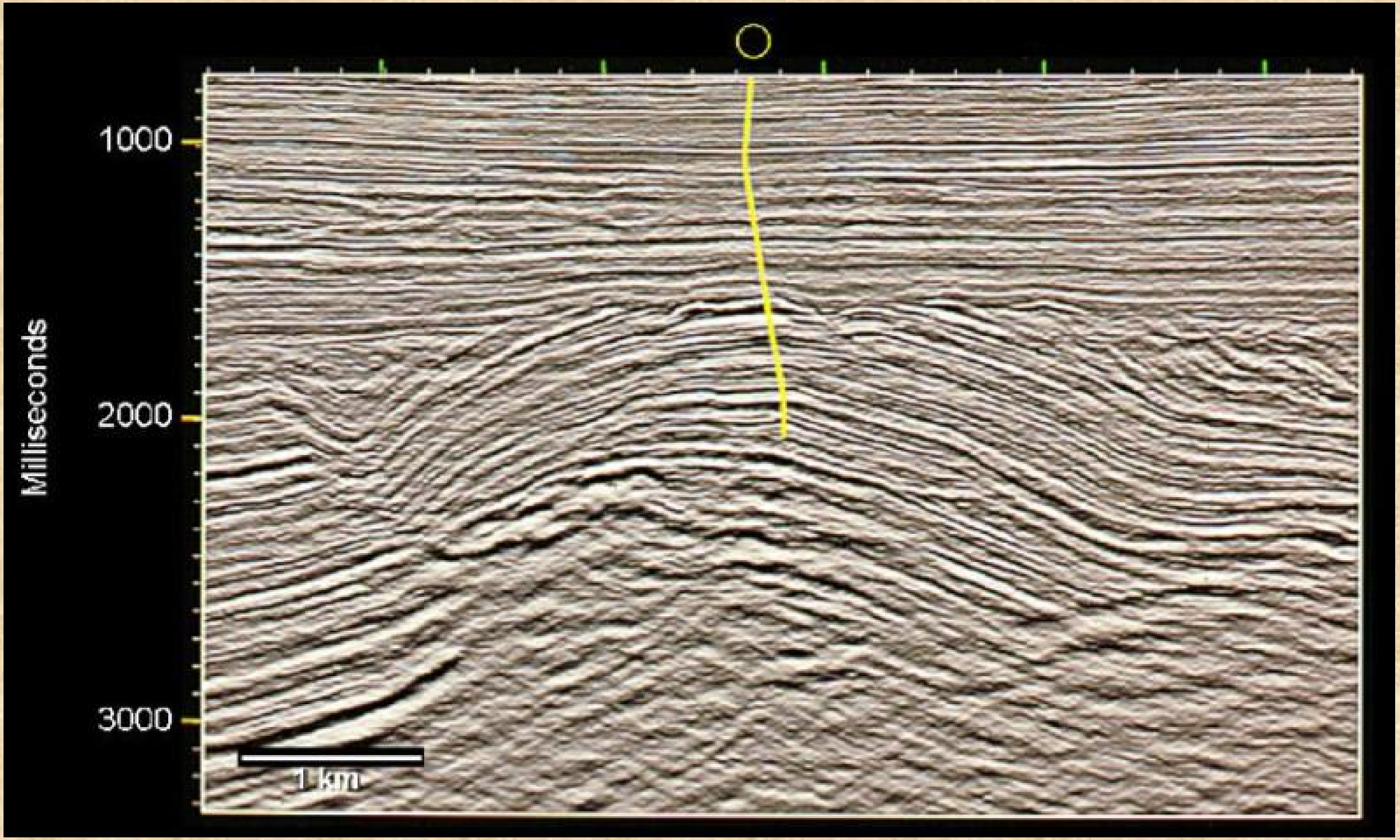
