III Resources Evaluation of the Methane Hydrate offshore Japan

III.1 Methane hydrate as a possible resource are BSR and MHCZ (concept of methane hydrate concentrated zone).

BSR is used widely offshore Japan and is considered to be the lower limit of MH from seismic exploration data, and suggest existence of MH. MH is expected to be one type of hydrocarbon that is capable of helping meet the demand for natural gas (which is primarily methane) in the future.

(1) BSR

On the lower limit border of the stable domain of MH, MH, which is a solid, exists over the border, and a fluid called methane and the water will exist under the border, and each of the matter properties are different. The wave of offshore seismic survey for hydrocarbons generates a reflection wave called BSR by impedance contrast due to the difference in such properties of matter. Therefore, BSR suggests the lower limit of the stable domain of MH and is therefore one of the means by which the existence of MH can be detected. A characteristic of BSR in seismic survey reflection waves is that they are approximately parallel with the bottom of sea, are oblique to the stratum border, and are in reverse to the phase reflection wave from the sea bottom. JOGMEC used seismic exploration data acquired by the "Kokunai Kiso-Chosa" exploration survey program carried out in Japan between 1971 and 2002. Based on the characteristics of this survey, the distribution situation of BSR caused by MH around offshore Japan was clarified in Phase 1 (Fig. 1, Hayashi et. al., 2010).

Exploratory wells were drilled in 16 places in order to obtain data to use to evaluate both the existence and quantity of MH in 16 sites in "METI Tokai oki - Kumano nada" in 2004. A new concept, known as MHCZ (Methane Hydrate Concentrated Zone), was introduced to examine natural gas resources.

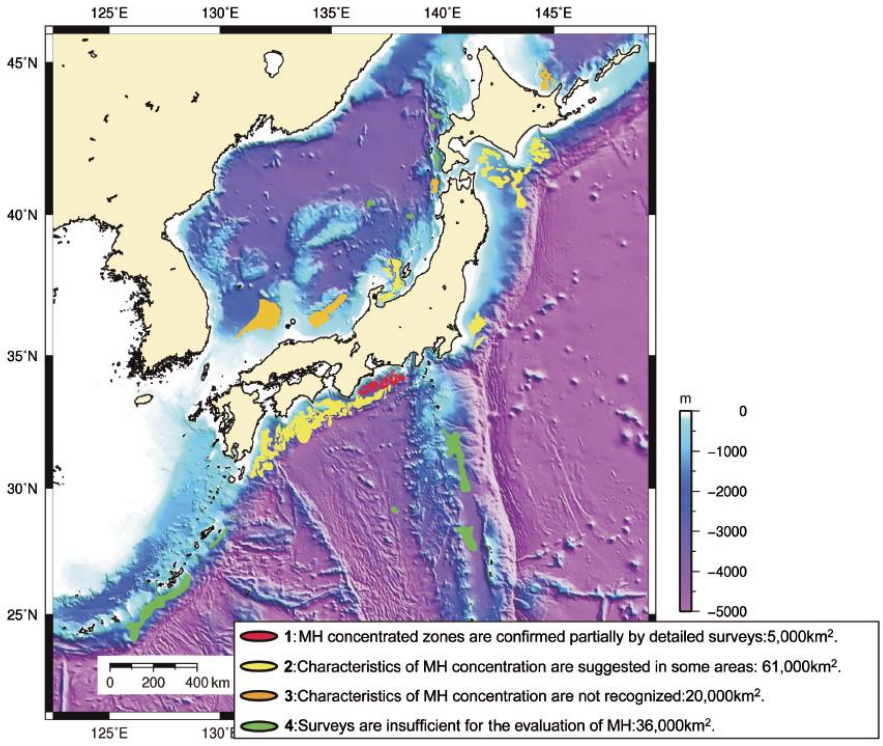

Fig. 1 BSR distribution chart (2009), (Hayashi et. al, 2010)

