Geo-scientific Studies on Methane Gas Hydrates

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Abstract

It has become recognized that the total amount of natural methane hydrates present globally below the earth's surface is likely to be very large and their carbon content might even be comparable to the whole reserves of oil/gas resource of the earth. Hence, those methane hydrates may be regarded to be part of our energy resource in future, although there certainly remains the problem of technologies which enable us to economically utilize them as a form of hydrocarbon resource. More than that, from the viewpoint of global carbon cycle consideration, methane hydrates are one of the important components in the natural system that has been controlling and now controls the greenhouse effect of the atmosphere, and have a significant impact on the global warming. For these reasons, we are engaged in scientific studies on the detection, characterization and quantification of methane hydrates found in the geological formations at depths down to several hundred meters below the ground-surface, which includes the seafloor in offshore areas adjacent to certain coastlines like those of the Japanese Islands.

This talk is intended to give an introductory scope to the participants about the geo-science research efforts on natural hydrates, by covering a few topics as follows:
First, the basic physico-chemical nature of methane hydrate is briefly reviewed. Secondly, our current knowledge on the world-wide distribution of methane hydrates is presented. Then as the consequence of those facts, a possible scenario of the dynamic behaviors of hydrate dissociation in the sedimentary formations in the context of carbon budget of the earth is mentioned. Finally, some subjects of geo-scientific studies on the distribution and behaviors of sub-surface hydrates, with an emphasis on the geothermal conditions, will be discussed.

Geo-scientific Studies

on Methane Gas Hydrates

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Contents

Natural Methane Gas Hydrate:

A. Methane Hydrate, what is it, and where we can find ?
B. Implications for the Earth's Environment
C. Geothermics and Methane Hydrates
D. Various Research Subjects

Chapter A.

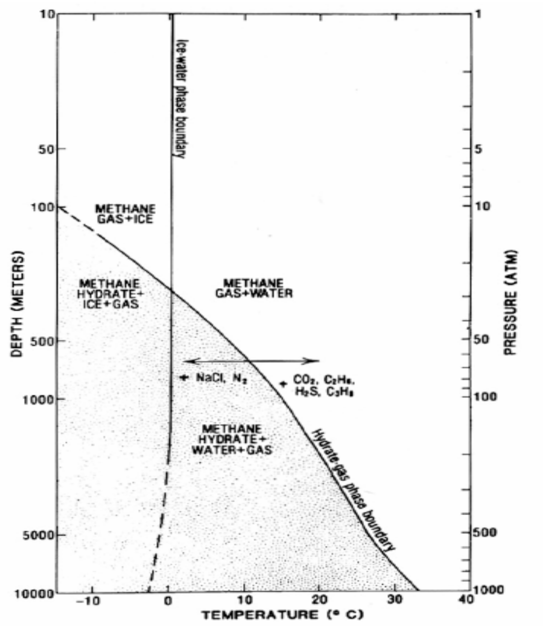
Methane Hydrate, what is it, and where we can find it ?

A-1) Basic facts about MH
A-2) Its distribution on the earth

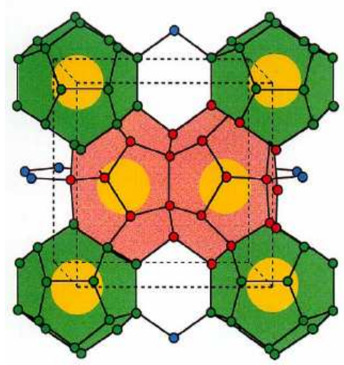
A-3) Case of onshore occurrence
A-4) Case of offshore occurence

A-1) Basic facts about Methane Hydrate

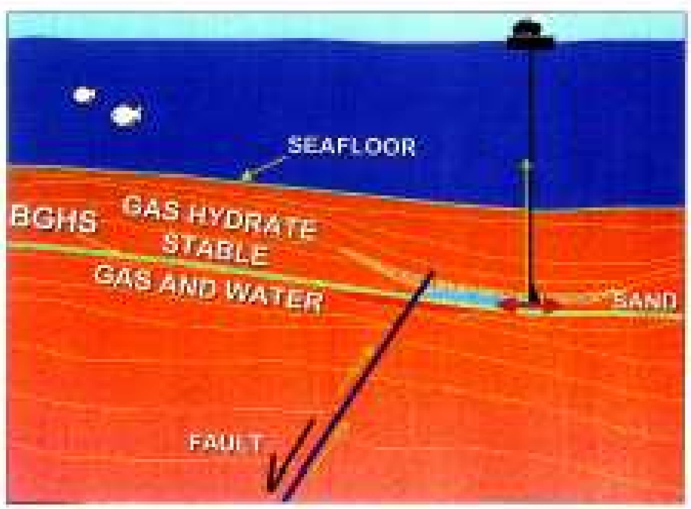
- Hydrates are solidified form of gas species (methane, ethane, etc.);
- Hydrates occur in nature under special P-T conditions;
- Their physical properties are unique.



