Identification of gas hydrate "concentrated horizons" in Umitaka Spur, off Joetsu, the eastern margin of Japan Sea

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Gas hydrate reservoir is confirmed in Umitaka Spur, off Joetsu, the eastern margin of Japan Sea. By combining the results of three research methods such as the Longing-While-Drilling (LWD), the coring for sample collection and the high-resolution 3D seismic survey (HR3D) reveal several horizons of gas hydrate "concentrated horizons" are identified that can be traced aerially.

How to recognize the "concentrated horizons"

The Vp values that are one of the continuous digital data of LWD from some drilling sites show several horizons of higher values occur in the background of low values. The samples collected by the coring being performed adjacent to the LWD sites confirmed that the high values of Vp zones correspond to the horizons. The observed pieces of gas hydrate mainly consist of the platy, veiny and granular types that occur in mud either densely or dispersedly. The abundance of the pieces of gas hydrate varies depending on the coring depths and drilling sites, and they are abundant where the Vp values are high. Carbonate nodules are scarcely found by the visual core description. The pattern of the variation of the Vp is almost common to many LWD sites and higher peaks or bumps occur almost the similar stratigraphic horizons. The patterns of the vertical change in Vp values give hints to correlate among different LWD sites, but they are hardly traceable inside the zone where Vp keeps abnormally high values for a long stratigraphic interval that is common in some mounds.

Corroboration by the HR3D

The analytical results by the HR3D confirmed that the correlation of “concentrated horizons” among the different LWD sites estimated by the pattern of Vp change was almost correct, and the correlation of this specific "concentrated horizons" can be traced as far as 2 km north and south. The striped structure observed in the HR3D generally develops almost in parallel except for some mounds and the interior of the pockmarks. Some biostratigraphic boundary determined by the change in diatom assemblage seems not to intersect markedly with the striped structure.

Implications

The types of gas hydrate indicates that those in the "concentrated horizons" were formed probably not contemporaneous with the deposition of the host muddy sediments, and it postdated some time after the deposition below the seafloor. However, details such as the depth of formation of "concentrated horizons", timing and cause(s) of gas supply, and the reason why gas hydrate *must* be concentrated in certain horizons are unknown.

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Keywords: shallow gas hydrate, concentrated horizons, Japan Sea

Pore space filling state of mud sediment in the gas hydrate area in the Japan Sea: assumption from oxygen isotopic composition of water fraction

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Gas hydrates in the Japan Sea occur massive, vein, and granular forms in fine-grained mud sediments. It is generally considered that the hydrate cannot be developed in micron-sized pore spaces in fine-grained sediments because of a reduced pore water activity and the capillary pressure in pores (Clennell et al., 1999). This appear a distinct contrast with pore-filling gas hydrates in sandy sediments, as observed in the Nankai Trough.
However, our analyses for the hydrate-bearing sediments recovered from Joetsu offshore imply that the gas hydrate at least partly fills the porosity of the mud sediments. Our analysis sequence consists three steps; the oxygen isotopes of the water fraction (porewater and hydrate) equilibrated with gaseous carbon dioxide, the methane/carbon dioxide ratio of headspace gas, and the porosity by measuring weight and volume of the dried sediments. We found that the difference in oxygen isotope between porewater and hydrate decreased down to <1.5 permil with increasing abundance of hydrate, which contradicts with theoretical calculation assuming fractionation in a closed system. Headspece gas of some mud sediments recorded extremely high methane/carbon dioxide ratio. These features imply the occurrence of hydrate in the porosity of the mud sediments. In addition, the porosity of the Joetsu sediments was clearly lower than the porosity of the other area (e.g., the Oki offshore). This can be explained by the pore-filling hydrate and/or free gas. Our findings improve the estimate of energy resource of the Japan Sea hydrate, and may contribute to future study for the hydrate recovery.
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Clennell et al., 1999. Journal of Geophysical Research 104, B10, 22,985–23,003.

Keywords: Gas hydrate, Japan Sea, Oxygen isotope

Time-series analysis of pore waters collected by OsmoSampler from the perspective of gas venting strength in shallow gas hydrate field, Japan Sea

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Recent marine surveys using ROV, fishery echo sounder, and multibeam echosounder have observed that the location and strength of gas venting on the seafloor have changed over periods as short as a few days in the shallow gas hydrate fields of the Japan Sea. It suggests geochemical environment of shallow gas hydrate system including gas venting may change quickly relative to other processes which occur on a geological time scale. Gas venting sites are characterized from the point of view of density (number) and volume of venting activity, and bottom material. The former at Torigakubi Spur offshore Niigata are very high, where the seafloor is covered with carbonate clasts of >50 cm and muddy sediments trapping gas bubbles. Carbonates on the seafloor are evident of active methane venting in the past. The venting density at Umitaka Spur offshore Niigata is also high, however, the volume is less than Torigakubi Spur, and bottom materials are mainly mud with small carbonates (2˜3 cm). There are no gas ventings during ROV investigations at Torimi Guri (reef) offshore Akita-Yamagata, where the bottom materials are mud.
To clarify how the difference of gas venting density and strength among sites have affected the geochemical environment including shallow gas hydrate system, we have collected interstitial waters at 30 cm below the seafloor for one year using a long-term osmotic fluid sampling system called OsmoSampler at three sites; significant venting site at Torigakubi Spur, venting site at Umitaka Spur and venting-free site at Torimi Guri, and have measured concentrations of dissolved ions and gases with a resolution of ˜1 day.
All the major ion concentrations show synchronous increase and decrease repeatedly over periods of 3˜5 days at all sites. Spiky changes are also present but appear irregularly. The range of synchronous change and frequency of spiky change are obviously different among sites. The largest synchronous change through one year is observed at Torigakubi Spur, which corresponds to high density and volume of gas venting. The higher density and volume of gas venting induces massive/rapid formation of gas hydrate, which may significantly control ion concentrations around gas hydrate deposits. The changes of methane concentration is also large at Torigakubi Spur, exceeding 10,000 mM, 5,000 times higher than other sites, the interstitial water may contain methane bubbles. There are no obvious correlations among methane concertation, venting density, and volume, this is because gas hydrate growth triggered by enhanced gas venting might have plugged the gas migration paths. We have clarified that the geochemical environments of interstitial water in shallow gas hydrate fields are constrained mainly by the density and volume of gas venting. Further investigations will clarify the relationship between venting strength and interstitial water geochemistry.
This study was conducted under the commission from AIST as a part of the methane hydrate research project funded by the Ministry of Economy, Trade and Industry, Japan.