(2) MHCZ as Methane Hydrate Concentrated Zone

The MHCZ is formed in turbidite sand mud in alternating layers that have high pore rates and that indicate high velocity with high ratio resistance, the P wave velocity structure than the class of neighboring MH existence by the well logging data (Fig. 2). As a result of the study carried out in the eastern Nankai trough area, the four indexes of detection for MHCZ were the presence of BSR, the turbidite sand, a strong amplitude reflection wave, and seismic wave high-velocity abnormality (Saeki others, 2010). Based on these indexes and analyses carried out using two and three-dimensional seismic survey data and exploratory well data (a core and well logging), a total of 16 MHCZs were detected in the eastern Nankai trough. For these MHCZ, the assumed volume of existing gas was calculated using a probabilistic technique (Fujii others, 2009).

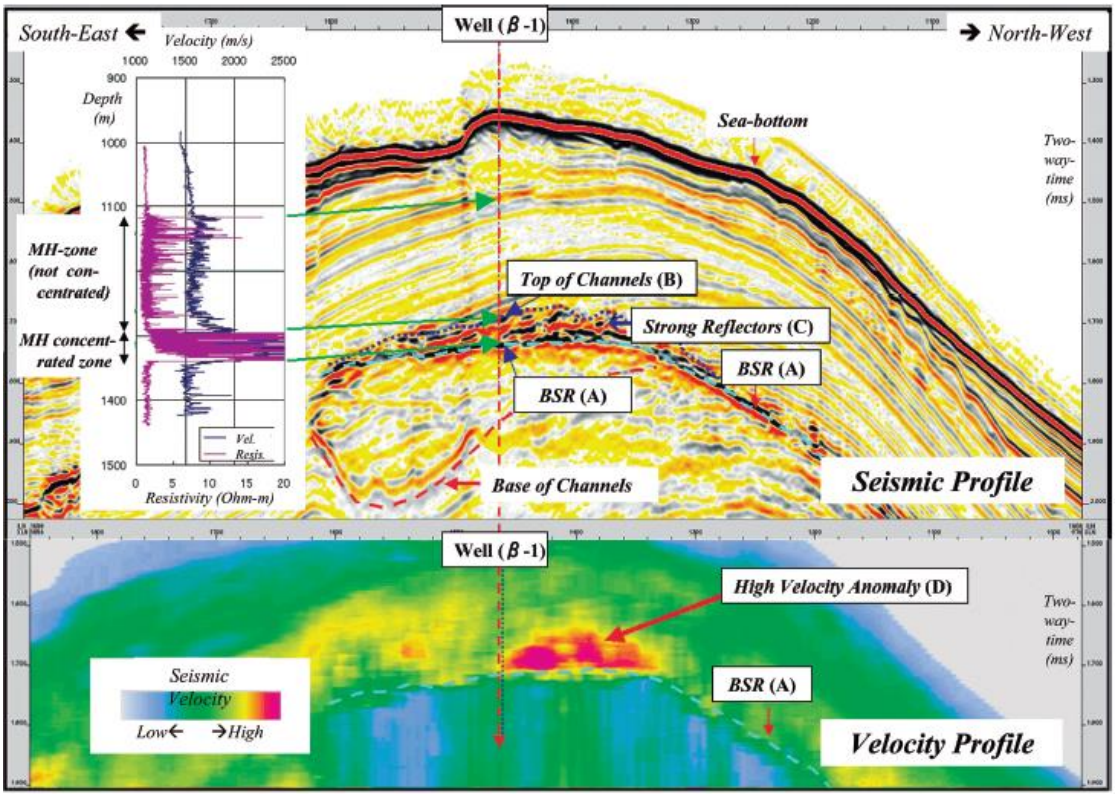

Fig. 2 Characteristic of MHCZ (Saiki et. al, 2010)

A study of Phase 1 provided many results regarding the potential quantity of MH. However, regarding its existence as well as properties and quantities of MHCZ in regions outside the eastern Nankai trough area, there are many questions that need to be answered. It was also necessary to evaluate it using quantitative techniques in MH systems such as the formation of, generation, migration, and accumulation of methane in order to examine the causation that a MHCZ could be formed even if the existence of MH was suggested via BSR.

