled in the shallow subbottom (mainly down to about 10m by the gravity coring), from the seafloor to the base of gas hydrate stability zone (BGHSZ), whose depths are 50 to 120 m bsf in the survey area.

LWD tools to hire for the survey consists of Schlumberger geoVISION (resistivity imaging and gamma ray), TeleScope (telemetry) , sonicVISION (acoustic), and proVISION (CMR: Combinable Magnetic Resonance). The LWD survey was planned to explore down to 150 m bsf to penetrate BGHSZ. 10 sites were drilled in gas chimney structures and one site was drilled as the reference nearby a gas chimney structure. While 9 wells were drilled down to 150 m bsf as planned, drilling at two wells were stopped because of the stiffness of the formation and gas emission from the seafloor at 80 m and 100 m below seafloor, respectively.

LWD data quality was very fine, excepting very shallow depth intervals from the seafloor to 10 - 20 m bsf in most of wells. Methane gas hydrate concentrated intervals were identified from the high resistivity, high acoustic velocity, low natural gamma ray intensity and low CMR porosity. LWD data of most of the drilled gas chimney structures show the intense anomaly to suggest high concentration of methane gas anomaly in the shallow intervals from the seafloor to several tens of meters and deeper intervals over the BGHSZ. These two intervals are continuous in some sites. Only the deeper interval was observed in the reference site. Most of anomalous intervals are shown by the series of spikes on acoustic logs and broader resistivity peaks.

This research is a part of METI's project entitled "FY2014 Promoting research and development on methane hydrate."

MIS24-05 Room:101B Time:May 27 17:15-17:30

Report on the drilling results of gas chimneys by R/V Hakurei (HR14) in the eastern margin of the Japan Sea

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Several gas chimney structures, which develop on the topographic highs in the off Joetsu and the off Akita - Yamagata areas in the eastern margin of the Japan Sea, were drilled and a lot of sediment, gas and water samples were collected by R/V Hakurei belonging to JOGMEC from 21st of June to 10th of July 2014. This cruise is named HR14. The drilling depths of the Joetsu knoll in the off Joetsu and Tobishima West in the off Akita - Yamagata areas is as deep as 122 m and 111.5 m, respectively, and the drilled cores penetrated through the expected base of gas hydrate stability zone (BGHSZ). By this, we could know the constituents and structure of the gas chimney structures from the surface to the BGHSZ.

Two neighboring sites are selected to drill on a small mound of Tobishima West by the results of the SBP in order to characterize the gas chimney structure; the one shows a clear stratified structure (RC1408) and the other shows a sonic blanking zone that is called a gas chimney structure (RC1407). The drilling results show the stratified part bears no methane hydrate as deep as around 48 m and consists of alternated thinly laminated and bioturbated layers that is the typical sediments of the Japan Sea. On the other hand, the gas chimney structure is found to be composed of silty clay with methane hydrate and carbonate nodules.

The occurrence and the vertical distribution of methane hydrate in the gas chimney structure show characteristic features. The surface methane hydrate obtained was subdivided into massive, granular, platy and veined types by the occurrence in the cores. Massive and granular types are common in the shallower horizons, while the platy and veined types develop well in the much deeper horizons. Methane hydrate was abundant in the shallower horizons than 40 m to 60 m in two long cores. Gas is also found as well as solid methane hydrate within both methane hydrate and mud.

A model of the subsurface distribution of the shallow gas hydrate and gas in the gas chimney structure is proposed by the drilling results. The proposed model of the gas chimney structure of the shallow gas hydrate, although, has a weak point that it is based only on the three different drilling sites and the lateral changes in the occurrence and amount of methane hydrate within each gas chimney structure is not clarified yet.

Observed vertical distribution of the types of methane hydrate denies a concept that a constant and continuous supply of gas in a stable stability zone of methane hydrate as long as a few hundreds of thousands of years. Instead a catastrophic methane event that occurred in recent years such as the last glacial maximum should have caused the distribution pattern of the types of methane hydrate observed.

We express sincere gratitude to all the persons in JOGMEC who engaged to operate R/V"Hakurei". This research is a part of METI's project entitled "FY2014 Promoting research and development of methane hydrate".

Keywords: shallow methane hydrate, Japan Sea, gas chimney, drilling

MIS24-06 Room:102B Time:May 28 09:00-09:15

Changes of pore water geochemistry constrained by gas hydrate formation/dissociation in the Japan Sea

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Gas hydrate is composed of water and gas, mostly methane in natural environment, its formation and dissociation must change the geochemical signature of pore water in sediment in response to the amount, rate, and sedimentary environment of the gas hydrate. The eastern margin of the Japan Sea is one of the places where very active methane accumulation through the gas chimney structure sustains the formation of dense and thick gas hydrates near the seafloor. We have collected large number of sediment cores on and around the gas chimneys and have measured the geochemistry of pore waters to examine the existence and potential of gas hydrate, material transfer via fluid, and relationship with biological activities and mineral precipitations. The profiles, however, have not reached well down to or below the massive accumulation zone of gas hydrates, the entire model of pore water changes has not been discussed well. We report the analytical results of pore waters collected successfully from the sediments within/deeper than the gas hydrate stability during the HR14 expedition and show that the pore water geochemistry has been modified strongly by the formation/dissociation of gas hydrate through the gas chimney structures compared to that outside the chimney.

