Significance of Natural Gases Dissolved in Aquifers as Energy Resources

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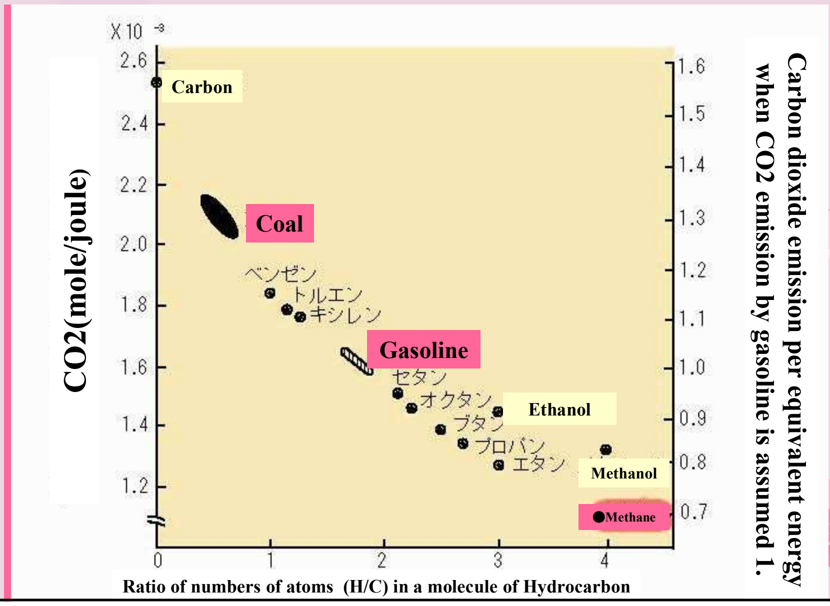
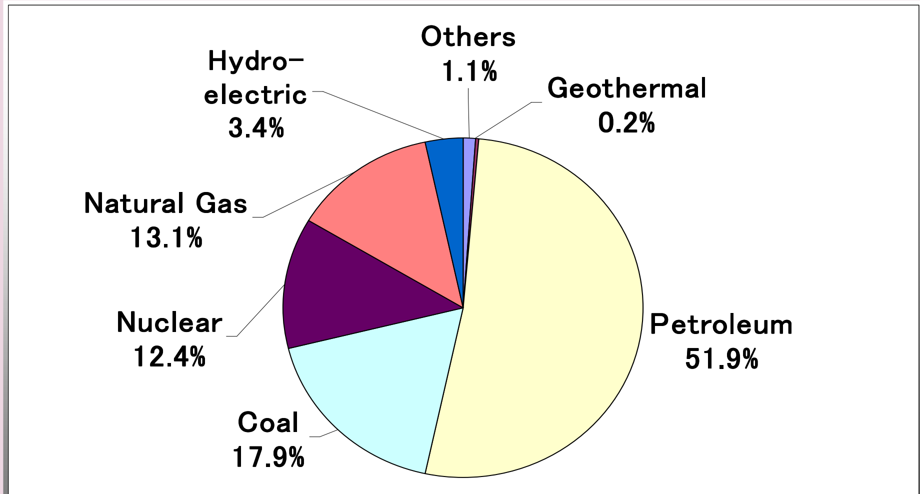
Natural Gases

- Flammable natural gases
  (Hydrocarbon Gases)
  - Gas dissolved in Aquifers
  - Structural trap gas
  - Oil-soluble gas
  - Coal bed gas
- Non-flammable natural gases
  (Carbon Dioxide, Nitrogen etc.)

CO2 Emission Variety per Unit Energy



Share of Primary Energy in Japan



Share of Primary Energy (2000)

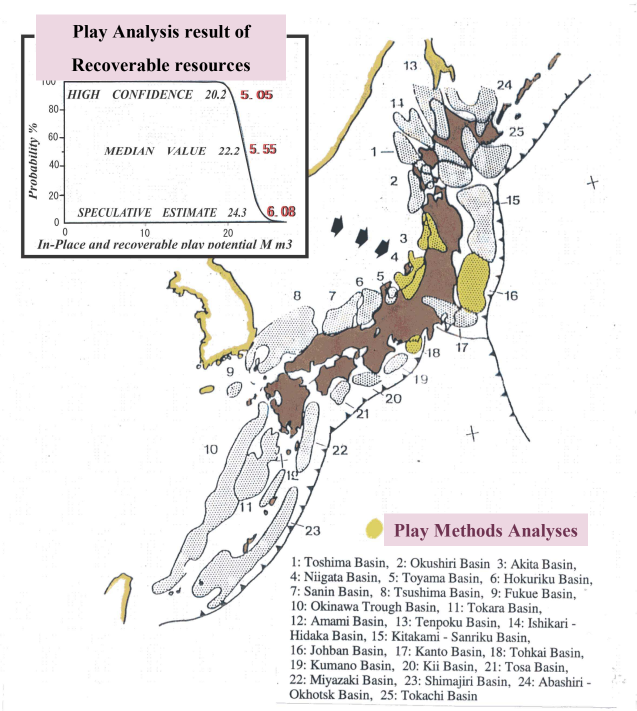
Petroleum Basins in Japan and Resources Analyses