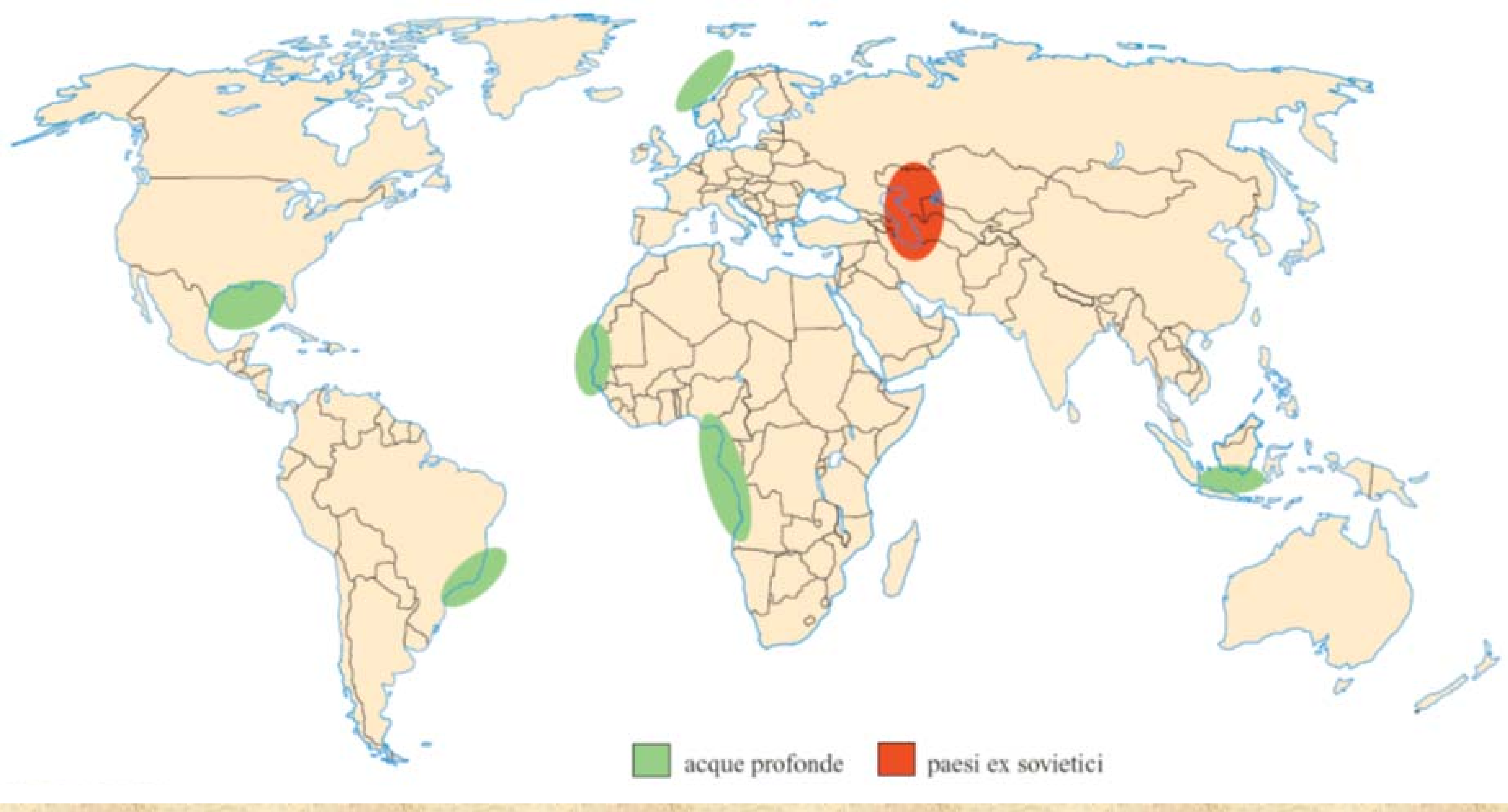
What has changed?

