GAS

JMA

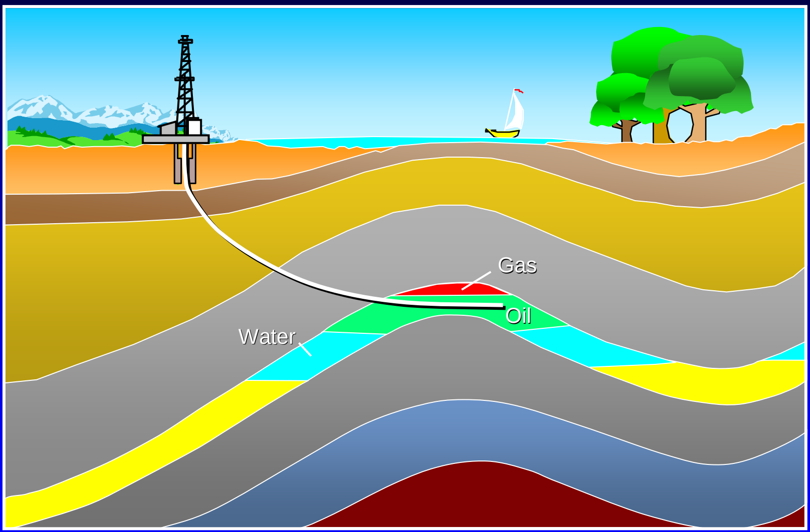
Gas resources: plentiful but…

- Gas Reserves (2004) = 6300TCF (180TCM); "underexplored"
- About 40% of gas (2500TCF) is stranded (Russia, Qatar, Australia, etc.)

- R/P ratio: ~90 years (versus oil at ~50)
- Associated gas is re-injected or flared

JMA

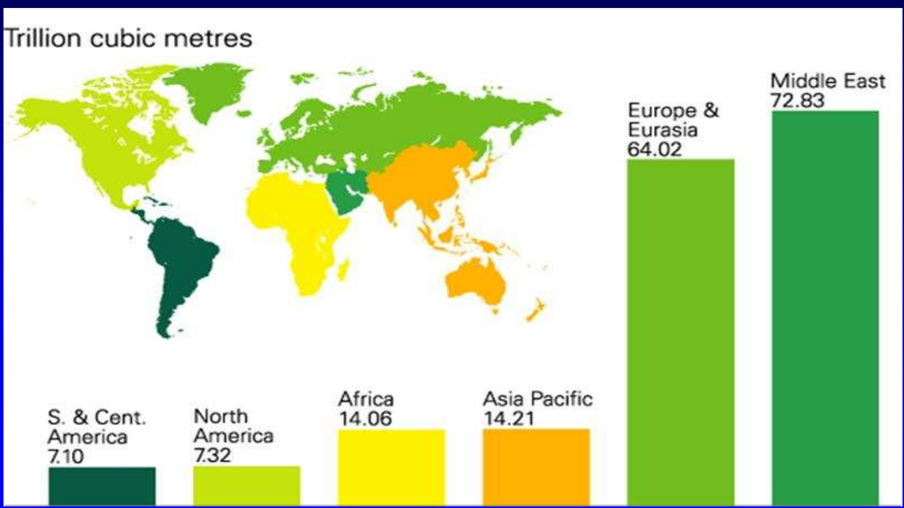
Gas used primarily for the drive



American Petroleum Institute, 1986

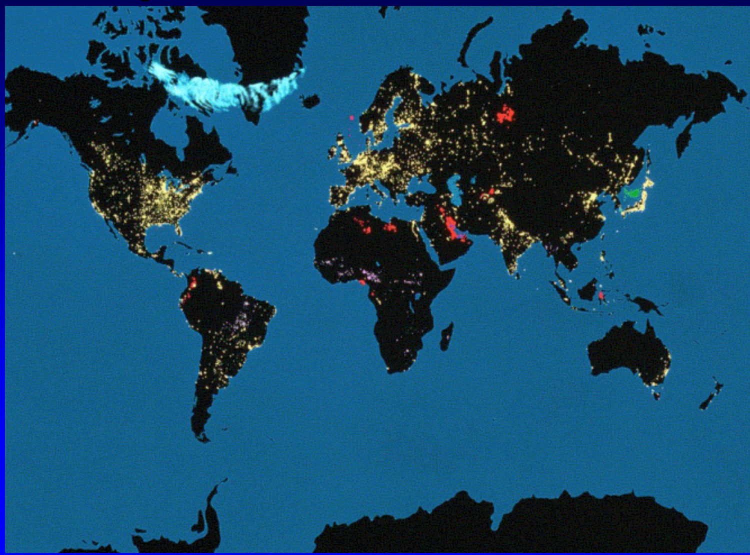
JMA

Gas Reserves



JMA

Flaring of associated gas (in red; 15 bcfd?)