The sulfate concentration of pore water at the site outside the gas chimney progressively decreases with depth, reaching 0 mM at 10 mbsf (sulfate-methane interface; SMI), and is stable at very low level. The chloride concentration is close to the seawater level throughout the sediment. The high concentration anomaly only of sulfate occurs exceptionally at 42 mbsf where the sediment core looked “wet/loose” , reflecting contamination of seawater during coring. The significant concentration of sulfate below the SMI is therefore useful for the correction of contamination with seawater/drilling mud. Contrary, the sulfate concentrations at two sites within the gas chimney are strongly variable below the SMI through the gas hydrate stability, indicating the contamination of seawater/drilling mud by the coring of tight gas hydrate layers or the intrusion of these fluids into the loosen sediment due to gas hydrate dissociation or gas expansion. After the correction of contamination with seawater/drilling mud, pore waters collected from gas hydrate-free sediment layers between dense massive/granular/platy gas hydrate accumulation zones are strongly enriched in chloride compared to the seawater value of 560 mM, reaching up to ˜1200 mM at 15 to 25 mbsf, and the in-situ chloride concentration (Cl-baseline) shifts to ˜600 mM to the bottom of gas hydrate stability at both sites. This is because the rate of gas hydrate formation and chloride exclusion from the crystal exceeds the diffusion of pore water. The most rapid and active formation of gas hydrate occurs as shallow as 15 to 25 mbsf in the research area, the formation of dense gas hydrates at these depths responsible for the topographic change like mound overlying gas chimney. The high Cl-baseline below this interval indicates active gas hydrate formation as well, the in-situ pore water geochemistry is essentially characterized by the rapid formation and distribution of massive gas hydrates within the gas chimney.

The concentrations of chloride from gas hydrate-bearing sediment and sometimes from normal sediment decrease by ˜200 mM from the Cl-baseline value. The former results from the dissociation of gas hydrate during the core recovery, and the latter indicates that the invisibly small gas hydrates existed in the sediments and dissociated. The chloride concentration also decrease to ˜400 mM below the gas hydrate stability, indicating the dissociation of all of the gas hydrates in sediments after the burial and subsequent diffusion of gas hydrate-derived fresh water into sediments.

This research is a part of METI’s project entitled “FY2014 Promoting research and development on methane hydrate” .

Keywords: Shallow gas hydrate, pore water, Japan Sea

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MIS24-07 Room:102B Time:May 28 09:15-09:30

The biomarker composition of petroleum-like substance isolated from methane hydrate in RC 1403 core

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A substance like petroleum was isolated from the thick methane hydrate layer located at the RC 1403 core depth of 27m. Similar petroleum-like substance was included in the rounded gravel bed above the methane hydrate layer.

After the isolation and separation of a biomarker, GC/MS analysis was performed. The nature of the substance like petroleum, origin, history of the heat and microorganism decomposition was argued. The hydrocarbon fraction and ketone/ester fraction were used for this study.

A hydrocarbon fraction is characterized by the existence of hump in the low carbon number area, and two kinds of bicyclic sesquiterpanes and small amount of C25 tetracyclic terpane. On the other hand, n-alkane nor acyclic isoprenoids such as pristine and phytane were not detected in the chromatogram of hydrocarbon fraction.The feature of hydrocarbon fraction resembled to the very heavy biodegraded oil.

Ketone/ester fraction was characterized by hopanic and hopenic ketone.

In a particular, the angiosperm marker such as upanoid ketone, ursranoid ketone was detected. The existence of angiosperm marker indicates that the source of substance like petroleum was affected by terrestrial higher plant.

This research is a part of METI's project entitled "FY2014 Promoting research and development on methane hydrate"

Keywords: Japan Sea, Methane hydrate, biomarker

MIS24-08 Room:102B Time:May 28 09:30-09:45

Profiles of methanol in pore water of deep-sea sediments in eastern margin of Japan Sea and around Oki islands

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Methane hydrate, a clathrate compound of methane in water cages, is recognized as an unconventional natural gas and has been studied for natural gas resource in future. For better understanding of shallow methane hydrate, it is of great interest to elucidate the microbial environment related to generation and consumption of methane. In geochemical approaches, the depth profiles of methane as well as CO_2, sulfate ion, and so on have been investigated. Although the other C1 compounds like methanol and formaldehyde may be closely related to microbial activity, a few studies have revealed profiles of methanol and formaldehyde in deep-sea environment. Yamamoto et al. (2011) reported that methanol concentration in deep-sea sediments of the off-Joetsu area, eastern margin of Japan Sea was lower than detection limit in shallow region and increased gradually with depth deeper than ~10 mbsf. The profile of formaldehyde had a similar trend to the methanol profile. The deepest sample was recovered from ~40 mbsf at that time. Therefore, we are keen to explore deeper region for further understating of depth profiles of methanol and formaldehyde. We had an opportunity to have deeper samples in HR14 cruise (June-July, 2014). The pore water samples were obtained by squeezing deep-sea marine sediments and measured by headspace GC/MS. The concentrations of methanol are below the detection limit in shallow region and increase from a certain depth. The tendency of the profiles is good agreements with the previous results by Yamamoto et al. (2011). The concentration at much deeper region does not monotonically increase, so that methanol would be not only diffused from deeper region but also affected by microbial activity. In addition, pore water samples around Oki islands were obtained in UT14 cruise (July, 2014) and analyzed by the same procedures to investigate methanol and formaldehyde profiles in different sampling locations. Methanol concentrations are below detection limit in most core samples. Nevertheless, high concentrations of methanol in pore water in shallow region were observed in PC1415. This may indicate that methanol distribution is not homogeneous even inside the mound of shallow gas hydrate. This study was supported by 2014 development and promotion program of methane hydrate.