Strong improvements in resource sciences and technology



Buried anticline in a seismic reflection image

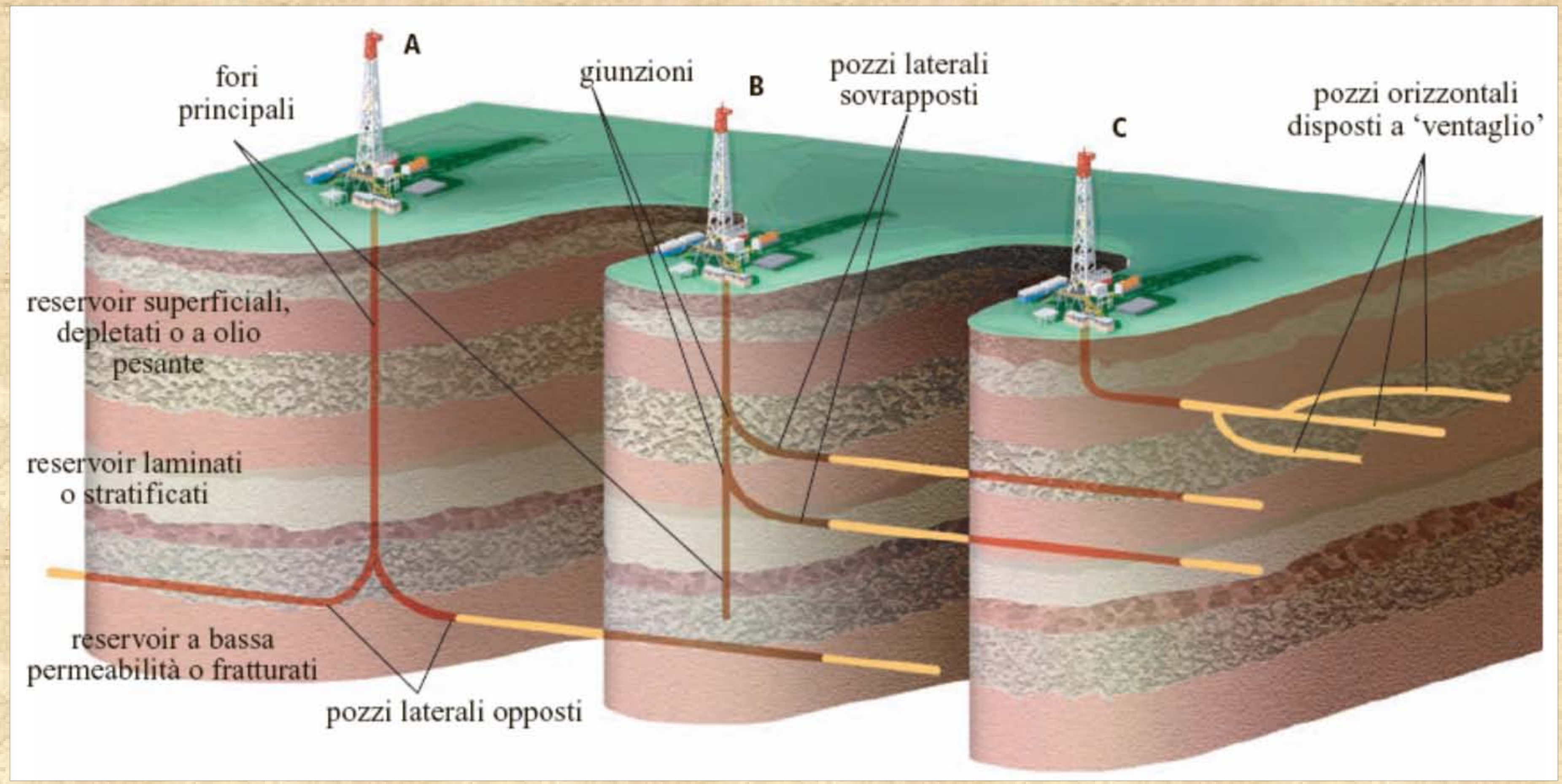
New AREAS



Prato, 2005

Improvements in **drilling** techniques

(e.g., directional drilling techniques)