JMA

Remote Gas Monetization Options

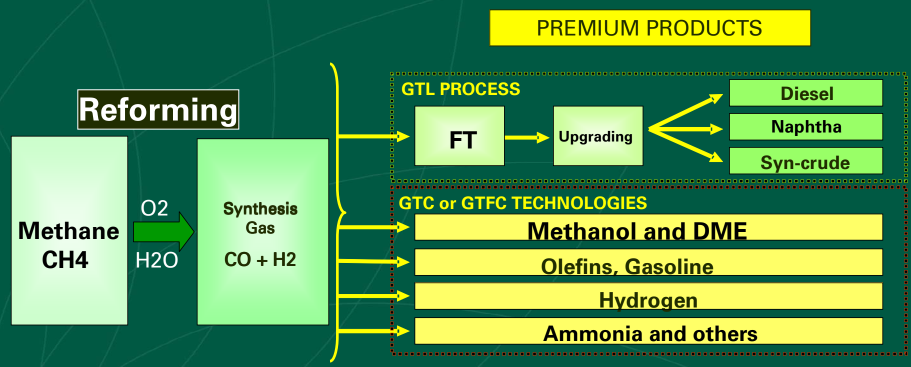
PIPELINE	PUSHING THE LIMITS ($25B)
LNG	TECHNOLOGY OF CHOICE TODAY
GTL (FT, Fischer-Tropsch)	BIRTH OF A NEW INDUSTRY (gas to liquid)
METHANOL	TRANSITION FROM CHEMICAL TO FUEL
DME	"SYN-LPG", ASIAN TIGER AWAKENS
CNG (compressed NG)	A NICHE FOR SMALL & SHORT (EnerSea)
GAS BY WIRE	DC TRANSMISSION COST DECREASING
HYDRATES	MOVING A LOT OF WATER
GAS BY BAG	A VERY SMALL NICHE

JMA

Gas by Bag

JMA

GTP: Inclusive term for all chemical gas conversion options

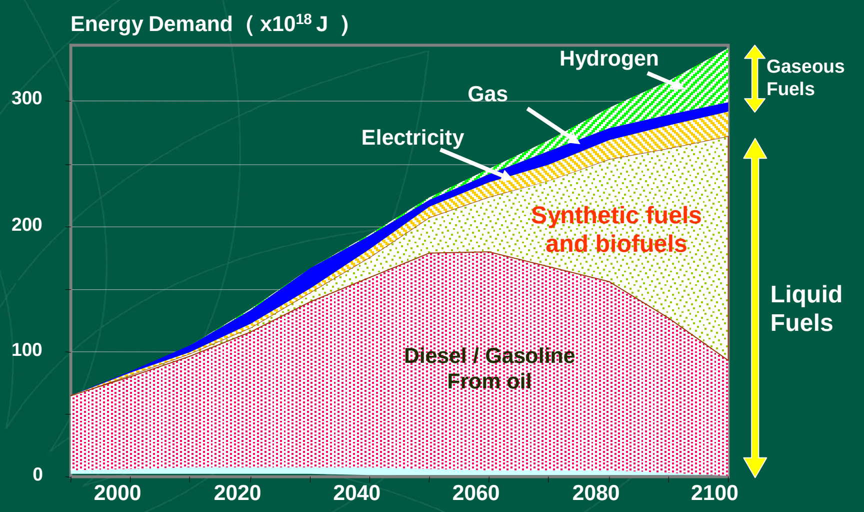


GTL: Gas to Liquids (FT- Fischer Tropsch)