Keywords: pore water, deep-sea sediment, water-soluble volatile organic compounds

MIS24-09 Room:102B Time:May 28 09:45-10:00

Cross section observation of shallow gas hydrates by Raman imaging

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Natural gas hydrate, an inclusion compound of natural gas in water cages, is found in deep-sea sediments and permafrost region. In eastern margin of Japan Sea, shallow gas hydrates have been found and recovered by piston coring (Matsumoto et al., 2011; Lu et al., 2011). X-CT observation of the shallow gas hydrates revealed that icy materials divided into two regions (darker and lighter regions) by CT-values (Tani et al., 2013). Since CT-values of ice and natural gas hydrate are close each other due to similar X-ray linear attenuation coefficients, it is difficult to specify which region is gas hydrate only by CT images. In this study, cross section of the shallow gas hydrate was observed by Raman imaging to understand the differences of the darker and lighter regions in CT-values. The sample recovered from the eastern margin of Japan Sea in UT13 cruise was measured by X-CT first and then broken into two pieces. The cross section was measured by Raman imaging. The results indicate that pieces of natural gas hydrate with a few mm in diameter are scattered in the sample. Comparison between Raman images and CT images reveals that the lighter region of icy materials in CT images is natural gas hydrate and the darker region is ice. This study was supported by 2014 development and promotion program of methane hydrate.

Keywords: shallow gas hydrates, imaging, Raman, X-CT, dissociation

MIS24-10 Room:102B Time:May 28 10:00-10:15

Analysis of benthic community food web at gas hydrate deposits of Joestu Basin

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The ocean floor ecosystem depends largely on photosynthetically-derived organic matter and the degraded products. Also, we can found some ecosystems supported by chemosynthetically-derived carbon in deep seafloor. Chemosynthetic organism uses inorganic material, such as sulfur and methane as source of energy. In some methane seeps, benthic chemosynthetic communities are dominated by macrobenthos, such as gastropod, bivalve, crustacean and pogonophoran. It is known that many red snow crabs often congregate around cold seep in the Sea of Japan and that *Provanna* known as a chemosynthetic gastropod species in hydrothermal vent and cold seep also inhabits. However, their relationship between their ecology and chemical energy derived methane seep remains unknown.

To better understand the ecology of benthic community at gas hydrate deposits of Joetsu Basin, we analyzed their food web using the stable isotopic ratios of carbon and nitrogen (δ^{13}C and δ^{15}N) for the surface sediment and benthic fauna, such as red snow crab, eelpout, whelk and polychaete. Carbon and nitrogen signature reflects carbon source and trophic level, respectively

Sampling of benthic fauna at seeps using a slurp gun and a strainer was conducted during 24-30 September 2013 at Umitaka Spur and Torigakubi Spur. We obtained surface sediment sample using MBARI ROV coring system at depths of 0-2.5 and 2.5-5 cm below seafloor. Sampling at reference site was conducted at Joetsu Knoll on 23 September 2013. Macrofaunal sample was dissected on board and frozen at -20 ℃. Meiobenthos were removed by sieving of sediment samples and frozen. In laboratory, faunal sample was powdered after freeze drying. We removed carbonate from the sample by HCl steam treatment. Sample was refilled after neutralization by NaOH steam and drying. We measured stable isotope signature using IRMS (Flash 2000, Thermo Scientific Inc.). Similarly, sediment sample was removed carbonate by HCl solution, dried on a hotplate and measured.

Our result shows that no distinct difference between the isotopic signature of red snow crab and one species of eelpout, *Bothrocara hollandi* collected both at seep site and reference site. Other macro carnivores such as a squid and some individuals of whelk also have similar isotope signature. Biplot of δ^{13}C and δ^{15}N values suggests that the red snow crab mainly eat small crustaceans including amphiphods and shrimps although we know the crab eats squids and cannibalizes by ROV observation at sea floor. Our results indicate that food habitat of red snow crab depends on photochemically-produced organic matter even in an individual inhabiting around methane seep. That means the red snow crab is a component of phototrophic ecosystem.

In this investigation, isotopic signature of Provanna collected at Joetsu Basin shows similar value with that of polychaete. We collected another species of eelpout, *Petroschmidtia toyamensis*, which have isotopic value showing they eats *Provanna* and polychaete differently from *B. hollandi* as a component of photosynthesis ecosystem. Our direct observation of gut supports the predator-prey relationship between the former eelpout and *Provanna*. Small δ^{13}C of *Provanna*, polychaete and *P. toyamensis* indicates that they depend on methane-derived carbon microorganism produced. That suggests that they are components of chemosynthetic ecosystem at Joetsu Basin.

Meanwhile, the δ^{13}C and δ^{15}N values of a whelk, *Buccinum tenuissimum* varied at site in spite of same species. We considered that the food habit of the whelk was affected by site-specific factors rather than the maturity.

Our research showed that we could analyze the benthic food web at seep site more precisely rather than direct observation and elucidate the dependence of benthic community on methane-derived carbon using stable isotope analysis of widespread species.

This work was conducted as a part of METI's methane hydrate exploration project.