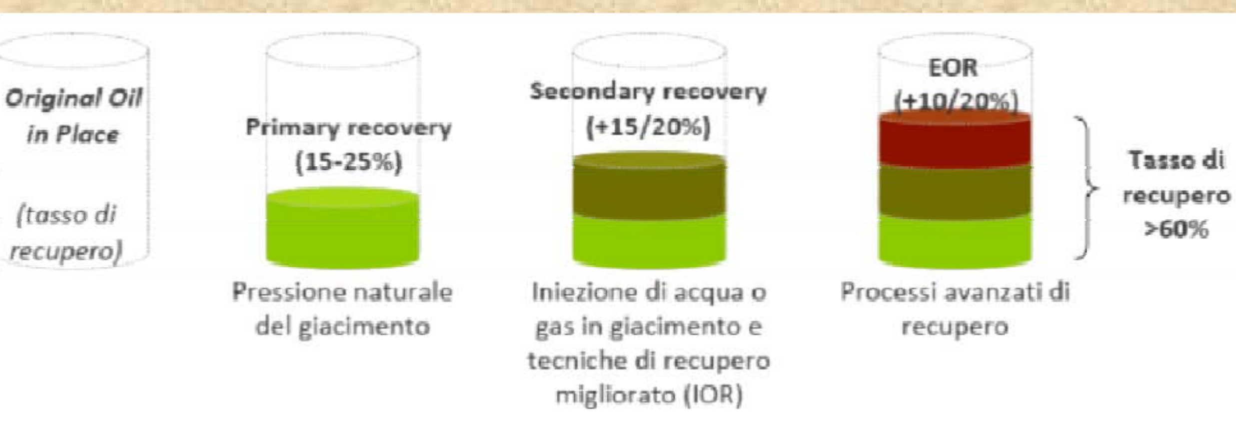
da Fraija et al., 2002

Techniques of

Improved Oil Recovery

and

Enhanced Oil Recovery