Keywords: Gas venting, Shallow gas hydrate, Japan Sea, Long-term fluid sampling system, Interstitial water, OsmoSampler

Compositional and textural trends of microcrystalline dolomite found within massive gas hydrate in Joetsu Basin

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Recent exploratory drilling of massive gas hydrates in the Sea of Japan has revealed the presence of relatively pure, spherical growths of microcrystalline dolomite. The absence of sediment in association with the dolomite suggests that they were formed within hypersaline fluid inclusions which are situated inside of the hydrate itself. Stable isotope analysis of the dolomites suggests that the carbon isotopes are in equilibrium with the dissolved inorganic carbon in porewaters, while oxygen isotopes are consistent with the depletion of ^{18}O during hydrate formation. Composition of the microcrystalline dolomite appears to be consistent with other hypersaline environments such as evaporative lagoons, where similar mineralization occurs, including characteristic pairing of sperical dolomite aggregates. XRD analysis indicates that other carbonates, such as aragonite and calcite, are completely absent and Mg/Ca ratios range from 0.76 to 1.04, with the highest ratios generally found in the deeper samples. SEM-EDS analysis of sections of polished grains indicates that the grains have hollow cores, and are uniform in Mg/Ca ratios from the outer portion to the inner portion. Anomalous Mg/Ca ratios in shallow hydrate may indicate areas where shallow hydrate exposures have been released from the seafloor, followed by renewed shallow hydrate growth.
Research was carried out on Expedition PS15 onboard the RV Poseidon. This study was conducted under the commission from AIST as a part of the methane hydrate research project funded by METI (the Ministry of Economy, Trade and Industry, Japan).

Keywords: methane hydrate, dolomite, clathrate, Sea of Japan, Joetsu Basin


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Characteristics of BGHS in shallow methane hydrate fields of Oki Trough, eastern margin of Japan Sea

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Off San'in region, such as Oki Trough and Tsushima Basin, is known as one of the methane hydrate fields in the eastern margin of Japan Sea. This study focuses on BGHS (Base of Gas Hydrate Stability) in the Oki Trough and evaluates the influences on accumulation and disassociation of methane hydrate.
BGHS in the Oki Trough is mainly controlled by geothermal gradient. In the southeastern margin of Oki Trough, the geothermal gradient is comparatively high: 115–124 degrees C/km (e.g., Yasui et al., 1966, 1968). On the other hand, our geothermal investigation in the southwestern margin revealed the geothermal gradient as 71 degrees C/km. BGHS depths were estimated at the site in 727 m water depth in the southeastern margin and at the site in 763 m water depth in the southwestern margin to be 83 mbsf and 157 mbsf, respectively.
BGHS response to the 120 m sea-level fall during the Last Glacial Maximum was simulated. At the southwest slope of Oki Trough, the BGHS becomes 27 m shallower than present, while the variation at the southeast slope is 14 m. The response of BGHSs to the sea-level fall is prominently involved in methane hydrate disassociation, which makes the submarine ground unstable. This study intends to make reference to the relation between topographic deformation, like pockmarks and submarine slides, and methane hydrate disassociation in the Oki Trough.
This study was conducted under the commission from AIST as a part of the methane hydrate research project funded by the Ministry of Economy, Trade and Industry, Japan.

Keywords: shallow methane hydrate , BGHS, Oki Trough, Japan Sea

Variety of near-surface gas hydrates at the southern Baikal basin

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Natural gas hydrate exists in the bottom sediment of Lake Baikal. Near-surface gas hydrate was first discovered at the Malenky mud volcano at the southern Baikal basin in 2000. In the framework of Multi-phase Gas Hydrate Project (MHP, 2009-2017), our international collaboration between Japan, Russia, and Belgium, has revealed distribution of near-surface gas hydrates at the southern Baikal basin, and found eight new places (Krasnyi Yar 1-3, Kedr, Mamay, PosolBank2, Kedr2, and Solzan). The total number of places where near-surface gas hydrates were found is 14 in the southern Baikal basin, and we report the characteristics of gas hydrates retrieved from these sites.
Gas hydrate crystals were quickly collected onboard and stored in liquid nitrogen. Samples of hydrate-bound gas were obtained onboard and stored in 5-mL vials. We obtained the powder X-ray diffraction (PXRD) patterns of the crystals and measured molecular and stable isotope compositions of the gas vials.
PXRD results showed that almost all samples belonged to the crystallographic structure I; however, some samples retrieved at Kedr and Kedr2 where massive and granular crystals were recovered in the last cruises (MHP-15 and 16) belonged to the crystallographic structure II.
According to the C_1/C_2 - $C_1d^{13}C$ diagram (Bernard *et al.*, 1976), the $d^{13}C$-dD diagram for C_1 (Whiticar, 1999), and the $C_1d^{13}C$ - $C_2d^{13}C$ diagram (Milkov, 2005), the gas characteristics show the following information:

1) Hydrate-bound hydrocarbons at the Krasnyi Yar 1-3, PosolBank2, and Solzan are mainly microbial origin, those at the Kedr and Kedr2 mud volcanoes are thermogenic origin, and those at the Mamay are in the field of mixed-gas between microbial and thermogenic.