GTC: Gas to Chemicals

GTFC: Gas to Fuels and Chemicals

Automotive Fuel Demand Scenario



Source: IEA

Non Conventional Fossil Fuels

JMA

“Unconventional” Gas

JMA

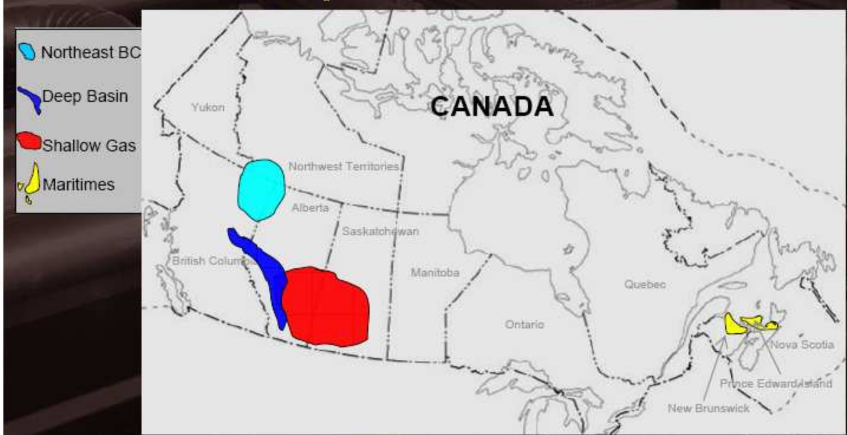
JMA

National Petroleum Council Study: Unconventional Gas is Increasingly Important

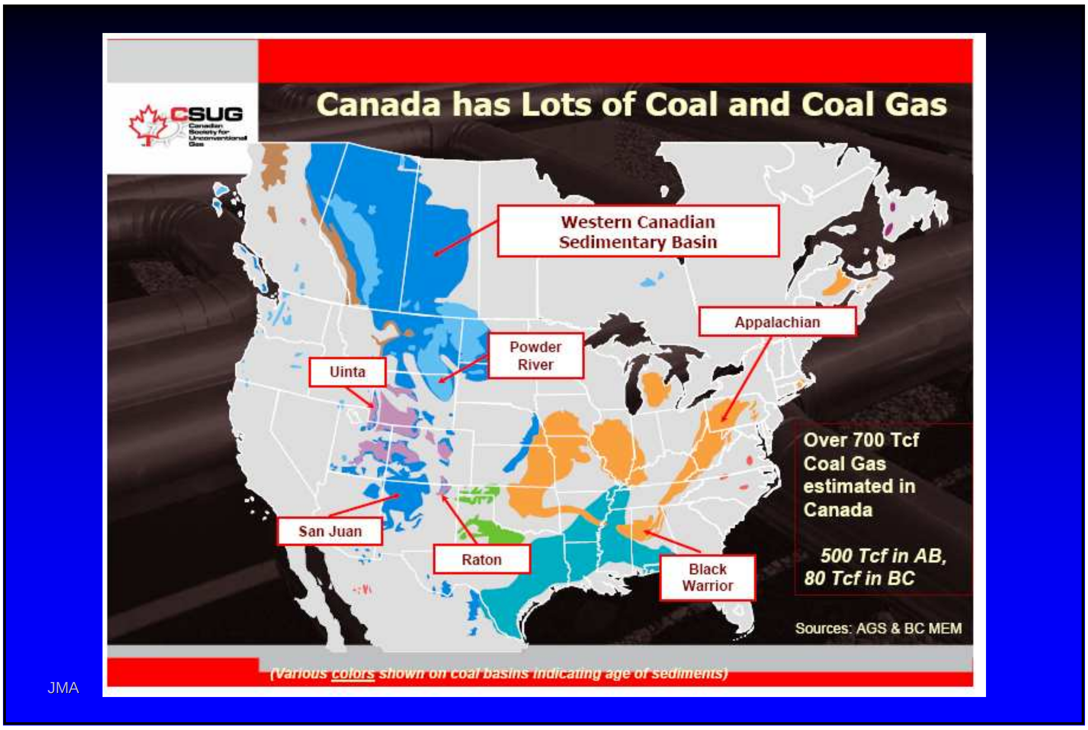
- "Conventional gas production will inevitably decline, and the overall level of indigenous production will be largely dependent on industry's ability to increase its production of *unconventional gas*"
- 80% of gas production in 10 years will be from wells yet to be drilled in North America
- By 2025, unconventional gas will account for about 80% of new drilling and 50% of gas production