Keywords: methane hydrate, benthic fauna, food web, stable isotope analysis

MIS24-11 Room:102B Time:May 28 10:15-10:30

Distribution of atmospheric gas concentration in eastern margin of Japan Sea: A preliminary report from the 7K14 cruises

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Hydrate of natural gas is widely distributed in marine sediments in the eastern margin of Japan Sea. The natural deposits of gas hydrates are estimated to hold higher reserves than known conventional gas reservoirs. An active seepage of gas from the seafloor has previously been reported from gas hydrate fields worldwide. Atmospheric methane (CH_4), major component of seep gases, is an important short-lived climate pollutant. Our objective was to measure the distribution of atmospheric CH_4 concentration over the sea surface of gas hydrate areas along the eastern margin of Japan Sea.

We used the R/V Kaiyo-Maru No.7 (Kaiyo Engineering Co., Ltd., Japan) for the survey in the Oki Trough and offshore Akita-Yamagata (Mogami Trough) from mid April to early June 2014. Continuous measurement of atmospheric CH4 was performed on the ship using a wave-length-scanned cavity ring-down spectrometer (WS-CRDS) (model G2201-i, Picarro Inc., USA). Air sample was collected from an air intake at the top deck of the ship using an air pump placed in the observation room. To our experience, the ship sailed at approximately 6 knot. Location data were obtained from the nautical GPS.

Observed CH_4 concentration over the sea surface was not uniform in Mogami Trough, while mostly uniform throughout the Oki Trough. In addition, there was a tendency that CH_4 concentration in Mogami Trough was higher than that in Oki Trough.

This research was a part of METI's project entitled "FY2014 Promoting research and development on methane hydrate".

Keywords: shallow gas hydrates, methane gas, distribution of gas concentration

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MIS24-12 Room:102B Time:May 28 10:30-10:45

Geochemistry of continuous pore water intake by Osmotic Fluid Sampler

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On the Umitaka Spur of the Japan Sea, methane venting on the seafloor has been observed by ROV Hyper Dolphin, its strength and location change in short period. These changes effect on chemical and ecological environment of pore water and shallow sediments, continuous observation of these fluctuations are key to understand the dynamics of gas hydrate system near the seafloor. We have applied an osmotic fluid sampling system (OsmoSampler) from September 2013 to October 2014 to collect pore waters near the seafloor continuously and show the variations of gas and fluid geochemistry associated with the activity of gas venting. Although the concentration of sulfate is lower than that of seawater, it fluctuates for days accompanying small variation of methane concentration. The concentrations of chloride and other major ions also fluctuate near the seawater value. These changes of gas and fluid geochemistry may reflect the change of methane flux and following formation/dissociation of gas hydrates.

This research is a part of METI's project entitled *FY2014 Promoting research and development on methane hydrate*.

Keywords: Gas Hydrate, Methane Flux, SMI

MIS24-13 Room:102B Time:May 28 11:00-11:15

3D Seismic Velocity Structures Associated with BSRs and Gas Hydrate Accumulations on Joetsu Knoll in the Japan Sea

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Characteristics of BSRs

In the eastern margin of Japan Sea, gas hydrates in shallow sediments are characterized by blanking or gas chimney associated to mounds and pockmarks on the seabed. SadoW 3D seismic survey was conducted by METI offshore Niigata in 2008. 3D seismic data on Joetsu Knoll shows aligned BSR bumps on the ridge characterized by structural and velocity pull-ups associated to seabed morphology initiated mainly by large-scale methane seepage.

In this area, multiple BSRs are commonly observed. BSR map was illustrated for the shallowest. For BSR identification, we prepared the curves of seabed depth vs. thickness of BGHS below seabed as a function of geothermal gradients with seabed temperatures. Estimated BGHS is governed by several unknown factors. BSR shows acoustic impedance change and corresponds to BGHZ or top of free gas. Free gas exists if mass fraction of upward flux of gas exceeds its solubility in liquid. Once fraction is less than its solubility, separation of BGHZ and BGHS occurs.

On the ridge of Joetsu Knoll, aligned BSR bumps are conspicuous and have upward correspondence to mounds and adjacent pockmarks on the seabed, some of which appear to be related to subvertical faults interpreted as venting passes, which show blanking. Pull-up effects of higher velocity above them exaggerate relief of bumps. Along 2D sliced lines, acoustic velocity is estimated by continuous velocity analysis. Zone of higher velocity more than approx. 1700m/s spreads above BSR, which sandwiches relatively lower velocity zone. Below BSR bumps, two types of spreading of lower velocity zones is prominent, i.e., downward and horizontal on strong reflectors.

Blanking has multifold background; intense gas hydrates formation, free gas venting passes and other seismic wave attenuation/scattering phenomena. Important point is that apparent amplitude features are dependent on the frequency bands of respective surveys. It has not been commonly mentioned that amplitude behaviors alone could not rule out others as possible origins. Velocity information is important to reason probable origins. Lower velocities just above BSR show velocity smearing related to resolution limit of the current velocity analysis. Note short scale complex subsurface structure deteriorates the accuracy of velocity estimate in conventional velocity analysis. This shortcoming shall be overcome by more advanced approaches for fine and accurate mapping. Velocity evaluations by FWI as an example are taken for some velocity model inversion.

Seismic line along LWD locations

GR14 LWD survey was conducted in 2014 by METI. On L18_Line 6 of METI SK13 AUV/SBP survey, a 2D sliced seismic line is taken along the line of GR14 sites D1-1 and D10-1 from 3D seismic data and velocity structure map is generated. At site D1-1 for LWD1410, seismic blanking is prominent above and below BSR. Just below BSR, lower velocity compartment is striking and prominent blanking zone above BSR shows higher velocity. At site D10-1 for LWD1409, above and below BSR there are no prominent seismic blanking zones. Just above BSR, laterally spreading higher velocity is prominent.