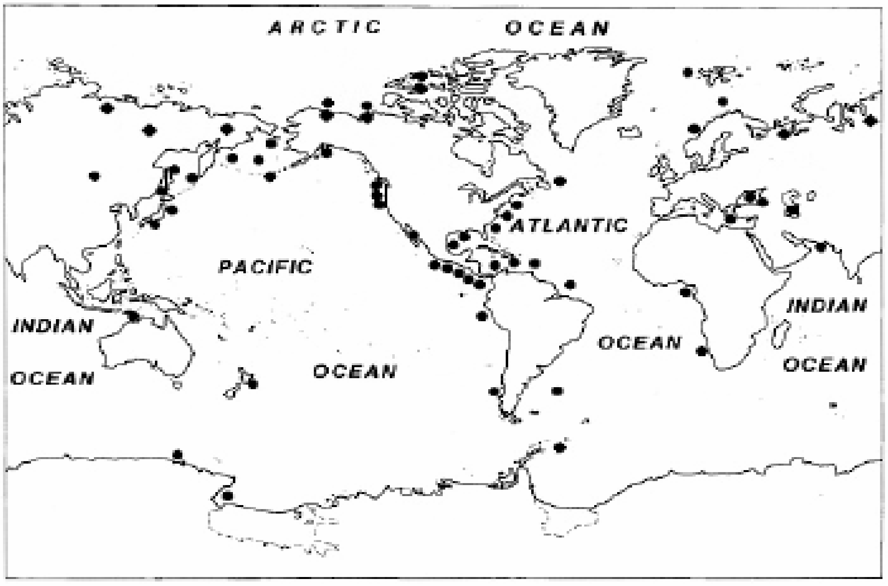
Phase Diagram (L) and Molecular Structure (R) of Methane Hydrate



Natural Hydrates:
A big Buffer-tank for Global Carbon Cycle, as well as our Fuel Resource (from: The Leading Edge Vol.22, 2003)

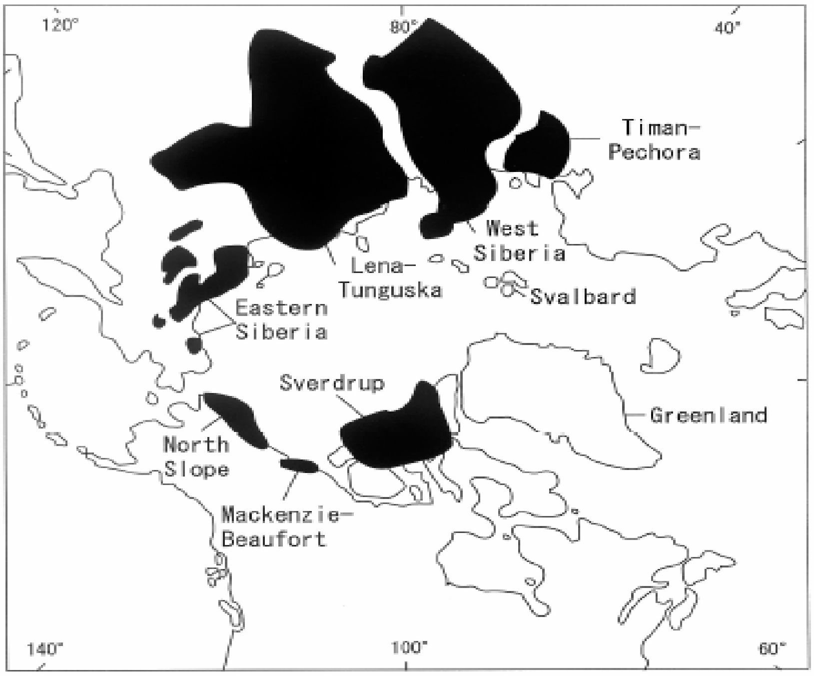


A-2) Distribution on the earth



On-land methane hydrate occurrences

- Mackenzie delta, Canada (Mallik site)
- North Slope, Alaska
- Siberian basins, Russia
- and others



Onshore hydrate drilling program, Mallik in Canada
taken from G.S.C. Bulletin Vol. 585 (2005)