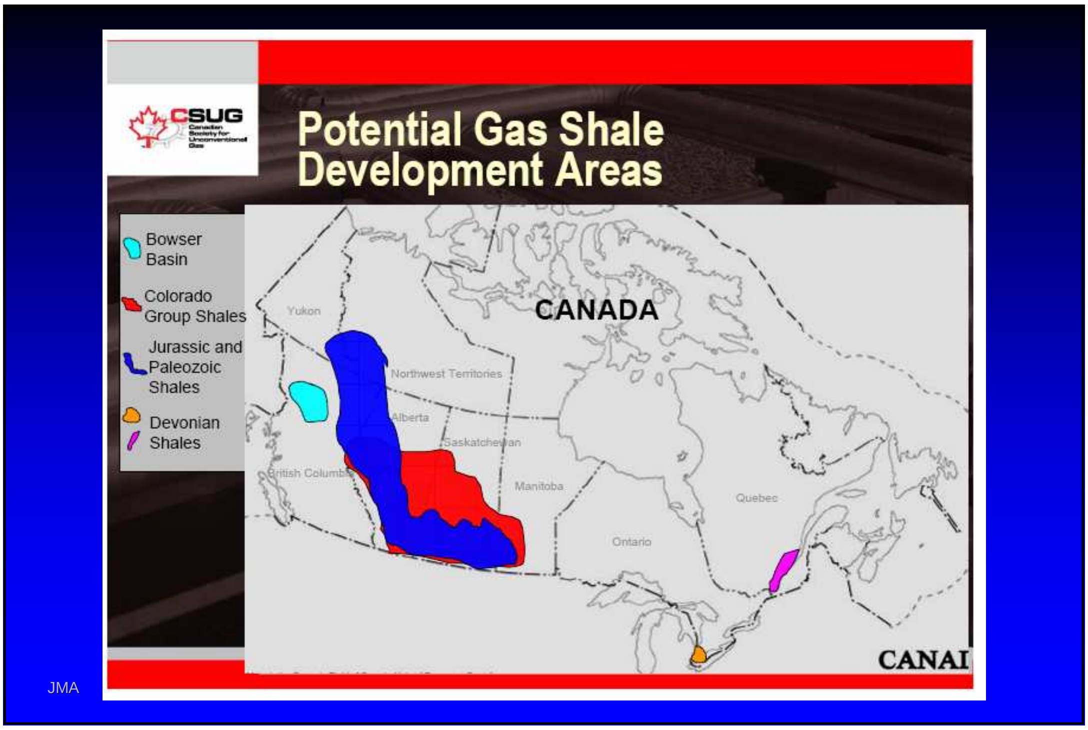
JMA

Potential Tight Gas Development Areas



JMA


CSUG
Canada has Lots of Coal and Coal Gas
Western Canadian Sedimentary Basin
Appalachian
Powder River
Uinta
San Juan
Raton
Black Warrior
Over 700 Tcf Coal Gas estimated in Canada
500 Tcf in AB, 80 Tcf in BC
Sources: AGS & BC MEM
(Various colors shown on coal basins indicating age of sediments)
JMA


CSUG
Potential Gas Shale Development Areas
Bowser Basin
Colorado Group Shales
Jurassic and Paleozoic Shales
Devonian Shales
CANADA
Yukon
Northwest Territories
Alberta
Saskatchewan
British Columbia
Manitoba
Ontario
Quebec
CANAI
JMA

Oil Shale

JMA

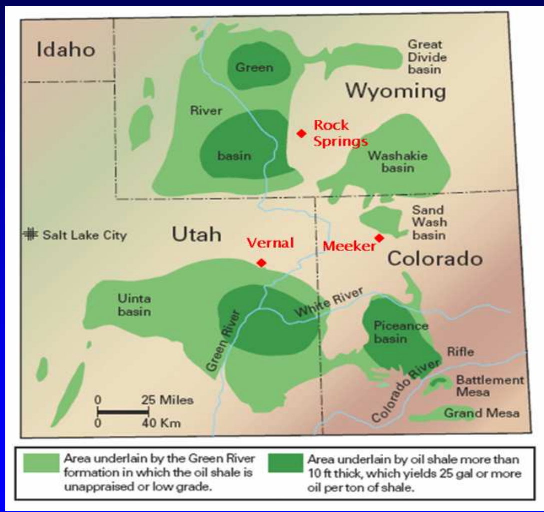
What is Oil Shale?

- Organic, lime-rich mud deposited in a lake.
- The organic material is kerogen, not oil, that upon heating produces crude oil and natural gas.

JMA

Green River Formation

Oil Shale Basins



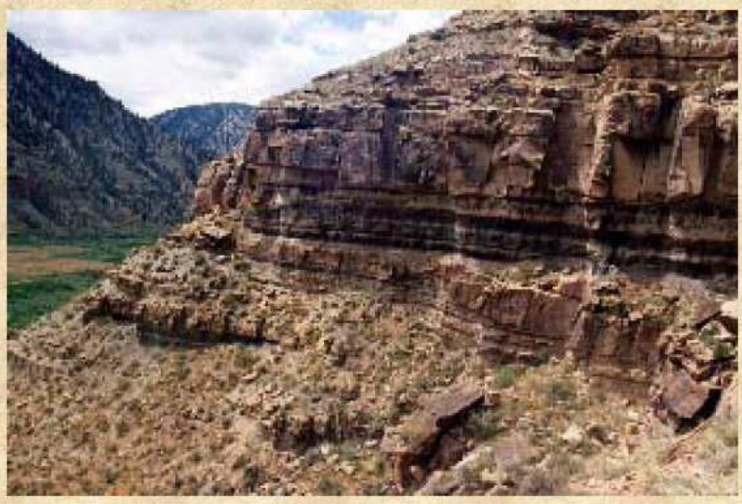
JMA

U.S. Green River Oil Shale Resources (in-place)

–Colorado	1000 billion bbls
–Wyoming	300 billion bbls
–Utah	321 billion bbls
–TOTAL	1621 billion bbls