Synthetic seismograms are computed by invariant imbedding method and compared with seismic data. Its frequency band of synthetics with Ricker wavelet source is adjusted to that of seismic data and amplitude of seismic data is adjusted to synthetic seismogram. Synthetic seismograms of LWD sonic show relatively higher amplitudes in later phases are partly caused by assumed density models and/or possible attenuation mechanism for seismic data. LWD resistivity converted to TWT indicates that estimated BGHZ does not correspond to BSR, which suggests higher LWD sonic velocities and/or probable frequency effects under the assumption of no separation of BGHZ and BSR in these locations and no specific site locality.

We would like to thank the permission of METI/JOGMEC for the usage of SadoW3D data in the current study and publication.

Keywords: Gas Hydrate, Blanking, Gas Chimney, FWI, Joetsu Knoll, SadoW 3D Seismic Survey

MIS24-14 Room:102B Time:May 28 11:15-11:30

Characteristics of natural gas hydrate retrieved at northern central Baikal basin

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Lake Baikal (Russia) is the solitary example of hydrate-bearing area in the environment of fresh water. Gas hydrate samples in sandy turbidites were first obtained at the southern Baikal basin in the Baikal Drilling Project in 1997. Multi-phase Gas Hydrate Project (MHP, 2009-2014), the international collaboration between Japan, Russia, and Belgium, has revealed distribution of gas hydrate in sub-bottom sediment at the southern and central Baikal basins. In the last cruise (MHP-14) we obtained gas hydrate crystals from four new places (Kukuy K-5, Khoboy, Akadem Ridge, and Barguzin) at the central Baikal basin. We report the characteristics of hydrate-bound gases at these sites.

Samples of hydrate-bound gas were obtained onboard and stored in 5-mL vials. We measured molecular and stable isotope compositions of the samples. According to the C_1/C_2 - $C_1\delta^{13}C$ diagram (Bernard *et al.*, 1976), the $\delta^{13}C$-δD diagram for C_1 (Whiticar, 1999), and the $C_1\delta^{13}C$ - $C_2\delta^{13}C$ diagram (Milkov, 2005), the gas characteristics show the following information:

1) Hydrocarbons at the Khoboy, Akadem Ridge, and Barguzin are microbial origin, and those of Kukuy K-5 is in the field of mixed-gas between microbial and thermogenic gases.

2) In the "Bernard diagram", hydrate-bound hydrocarbons of Kukuy K-5 locate on the mixing line of microbial gas at the Kukuy K-9 and thermogenic gas at the Kukuy K-4, those are the end members at the Kukuy Canyon area.

3) C_2 $\delta^{13}C$ of the hydrate-bound gas at the the Khoboy, Akadem Ridge, and Barguzin are low (less than -50 ‰), indicating microbial C_2. Microbial C_2 in the hydrate-bound gas has been observed at the Krasnyi Yar and Peschanka P-2 at the southern Baikal basin, and the Ukhan and Unshuy at the central Baikal basin.

4) The site Barguzin locates only 7 km distance from the site Gorevoy Utes, where oil-stained gas hydrate with thermogenic gas was retrieved.

Bernard BB, Brooks JM, Sackett WM (1976) Natural gas seepage in the Gulf of Mexico. *Earth Planet Sci Lett* **31**: 48-54.

Milkov AV (2005) Molecular and stable isotope compositions of natural gas hydrates: a revised global dataset and basic interpretations in the context of geological settings. *Org Geochem* **36**: 681-70. doi:10.1016/j.orggeochem.2005.01.010

Whiticar MJ (1999) Carbon and hydrogen isotope systematics of bacterial formation and oxidation of methane. *Chem Geol* **161**: 291-314. doi:10.1016/S0009-2541(99)00092-3

Keywords: gas hydrate, crystallographic structure, Lake Baikal

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Micropore effect on dissociation process of methane hydrate and fractionation of stable isotopes

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Gas hydrates are clathrate compounds that the guest-gas molecules are trapped in host-cages composed of water molecules, and are stable at low temperatures and high pressure conditions. Natural gas hydrate exists in the sea bottom sediments off Sakhalin Island (Sea of Okhotsk), those comprised of diatom with many small pores. Sediment particles may affect to formation and dissociation processes of gas hydrate because their small pores change equilibrium pressure of gas hydrate. Isotopic fractionation of guest gas between gas and hydrate phases has been reported (Hachikubo *et al.*, 2007), however, little is known about the effect of micropore on the fractionation of stable isotopes. We conducted calorimetric measurements of methane hydrates (MH) formed with silica-gel pores to investigate thermal properties of MH in the small pores, and measured isotopic difference in methane molecules between MH and residual gas at their formation process.

The silica-gel sample (pore diameter: 15 nm) was dried at 423 K for 24 hours and then adsorbed water in a chamber for three days. Methane hydrates were formed with the adsorbed water in silica-gel pores under high pressure of methane (10 MPa) at 273.2 K. Silica-gel samples with methane hydrate were stored in liquid nitrogen and the residual gas was also sampled. Thermographs of the hydrate sample were obtained by a calorimeter. Stable isotopes (carbon and hydrogen) of hydrate-bound and residual methane were measured by an IRMS.

The thermograph revealed that a broad peak around 173 K and other peaks ranged from 193 K to 203 K corresponded to dissociation of pore and bulk hydrates, respectively. Because the dissociation of hydrate formed ice and plugged the pores, a large endothermic peak appeared in the range from 223 K to 273 K and the internal pressure increased due to dissociation of confined hydrate.