Based on the above, the following two items were determined as research themes for Phase 2 and 3 of the natural resources evaluation program to be carried out offshore Japan.

・Resources evaluation of the methane hydrate offshore Japan,

・Examination of the MH system.

References

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III.2 Resources Evaluation of the Methane Hydrate Offshore Japan

For the purpose of achieving a deeper understanding of the availability of methane hydrate offshore Japan in Phase 2 and 3, JOGMEC carried out an evaluation of MH using the interpretation technique based on the index of the MHCZ and BSR provided for in Phase 1. The data sets used were old digitized 2D seismic data, however, some reprocessed seismic data as well as new 2D/3D seismic data were also utilized. The new 2D/3D seismic data were acquired as a result of using the "Shigen" seismic survey vessel, a vessel that is used for the conventional hydrocarbon exploration program of Japan. In respect of the quantity of new data that JOGMEC used for evaluation purposes, new 2D seismic data for approximately 18,000 km3 and 3D seismic data for 24,000km3 was acquired by the "Shigen". Additionally, after direct confirmation of the existence of methane hydrate by well, we can call it with MHCZ.

III.2.1 BSR Distribution

BSR is a reflection that extends obliquely from the geological bedding plane. It appears in reverse phase to the reflection from the seafloor. An understanding of the BSR distribution area is also important as it serves as an indicator as to whether MH is present on the upper level, and also provides insights into the planar spread of MH.

In Phase 1, the BSR distribution map (2000) shown in Fig.1 was updated by interpreting data from the Geophysical Survey and Basin Evaluation Project that was acquired before 2006. Fig.2 shows the BSR distribution map (2009), with Table.1 providing its color classification.

Phase 2 and 3 built on the knowledge obtained in Phase 1; interpretation work was carried out by adding Geophysical Survey and Basin Evaluation Project data acquired after 2007. In addition to this, the reprocessing and reinterpretation of some of the Phase 1 seismic data led to the BSR distribution area being updated.

Improvements on Phase 1 include the broadening of the existing BSR distribution area by interpreting newly acquired 3D seismic data which cover the existing 2D seismic survey area and refinements within the distribution area. It also provides confirmation of the new BSR distribution area by an interpretation of 2D seismic data that fills in a blank area that existed in Phase 1.

At present, the work of interpreting the existing seismic data is continuing. It is hoped that in future, such interpretive work will be added to by newly disclosed 2D or 3D seismic data and also that the BSR distribution map will be updated.