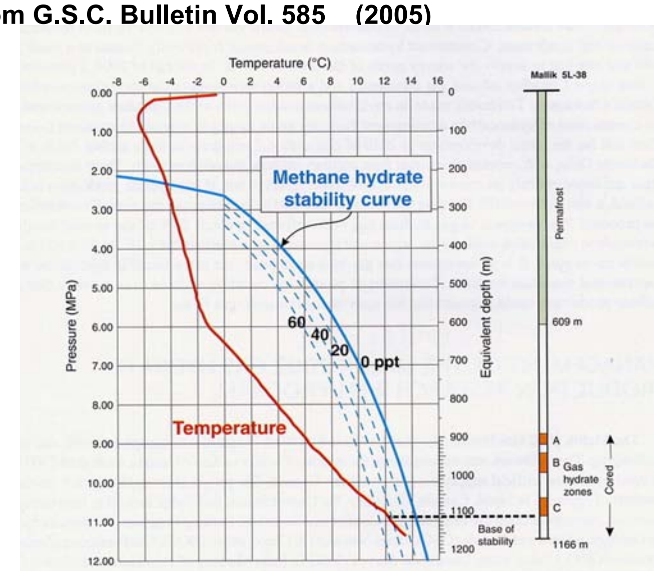
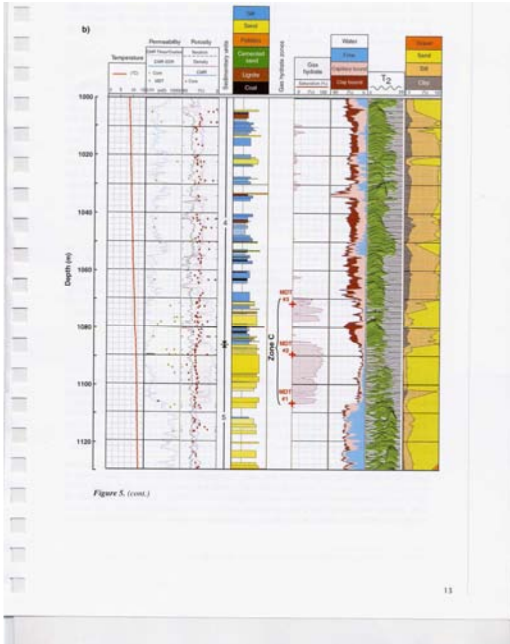


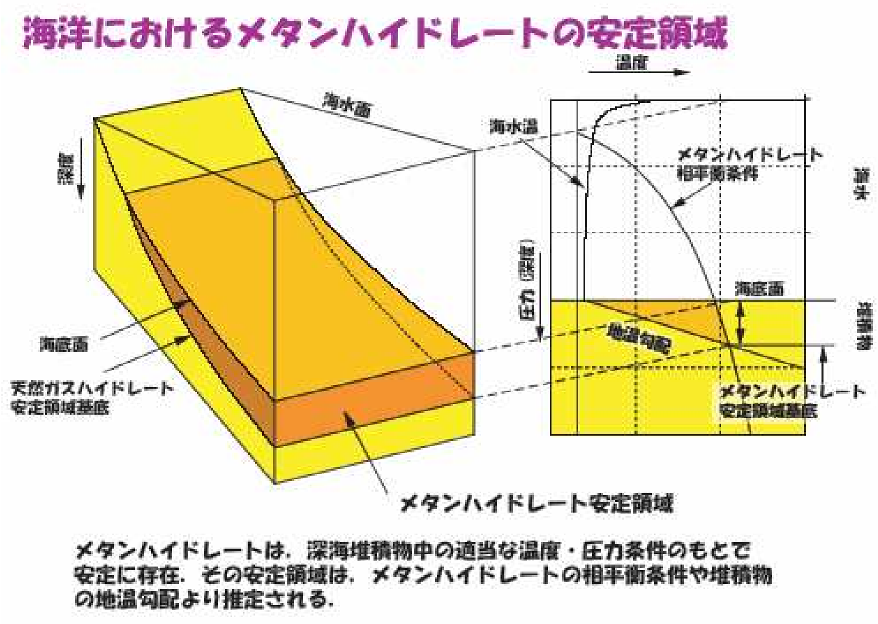
Figure 4. Temperature versus depth plot for the JAPEX/JNOC/GSC et al. Mallik 3L-38 well, as determined by Henninges et al. (2005) using fibre-optic distributed temperature sensing (DTS) cables. Phase-equilibrium curves for methane hydrate stability at 0, 20, 40, and 60 ppt (parts per thousand) water have been plotted to allow estimation of in situ stability (after Sloan, 1998).

From Dallimore et al. (2005)



Offshore methane hydrate occurrences
(case of vicinities of the Japanese Islands)

- High-P, Low-T is the general requirement of MH occurrence
- Geological conditions which favor the accumulation of methane
- Along the Pacific margin, including the *Nankai slope* area
- Also on the Japan Sea margin



Chapter B.

