II Current Situation Regarding Methane Hydrate R&D

II.1 Some key points about the characteristics of methane hydrate

Methane hydrate (known as MH) is a composition of methane and water that is formed under certain temperature and pressure conditions. The vast abundance of this material is thought to exist in the earth's crust and is considered to contribute to the global carbon cycle, to climate change, and also to large-scale submarine landslides. In the petroleum industry, naturally occurring MH has been known to be a causative effect of geo-hazards that threaten deep-water marine drilling operations. On the other hand, this substance is expected to become an alternative hydrocarbon resource that has the capacity to replace conventional natural gas.

Under ambient conditions (with pressure at 100kPa), MH can begin to form when the temperature falls to −80°C or less. Alternatively, when the pressure approaches 2.6 MPa, MH can begin to form when the temperature reaches 0°C. In either case, methane should supersaturate the water. The latent heat of MH dissociation is 436kJ/kg. This is a value that is 1.3 times larger than that of ice. It is also larger than the energy required to heat the same mass of water to a temperature just below boiling point. The implications of this are, firstly, that dissociation of MH is endothermic, and, secondly, that a large amount of energy is required to exist in order to dissociate MH into its constituent parts of liquid water and vapor methane.

The phase diagram of the methane-water system is shown in Fig.1. The phase equilibrium curve of MH and vapor phase methane vary with solute concentration in the water. When the phase equilibrium curve moves mainly in the destabilizing direction, the solute is known as a gas hydrate inhibitor (thermodynamic inhibitor). A material with high solubility and low molecular mass is known as an effective gas hydrate inhibitor. A material that delays association of gas hydrate is known as a kinetic inhibitor. A material that is responsible for the opposite effect (i.e. that accelerates this association) is known as a gas hydrate promotor. Alcohols (ethanol, glycol, etc.) and salts (Sodium Chloride etc.) are used as inhibitors.