now avg. recovery 30-35%

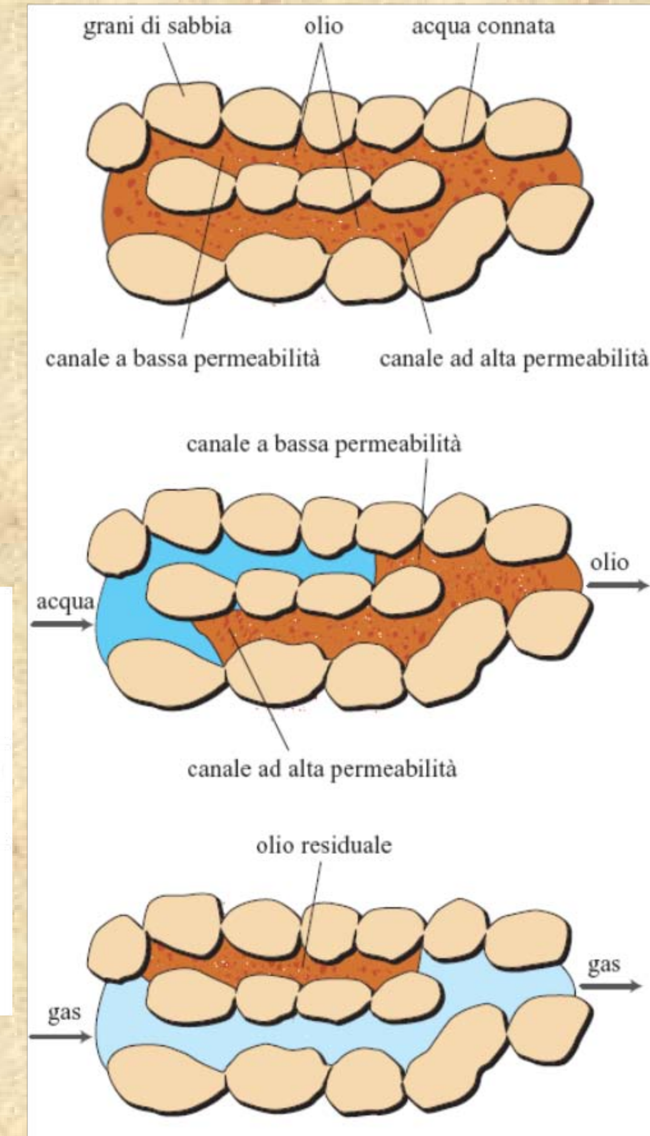
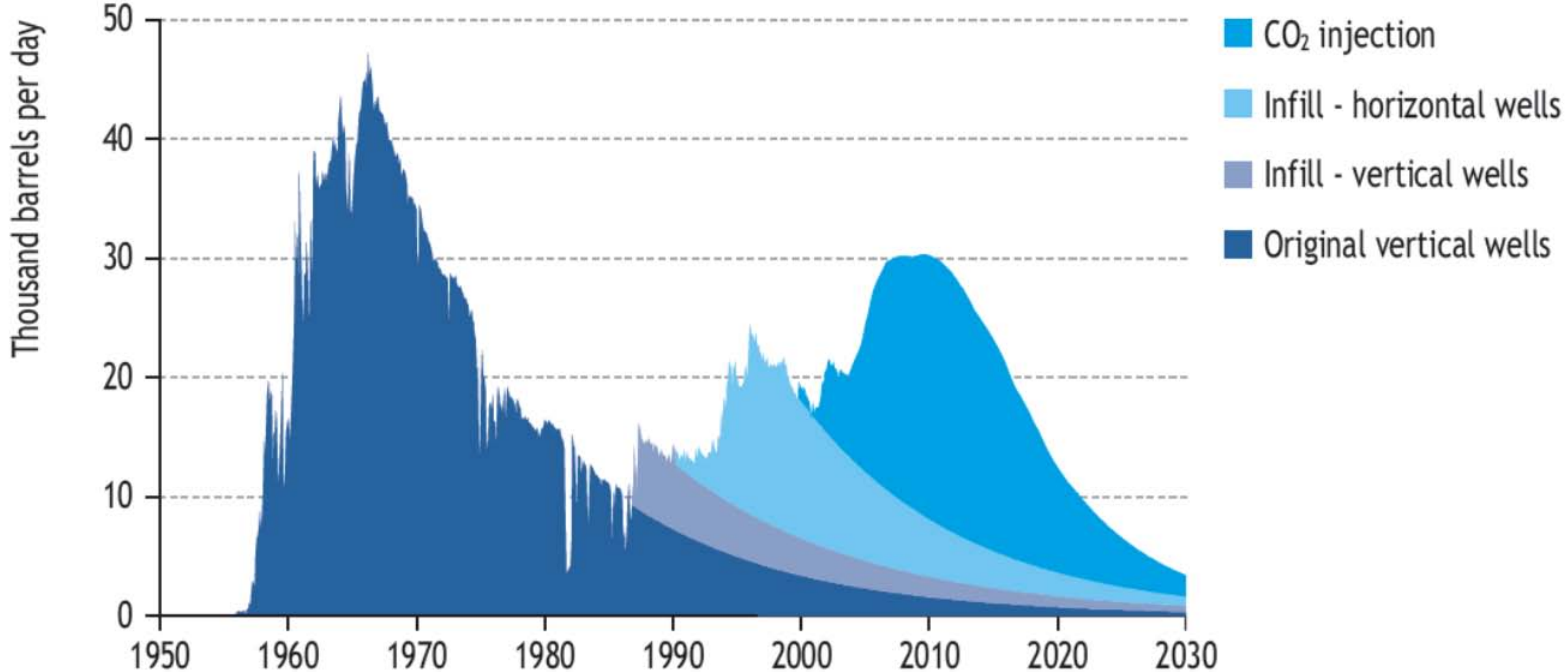