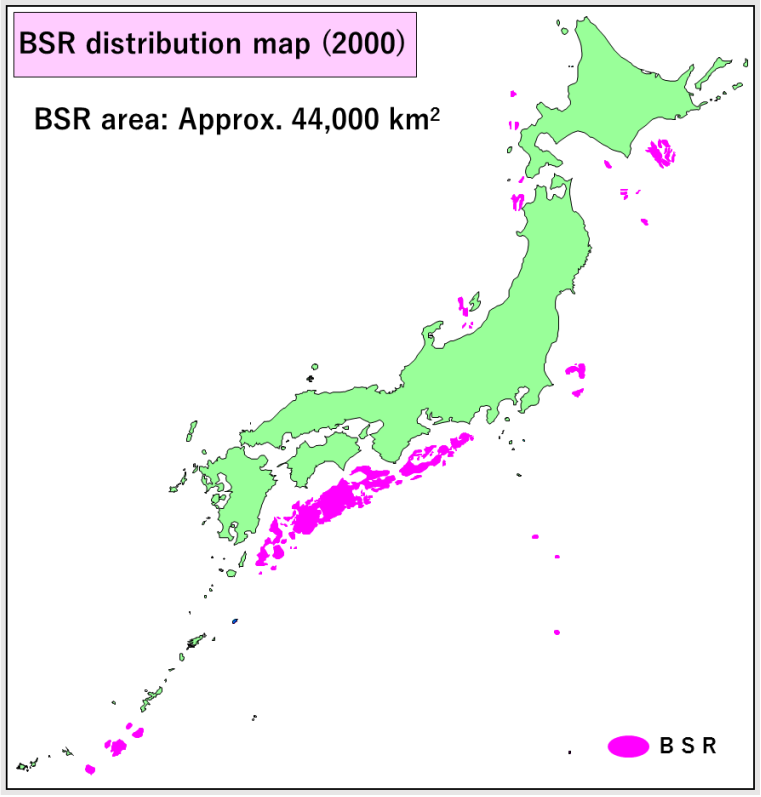

Fig.1: BSR distribution map offshore Japan (2000)

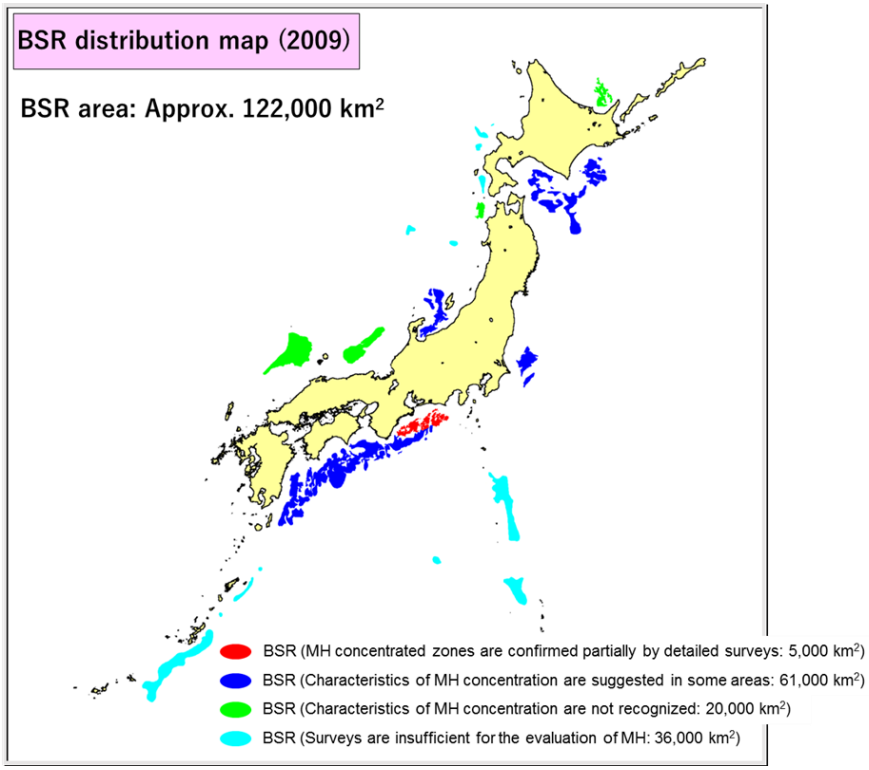

Fig.2: BSR distribution map offshore Japan (2009)

Table.1: Color classification in BSR distribution map (2009)

	Concentrated zones in part of the area are confirmed by detailed survey	Characteristics suggest concentrated zones are confirmed in part of the area	Characteristics suggest concentrated zones are not confirmed	There is little survey data
Colore	Red	Blue	Green	Light blue
BSR	Yes	Yes	Yes	Yes
MH Concentrated zone	Suggested	Suggested	Not suggested	Not suggested
Analysis of 2D seismic data	Done	Done	Done	Done (Little survey data)
Analysis of 3D seismic data	Done	Partially done	Not done	Not done
Drilling survey	Done	Not done	Not done	Not done
Existence condition/ Estimate of abundance (present time)	Possible	Difficult	Difficult	Difficult