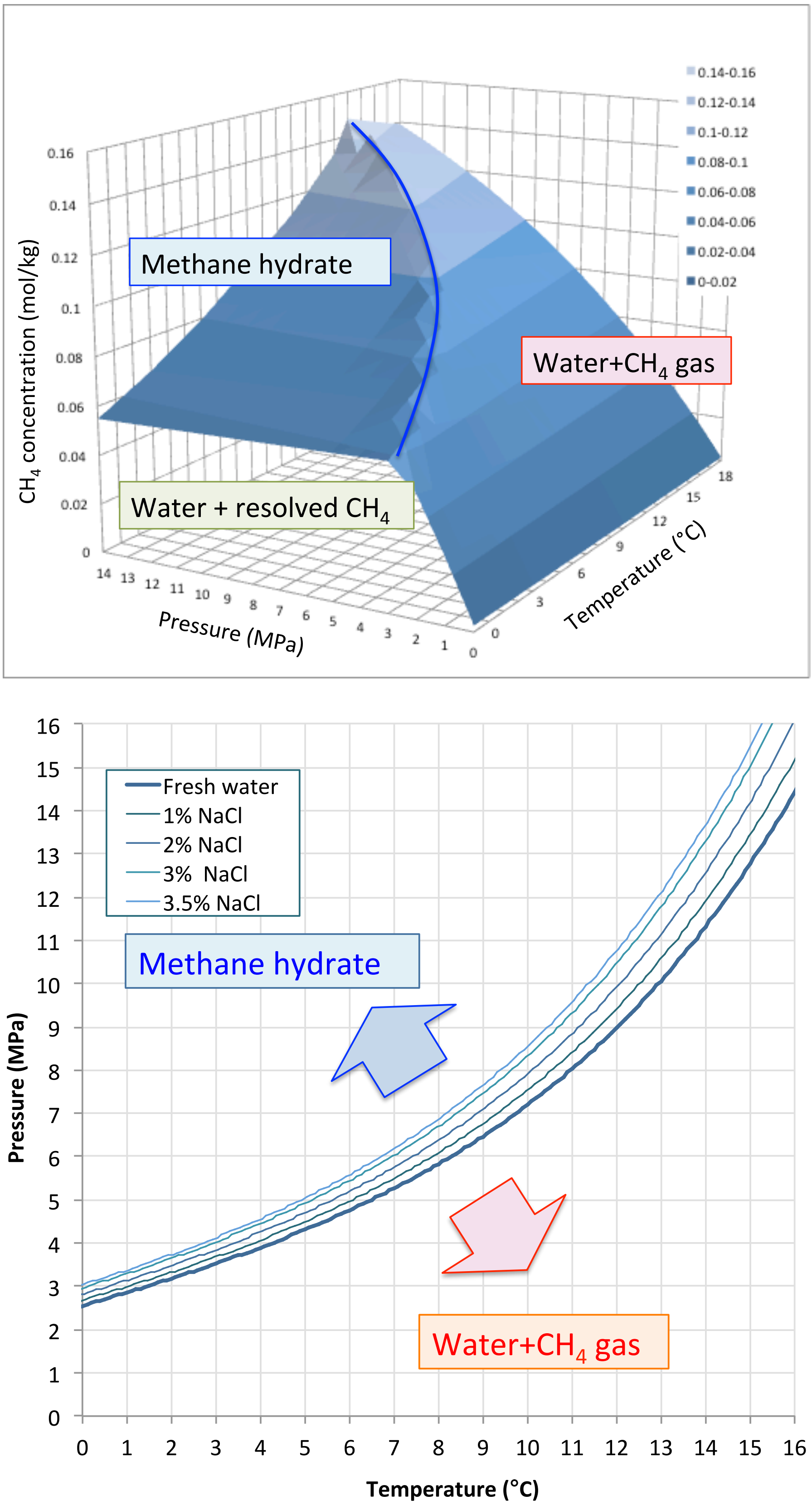

Fig.1　Phase diagrams of methane and water system.

On earth, MH is stable in shallow underground deep water regions (i.e. in water depths greater than 400 m and at several hundreds of meters below the sea floor) or beneath permafrost in Arctic areas or else in high altitude mountain regions. Naturally occurring MH is found in several forms, such as the filling in pore spaces in sandy sediments, as a bulk crystal taking the shape of veins or lenses in clayey sediments, or the filling of fractures or faults (Fig.2). In order to gain insights into association and dissociation of MH for the purposes of resource development or in the context of specific environmental and climate conditions, knowledge of the physical properties of the sediment, in particular hydraulic (permeability), thermal (heat capacity and thermal conductivity), and mechanical (strength and elasticities) are as important as an understanding of the properties of MH itself.

Because a sediment containing MH has properties that differ from those containing no MH material, the presence of MH can be detected by use of those geophysical exploration techniques that utilize both elastic waves and electromagnetic methods. The most well-known indicator of MH is the Bottom Simulated Reflector (BSR) by which MH can be detected using seismic exploration. In this case, the lateral extent of MH can be estimated by this reflection.