Implications for Global Environment

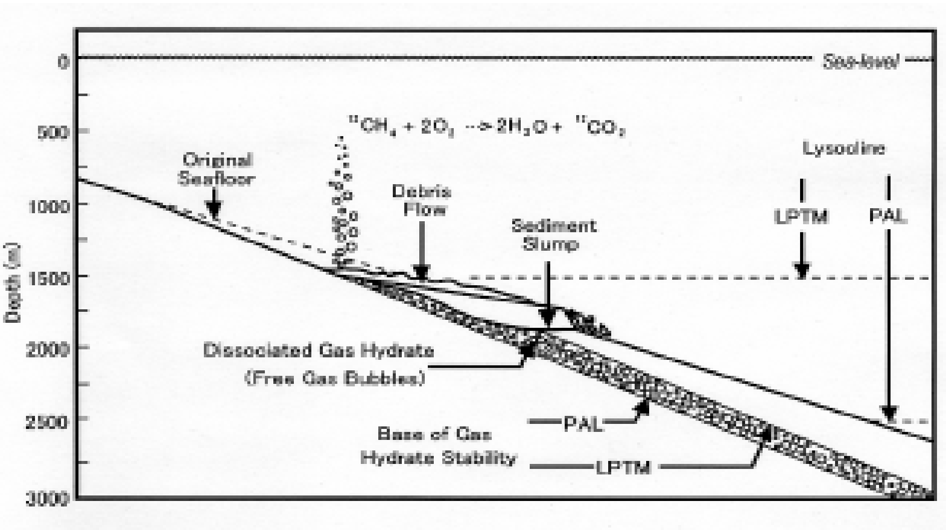
1) Methane hydrate quickly dissociates into gas phase at certain (P,T) condition, with a remarkable change of volume.

2) The phase change (P,T) is close to that normally found in the sub-sea formations of continental margin areas.

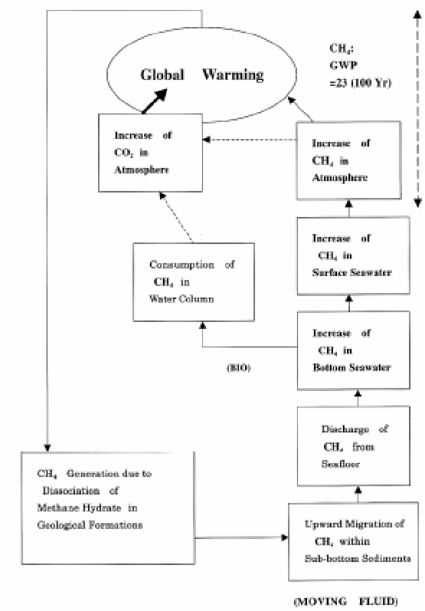
3) Natural feed-back system has not yet been clarified.

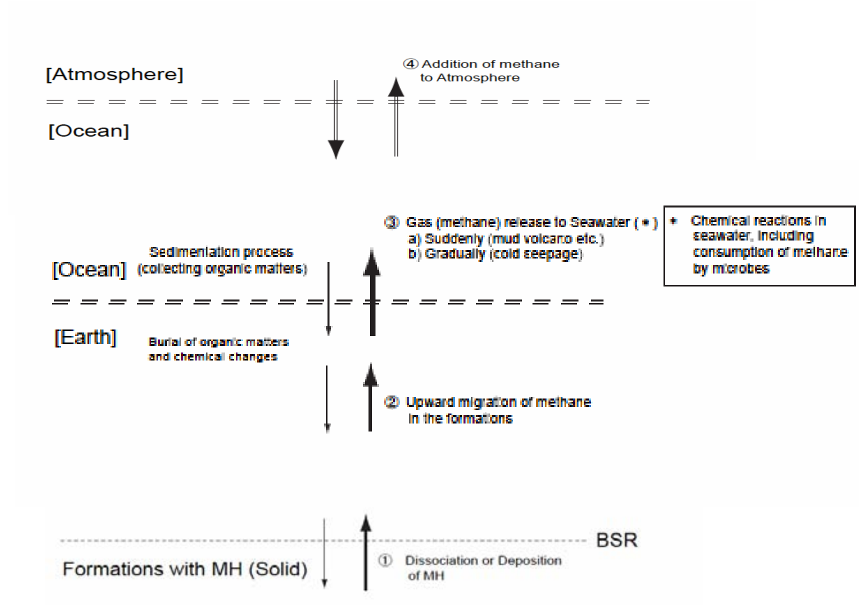
4) If large amount of CH4 gas is released to atmosphere, it does enhance he so-called greenhouse effect.

Sub-sea landslides might be caused by the act of hydrate dissociation (from Dickens, 2001)



Global warming and the role of MH (positive F.B. !)





Chapter C.

Geothermics and Submarine Hydrates

(Originally for "Geo-Temperature Workshop" held @JAMSTEC Tokyo, on June 16, 2006)

A review on BSR-derived HF
in Japanese offshore areas

- In the beginning :
  Yamano et al. (1982)
  pointed out the usefulness of hydrate BSR as novel data-source for HF estimation (giving a continuous HF profile).

