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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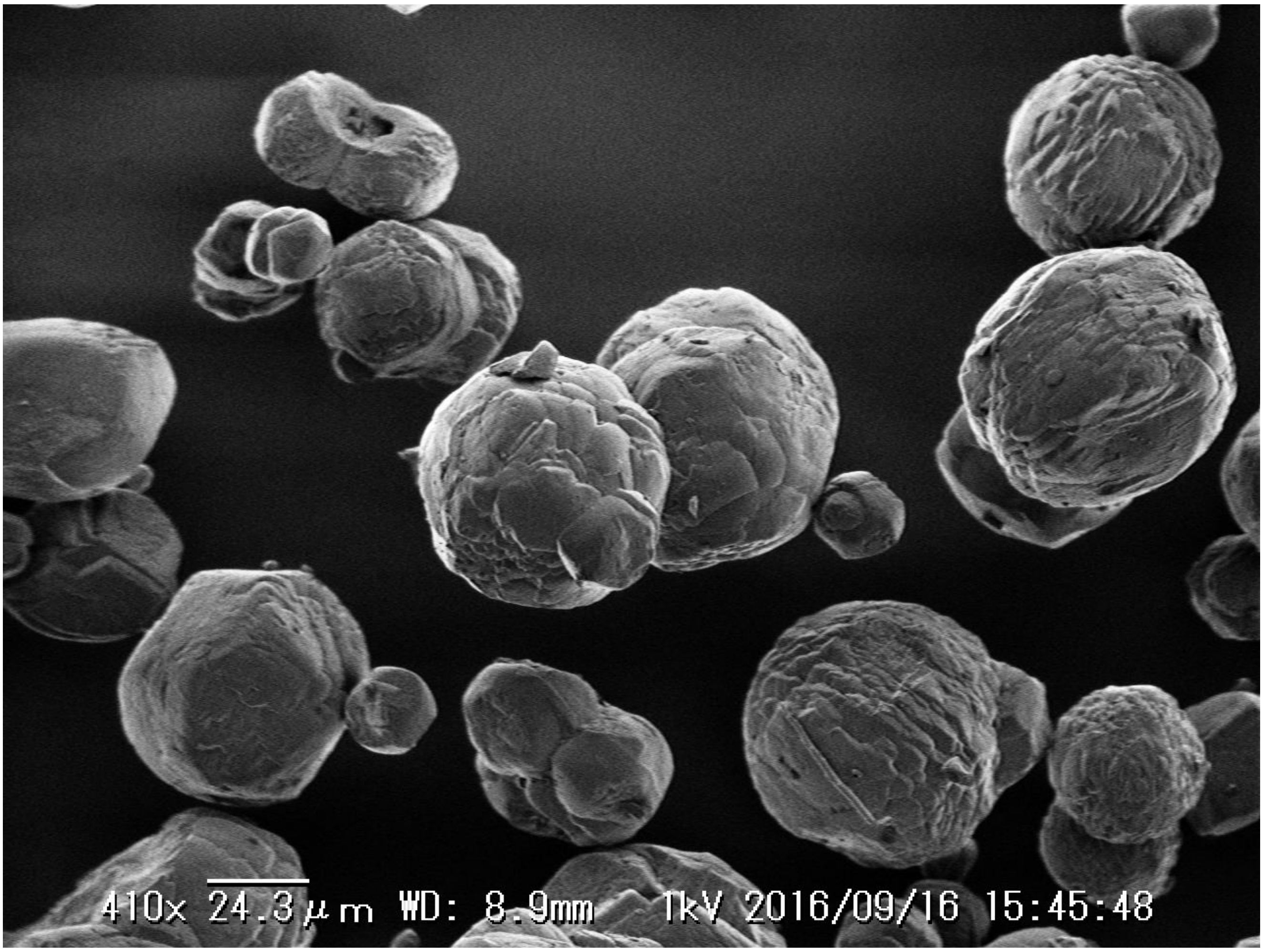
Recent exploratory drilling of massive gas hydrates in the Sea of Japan has revealed the presence of relatively pure, spherical growths of microcrystalline dolomite. The absence of sediment in association with the dolomite suggests that they were formed within hypersaline fluid inclusions which are situated 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