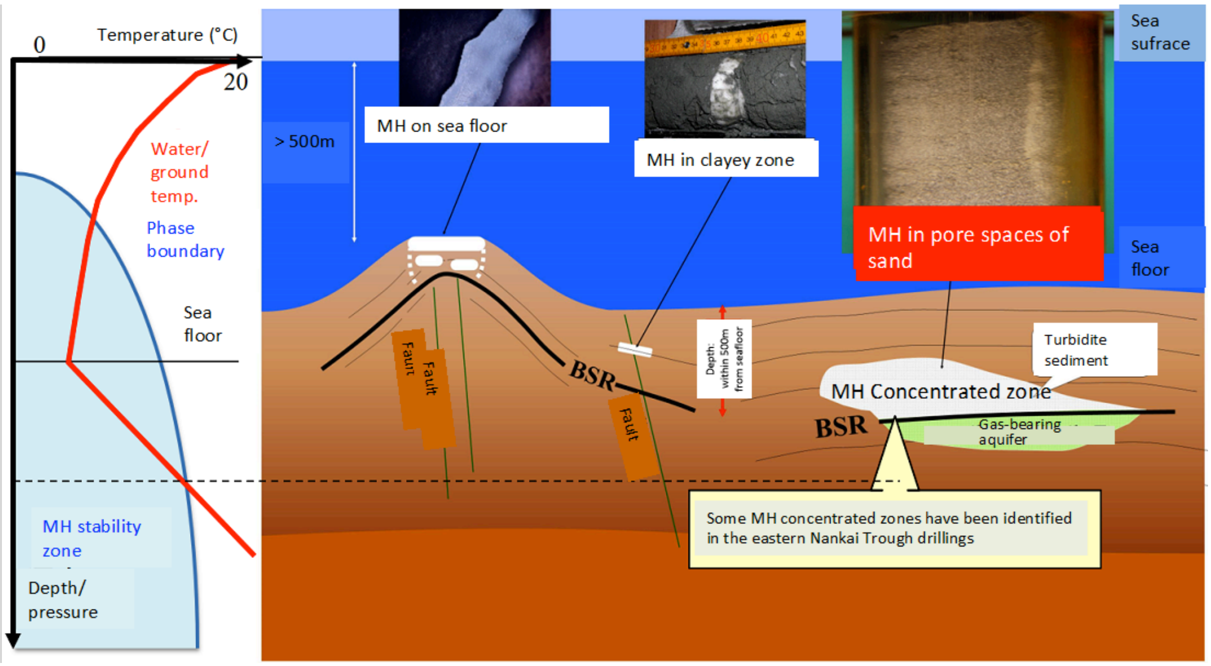

Fig.2 Type of occurrence of MH with temperature distribution in sea and ground.

Many attempts have been made to correctly estimate the quantity of MH residing in the earth's crust. However, since the estimated value varies with both the process of evaluation and the data used, at this stage it has not been possible to estimate the degree of precision required. On the other hand, uncertainty with respect to this evaluation has been shrinking due to the continued accretion of data built up by global exploration.

In the early stages of this study, it was estimated that 10^3～10^6 Gt of carbon mass (in 10^{15}～10^{18} m^3 in methane gas volume under ambient conditions) was laid down by pressure and temperature conditions [2]. However, the most recent estimations are in the range of 100～10^5 Gt in carbon mass (10^{14}～10^{17} m^3 in methane gas volume under ambient conditions) [3]. Those estimations only portray the amount of gas in place, and since they do not portray its recovery rate, they cannot be considered to be a true measure of the volume of methane that would be available for use as a resource. Incidentally, the total recoverable volume of natural gas is estimated as being 10^{14} m^3, additionally, world-wide gas consumption annually is estimated to be 4×10^{12} m^3. [US Energy information administration, 2010.]

With regard to the status of this resource on Japanese territory, an estimate of recoverable methane gas was made in 1996. It was based on the BSR area known at the time, and was based on certain assumptions about the vertical distribution of methane (2 m of MH-bearing sediment with 25 % of MH volume fraction and same gas volume of free gas below BSR) and a hypothetical recovery rate (10 % for MH and 75 % for free gas). The value derived for the volume of methane gas under ambient conditions was 2.27×10^{12} m^3. This figure was interpreted in some quarters as being "two-orders of magnitude larger than the annual domestic gas consumption of Japan (5.4×10^{10} m^3)"; thereby demonstrating that 100 years of domestic gas consumption could be supplied by MH. However, the value contained a large deal of uncertainty due to the fact that knowledge concerning the occurrence of MH as well as production techniques were at the time rather limited. To put this into perspective, domestic gas consumption in the year 2016 is approximately 1.11×10^{11} m^3. This is almost double that of 1996 and so the "100 years" reference above is highly exaggerated even if the estimation itself is correct.

During the Phase 1 study using seismic survey data and drilling results, MH21 has made a probabilistic estimation of the volume of gas in the eastern Nankai Trough. The median value of this estimate was 1.1×10^{12} m^3. Half of this volume exists in an MH-concentrated zone. This zone contains a high saturation of MH that occurs in substantial intervals in sandy sediment.

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II.2 Overview of MH21 R & D in Phase 2 and 3, and Recent Overseas R & D Trends

II.2.1 Overview of MH21 R & D in Phase 2 and 3

- After the distribution chart was announced in 2000, we reviewed seismic survey data acquired from research into areas surrounding Japan. We then published a new BSR distribution chart in 2009.
- AIST and The University of Tokyo conducted a scientific survey to search for MH in the Eastern Japan Sea. (June 2010)
- JOGMEC partnered with ConocoPhillips to carry out a technology test on the North Slope of Alaska. This test was the first ever field trial of a methane hydrate production methodology whereby CO_2 was exchanged in-situ with methane molecules within a methane hydrate structure. (January - April, 2012)
- The First Offshore Production Test in the World. (Feb 2012 - Aug 2013)
  We conducted the world's first offshore production test of methane hydrate using the depressurization method off the coasts of the Atsumi and Shima Peninsula in Japan, and produced approximately 120,000 m3 (approximately 20,000 m3/day) of gas during a six-day testing period (January - March 2013). The test was closed due to bad weather forecasts and sand production issues. We subsequently worked on plug and abandonment of boreholes (August 2013).
- JOGMEC signed a MOU (Memorandum of Understanding) with NETL (National Energy Technology Laboratory), an affiliate of DOE (U.S. Department of Energy), concerning collaboration aimed at realizing a methane hydrate onshore production test. (Nov 2014)
- The Second Offshore Production Test (May 2016 - June 2018)
  We conducted the Second Offshore Production Test using the depressurization method in the same area that the first test was carried out. We produced approximately 40,000 m3 of gas for 12 days on AT1-P3, and approximately 220,000 m3 of gas for 24 days on AT1-P2 continuously (April - July 2017). Although sand production problems occurred on AT1-P3, there were no sand-related problems on AT1-P2 and the test was completed. We worked on plug and abandonment of all boreholes (March - June 2018).
- JOGMEC cooperated with DOE/NETL and drilled a stratigraphic test well in the Prudhoe Bay Unit in Alaska. (December 2018)
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□.2.2 Recent Overseas R & D Trends