Many research works along this idea have followed it until present day:

i.e., Akazawa et al. (1996) for Kumano Basin, Nankai Trough;
Ganguly et al. (2000) for Cascadia
and some others.

However, there are basic unsolved problems in the method of "BSR-derive Heat Flow" !!

1) Does "BSR" really coincide with the phase boundary (P,T) of gas-hydrates, or not ?

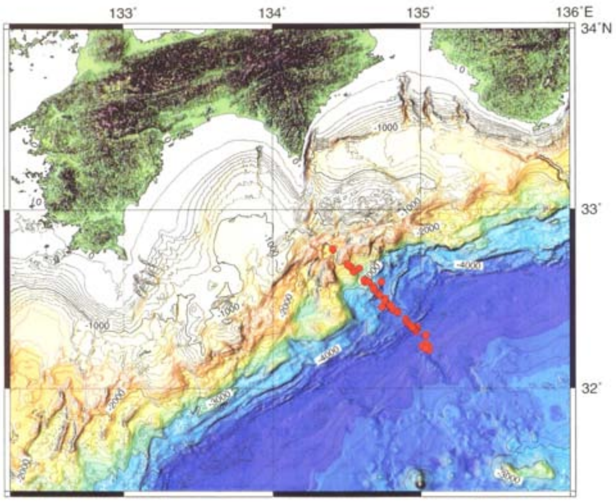
2) Pressure in-situ has never been reported (hydrostatic or lithostatic not clarified yet).

3) Thermal Conductivity used is from
conversion of seismic velocity, therefore it
contains uncertainly.

AS A WHOLE
ACCURACY MAY NOT
BE VERY HIGH.

四国沖の実験海域周辺の海底地形図

Topographic Map Showing the Survey Area off Shikoku.



赤丸は NGH99 実験航海での地殻熱流量測定点

Seismic profile off Shikoku Is.

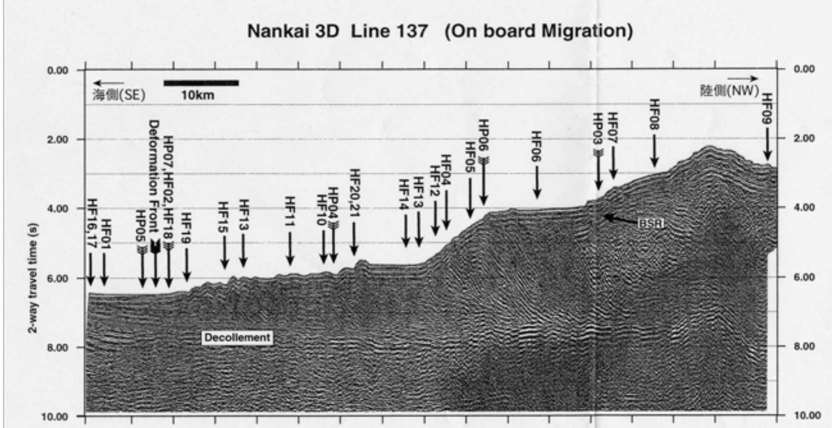
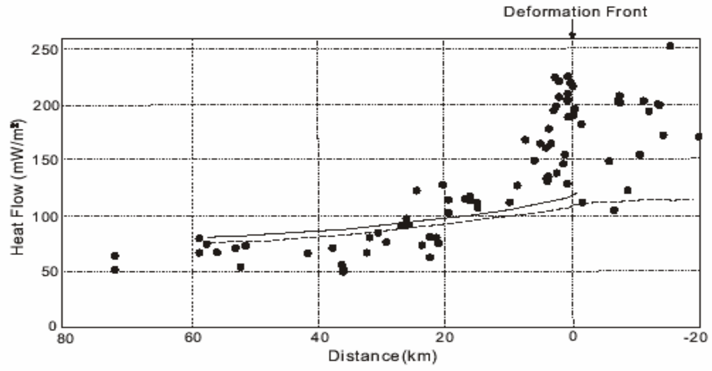


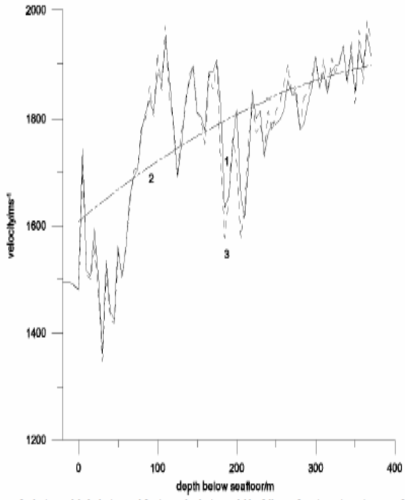
図5-1-2 Ewingの航海(Line137)で得られた西部南海トラフの地震探査断面図
(熱流量測定点を矢印、採泥点を羽矢印で示す)