Play Methods

Volumetric Methods

Total Hydrocarbon Resources

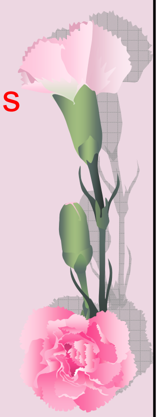
= 1.0~1.3 billion KL



Characteristics of Two Basin Types

Japan Sea Side
- Marginal Sea
- Back Arc Basin
- Rifted Basin
- High Heat Flow
- high TOC Content (=~2%)
- Type I Kerogen

Pacific Ocean Side
- Open Sea
- Fore Arc Basin
- Accretionary Prisms
- Low Heat Flow
- Low TOC Content (=~0.5%)
- Type III Kerogen

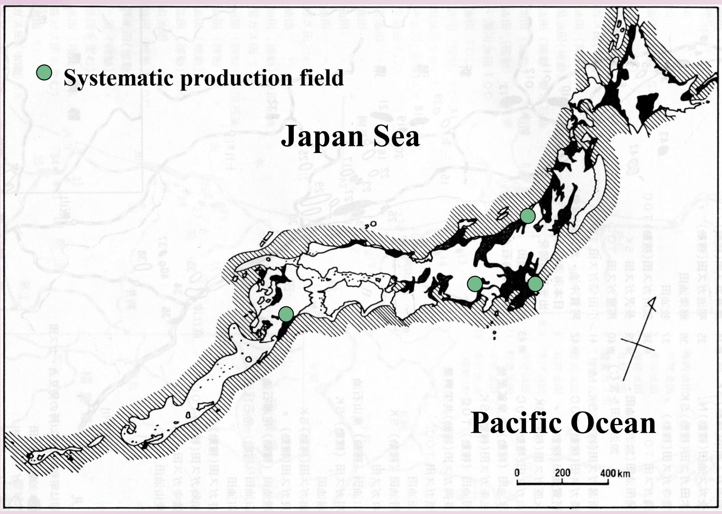


Natural Gas Production in Japan in FY 2005

	Oil field	Gas Field	Coal Field	Total	%
Hokkaido		415,035		415,035	13.2
Akita	27,752	15,915		43,667	1.4
Yamagata	4,591			4,591	0.1
Fukushima		176,730		176,730	5.6
Niigata	3,658	2,015,152		2,018,810	64.3
Nagano		71		71	0.0
Chiba		474,779		474,779	15.1
Miyazaki		4,093		4,093	0.1
Others		2,022	99	2,121	0.1
Total	36,001	3,103,797	99	3,139,897	100
%	1.1	98.9	0.0	100.0	

(Unit 1,000m3)

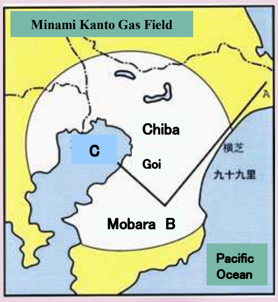
Distribution of Natural Gases Dissolved in Aquifers in Japan

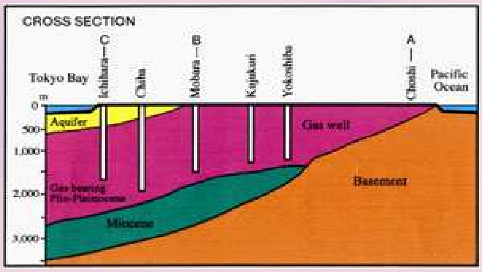


Minami Kanto Natural Gas Field

The Minami Kanto gas field contains a maximum recoverable reserves of 375 BCM, which is the largest field of gas dissolved in aquifer in Japan.