δD of hydrate-bound methane was 6.2-7.2 ‰ lower than that of residual methane in the formation processes, agreed fairly with the result of Hachikubo *et al.* (2007). While there was no difference in the case of δ^{13}C (Hachikubo *et al.*, 2007), our results showed that δ^{13}C of hydrate-bound methane was several ‰ higher than that of residual methane, suggesting effect of micropores.

Hachikubo A, Kosaka T, Kida M, Krylov A, Sakagami H, Minami H, Takahashi N, Shoji H (2007) Isotopic fractionation of methane and ethane hydrates between gas and hydrate phases. Geophys Res Lett **34**: L21502. doi:10.1029/2007GL030557

Keywords: gas hydrate, micropore, diatom, stable isotope, isotopic fractionation, calorimetry

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Importance of physical property evaluation for methane hydrate R&D and pressure coring-analysis operation

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In the cases of either natural phenomenon or an artificial operation for resource development, a gas hydrate dissociation process can be regarded as transportation of heat and fluid masses in porous media. Because the convection term is dominant, the heat transport is highly affected by the fluid flow. The reasons why those basic physical problems are complicated are intrinsic complexity of geological formations, alternation of the physical parameters due to hydrate dissociation, and mechanical behaviors of soft sediments that can transform the properties dynamically. Therefore the focus of studies on the energy production technique from gas hydrate deposits is to understand the hydraulic, thermal, and mechanical properties and processes.

In the study program of the MH21 research consortium, evaluation of such physical properties, their distribution in geological formations, and dynamic behavior of them have been investigated through seismic surveys, drilling operations including geophysical logging, sampling and in-situ testing, laboratory experiments, numerical simulation, and so on. As one of those efforts, pressure core sampling in which the in-situ condition is kept, and measurement of the properties of the retrieved sample are especially important.

In June and July of 2012, the MH21 consortium has conducted core sampling operation in Daini Atsumi Knoll of the eastern Nankai Trough using a pressure coring device and D/V Chikyu (JAMSTEC). In the operation, about 35m samples were recovered by the device, and majority of them were fully or partially pressure-preserved.

After the on-board analyses, some of those retrieved samples were delivered to onshore laboratory testings under more controlled conditions. The main purpose of the study is to measure hydraulic and mechanical properties. Also relationship of the properties and geological features are important, and analyses on them could drive important knowledge about the sedimentation conditions of them.

A part of the study was conducted under Japan-US collaboration. The results are publicized in a special issue of Journal of Marine and Petroleum Geology. In this presentation, objectives, core sampling operation, and analysis flow are presented.

Keywords: methane hydrate, pressure core, hydraulic, mechanics, physical properties

MIS24-17 Room:102B Time:May 28 12:00-12:15

Crystallographic features of natural gas hydrates recovered by pressure coring in the eastern Nankai Trough area

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Natural gas hydrates are crystalline clathrate compounds that natural gas components are incorporated into cage-like frameworks consist of hydrogen-bonded water molecules. Natural gas hydrates are stable under high pressure and low temperature conditions such as deep marine environments. Crystallographic structures of gas hydrates are related to amount of trapped gas or thermodynamically stable condition for natural gas hydrates, which are important to characterize natural gas hydrate reservoirs.

In this study, the crystallographic properties of the natural gas hydrates recovered by pressure coring in the eastern Nankai Trough area were characterized by the spectroscopic analyses. The hydrate-bearing sediments were recovered from the eastern Nankai Trough area during the 2012 JOGMEC/JAPEX Pressure coring operation, aboard the DV Chikyu.

The primary hydrocarbon component is microbial methane for gases released from the hydrate-bearing sediments. The released gas contained trace amounts of ethane and heavier hydrocarbons. NMR and Raman spectroscopic analyses reveal that the crystallographic structure is structure I and the hydration number is 6.1.

This work was supported by funding from the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) planned by METI.

Keywords: gas hydrate, methane hydrate, hydrocarbons, pressure-coring, crystal structure

MIS24-18 Room:102B Time:May 28 12:15-12:30

Pressure Core Analysis on Permeability of Methane-Hydrate-Bearing Sediments

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Permeability is the most important factor affecting the gas productivity of hydrate-bearing sediments. In this study, effective water permeability of hydrate-bearing sandy sediments was measured by core-flooding test. The core samples were recovered under pressure from a methane hydrate reservoir located at the Daini-Atsumi knoll in the Eastern Nankai Trough off the shore of Japan. The cores were shaped cylindrically with liquid nitrogen spray after rapid pressure release and inserted into a core holder to maintain the hydrate phase stable P-T conditions and to apply a near in situ effective stress. The results showed that the effective water permeability in hydrate-bearing sandy sediments was in the range of 1-100 md. After depressurization-induced hydrate dissociation, absolute permeability of host sediments was analyzed. Absolute permeability of sandy host sediments was estimated to be up to 1.5 d. The results indicate that the hydrate-bearing sandy sediments at this location have promising permeability conditions for achieving depressurization-induced gas production. In addition, the change of absolute permeability caused by depressurization-induced gas production was analyzed. It was found that absolute permeability was reduced by the high effective stress and fresh water originating from hydrate dissociation most likely due to the sediment compaction and the clay swelling. Although depressurization is a promising method for the gas production at this location, the results indicate that reservoir formation damage should be considered during long-term gas production.

This study was financially supported by the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) to carry out Japan's Methane Hydrate R&D Program conducted by the Ministry of Economy, Trade and Industry (METI).