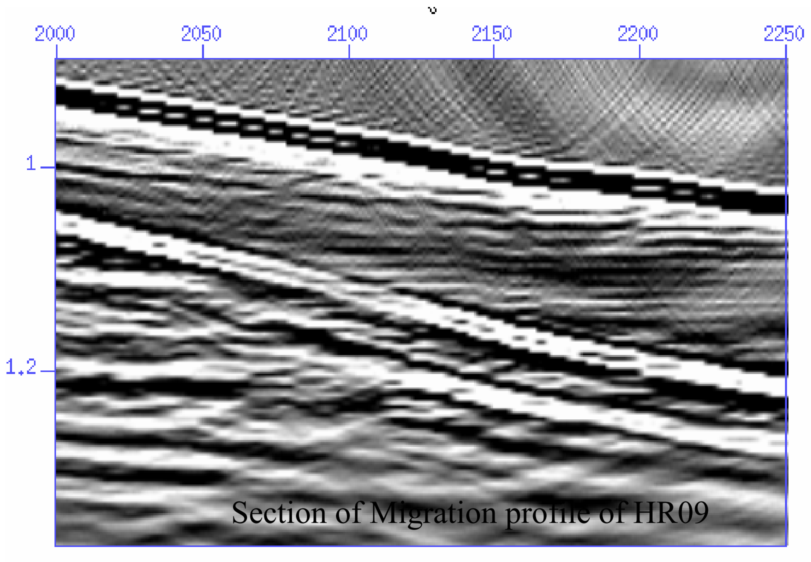
We should be fully aware of all those facts that have become available by recent gas-hydrate field programs.

- Seismic "hydrate-BSR" sometimes <u>does not correspond</u> to phase boundary (P,T) of methane-hydrates.

Song, Matsubayashi, and Kuramoto(2003) →



Comparison of velocity models 1. the inverted 5m-interval velocity model by full waveform inversion using curve 3 in figure 6 as the starting model; 2. Velocity trend model based on curve 1 in figure 6; 3. the inverted 5m-interval velocity model by full waveform inversion using curve 4 in figure 6 as the starting model.



Four CMP gathers around CMP 2140 are combined to form a supergather with the group interval of 12.5m to avoid the spatial alias problem. At CMP 2140, the first BSR and the second BSR are clear, where the slope of the first BSR is about 4°, both the seafloor and the second BSR subparallel to it and a one-dimensional structure can be approximately assumed. Then it is transformed to the data in intercept time-slowness domain.

Problem of **Double-BSR**

Marine Geology 187 (2002) 161–175

MARINE GEOLOGY

www.elsevier.com/locate/margeo

Observation and tentative interpretation of a double BSR on the Nankai slope

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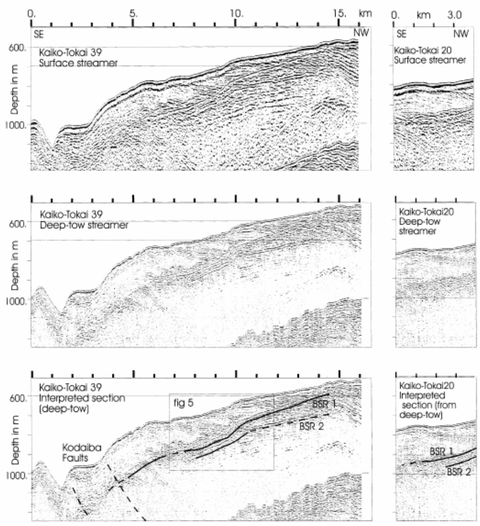
Received 16 March 2000; received in revised form 21 December 2000; accepted 15 June 2001

Abstract

Seismic data collected during the French–Japanese KAIKO-Tokai cruise of R/V *L'Atalante* on the upper slope of the eastern Nankai margin reveal the simultaneous presence at two distinct depths below the seafloor of two bottom simulating reflector (BSR)-type reflectors. The upper BSR is traced as a continuous reflector over about 10 km. As water depth decreases from 850 m to 550 m, its depth below seafloor decreases from 200 m to 40 m. The lower BSR is traced at 50–100 m below the upper one. The two BSRs end abruptly near the summit of the Daichii-Tenryu Knoll into an area where the 3.5-kHz record suggests active gas expulsion through the seabed. The observed depth of the upper BSR fits the predicted one for the base of the methane gas hydrate stability zone as estimated from present temperature and pressure conditions at the seafloor and in the slope sediments. Thus, we interpret the upper BSR as an active methane hydrate BSR. We further suggest that the lower BSR is a residual hydrate-related BSR. This could have followed a recent migration of the base of the methane hydrate stability zone from the lower BSR to the upper one. As possible causes for this migration we discuss sea bottom warming and tectonic uplift. The BSR migration could have occurred as a response to a 1–2°C sea bottom warming or, with an equivalent effect, an event of fast uplift of the seafloor by about 90 m. We do not discard other interpretations of the lower BSR, such as an active hydrate-related BSR formed from a mixture of gases.