III.3 Methane Hydrate System Evaluation

Recognition and identification of the methane hydrate concentrated zone (MHCZ) at the Daini Atsumi knoll production test site bring into focus two fundamental questions in terms of the petroleum systems. The first is clarification on whether the origin of methane is biogenic or thermogenic. The second is how methane is generated and also migrated. Figure 1 illustrates the basic components that are considered in the evaluation of methane hydrate systems. These are as follows: the generation of thermogenic and biogenic methane, free gas methane, methane dissolved in pore water and seawater, migration paths, hydrate stability zones, bottom simulating reflectors (BSR), and hydrate formation.

During Phase 2 and 3, two investigations were conducted. In the first, microbiologically studies of cores acquired in the Daini Atsumi knoll area were carried out, and in the second, simulation studies of methane generation, migration, and hydrates formation using a basin simulator were carried out.

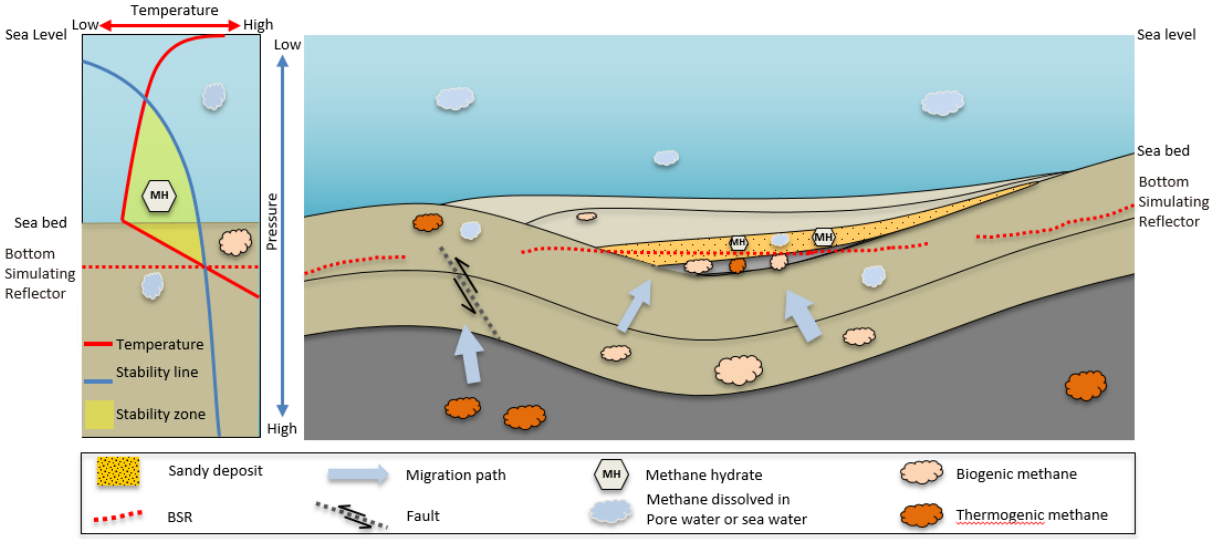

Fig. 1: Methane hydrate system evaluation and its components considered in this study

III.3.1 Microbiological Study of Methane Generation

Studies of methane generation were carried out with a focus on two factors. They were the understanding of the origin of methane, and also the pressure and temperature conditions required for methane generation activity. During Phase 2 and 3, laboratory analysis of microbiological studies and carbon isotopes were carried out utilizing cores from Tokai Oki- Kumanonada exploratory wells in addition to the test site wells in the Daini Atsumi production area. Analysis of the results reveals the presence of the Pentamethylicosane (PMI) biomarker, and also that the origin of methane is biogenic (Amo et al. 2011 and 2016). The PMI results pointed to the fact that methane generation activity was high in both the methane hydrate concentrated zone (MHCZ) and below it.