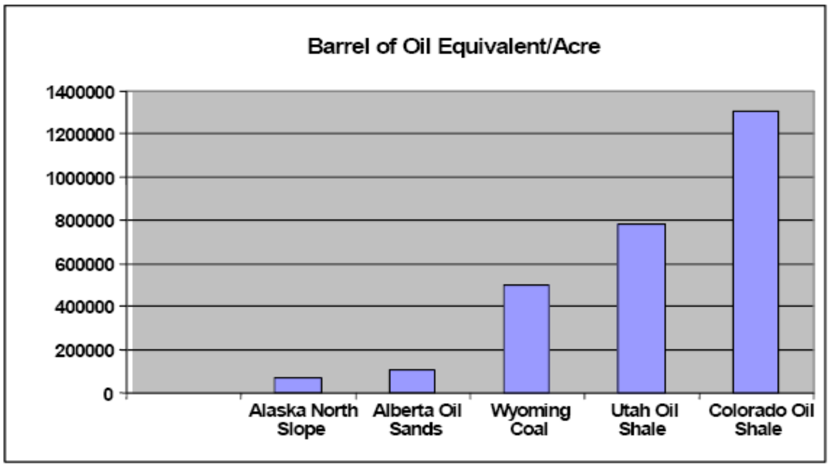
–Source: Bartis and others, 2005, Rand Corporation

JMA



JMA

Energy Concentrations



–Source: DOE Office of Naval Petroleum and Oil Shale Reserves, 2005

JMA

How Can it be Recovered ?

Mining & surface retorting

(Photo on left by Heikki Bauert, Estonia)

Underground in-situ retorting

(Photo on right from Shell Oil)

JMA

Environmental Concerns

- Disturbance of land surface
- Disposal of spent shale
- Impacts on water and air quality
- Impacts on sensitive species
- Energy efficiency

JMA

Conclusions Oil Shale

- One oil shale mine of 5120 acres could replicate 2005 oil production from over 2300 wells for 40 years.
- **Conflicts exist with conventional oil and gas development, tar sand resources, as well as wilderness study areas.**
- Required environmental studies and testing/scale-up of oil shale recovery technologies make commercial oil shale industry unlikely before 2020.

JMA

Tar Sand Resources

JMA

Tar Sands

- Definition: A type of oil sand or sandstone from which the lighter fractions of crude oil have escaped, leaving a residual asphalt to fill the interstices

JMA

JMA

AMERICA'S OIL SANDS RESERVES ARE NO LONGER "THE FORGOTTEN RESOURCE."

- Oil prices ranging from $ 40.00 USD to $ 60.00 USD per barrel makes oil sand extraction extremely cost effective and provides a well-insulated profit margin for the Company.
- The United States has over 80 billion bbls of proven oil sands resources, including 32 billion bbls in Utah alone. (DOE Estimates)
- The partnership is actively pursuing additional oil sand leases.
- Heavy oil refining infrastructure is available in nearby Salt Lake City.

NEVTAH CAPITAL MANAGEMENT INC.

JMA

"Heavy Oils" : Resources of 4000 to 5000 Gb (OIP)

Potential Reserves depends on recovery factors

Considerable Potential Reserves : # 500 to 1000 Gb

- equivalent to 50-100% of worldwide conventional oil reserves
- 5 to 10 times (?) the ultra-deep offshore potential reserves
- mainly (80%) in extra heavy oil, tar sands and bitumens
- mainly (80%) in North and South America
- less than 1% produced or under active development

ASPO Annual Meeting 2003 - Rueil- 26-27 May 2003 4

TOTAL

JMA

Mining Extraction

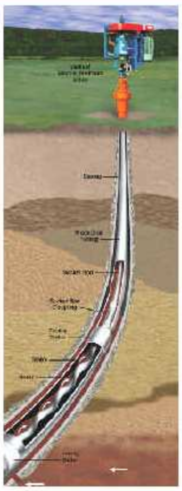
- Proven technology
- High Recovery Factor
- Decreasing operating costs :
  - ✓ 1980's : > 25 US$/bbl
  - ✓ 2002 : 8 - 12 US$/bbl
- Limited GHG emissions

BUT :

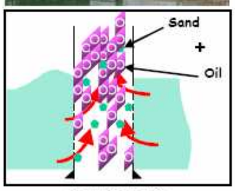
- Overburden limited to 50-75 m
- ➡ suitable to less than 10% of Oil in Place in Athabasca

JM

Cold Production



- Proven technology
- Fair productivities with horizontal wells (Venezuela) or with CHOPS (Canada)
- Limited investments
- Limited operating costs (2 to 4 US$/bbl)
- Available artificial lift technologies: PCP, rod pumps
- No GHG emissions



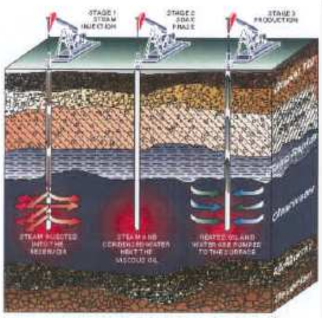
CHOPS

BUT :

- Poor recovery factors (# 5 to 10%)
- Unsuitable for bitumens (too viscous)
- Unsuitable for reservoirs with active aquifer