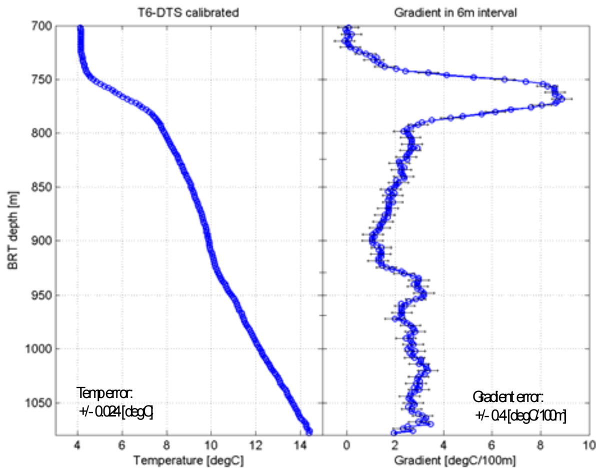
Keywords: active margins; bottom-simulating reflectors; gas hydrates; fluid dynamics

J.-P. Foucher et al. / Marine Geology 187 (2002) 161–175 165



From top to bottom : depth migrated surface profiles 20 & 39, depth migrated deep-tow Pasisar profiles 20 & 39, and interpreted sections. Vertical exageration : approx. 13.

Fig. 3. Seismic sections 20 and 39 (locations in Fig. 1) showing the two BSRs in water depths of 550–850 m. Seismic section 20 ends after a short distance upslope along the double BSR extension (Fig. 1).



Temperature profile obtained by a new sub-sea DTS fiber optic measurement system within a exploration hole (No.14) at eastern Nankai site (<u>Fukuhara et al., "Proc. of ICGH-5" in 2005</u>)

Remarks for the results of Fiber Optic measured T profile:

For the T(z) measurement at the east Nankai (as part of Japan's "MH21" National Program) site using a sub-sea Fiber Optic temperature system, some important problems are not settled yet.

- **Measurement time was only 50 days, hence observation of T was not long enough for "thermal equilibrium condition", while the time-constant involving hydrates should be much longer.**
- **Water flow upward through the bore is suspected, which may be disturbing the true formation T(z).**

Chapter D.

Various Research Subjects Related to Natural Methane Hydrates

D-1) Geophysical detection methods;
D-2) Fluid geochemical studies on hydrates;
D-3) Seafloor geological phenomena (i.e., cold seeps) and hydrates;
D-4) Dynamic modeling;

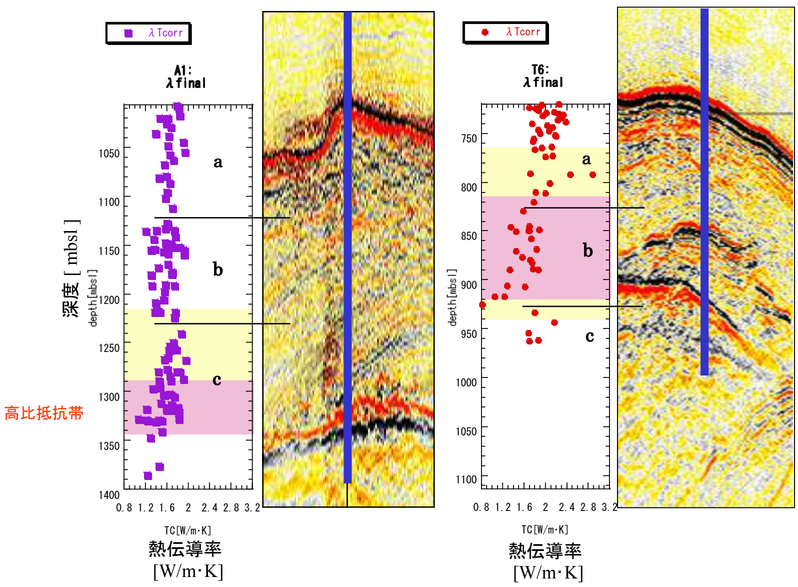
etc. , etc.