Culture experiment results of microbes contained within the core (having pressure values ranging from between 5 to 15 MPa) provided information that the peak temperature of methane generation activity was between 30 and 40ºC.

III.3.2 MH System Evaluation Using Basin Scale Simulator

PetroMod, a basin scale simulator (a product of Schlumberger), is designed to model and simulate petroleum systems in sedimentary basins. It simulates maturation of kerogen, and the generation, migration and accumulation of hydrocarbon during the development of the sedimentary basin across geologic time. PetroMod has three modules that are used to model hydrate formation and the hydrate stability zone. These are

1. Module that enables handling of vapor, liquid and hydrate phase
2. Module that enables modeling of biogenic methane generation

3. Module that enables the methane hydrate stability zone to be modeled.

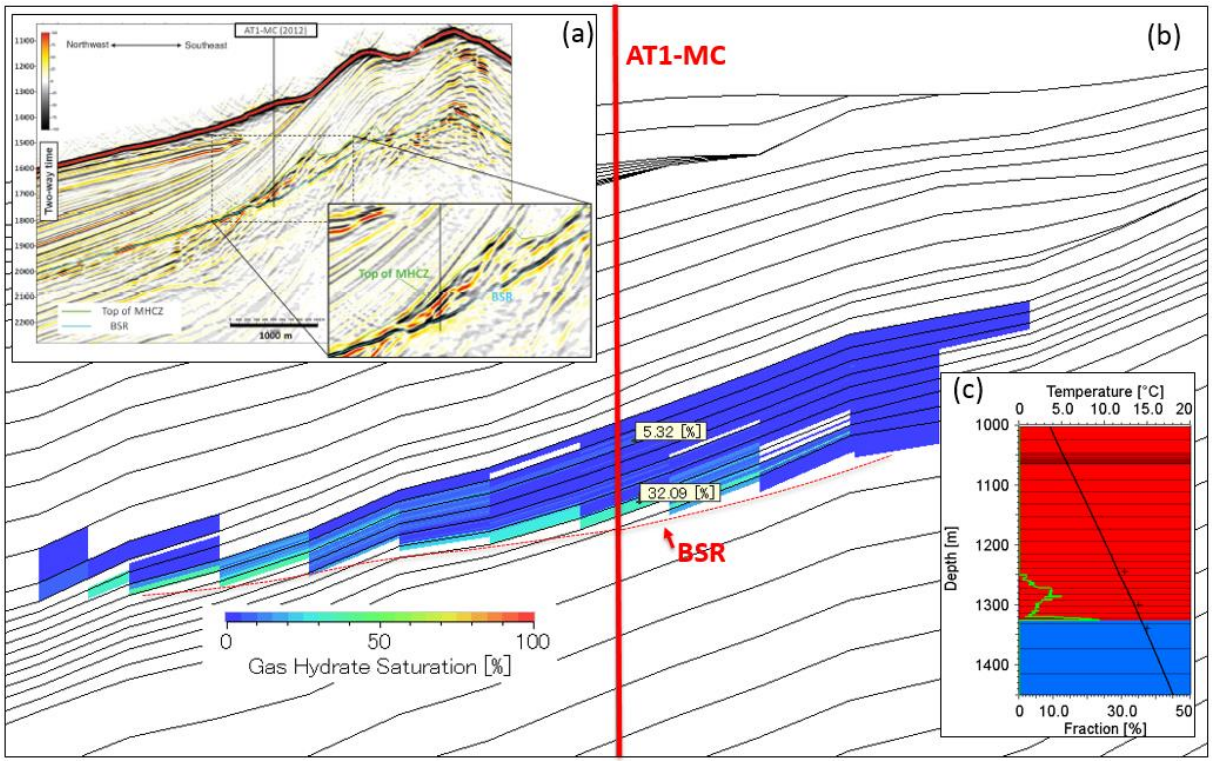

Fig. 2. Simulation results from Daini Atsumi Knoll Area. (a) MHCZ interpreted on seismic profile, (b) Hydrate saturation simulation results at AT1-MC wells and its vicinity, and (c) Temperature (solid line is simulation result and three plus symbols (+) are measured data at AT1-MC well). Green line is simulated hydrate saturation, red shading shows hydrate stability zone, and blue color shows unstable zone.