2) C_1dD of the hydrate-bound gas at the Krasnyi Yar 1-3, PosolBank2, and Solzan distributed around -300 permil, and those at the Kedr and Kedr2 were around -270 permil due to the effect of thermogenic methane.

3) $C_2d^{13}C$ of the hydrate-bound gas at the PosolBank2 was around -30 permil, and that at the Solzan was around -70 permil, indicating the effect of microbial C_2. The latter $C_2d^{13}C$ at the Solzan is the lowest value of hydrate-bound C_2 in the world.

4) $C2d^{13}C$ of the hydrate-bound gas at the Kedr and Kedr2 mud volcanoes showed that $C_2d^{13}C$ of the structure II was around 10 permil lower than that of the structure I, suggesting that the structure I dissociated and formed the structure II according to an isotopic fractionation.

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Keywords: gas hydrate, crystallographic structure, Lake Baikal

Gas plume and anomaly atmospheric CH_4 concentration

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Geological sources of greenhouse gases (e.g., methane (CH_4) and carbon dioxide (CO_2)) in the onshore area emit directly into the atmosphere. On the other hand, CH_4 release from the offshore area is certified as 'gas plume' in the water column. The gas plume is vertical acoustic anomalies in the water column and composed of the gas bubbles. The gas plume observed in the Japan Sea is CH_4 gas supplied through gas chimney. Massive nodular hydrates (shallow gas hydrate) are locally concentrated with high CH_4 flux via gas chimney. Exploration of gas plume is one method of investigating the accumulation zone of shallow gas hydrate. If the gas forming gas plumes reaches the atmosphere, the atmospheric CH_4 increase. We investigated the relationship between gas plume locations and anomalies of atmospheric CH_4 concentration.

We observed the higher CH_4 concentrations nearby a gas plume point (<5 km) in some gas plume site. Since the anomaly of atmospheric CH_4 concentration may be attributed to anthropogenic origins from land, satellite data (ASCAT and WindSat) observing the wind direction were used to screen wind directions. The water temperature profile differed depending on the sea area, and it seemed to be related to anomaly atmospheric concentration.

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Keywords: Shallow gas hydrate, Gas plume, Methane (CH4)

The discovery of chemosynthetic *Calyptogena* in the high methane activity area off Hidaka, Hokkaido.

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Methane seeps has been reported so far off the southeast of Hokkaido (off Hiroo) (Fujikura et al., 2012, etc.). There is a possibility that there is methane seep also off the southwest of Hokkaido (off Hidaka) from the interview survey of the fishery cooperative, and from August 1 to 7, 2016 in the ocean survey by the TR/V Umitaka maru (UT 16 Leg. 2) was carried out. The survey was conducted at four stations in the Hidaka trough using Okean grab sampler, piston corer, CTD. We report were collected *Calyptogena* bivalve is a chemosynthetic organism by Okean grab sampler at one station.
In this survey, sediments were collected by the Okean grab sampler at three stations (depths of 692 to 988 m) off Hidaka. Three empty conjoined valves (dead specimens) and fragments were collected from St. G1603 (depth of 970m). Sediment in the sand and mud, polychaetes and ophiuroids were collected along *Calyptogena*.
In the northern wall of the Hiroo Submarine Canyon off the southeast of Hokkaido (water depth 1240 m), methane seep and habitat of *Calyptogena* species have been confirmed (Fujikura et al., 2013). Comparison of Hidaka’s specimens and Hiroo’s specimens showed that the shell shape was similar, but the form of the hinge was different and considered to be a different species. It is known that there are species differentiation due to difference in inhabitant depth (Fujikura et al., 2000). The habitat depths of off Hidaka and off Hiroo is almost the same depth, but the districts are about 260 km apart. But, Hiroo’s species occurs in the north wall of the Hiroo Submarine Canyon, where the subduction activity is much higher than the locality of Hidaka’s species which was collected from the immediate west of Hidaka Trough (970-1300 m depth). The occurrences of these two species from nearby localities must be considered from viewpoints of geological setting comparing tectonical characteristics of both localities.
In the place where Hidaka’s specimens were collected, gas chimneys and plumes were observed at the flat bottom of the central northern part of the Hidaka trough, and gas hydrate was confirmed by the piston corer at the same place. According to this discovery, it can be said that in the waters of the Pacific Ocean side of Hokkaido, it is found that *Calyptogena* species can be a clue to the detection of the surface gas hydrate, which is also an important discovery from the resource exploration.