Gas Reservoir: Pliocene to Pleistocene
Poor Gas Reservoir: Miocene
Basement Rocks: Cretaceous to Lower Miocene



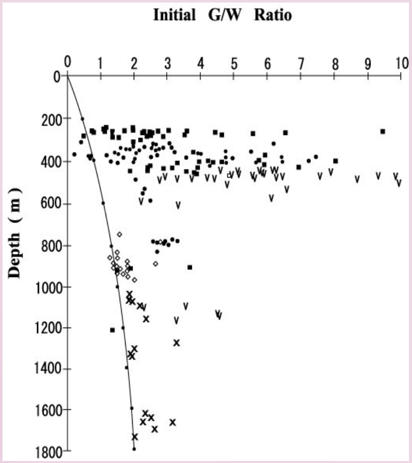


Minami Kanto Gas Field

- Production from seepage started in 1596.
- Well production started in 1891.
- Recoverable Reserves; 375 BCM
- Production; 474 MCM

Two Types of Natural Gases Dissolved in Aquifers

- Conventional Type
  G/W ratio ; around 2 to 4
- Mobara Type
  G/W ratio ; 4 to over 60



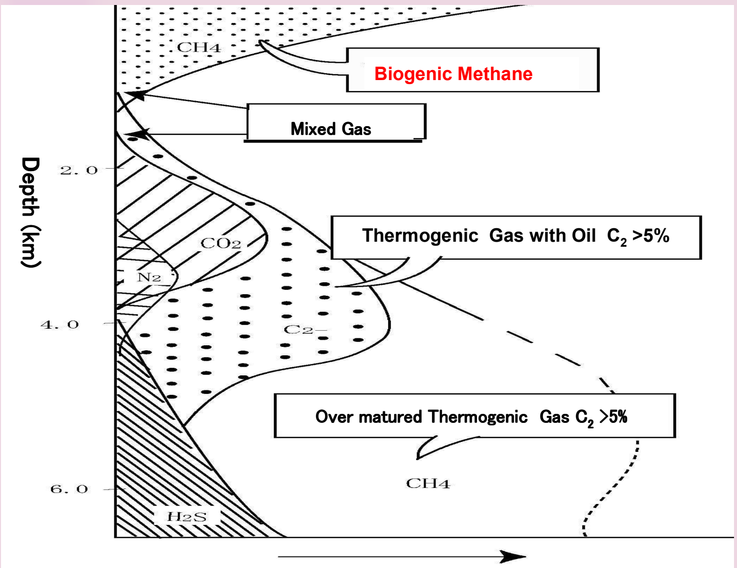
Characteristics of Mobara Type

- Large G/W ratio (4 to more than 60).
- High content of methane (99%).
- Horizon and depths of production are quite limited.
- Brine contains about 100 ppm of Iodine 100 times more than that in sea water.

Why Mobara type has large G/W?

- Source and reservoir rocks (Kazusa Group) of Mobara type of gas dissolved in aquifer are deep sea turbidites.
- Benthos in the Kazusa Group indicates that paleo-depths were more than 800 meters which is enough deep to produce gas hydrated layers.
- Mobara region has been uplifted more than 2,000 meters since the sedimentation of tha Kazusa Group.
- Above facts indicate that ascending methane was trapped in the hydrated layer at once, and that the hydrated layers was dissolved during the uplifting stage. Therefore, the highly oversaturated dissolved gases are trapped in the Kazusa Group at present.
- The condensed gases in the Kazusa Group formed in above process made high G/W ratio at initial production stage.

Origin of Hydrocarbon Gases



Geochemical Process in Shallow Sediments

Sea water

Methane Oxidation

The methane consumption germs oxidizes and changes slipped methane into CO_2, HCO_3^{-}

Seafloor

Colony of chemical synthesis creatures

Tube worm, the sulfur oxidation bacteria, etc.

The bacterial mat, The colony of the sulfur oxidation bacteria

Oxidation of Hydrogen Sulfide, and organic material formation from CO_2 and H_2O

$H_2S+2O_2 \rightarrow SO_4^{2-}+H^+$

Sulfuric acid deoxidization zone

Sulfuric acid deoxidization

The resolution of the organic material by the sulfuric acid deoxidization bacteria which used the sulfuric acid ion of the seawater origin in interstitial water.

$CH_2O+SO_4^{2-} \rightarrow H_2S+HCO_3-$

SMI

Methane oxidation

$CH_4+SO_4^{2-} \rightarrow HCO_3^{-}+HS^{-}+H_2O$

$CH_4+2H_2O \rightarrow CO_2+4H$ Consumption of methane and hydrogen production by the methane bacteria.