JM

Huff & Puff

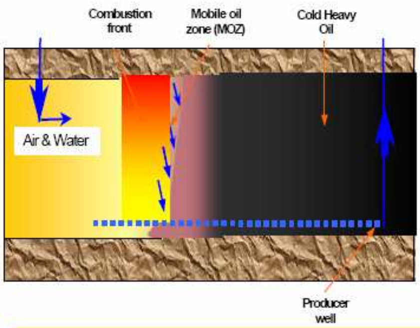


- Proven technology :
  - Canada : Cold Lake, Wolf Lake & Primrose
  - Venezuela : Maracaïbo & Oriente Basins
  - California : Kern River
- Limited operating costs :
  - 4 to 5 US$/bbl

BUT :

- Limited recovery factors (< 15-20%) : only stimulation around wellbore
- Consumption of energy and increase of GHG emissions

In Situ Combustion

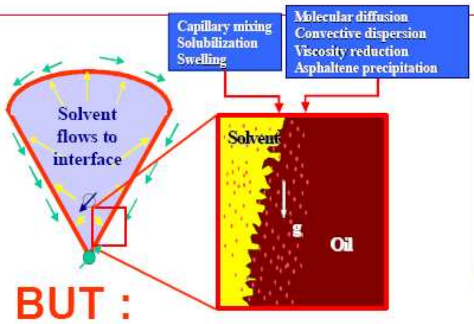


- Old technology (1960's)
- High Recovery Factor :
  - up to 60%
- Self-generation of energy (coke consumption)
- In situ upgrading (thermal cracking)

BUT :

- Field tested nearly exclusively on light oils
- Not so many successes (operational and safety problems)
- Pattern adapted to extra-heavy oil & bitumen to be found and field tested ...

Solvent Injection



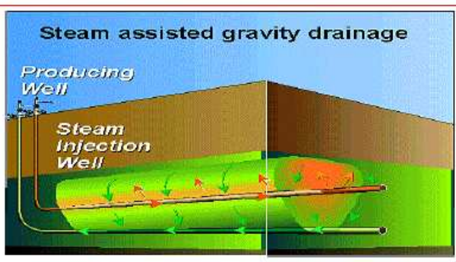
- High Recovery Factor :
  - up to 60%
- Low energy consumption
- In situ upgrading (asphaltene precipitation)
- No boiler feedwater treatment
- Limited GHG emissions

BUT :

- Slow process (molecular diffusivity much smaller than thermal diffusivity)
- Start-up not so easy : need for warming with steam ?
- Possible "killing factor" : solvent loss in reservoir ?
- Not yet field tested : first pilots being launched in Alberta
- Not mature enough for industrial application until some years

TOTAL

Steam Assisted Gravity Drainage (SAGD)



- High Recovery Factor :
  - up to 60%
- Quick process (high thermal diffusivity)
- Proven technology :
  - several pilots since 1980's in Alberta and elsewhere
- Mature enough for medium scale field tests

BUT :

- Huge need of energy : 1500 MW for 100,000 bopd !!
- "Killing factor" : steam oil ratio (has to be < 3 vol./vol.)
- Large GHG emissions : up to 15,000 Tons/day of CO_2 for 100,000 bopd
- Requires technics adapted to high temperatures (artificial lift, metering, surface pumping, …)

TOTAL

Impediments to Tar Sand Development

- Economics – cost to mine and produce more expensive than conventional oil production
- Some of same environmental concerns as oil shale
- Federal deposits previously leased with oil and gas as Combined Hydrocarbon Leases

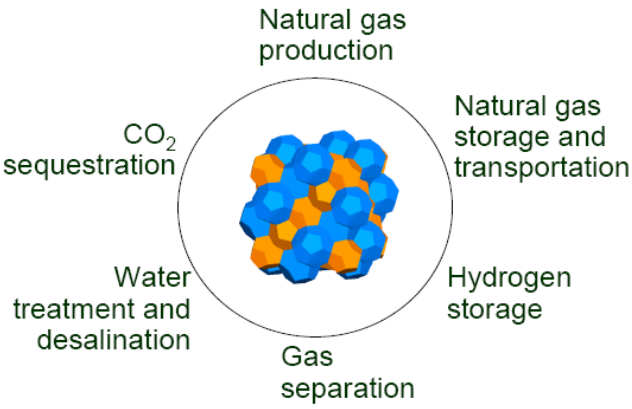
JMA

Gas Hydrates

JMA

Why We Are Interested?

Several Applications of Gas Hydrates Are Currently Investigated

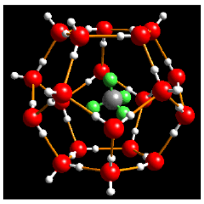


JMA

What is Gas Hydrate?