The workflow of the MH system evaluation includes preparation of input data, building of a facies model, and simulation of methane generation, migration, the hydrate stability zone, and hydrate formation. Based on available seismic, velocity and logging data, interpretations of geologic horizon and gridding were initially conducted. Following on from this, the building of velocity models and the conversion of time domain geologic horizons into those of depth were carried out. Finally, using depth geologic horizons that were based on logging and core data, seismic facies analysis, and existing geological reports, a 3D grid was created and distributed by appropriate facies based on logging and core data, seismic facies analysis, and existing geological reports. Source rock parameters and boundary conditions were set and simulations were run. The simulation results were calibrated with the depth of BSR, measured pressure, and the temperature at the well.

Simulation results of methane masses were analyzed in terms of four components: total generated methane, methane in the hydrate, free gas methane, and dissolved methane in pore water. Three candidate offshore areas selected from resource assessment study: Chubu District Pacific Side, Chugoku-Shikoku Pacific side, and the Kyushu Pacific side. These were simulated and analyzed. A hydrate saturation result from Chubu

District Pacific side is illustrated in Figure (2). Simulated results reveal that methane generation has begun at the epicenter of mini-basins and then migrated along the up dip direction until it began to accumulate in lobe and channel-type turbiditic sandy deposits (Fujii et al. 2016).

III.3.3 Summary and Future Work

Biomarker and cultural experiments of microbes collected from the core were carried out. The results suggest that the peak temperature for methane generation was between 30 and 40 ºC. Temperatures within this range were applied in the simulation.

Evaluation of the MH system was carried out in order to better understand the mechanism of methane generation, migration, and hydrate formation by using a basin scale simulator. Simulation studies within the Daini Atsumi knoll area were conducted and calibrated by using measured pressures and temperatures at AT1-MC. Simulated results of the distribution of MHCZ closely matched with the distribution of MHCZ interpreted from the seismic profile. Using knowledge acquired from modeling and simulation results from the Daini Atsumi knoll area, MH system evaluation of additional two offshore areas were conducted. Although pressure and temperature values were lacking in terms of calibration, the depth of BSR and the distribution pattern of the prospect on the seismic profile were used to calibrate the simulation results. In future, conducting of mass analyses of the two areas are expected to be required.

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III.4 Summary of Resources Evaluation of MH

During Phase 2 and 3 of the natural resources evaluation of methane hydrate offshore Japan, JOGMEC carried out two programs. The first was "Resources evaluation of the methane hydrate offshore Japan", and the second was "Methane Hydrate System Evaluation".

The initial program, "Resources evaluation of the methane hydrate offshore Japan", was conducted in order

to evaluate whether or not the MHCZ sand type exists of offshore Japan. While making use of some of the reprocessed seismic data, it also employed entirely new seismic data. The BSR map created from Phase 1 was revised. In addition, JOGMEC carried out an evaluation of the MHCZ offshore Japan in regions other than the eastern Nankai trough area. In the other program, "Methane Hydrate System Evaluation," JOGMEC added two sea areas on the eastern Nankai trough and carried out methane Hydrate Basin simulation in two and three dimensions.

In order to better conceive this process, flowcharts of the evaluation of methane hydrate (shown below (fig. 1)) were created by JOGMEC.