$H^++4H_2+SO_4^{2-} \rightarrow HS^-+4H_2O$ Hydrogen oxidation by sulfuric acid deoxidization bacteria

Methane formation zone

Methane formation by the methane bacteria

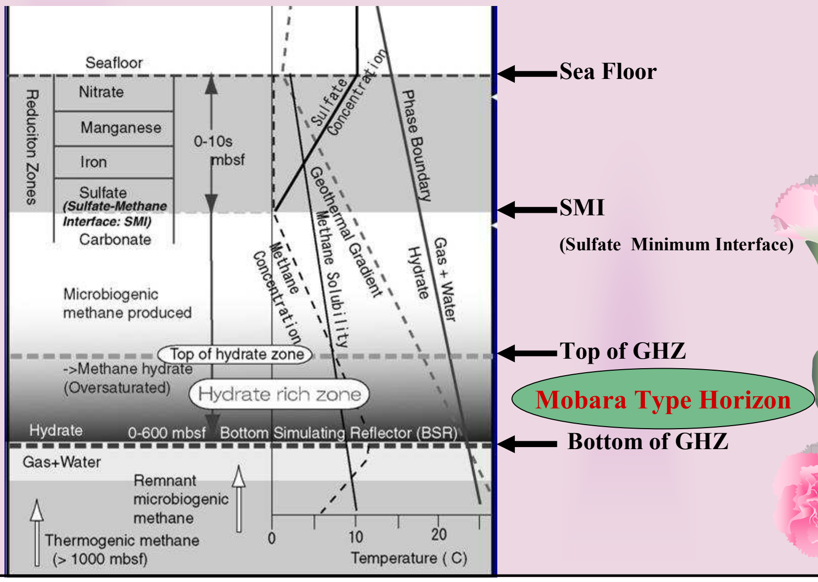
Fermentation (resolution of the organic one) $2CH_2O \rightarrow CH_4+CO$

Oxidation of hydrogen (deoxidization of the carbon dioxide) $CO_2+4H_2 \rightarrow CH_4+2H_2O$

The precipitation of calcium carbonate

- HCO^{3-} which is formed by the methane oxidation, sulfuric acid deoxidization and methane oxidation.
- Ca and the reaction in gap water and seawater Ca^{2+} +HCO3$^-$ →CaCO3+H^+
- Reaction with Calcium in interstitial water and seawater $Ca^{2+}+HCO_3^- \rightarrow CaCO_3+H^+$

Geochemical Environment beneath the Sea Floor



Composition of Natural Gas Dissolved in Aquifer

Type of Gases	Composition
Methane	99.0%
Carbon dioxide	0.5%
Nitrogen	0.4%
Others	0.1%

Heating Value = 39 mega joules per cubic meter

Classification of natural gases in sedimentary basins and research issues

Origin	Reservoir	Occurrences	Research Item
Thermogenic Gases	**Structural Natural Gases**		
	Basement rock reservoir		Granite Reservoir, Volcanic Reservoir
	Deep reservoir	**Low permeability**	**Tight sand Gases**
		Low permeability	**Shale Gases**
(Deep Natural Gases)			**Deep Gases**
			Microbial Gases with subduction
(Natural Gases originated from Coal)		**Variable occurrences**	**Coal Bed Methane**
			Gases from Originated from Coal
	Natural Gases dissolved in oil type.		
	Methane Hydrate	**Low permeability** Solid→Vapor	
Biogenic Gases	**Natural Gases dissolved in water type.**	**High pressure type**	Mobara Type
		Intermittent gas rift type	**Geo-pressured Type** (Mexico Bay)
		Conventional Type	
Ultra-Deep Gas	**?**		

Unexpected Gas explosion by Leakage of Natural Gas Dissolved in Aquifers in Tokyo

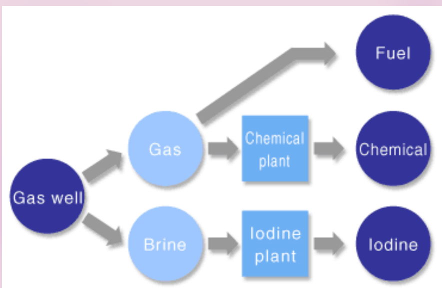
Hot spring
in Shibuya
@1500m
June 19, 2007

Drilling for Hot Spring
in Kita-ku
@1500m
Feb. 10, 2005

Water soluble natural gas / brine / iodine -Kanto (Chiba) Gas Field-

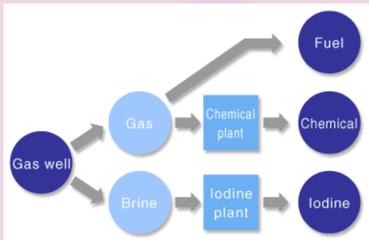
Underground water layers in the stratum 2-12 million age contain lots of salt and natural gas in the stratum 2-12 million age.