Some countries conduct geological exploration and development of production technology.

After MH21's offshore production test, China conducted production tests onshore and offshore. India also began studies aimed at realizing offshore production tests. On the other hand, Korea postponed offshore production test plans. America worked with Japan to conduct a $CO2/CH4$ exchange method and a depressurization method onshore in Alaska in 2012.

(1) China

China conducted a small scale onshore production test in a permafrost-affected area in Qilianshan, Qinghai in 2009. Following that, China conducted a production test in the Shenhu area from May to July 2017. They implemented the hydraulic fracturing technique to improve the permeability of silty formations with pore filling-type methane hydrate reserves. In addition, they implemented the depressurization method. It was announced that the test lasted for 60 days and that the total gas volume was over 300,000 m3.

China approved the listing of methane hydrate as the country's 173rd mineral variety on November 2017. In December the same year, media reported that China would establish a national laboratory for methane hydrates, to be run by China National Offshore Oil Corp. [1] Media reports also stated that a research center base for exploring methane hydrate will be completed in 2021 in Guangzhou, Guangdong.[2] It is reported that China would drill other wells within two years with an aim of beginning commercialization around 2030[3].

(2) Korea

Korea drilled a survey well in Tsushima Basin in 2010 and obtained a core of filling-type methane hydrate (UBGH-2). Although there were plans to carry out an offshore test, it appear testing has been postponed.

(3) Taiwan

A team of Taiwanese and French researchers extracted frozen methane hydrates from the seafloor in June 2018. It was reported that a Taiwanese-German research team was to embark on a 34-day methane hydrates exploration mission in October 2018.[4]

(4) India

Japan cooperated in drilling 42 wells in the area considered to contain pore filling methane hydrate in the Bay of Bengal in 2015 (NGHP-02).

There was a report in May 2018 that the government had given the nod to the launch of the third stage of the program (NGHP-03), which includes conducting of a pilot test.

ONGC (Oil and Natural Gas Corporation) set up a dedicated gas hydrate research center at Panvel (Navi Mumbai).[5]

JOGMEC is a member of the Advisory Committee and provides advice. Also, the MOU on DGH and JOGMEC's MH research, which has been linked since 2007, is still ongoing.

(5) U.S.A.

In 2012, NETL jointly conducted a CO_2/CH_4 exchange experiment with ConocoPhillips and Japan (JOGMEC).

GOM2 Expedition-1 Successfully Samples Gas Hydrate Reservoirs in the Deepwater Gulf of Mexico.[6] Exploration including pressure coring is planned during the final stage of the project.

NETL and JOGMEC signed a MOU in November 2014, concerning collaboration aimed at realizing a methane hydrate onshore production test and together drilled a stratigraphic test well in Prudhoe Bay Unit in Alaska in December 2018.

(6) Germany

Submarine Gas Hydrate Reservoirs (SUGAR) was launched in 2008 and completed in 2018. It was announced by local companies participating in the project that there are development examples of environmental monitoring technology as well as development examples of reservoir simulator LARS (LArge Reservoir Simulator).[7]

(7) New Zealand

As a member of the Advisory Board for the Gas Hydrate Resources (GHR), JOGMEC researcher provides advice.

(8) EU

The kick-off meeting in Marine gas hydrate, an indigenous resource of natural gas for Europe (MIGRATE) was held in October 2015. JOGMEC ran a presentation about Japan’s gas hydrate program at the meeting. The organization regularly holds working group meetings and workshops.[8]

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