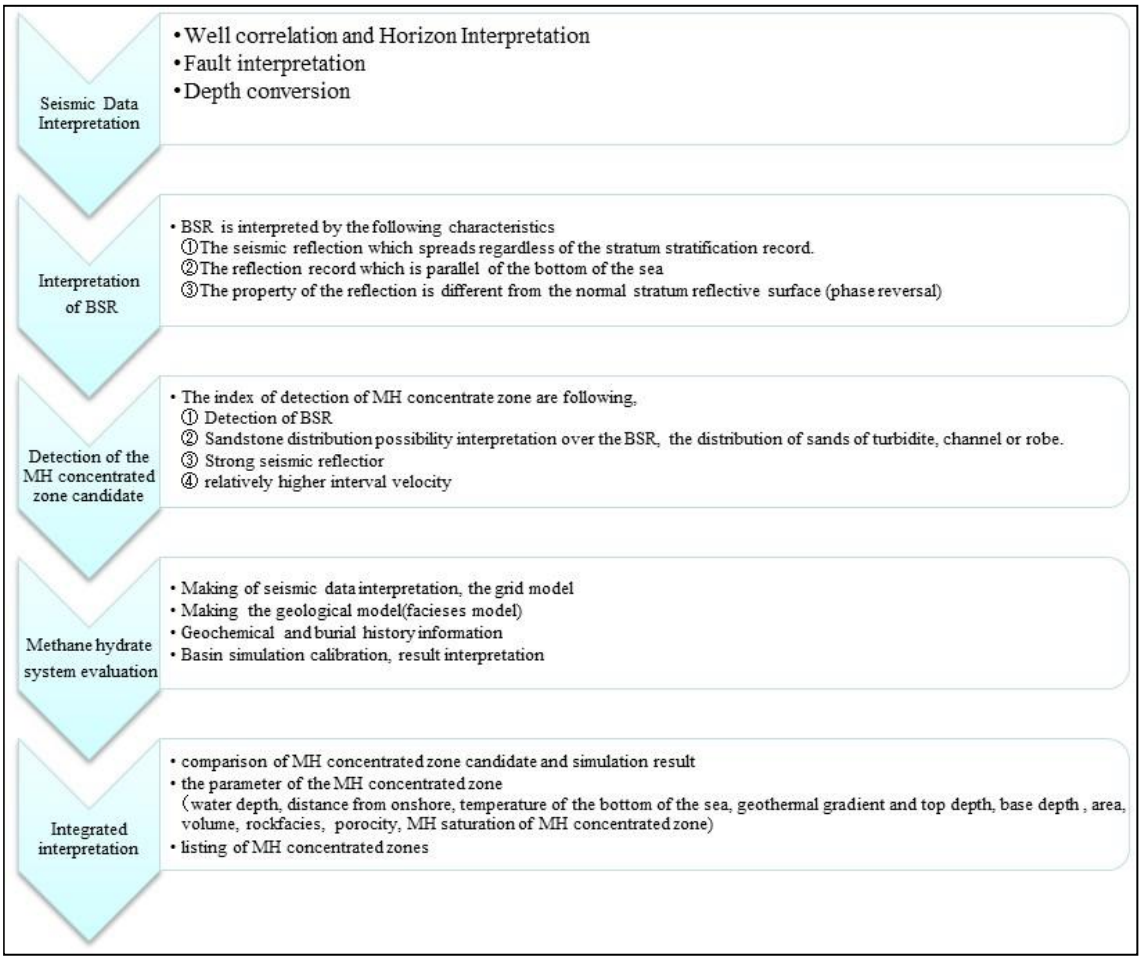

Fig. 1 Evaluation flow chart of sand type methane hydrate

In places that we can expect the quality of interpretation of data by the reprocessing of two-dimensional seismic data in the sea area where a MHCZ may exist, improved reprocessing is carried out in order to evaluate the MHCZ.

JOGMEC carried out simulations in order to evaluate the MHCZ at a certain scale.

When in future it becomes easier for a Japanese oil gas company to examine the exploration and development potential of an ocean area containing methane hydrate, these results are to be expected.