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Keywords: shallow gas hydrate, Calyptogena, methane seep

Characterization of topography-bottom sediment-benthos in shallow gas hydrate fields of the Japan Sea

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Wide distribution of mounds and pockmarks that were formed due to the formation and/or dissociation of shallow gas hydrates have been observed in the Mogami Trough, Joetsu Basin, and Oki Trough, Japan Sea. ROV researches have found the outcropping of gas hydrate near the seafloor, gas seepage and distribution of carbonate clasts and bacterial mats on the seafloor which resulted from high gas (methane) flux from deep sediment to the water column in those areas. We also found that the distribution densities of *Zoarcidae* (Genge fish in Japanese) and red snow crab are significantly high in those areas, the distribution of shallow gas hydrate, essentially methane, likely controls the distribution and relationships among topography, bottom sediment, and benthos. In this study, we integrate the bathymetry and backscatter data with the data of seafloor observation using ROV in order to characterize the seafloor environments including shallow gas hydrate deposits.

High backscatter areas are often observed on the summit of mounds or topographic high, rather than within the pockmark and on the flank. Carbonate clasts and bacterial mats distribute in relatively narrow region within the high backscatter area, their distributions, however, do not overlap each other. Methane flux/concentration is not the only process which can constraint the precipitation of carbonate and cultivation of bacterial mats together. The *Zoarcidae* and red snow crab likely live on the high backscatter areas except within the pockmarks, the topography, controlling bottom current, slope angle etc., as well as bottom sediment type may constraint their distributions. Our results show the importance of integrated seafloor data for assessing the effects of gas hydrate formation/dissociation on the seafloor environments.

This study used data collected during the academic researches and expeditions conducted under the commission from AIST as a part of the methane hydrate research project funded by the Ministry of Economy, Trade and Industry, Japan.

The permeability estimated from Logging-While-Drilling (LWD) data, obtained by methane-hydrate bearing sediments of the Daini-Atsumi Knoll, Northeast Nankai Trough

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Abstract

It is quite important to understand the permeability of pore-filling type hydrate-bearing sediments for considering how to construct methane-hydrate reservoir and to migrate hydrocarbon. Especially, in case of adopting depressurization method for gas production, the permeability of methane-hydrate bearing sediments is one of the most effectible physical properties for gas production rate. Thus, the many researchers have tried to grasp the permeability from measuring cores and from analyzing logging data. We, JOGMEC was carried out the pre-drilling campaign at 2016 for the 2nd offshore gas production test planned at 2017. The bottom simulating reflector (BSR) was penetrated by two research wells which were drilled with several kind of Logging-while-Drilling tools, and many new dataset were obtained. One of the new datasets was obtained by NMR tool, and we estimated the initial permeability of methane-hydrate bearing sediments using T2 distribution with Timur-Coates equation. Also, we calculated absolute permeability of those sediments using porosity measured by density-logging tool with Koizney-Carman equation, which referenced core permeability.

On the basis of core permeability, we found out that the constant for Timur-Coates equation for permeability computed from logging data is 50000, which value is coincident with the constant of the permeability analysis at the 2004 drilling campaign; i.e., the campaign was Kiso-shisui, Tokai oki - Kumano nada. The result of permeability computing, the permeability for muddy sediments was around 0.01-1mD, and that of sandy sediments was around 1 - 1000mD, which depends on methane hydrate saturation. We will present the result of permeability analyses, and discuss those permeability values validities for methane-hydrate sediments.

Acknowledgements

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Keywords: Gas Hydrate, Permeability, Turbidite, Logging-While-Drilling (LWD), Initial Effective Permeability, Absolute Permeability

Measurement of dissociation heat of N_2, O_2, and Ar hydrates

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Gas hydrates are crystalline clathrate compounds composed of gas and water molecules, and stable under low temperature and high pressure conditions. Dissociation heats (enthalpies) of gas hydrates have been obtained from their phase diagrams using the Clapeyron equation; however, the application has also been difficult due to low quality of the phase data. Dissociation heat of N_2 hydrate was reported by Kang *et al.* (2001), but the value is thought to be overestimated because it is larger than that of methane hydrate. Dissociation heat of O_2 and Ar hydrates have not reported yet. In this study, we applied calorimetric technique to determine their dissociation heat.
The samples of gas hydrates were synthesized from fine ice powder and guest gases at 273.2 K and the pressure condition of 20MPa (N_2) and 16MPa (O_2 and Ar). The ice powder started to melt and formed these gas hydrates. Approximately 1 g of each hydrate sample was set in a pressure cell specially designed for a Tian-Calvet type heat-flow calorimeter, and its dissociation monitored. The experimental setup and technique were the same as the one that was used previously by Hachikubo *et al.* (2009; 2012).
Dissociation heats of N_2, O_2, and Ar hydrates from hydrate to gas and ice are 12.8±0.2 [kJ mol^{-1}], 12.6±0.1[kJ mol^{-1}], and 13.2±0.1[kJ mol^{-1}], respectively. Yoon *et al.* (2003) reported that dissociation heats of N_2 and O_2 hydrates are 12.18 [kJ mol^{-1}] and 11.52 [kJ mol^{-1}], respectively, using the Clausius-Clapeyron equation. Therefore, our data are several percent smaller than the previous report.

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Keywords: gas hydrate, dissociation heat, hydration number, calorimetry

Isotopic fractionation process of guest gas at the formation of nitrogen hydrate

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Gas hydrates are crystalline clathrate compounds composed of water and gas molecules that are stable at low temperature, high partial pressure of each gas component, and high gas concentration. Nitrogen hydrate exists in Greenland and Antarctic ice sheets as an air (N_2 and O_2 mixed gas) hydrate. Recently, existence of nitrogen hydrate has been expected in the Titan (the largest moon of the Saturn). On the other hand, isotopic fractionation of carbon and hydrogen in methane and ethane during the formation of gas hydrates was reported by Hachikubo *et al.* (2007). In this study, we report isotopic fractionation of nitrogen during the formation of nitrogen hydrate. The samples of nitrogen hydrate were experimentally prepared in a pressure cell and isotopic compositions of both residual and hydrate-bound gases were measured. d^{15}N of hydrate-bound molecules was about 0.2 permil higher than that of residual gas molecules in the formation processes. Temperature effect on the isotopic fractionation was small between 226K and 273K.