fig. 11. Spiazzamento degli idrocarburi alla scala dei pori della roccia serbatoio.

• A case study of oil reserves growth: the impact of technology on oil production from the Weyburn field in Canada



Source: PTRC Weyburn-Midale website (www.ptrc.ca).

World Energy Outlook 2008

non conventional resources

Conventional Reservoirs

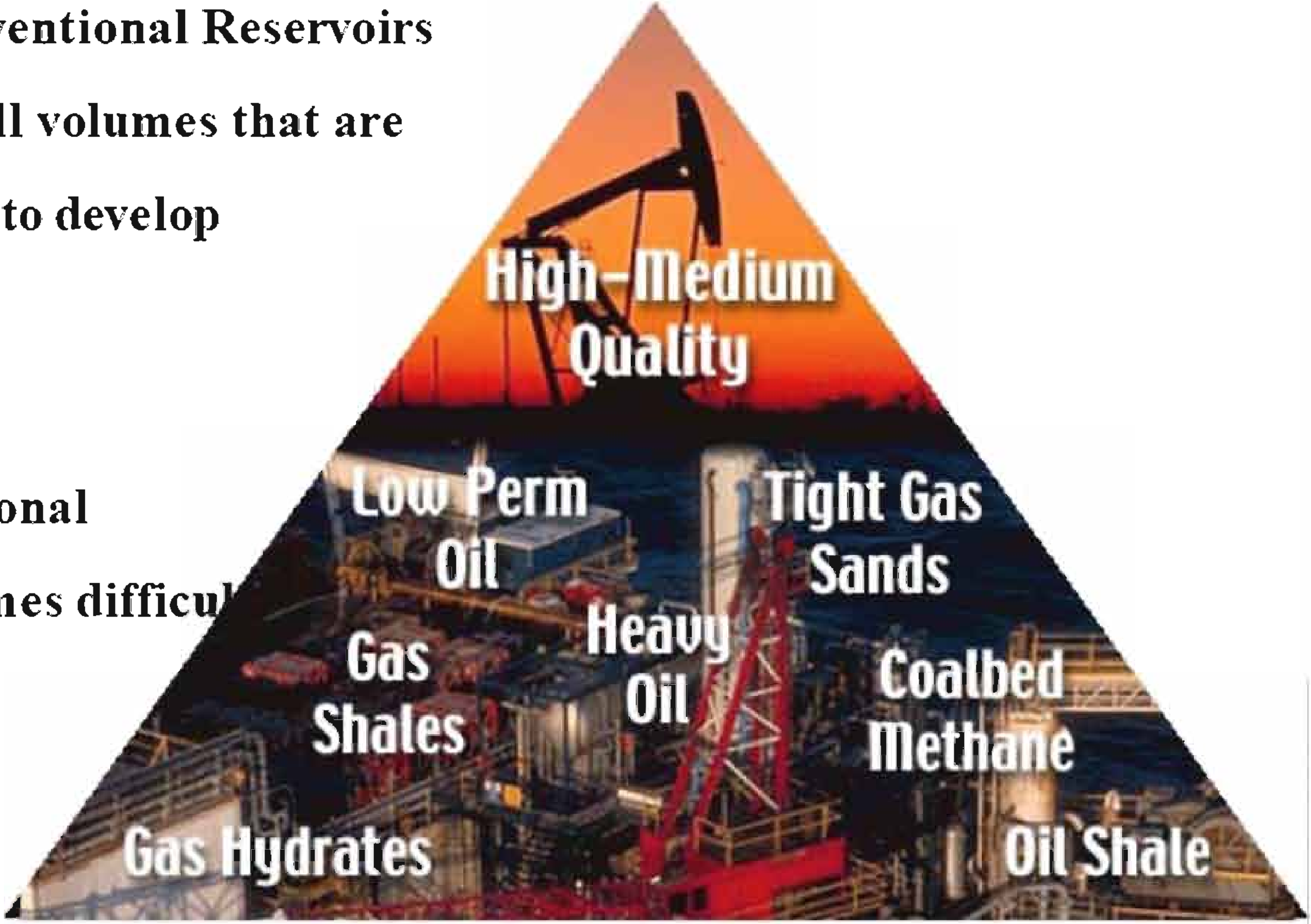
Small volumes that are

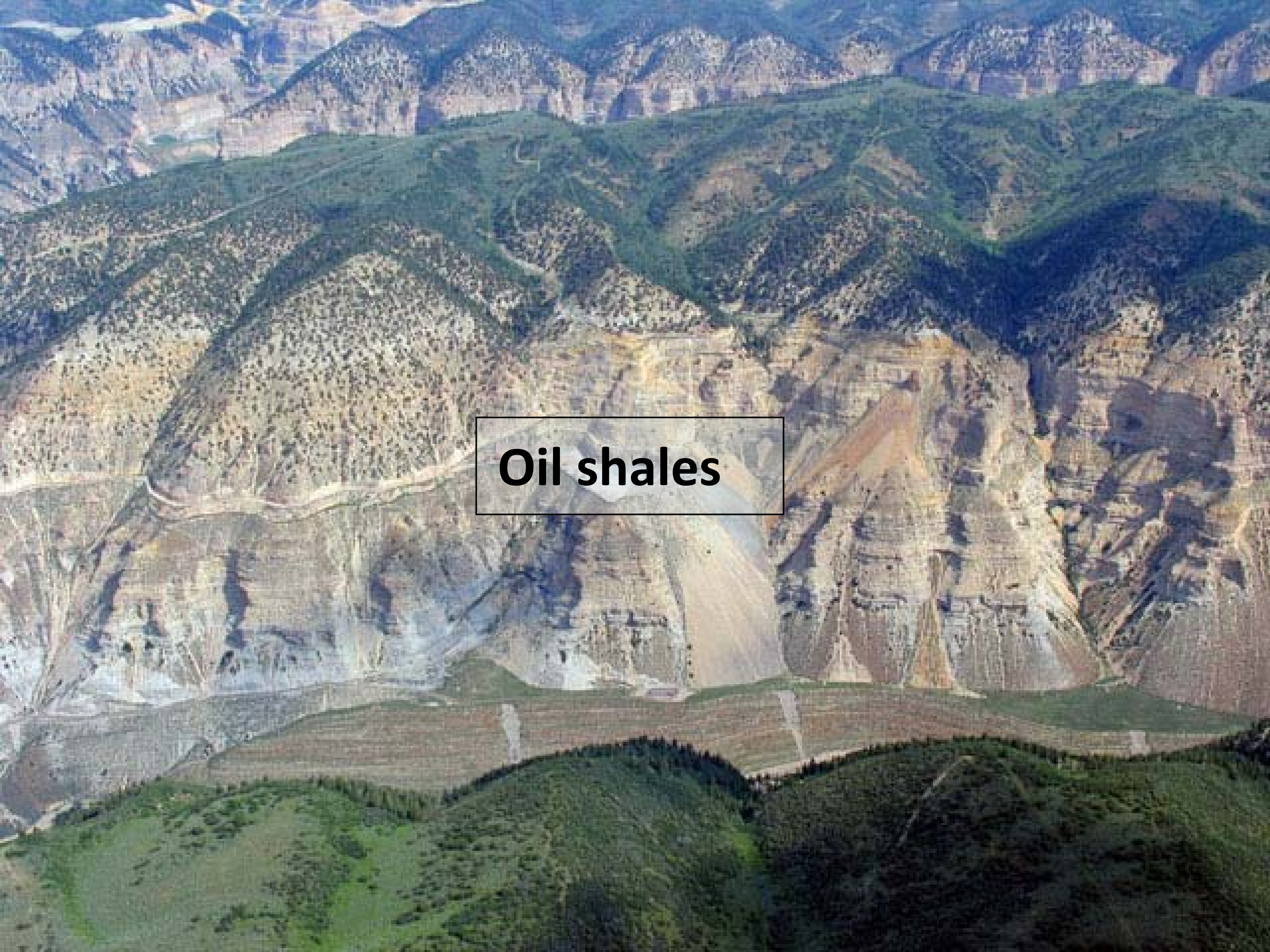
easy to develop

Unconventional

Large volumes difficul

to develop