Keywords: pressure coring, Nankai Trough, turbidite, flooding test, effective permeability, absolute permeability

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MIS24-19 Room:102B Time:May 28 12:30-12:45

Geomechanical Properties of Methane Hydrate-Bearing Sediments from Pressure Coring at the Eastern Nankai Trough

YONEDA, Jun[1*] ; MASUI, Akira[1] ; KONNO, Yoshihiro[1] ; JIN, Yusuke[1] ; KIDA, Masato[1] ; NAGAO, Jiro[1] ; TENMA, Norio[1]

[1]AIST

Geomechanical properties are essential parameter for methane gas extraction from methane hydrate to achieve safe and secure production. In this study, natural methane gas hydrate-bearing sediments were subjected to triaxial tests using transparent acrylic cell to investigate the strength and stiffness of sediments from deep seabed in the Eastern Nankai Trough. The samples were recovered using pressure coring which is a progressive technology to maintain the pore fluid pressure from in-situ to the laboratory. Triaxial compression test of hydrate-bearing sediments at in-situ pressure conditions were successfully done without any hydrate dissociation. The digital photographs were taken during the tests and the local deformation of sediments was quantified in each 0.1% of axial strain level by image processing technique. From the results, hydrate-bearing sediments showed brittle failure with shear banding as evidenced by the stress-strain softening response. In contrast, hydrate-free sediments showed ductile failure mode. The shear strength increases with hydrate saturation. This result is consistent with the results of synthetic hydrate-bearing sediments. Local strain which was calculated from local deformation showed that there is the distribution in stiffness in each centimeter due to distribution of hydrate saturation. This study successfully demonstrates the use of pressure core samples to investigate geomechanical and geotechnical properties of intact hydrate-bearing sediments at in-situ pressures.

This study was financially supported by the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) to carry out Japan's Methane Hydrate R&D Program conducted by the Ministry of Economy, Trade and Industry (METI).

Keywords: pressure core, triaxial test, strength, stiffness, image processing, shear band

MIS24-20 Room:102B Time:May 28 14:15-14:30

Thermal constants of methane hydrate-bearing sediment and surrounding mud core samples recovered from Nankai Trough well

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This study presents measurements of the thermal constants of natural methane-hydrate-bearing sediments samples recovered from the Tokai-oki test wells (Nankai-Trough, Japan) in 2004. To investigate the influence of sediment composition on the thermal properties, the thermal constants of natural hydrate-bearing sediments were measured at 5 ℃ and 10MPa over a porosity range of $0.41 \leq \psi \leq 0.47$. In this porosity range, the thermal conductivity of natural hydrate-bearing sediments decreased slightly with increasing porosity. The specific heat of the hydrate-bearing sediments was almost constant and independent of porosity. The thermal diffusivity of hydrate-bearing sediment decreased with increasing porosity.

We also used simple models to calculate the thermal conductivity and thermal diffusivity. The results of the distribution model are relatively consistent with the measurement results. In addition, the measurement results are consistent with the thermal diffusivity, which is estimated by dividing the thermal conductivity obtained from the distribution model by the specific heat obtained from the arithmetic mean.

The thermal conductivity of silt soil in the mud layer sample was estimated by the distribution model, the result of which was much lower than that of the sand soil in hydrate-bearing sediment. This suggests that small grains influence the thermal conductivities.

Acknowledgments. This work was financially supported by MH21 Research Consortium for Methane Hydrate Resources in Japan on the National Methane Hydrate Exploitation Program planned by the Ministry of Economy, Trade and Industry.

Keywords: methane hydrate, thermal conductivity, thermal diffusivity, specific heat, gas hydrate-bearing sediment, hot-disk transient method

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MIS24-21 Room:102B Time:May 28 14:30-14:45

Development of pressurized subsampling system for structural imaging of pressured methane hydrate bearing sediments

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Gas clathrate hydrates (gas hydrates, GHs) are ice- like crystalline compounds consisting of gas and water molecules, in which the gas molecules are stored in a framework of water. GHs exist in oceanic and permafrost sediments; because they are a primary means of storing methane (CH_4), natural GHs are of interest as a potential new energy resource. On March 12, 2013, the first off-shore gas production test from the sandy GH layer in the eastern NT area; CH_4 gas productions were produced from the offshore hydrate layer. Here, porosity of GH bearing sediment is a key of gas production efficient from natural gas-hydrate reservoir. Developable natural GHs by conventional gas/oil production apparatus almost exist in unconsolidated sedimental layer. Because sand matrix in GH sediments could have been changed by freezing water in pores in the case of quenched sample, porosity discussed using quenched GH bearing sediment may be over estimated comparing with nature of sediments at in situ condition. Therefore, we developed in situ sub-sampling system for pressured natural GH sediments due to in situ porosity estimation. In this study, we demonstrated sub-sampling from an artificial GH sediment and confirmed sub-sampling results through micro-imaging.

This work was supported by funding from the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) planned by the Ministry of Economy, Trade and Industry (METI), Japan.