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Keywords: gas hydrate, stable isotope, nitrogen

Raman spectroscopic analysis of mixed-gas (methane and hydrogen sulfide) hydrate

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Natural gas hydrates in subsurface marine sediment encage hydrogen sulfide. Microbial community produces hydrogen sulfide from methane ascending from deeper sediment layer and sulfate supplied from sea water. The existence of hydrogen sulfide decreases the equilibrium pressure of natural gas hydrate. Therefore, near-surface gas hydrates might exist in shallower area (i.e. less than 300m below sea level). On the other hand, hydration number decides the amount of gas in an unit volume/weight of crystal. In the case of ideal full-occupation of hydrate cages, the value of hydration number is 5.75 (Sloan and Koh, 2008). However, actual hydration number is estimated to be around 6, because small amount of empty cages decrease the free energy and stabilize the crystal. The cage occupancies and the hydration numbers can be estimated from these Raman peak intensities using a statistical thermodynamic model (Sum et al., 1997); however, the effect of hydrogen sulfide on the estimation has not examined yet. In this study, we synthesized methane and hydrogen sulfide mixed-gas hydrate and obtained their Raman spectra.
The mixed-gas hydrates were synthesized in a pressure cell, and retrieved the crystals at the temperature of liquid nitrogen. Hydrate-bound and residual gases were also sampled and their gas compositions were determined using gas chromatograph. Raman spectra were obtained at 123 K in the range 2,800-3,000 cm-1 and 2,500-2,700 cm-1 for the C-H stretching peaks of methane and the S-H stretching peaks of hydrogen sulfide, respectively. The Raman peaks were fitted using a Voigt function to obtain the integrated intensities of the two peaks corresponding to methane and hydrogen sulfide encaged in the large and small cages of the cubic structure I.
The methane peak ratio of large to small cages first increased with the composition of hydrogen sulfide (up to several percent), and then decreased and converged with the number of 3.2. On the contrary, The hydrogen sulfide peak ratio distributed from 2.4 to 2.8, increased with the composition of hydrogen sulfide, and then converged with the number of 3.2. These results suggest that molecules of hydrogen sulfide prefer to be encaged in small cages, although the molecular diameter of hydrogen sulfide is larger than that of methane.

Sloan and Koh (2008) Clathrate Hydrates of Natural Gases, 3rd ed., CRC Press: Boca Raton, FL, USA

Sum et al. (1997) Measurement of clathrate hydrates via Raman spectroscopy. J Phys Chem B 101: 7371-7377.

Keywords: gas hydrate, hydrogen sulfide, Raman spectroscopic analysis

Gas hydrate dissociation behavior from temperature monitoring data

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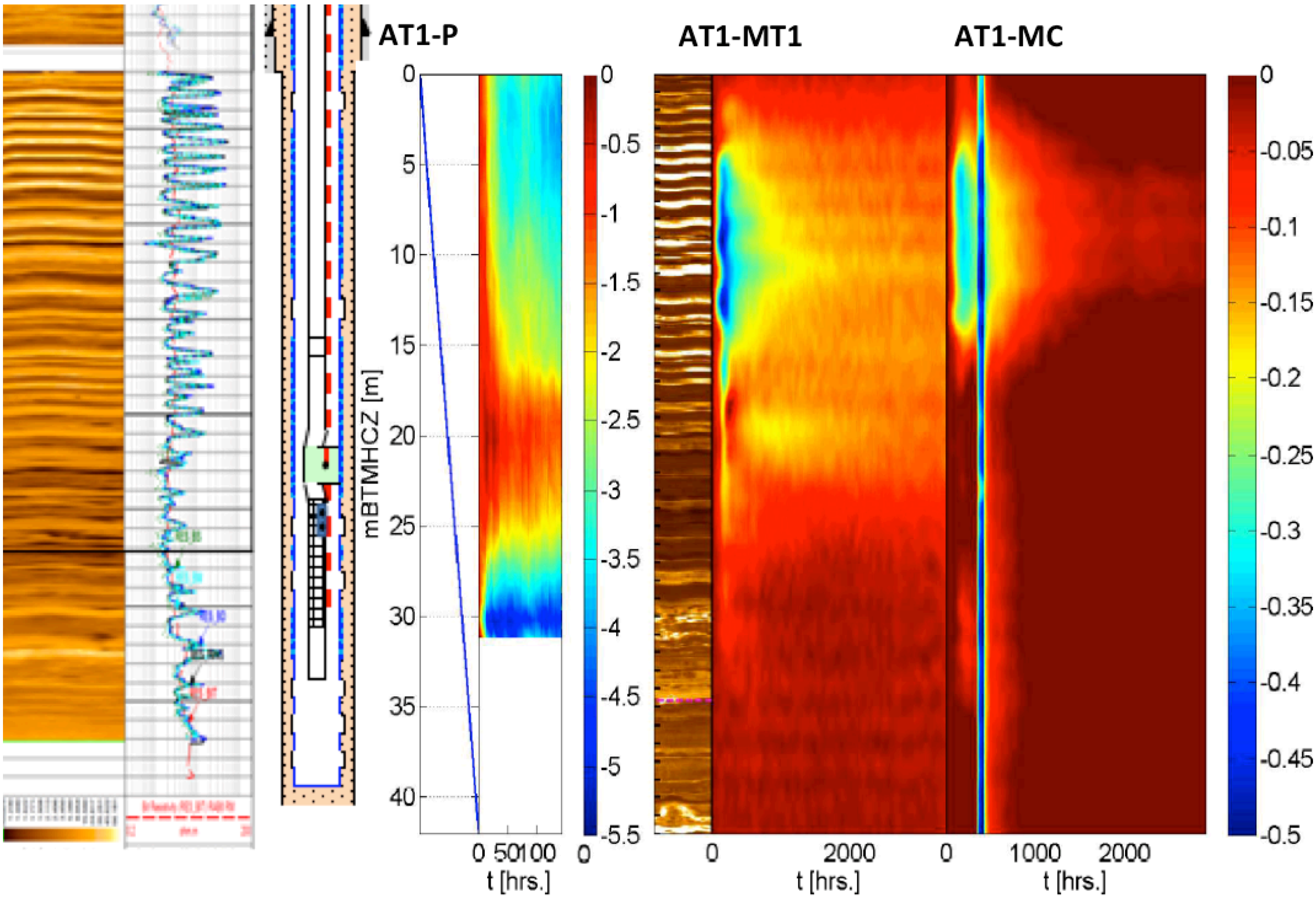
Because the gas hydrate dissociation is an endothermic process, temperature measurement is an important way to know the response of gas hydrate reservoir to the application of some gas production techniques. Furthermore, a heat source, and how efficiently the heat is supplied form the formation are critical knowledge to evaluate effectiveness of the depressurization method as a practical gas production technique that depends on natural heat supply from formations.