This aquifer is called brine. The brine has also high concentration of iodine.



Brine

- The salt concentration in brine is almost the same as in sea water.
- Iodine in brine is more or less 100ppm, nearly 2,000 times higher than in sea water.
- 30-50% of the total world production of iodine has been produced in the Kanto gas field. (about 8,000 tons of production in 2005)



Origin and Reserves of Iodine

- The formation of brine layer is presumed to be the accumulation of seaweeds (seaweeds contain lots of iodine and it used to be obtained from seaweeds ashes) .
- Other organic substances piled up together with earth and sand on the ancient sea bottom, where iodine had been concentrated through many years.
- Recoverable iodine reserves in the Minami Kanto Gas fields are estimated 4 - 9 million tons.

Composition of Brine in Kanto

Area	Well Name	Br	I	H-Cl
Chouja	SR1	116.0	84.5	4.57
Naruto	R10	118.9	66.1	3.41
Chiba	KenR!	100.1	47.2	2.41
Yotukaido	R2	122.6	80.4	4.15
Ryuugasaki	ShintoneR1	74.1	26.7	1.38
Edogawa	ER2B	87.6	39.5	2.12
Edogawa	ER10C	82.2	82.2	4.25
Koto	KOTOSHI1	36.3	36.3	1.86
Oomori	OomoriR1	30.5	30.5	2.10

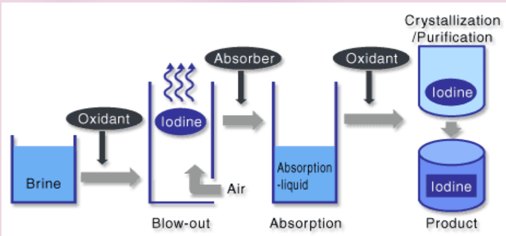
Production Process of Iodine

- Japanese gas companies employ mainly two methods for manufacturing iodine.
- The blowing-out method (New)
  Adding oxidant to brine, air easily vaporize iodine.
- The ion-exchange resin method
  This method uses ion-exchange resin that absorb iodine. The advantage includes relatively low cost.

Production Process of Iodine

"Blow out process"

Iodine contained in brine in the form of iodine compound ions (I-) is limitedly around 100ppm and the "Blow Out Process" is suited for the extraction of iodine from such low content solution. Sand and other impurities are first removed from brine by sedimentation and an oxidant is added to it to extricate iodine (I2). Then air is introduced to "blow it out" and After that, iodine is extracted, crystallized and purified. This process is widely employed by many companies in Japan and U.S.

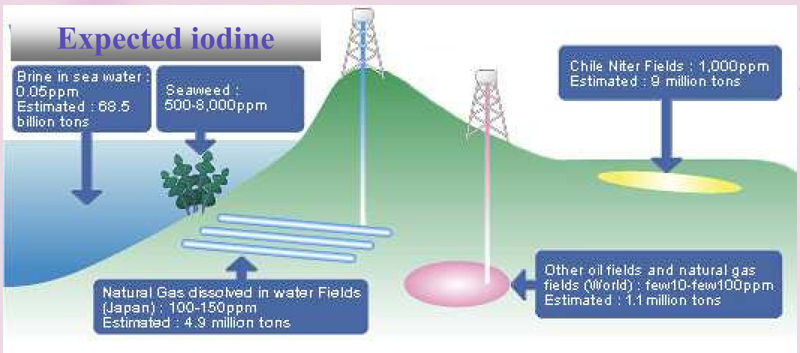


Recent Patents:

Japanese Patents
Nos.2732635,
2732636,
2732637,
2732642

Potential of Iodine

- Recoverable iodine reserves in the Minami Kanto Gas fields are estimated 4 - 9 million tons.



Summary

- Production of natural gases dissolved in aquifers share about one third of total gas production in Japan.
- Special production type of gas fields with high G/W ratio, called "Mobara Type", exist in the Minami Kanto gas field. The horizons with high G/W ratio are quite limited and are considered to be paleo-hydrated horizon. The hydrate dissociation may cause high G/W production rate.
- High content of iodine originated from sea weeds is contained in brine, and recently a new "blow out method" is commonly employed to extract iodine from brine by the Japanese gas companies.