Hydrate is a crystalline solid consisting of gas molecules, usually methane, each surrounded by a cage of water molecules

Each volume of hydrate contains up to 160 volumes of methane (natural gas)



- There is a large quantity of methane clathrate on the ocean floor 10^{12} kg (Kvenvolden ,K.A. *Ann. N. Acad. Sci. 1994*, ***715***, *232-246)*
- *Possible energy source and transport medium.*

- Gas hydrates also known as clathrate hydrates are crystalline compounds with structures consisting of a lattice of water molecules hydrogen bonded together, which encage molecules of smaller-diameter gases (Stern, L.A.; *Science 1996,273,1843-1848)*

Frozen gas hydrate sample in a foam box

JMA

Animals have even learned how to “eat” hydrates for energy

JMA

Where does the gas come from?

Biogenic Hydrate ~99 %

Microbial activity in the upper several hundred meters of shelf sediment

Thermogenic Hydrate

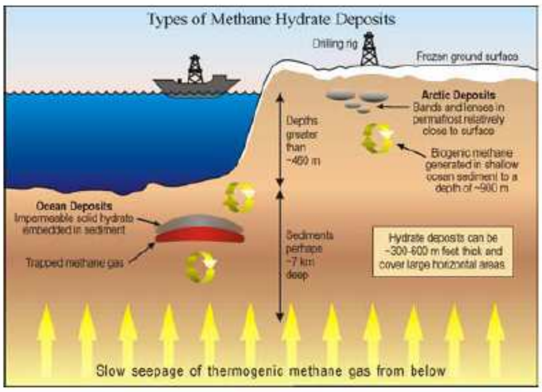
Thermal breakdown of organic material at greater depths, similar to conventional oil and gas.

JMA

Where does gas hydrate exist?

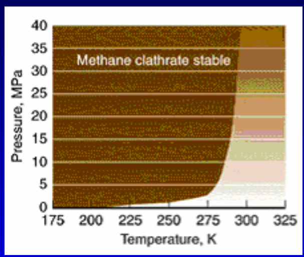
Where gas and water are present at:

- Moderately low temperatures and Moderately high pressures

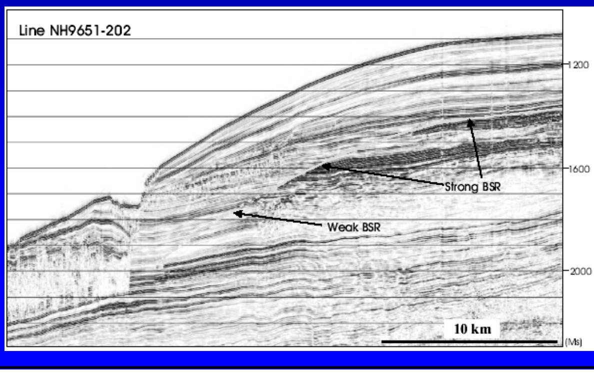


JMA

Methane Hydrates

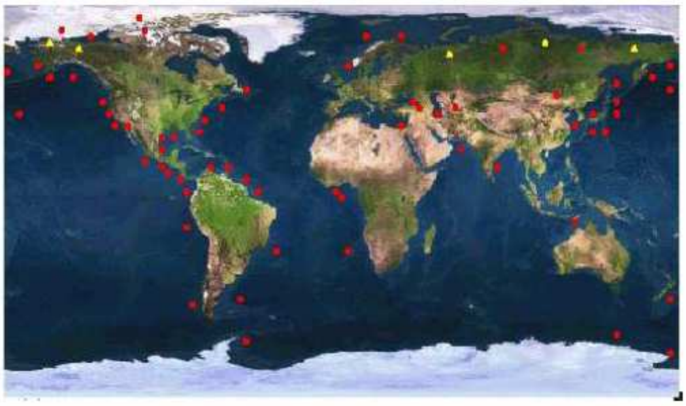


- Extremely temperature and pressure dependent
- Detected by presence of Bottom Simulating Reflector



JMA

Where are hydrates found on Earth?

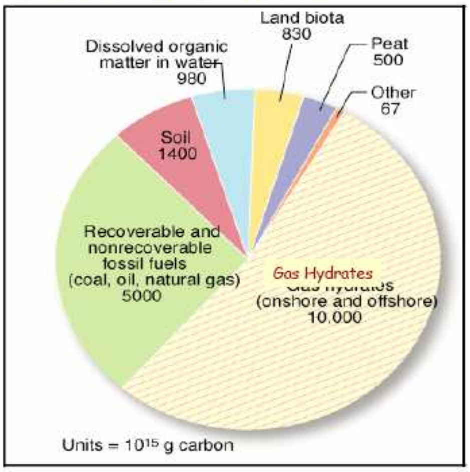


Hydrate forms on continental shelves and in the arctic

JMA

How much may exist?

Hydrate binds immense amounts of methane in sediments.