The program of the 2013 first offshore production test of methane hydrate in the Eastern Nankai Trough included temperature monitoring in the production hole (AT1-P) and monitoring holes (AT1-MT1/MC). In all wells, some degree of temperature drop was observed.

During the six-days of the depressurization operation, maximum 5 K and 0.5 K in P and MT1 wells respectively. The vertical profiles of the temperature drop show high degree of heterogeneity, and the dissociation process reached in a localized region of the monitoring well. The water production zone in the production well was also concentrated at a specific depth.

Rapid temperature changes were observed in every well when the sand production event happened and terminated the flow in the seventh day of the test. The data show that the sanding occurred at a specific depth with strong water flow, and effect of it reached the monitoring hole location of 20 to 30 m far away.

Keywords: Gas hydrate, Thermal behavior, Depressurization, Downhole measurement


AT1-P
AT1-MT1
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-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5

4-Component seismic survey in the second offshore production test of methane hydrate

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JOGMEC carries out 4-component seismic surveys before and after an offshore production test and grasps a change in physical properties by dissociation of methane hydrate (MH) three-dimensionally and evaluates MH dissociation behavior from those data comparisons.
The 4-component seismic survey data was acquired three times in August, 2012 before the production test, in April and August, 2013 after the test in the first offshore production test. The result could show the change in physical properties by the data comparison between before and after the test. On the other hand, improvements of quality of acquired data such as a design of receiver and source points, accuracy of source points and cause of a change in physical properties by data comparison between before and after the test were mentioned as a problem. So, the problems experienced in the first production test were improved for a data acquisition of the second offshore production test. A preliminary simulation was carried out. As a result, it was confirmed that the improvement of the resolution of MH around the production well was possible by the following matters;
・One OBC (Ocean Bottom Cable) would be manufactured additionally and two OBCs would be used.
・Two OBCs would be set in east and west so as to insert the production well. Those direction would be made north and south.
・Source points would be arranged in the range of 4 km north and south and 3 km east and west centering on the production well.
・In order to improve the accuracy of the source points, GPS antenna would be installed at the center of the float hanging an air-gun.
So, one OBC was produced additionally in FY2016 and the 4-component seismic survey data before the test was acquired by the specifications according to the results of the simulation around the production well of the second offshore production test in August, 2016.
From the comparison of the profiles between the acquired data and the data of Daini Atsumi Knol in the geophysical survey project in ‘Tokaioki to Kumanonada ‘took in 2002, it could be confirmed that the resolution in the MH reservoir, below BSR (Bottom Simulating Reflector), and between the sea bed and the top of the MH reservoir was improved. Therefore, more accurate reservoir structure grasp and the evaluation of MH dissociation behavior by comparing to the data after the test will be expected.
This study shows an example of interpretation of the profile before the test.
This study is performing as part of resources assessment of MHs offshore surrounding Japan that JOGMEC is conducting as a member of a research group for resources assessment of Research Consortium for Methane Hydrate Resources in Japan (MH21).