Geophysical detection methods

- Multi-channel Seismic Profile
- Electrical Resisitivity Survey
- Heat Flow Measurement
- Others

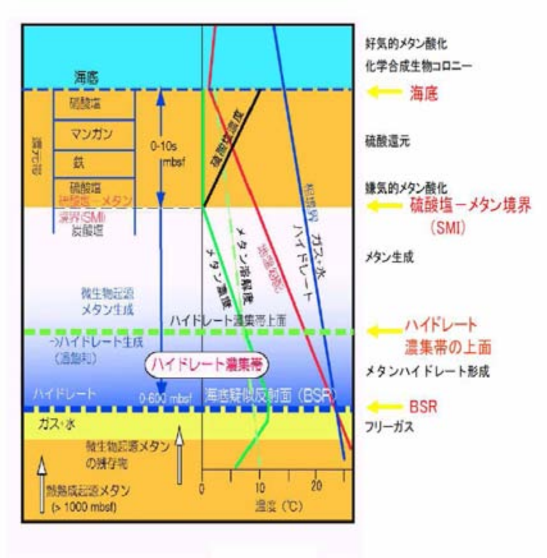
Thermal Conductivity of Cores（as referenced to seismic profile ）

A Site, Nankai　　　T site, Nankai



Geochemical studies

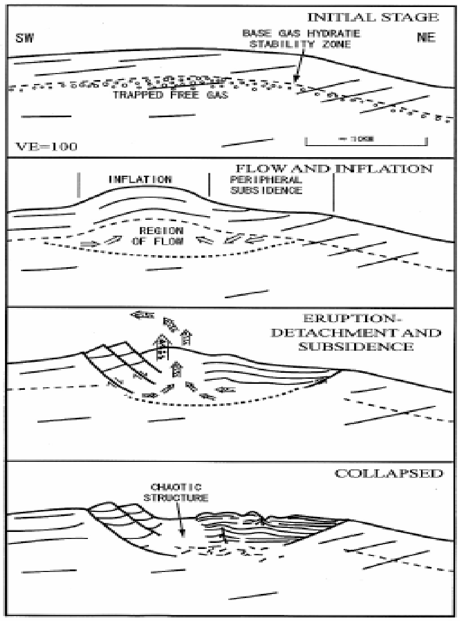
- Dynamic behavior of fluids in the sediments are playing a major role in accumulation process of ***methane hydrates***.



Hydrates and seafloor pock-marks

- Relationship of forming process of seafloor pock-mark structures and accumulation and release of methane to seawater

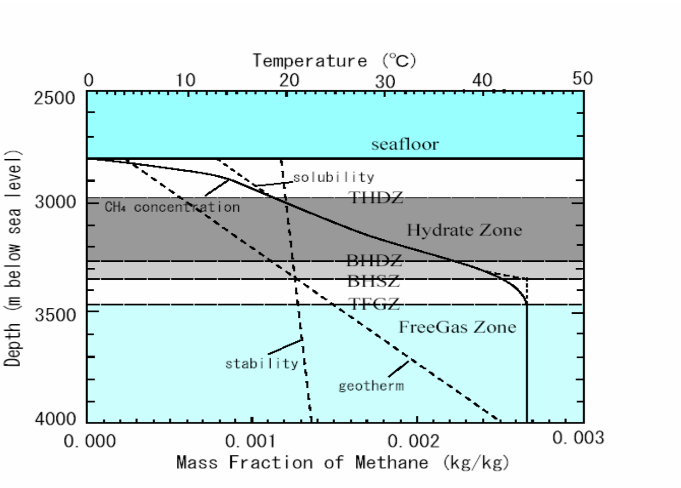
(Dillon et al., 2001)

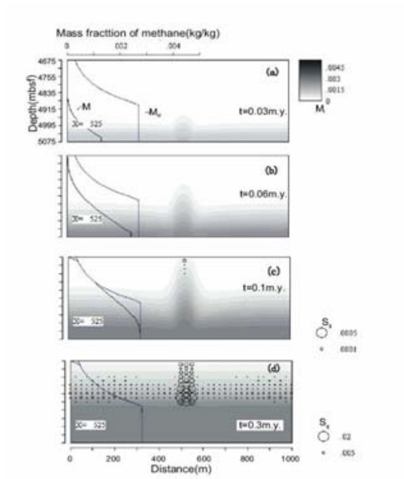


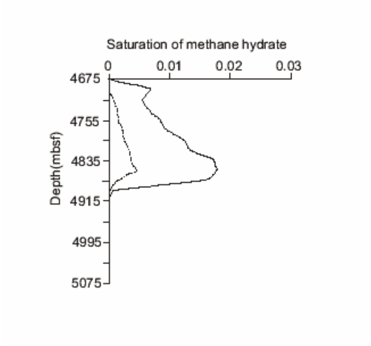
Numerical Modeling of Fluid/Energy Transfer

We can numerically simulate the physical processes which involve fluid transport and methane hydrate formation/dissociation in sediments, as function of time.

Ex. Model by Xu and Ruppel (1999)







- Example of numerical modeling results by He, Matsubayashi, and Lei (2006)

Suggested books to read on the topics

- Natural Gas Hydrates - occurrence, distribution, and detection (2001) Eds. by C.K. Paull and W.P. Dillon) Geophys. Monograph 124, A.G.U.
- Methane Hydrates in Quaternary Climatic Change (2003) J.P.Kennett et al., A.G.U.

Geo-scientific Studies

on Methane Gas Hydrates

End

Thank you !!