Keywords: Pressurized core, Methane hydrate, X-ray CT

MIS24-22 Room:102B Time:May 28 14:45-15:00

Characterization of grain-size distribution and mineral composition of hydrate-bearing sediments in the Nankai Trough

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[1]MHRC/ AIST, [2]JOGMEC

Gas hydrate-bearing sediments taken by a hybrid pressure coring system (Hybrid PCS corer) were recovered from the eastern Nankai Trough region at the AT-1 well during the 2012 JOGEMC/JAPEX Pressure coring operation using D/V Chikyu. The recovered sediments are mainly composed of the unconsolidated sand and mud alternation layers, which can be interpreted as turbidite and hemi-pelagic mud, respectively. Gas hydrates accumulated in unconsolidated sands as a pore-filling morphology. The purpose of our study is to prepare the standard samples, which represent the sedimentary features such as grain size and mineral composition in the eastern Nankai Trough sediments. For preparing the standard sample appears to be important for laboratory experimental studies such as physical properties from the engineering point of view.

Using the gas hydrate-bearing sediments, the sedimentary features such as gain size and mineral composition were analyzed systematically. Based on this grain size distribution data, we categorized typical three kinds of standards samples: silty sand, sandy silt, and clayey silt, respectively. As a result of mineral composition analysis of sediment measured by X-ray diffraction (XRD), the bulk mineral compositions are characterized by 10 compositions, i.e., the quartz, hornblende, feldspars (orthoclase, Plagioclase), pyrite, smectite, kaolinite, calcium carbonate, chlorite, and mica. These mineral compositions are strongly correlated with grain size features such as median or means sizes. According to the above results, we prepared typical three kinds of standard samples, and measured pore-size distribution and permeability features using the nuclear magnetic resonance (NMR) method. In the presentation, we will compare with those physical features between standard samples and natural sediments from the eastern Nankai Trough.

This work was financially supported by the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) of the National Methane Hydrate Exploitation Program planned by the Ministry of Economy Trade and Industry (METI).

Keywords: Nankai Trough, gas hydrate sediments, grain size, mineral composition, sediment core, standard sample

MIS24-23 Room:102B Time:May 28 15:00-15:15

CMR log analysis of the First Offshore Production Test at Daini-Atsumi knoll in the eastern Nankai Trough

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As preparatory drilling operations for the first offshore methane hydrate(MH) production test, monitoring wells (AT1-MC and AT1-MT1) and the upper part of production well (AT1-P) were drilled in FY2011. To confirm methane hydrate bearing circumstances, logging while drilling (LWD) and wireline logging (WL) were performed in AT1-MC. The production test was started on March 12, 2013. After a large amount of sand was produced on March 18, the production test was closed. During well-abandonment operations in August 2013, two LWD wells (AT1-LWD1 and AT1-LWD2) were drilled around the AT1-P, and open-hole WL were performed at the two wells.

The objectives of this study are to understand the characteristics of MH reservoirs and to confirm dissociation behavior of MH in the offshore production test field by analyzing logging data acquired in the wells that of AT1-MC, LWD1 and LWD2, especially CMR(Combinable Magnetic Resonance ; principle is same as Nuclear Magnetic Resonance) logging data. In AT1-MC, we acquired CMR data before the Test. In AT1-LWD1 and LWD2, we acquired CMR data after the Test.

CMR can measure T2 relaxation time, which indicates the amount of proton. But it can not measure rigid proton like in the ice, also included in MHs. This feature is usable to estimate MH dissociation behavior. Because, if the MH dissociate, water volume increase in the sediment. It may cause the change of T2 distribution that T2 relaxation time shifts to the longer time and the peak of T2 distribution increases. In addition, T2 distribution includes pore size information that short T2 relaxation time correspond to smaller pore and long relaxation time correspond to larger pore. Therefore, we might be able to discuss dissociation behavior.

In this study, we compared log plot of AT1-MC, LWD1 and LWD2. We can confirm some T2 distribution shift to the longer relaxation time in MH-bearing sandy layer in the AT1-LWD1, LWD2. Then, to observe the details, we separate the relaxation time to 8 bins. As a result of comparison of T2-mean(T2 logarithmic mean) in the each bin, T2-mean shift particularly observed in short relaxation time interval. The T2-mean of short relaxation time about AT1-LWD1 and LWD2 is longer than AT1-MC. It probably indicates dissociation of MH.

This study is a part of the program of the Research Consortium for Methane Hydrate Resource in Japan (MH21 Research Consortium).

Keywords: Methane Hydrate, NMR

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MIS24-24 Room:102B Time:May 28 15:15-15:30

Density structure of the pore-filling-type methane-hydrate reservoir at the Daini?Atsumi Knoll, Central Japan

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The permeability of methane hydrate sediments is controlled by the lithology of the sediments and the saturation of methane hydrate in pore spaces. Thus, estimates of porosity in the reservoir are important. However, sediments in gas hydrate reservoirs are soft; thus, disturbances during drilling easily degrade the quality of data, despite the sediment-reinforcing effects of gas-hydrate crystals. Hence, methods for correcting the measured properties of sediments are quite important. We obtain the density (porosity) structure of sediments within and above the methane hydrate reservoir. Due to uncertainties in the density logs, we corrected the logs using borehole caliper data, which is sometimes negatively correlated with density. The corrected density data agreed well with results inferred from analysis of sediments recovered in pressure cores. On these samples, we conducted mercury injection porosimetry on frozen depressurized samples from 2004 and 2012 and also determined density from the onboard multisensor core logger (MSCL) data on conventional cores, especially in methane hydrate concentrated zone (MHCZ). Our results allow us to divide the sediments above the gas hydrate stability zone (GHSZ) on Daini-Atsumi Knoll into four zones.The zone boundaries correspond to facies boundaries. This implies that the sedimentary facies strongly influenced not only the lithology, but also physical properties such as density (porosity).

Keywords: Gas hydrate, Logging-while-drilling (LWD), Density log, Borehole enlargement, Sedimentary facis