Keywords: 4-Component seismic survey, OBC, Methane Hydrate

Methane Hydrate Potential of the Hidaka Trough, Offshore Japan

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JOGMEC, as a member of research group for resources assessment of Research Consortium for Methane Hydrate Resources in Japan (MH21), has been conducting resources assessment of methane hydrate (MH) offshore surrounding Japan.
This study aims to investigate the gas hydrate potential by the analysis of the 3D seismic reflection survey. In terms of resources assessment, it is important to understand the character and distribution of the BSR (bottom simulated reflector), sand distribution, high velocity anomaly and strong amplitudes above BSR to interpret the methane hydrate concentrated zones (MHCZ) quantitatively.
The 3D seismic reflection data (4800 m streamer, 384 channels, 48 fold) acquired in 2013 and 2014 by geophysical vessel ‘Shigen’, which is owned by Agency for Natural Resources and Energy. We investigated the potential of methane hydrate as resources in the Hidaka trough by the 3D data in Hidaka trough which located in the south Hokkaido government, Japan.
The BSR exists in quaternary sediment and extends over a broad area of the Hidaka trough. Amplitudes of BSR are various and some of them associate with amplitude versus offset (AVO) anomaly. Quaternary sediment is interpreted as hemipelagic and gravity flow deposit. Low amplitude anomaly below BSR associated with low interval velocity and pull down effect are observed as large gas chimney. Topographical anomalies like small diapir with high amplitude indicates hydrate mounds on the water bottom. They suggest that hydrocarbon matured and generated in deep area, then it migrated and trapped to shallow sediment through several faults caused by tectonics in the foreland basin. It is obvious that hydrate in the basin are closely related to the petroleum system.
Even the focused area has not been drilled, the analysis of 3D seismic data and its interpretations are useful to understand thermal structure, fluid migration, and estimation of the MHCZ in the basin.

Keywords: Methane Hydrate, Seismic Reflection

Methanogenesis and methane consumption within the gas chimney structure in Hidaka Trough, offshore Hokkaido: implications from pore water and gas geochemistry

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Hidaka Trough, offshore Hokkaido, is characterized by gas chimney structures, methane plume, and degassing structures that indicate gas migration from deep sediments to the surface area. This methane is strongly associated with microbial mediated chemical reactions in shallow sediments. This study aims to figure out the microbial processes such as methanogenesis and methane consumption, characterizing geochemical environment in shallow sediments, by analyzing concentrations of dissolved ions and hydrocarbons, and stable isotopic composition ($\delta^{13}C$) of dissolved carbons collected from mounds with gas chimney structures in Hidaka Trough.

Sulfate is depleted strongly near the seafloor at the sulfate-methane interface (SMI), indicating the domination of reductive environment near the seafloor. Sharp negative peak of $\delta^{13}C$ of dissolved inorganic carbon (DIC) locates at the SMI, indicating the anaerobic methane oxidation predominates for the sulfate consumption at this interval. We examined $\delta^{13}C$ of methane and dissolved hydrocarbon composition to distinguish the gas source. Although the biogenic methane is transported from deep sediments, it receives a certain amount of methane of thermogenic origin. In addition, by comparing $\delta^{13}C$ of methane with DIC, biogenic methane produced by microbial mediated CO_2 reduction pathway is also significant. Methane produced by microbial mediated CO_2 reduction within upper methanogenesis zone and biogenic and/or thermogenic methane derived from deep sediments contributes to the shallow reductive environment within gas chimney structures in Hidaka Trough.

This study used data collected during the academic researches and expeditions conducted under the commission from AIST as a part of the methane hydrate research project funded by the Ministry of Economy, Trade and Industry, Japan.

Geochemistry of methane in surface sediment of shallow gas hydrate deposits in the Oki Trough and Joetsu Basin, Japan Sea

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Shallow gas hydrate deposits have been developed, often accompanying subsurface gas chimney structures and gas seepage on the seafloor, in the Oki Trough and Joetsu Basin areas in the Japan Sea. High gas concentration, mainly methane, is a key for characterizing and constraining the reaction and behavior of carbon in the seafloor˜sub-seafloor environments. Here we present the analytical results of sulfate concentration and isotopic composition and concentration of gases dissolved in pore waters collected from the intensive shallow gas hydrate coring program in 2015 (PS15) in order to discuss the biogeochemical processes around the sulfate-methane interfaces (SMI) in these fields.
The depths of SMI are shallow and $\delta^{13}C$ values of methane below the SMI are high in the Joetsu Basin compared to the Oki Trough, reflecting that higher methane flux is caused by higher contribution of thermogenic gas. The $\delta^{13}C$ values show negative peaks around the SMI, which are relatively large in the Joetsu Basin, reflecting the carbon recycling between anaerobic methane oxidation and microbial methane production around there. The rapid decreases of C1/(C2+C3) ratios around the SMI are also caused by the anaerobic oxidation of methane. The C1/(C2+C3) ratios are entirely high in the Joetsu Basin, resulting mainly from ethane enrichment in the Oki Trough. Differences of gas source is one of the important factors controlling shallow biogeochemical processes.
This study was conducted under the commission from AIST as a part of the methane hydrate research project funded by the Ministry of Economy, Trade and Industry, Japan.

Keywords: shallow gas hydrate, Japan Sea

Ionic analusis of seawater and interstitial water in methane hydrate fields off Sain'in region of estern Honshu, Japan

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In order to assess geochemical condition, we measured dissolved ion of seawater and interstitial water in methane hydrate fields off San’ in region of western Honshu, Japan. Sediment samples were obtained in Tsushima Basin, Yamato Basin and Oki Trough using in July 2016. The methane flux in study area is comparatively high. Although methane hydrate has not been recovered in study sites, methane hydrate is probably embedded in deeper horizons, as indicated by chloride concentrations.

Keywords: Methane hydrate, Interstitial water

Geochemical characteristics of hydrocarbon gases within gas chimney structures in the Tsushima Basin and the Oki Trough, Japan Sea

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Shallow gas hydrate often develops in gas chimney structure with mound/pockmark in the Japan Sea, however, the distribution and reaction of gas inside the chimney is not well understood. We retrieved cores from the well-develop gas chimneys with mound in the southeastern margin of Tsushima Basin and western and eastern Oki Trough to examine the relationship between the geochemical composition of gas and geological structure of gas chimney in the Japan Sea of Southwest Japan.