JMA

Methane Production from Hydrate Mackenzie Delta, Canada Mallik Production Experiment 2002

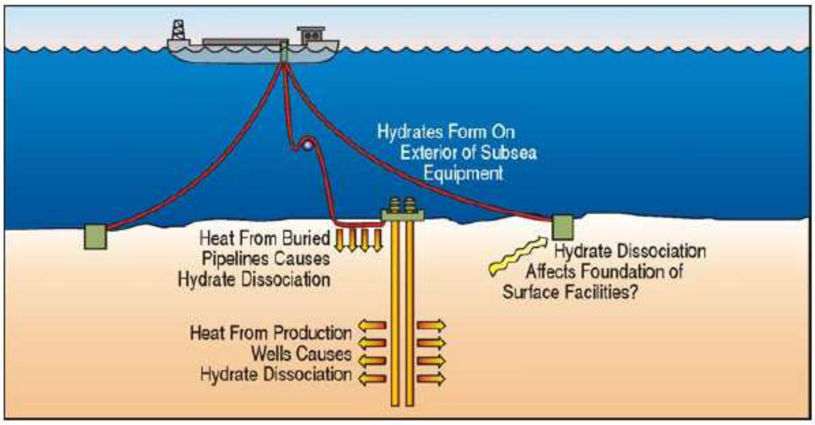
Participants:
Canada, Japan, USA, Germany, India, and ICSDP
International Continental Scientific Drilling Program

Well tests prove for the first time that gas production from hydrate is technically feasible

Gas hydrate melted and methane released by heating and/or depressurizing the reservoir

JMA

Hydrates as a Hazard



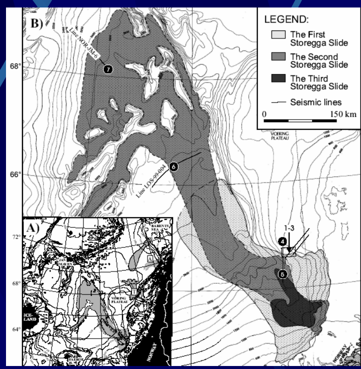
JMA

Slope Stability

- Hydrates
  - Strengthen slopes when they associate
    - Fill interstitial pore spaces with solid material
  - Weaken Slope when they dissociate
    - Cause pockets of high pressure gas
- Instability triggering mechanisms
  - Rapid sedimentation, excess pore pressure, ice weight, or ice induced forcing in glacial areas as well as gas and earthquake triggering
- Resulting massive sediment transport
  - Tsunamis

Storegga Slide

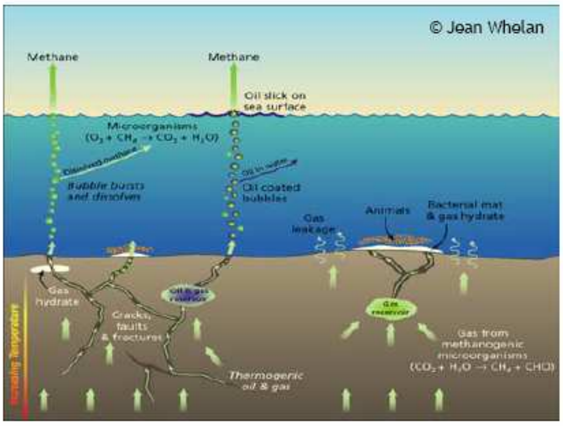
- Norwegian margin south of the Voring Plateau
- Identified in 1983, by T. Bugge
- 3 Stage Slide, Largest ever recorded, occurred 8 ka ago (8000 calendar years ago)
- Moved 6000 cubic km of sediment
- Headwall 290 km long, 10-20º slope
- Deposits 800 km from ledge



Storegga Slide Theory

- Hydrate Dissociation – Sea Level Rise, Warm Water Inflow
  - Sea Level Rise caused disruption of hydrate stability in the area
  - Dissociating hydrates caused huge pockets of compressed gas
  - Escaping gas triggered gigantic landslide

Hydrate and Global Climate Change



- Methane is a powerful greenhouse gas
- Hydrates sequester methane in the subsurface
- Hydrate may release methane to the ocean and atmosphere
- Massive releases of methane from hydrates may have occurred in the geologic past

JMA

Gas Hydrates are Future Resource

- Japan/Canada/U.S. leading research efforts
- 25 MM$ in 2002 Mackenzie Delta Mallik project
- "Hot Ice No. 1" drilled in Alaska 2003-04
- 30+ wells drilled offshore Japan
- 2005 "Voyage of Discovery" in Gulf Coast and test planned offshore Vancouver Island
- NRC estimates production tests within 5 years

JMA

LINKS

http://www.aapg.org/slide_bank/

http://www.spe.org/spe-app/spe/industry/index.htm

http://www.energy.gov/

http://www.eia.doe.gov/

JMA