Concentrations of sulfate dissolved in pore waters rapidly decrease with depth to the sulfate-methane interface (SMI). Contrarily, concentrations of methane increase downward from the depth of the SMI. Methane/ethane ratios are low (<100) above the SMI, however, those rapidly increase below the SMI. This is because methane was preferentially oxidized by the sulfate at the depth of SMI and methane was generated by methanogenic bacteria above the SMI. The highest methane flux is observed in the western Oki Trough area where the thermogenic methane are most dominant below the SMI among sites. This site is characterized by the subsurface structure of a large-scaled gas chimney complex and the thermal gradient as high as 57mK/m, indicating that thermogenic methane is produced in relatively shallow sediment and is efficiently delivered to the near-surface environments.

Keywords: gas chimney, hydrocarbon gas, Japan Sea

Biogeochemistry of the seawater-seafloor of Oki trough

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Recently, Shallow methane hydrates near the seafloor has been found in the Japan Sea including Oki Trough area, there are also found characteristic submarine topography such as mound/pockmark topography and chimney structure indicate shallow methane hydrates existence. Some of these features often accompany active methane seepage (methane plume), they cause the local changes of biogeochemical environments near the seafloor. Understanding impact shallow methane hydrates work seafloor environment and water column play important role in understanding ocean environment including shallow methane hydrate areas. We have collected seawater and sedimentary pore water samples in order to characterize the biogeochemical processes associated with the high methane delivery and accumulation. The sampling sites are focused in an area where mound-gas chimney structures are well developed at water depths of 760 m, situated in the Oki Trough of the Japan Sea, ~120 km offshore Tottori.
Concentrations of methane dissolved in water columns collected from fixed point observation of offshore Tottori show little variations near the seafloor, but some variations near depth from 200 meters below the sea-level (mbsl) to 400 mbsl. The concentration of methane dissolved in the seawater is high between 200 and 400 mbsl, which may reflect the formation of shell-like methane hydrates on the surface of the methane bubbles near the seafloor and its dissociation around the upper limit of the hydrate stability around 400 mbsl, and subsequent methane release into the seawater.
Concentrations of methane and ethane dissolved in the sedimentary pore waters collected from the same location are relatively high, comparable to the sites in Offshore Joetsu, and the concentration of sulfate rapidly decrease downward to the sulfate-methane interface at <1.5 meters below the seafloor, methane flux is as high as those in the Offshore Joetsu sites. The chemical compositions of these gases are similar to the sites where bacterial mats and carbonates with frequently high concentrations of methane are widely observed in other areas of Oki Trough.
This study was conducted as a part of the shallow methane hydrate exploration project of METI and the expeditions by the Tottori Prefecture Fishery Research Center.

Investigation of Gas Hydrate Petroleum System in the Miyazaki-oki Forearc Basin, Japan: Preliminary Results

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JOGMEC Methane Hydrate R&D Group has been conducting long-term feasibility studies to assess the available gas hydrate resources in the eastern Nankai Trough, Japan. In order to understand methane generation, migration and accumulation mechanism of gas hydrate, petroleum system modeling (PSM) approach has been utilized for the resource assessment study of the eastern Nankai Trough with provable results. We have applied the modeling approach of the eastern Nankai Trough study in exploring methane hydrate resource assessment of Miyazaki Oki area. This study presents preliminary results of 1D and 2D modeling study of Miyazaki Oki area in investigating sensitivity of lithology and petroleum systems parameters to simulate gas hydrate stability zone (GHSZ) to match with interpreted bottom simulating reflectors (BSRs).

Study area comprises lower Miocene to Pleistocene, deep to shallow marine sedimentary successions of Hyuganada group and Miyazaki Group overlain the basement Shimanto Group. Based on 6 interpreted sequence boundaries from 3D migration seismic and velocity data, construction of a depth 3D framework model is made and distributed by a conceptual submarine fan depositional facies model derived from seismic facies analysis and referring existing geological report. In contrast to the eastern Nankai Trough, the Miyazaki Oki area is lack of calibration data such as pressure and temperature but an exploratory well, Udo Oki-1X, was drilled in the vicinity of the study area. The exploratory well covers most of Miyazaki group where geochemical data, lithology, temperature and vitrinite reflectance are available. Referring to this well, pseudo wells are constructed and sensitivity analyses of lithology and petroleum system parameters are performed. These 1D pseudo well results are applied to 2D modeling and migration simulation. Biogenic methane generation models, Gaussian distribution with peak temperature (model applied in the eastern Nankai Trough models) and Middleburg model based on sedimentation rate, were applied to generate biomethane. PetroMod compaction and permeability curves are assigned for each lithology and hybrid algorithm (combination of Darcy and Flowpath) were used in migration simulation process.

The 2D modeling study has confirmed that lower boundary of GHSZ at pseudo wells has been simulated with sensitivity of a few tens of meters in comparing with interpreted BSR. Furthermore in terms of geological properties, as gas hydrate accumulation increases, trends of reducing effective porosity and permeability are also observed accordingly. Preliminary results of 1D and 2D modeling will be applied to 3D model to investigate migration of biomethane and accumulation of methane hydrate in spatial distribution. As the future works, simulation run of 3D base case model, investigation of structural development and updating facies distribution are planned to perform.

Keywords: Miyazaki Oki, Gas Hydrate Stability Zone, Petroleum System Modeling, BSR