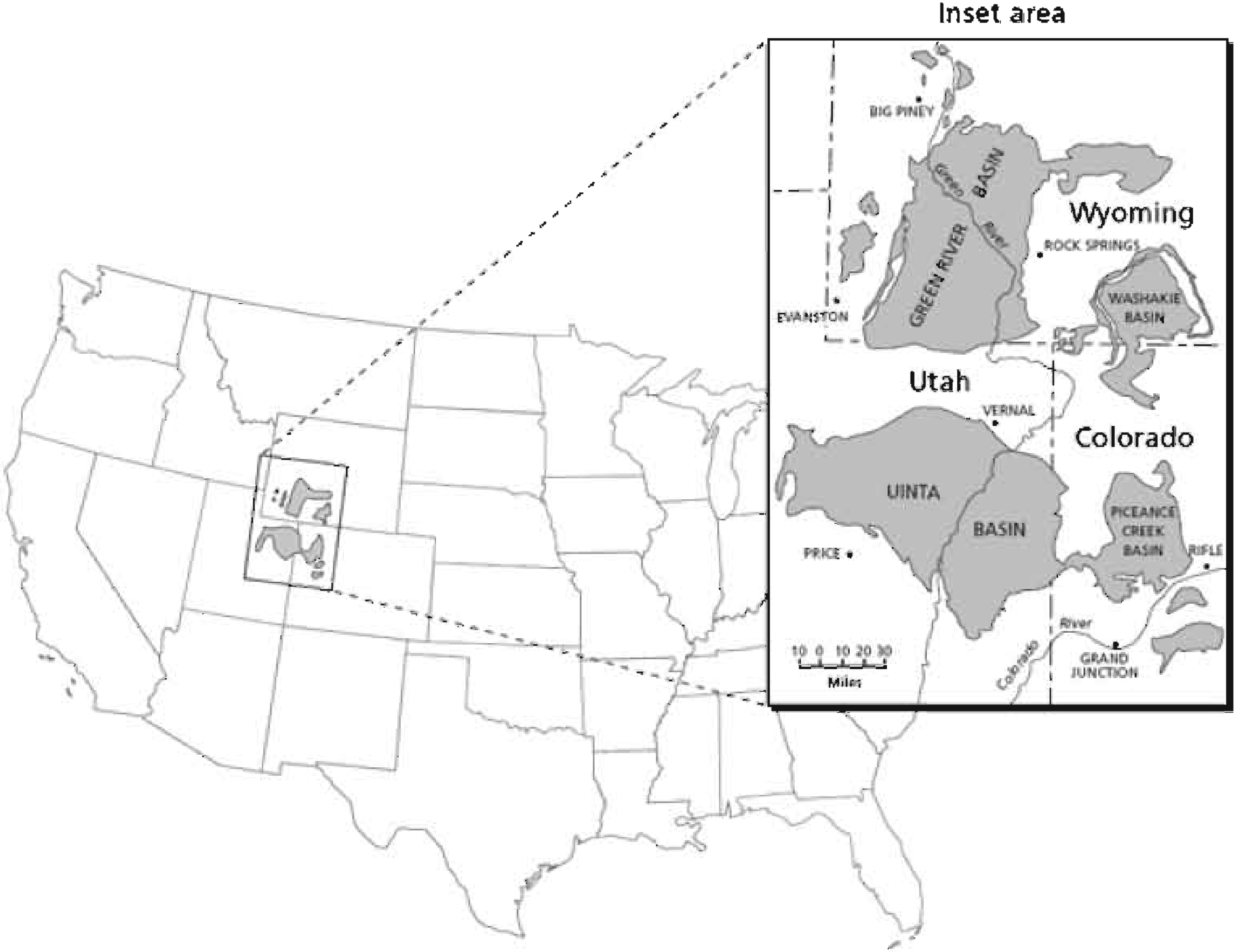



Oil shales

Oil shale
immature source rock

Oil Shale = fine-grained sedimentary rock (slate) strongly enriched in kerogen, which can produce hydrocarbons when heated

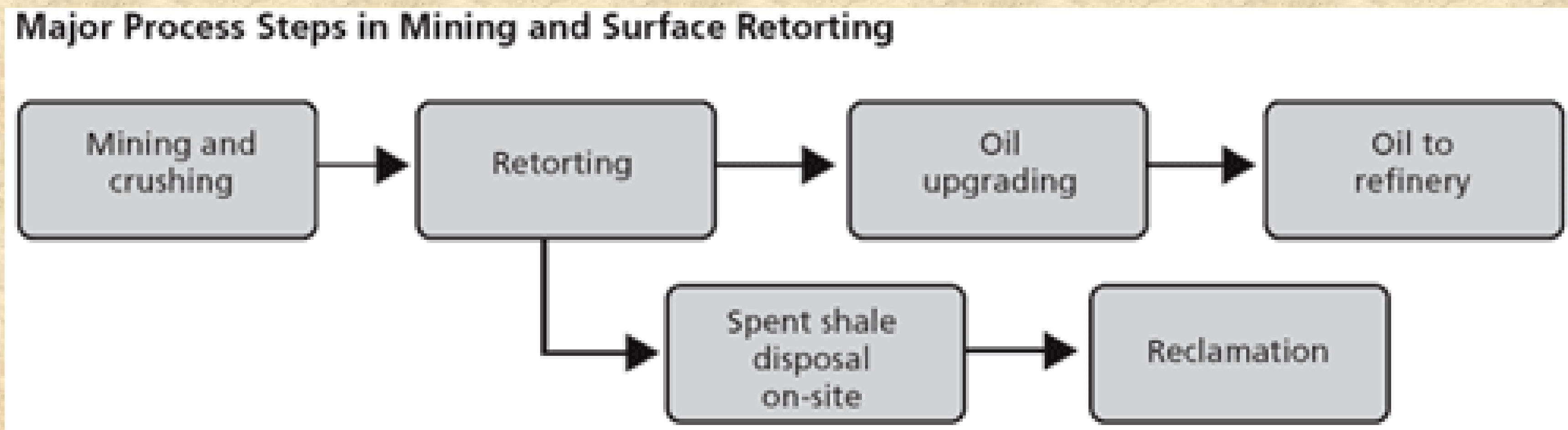
Location of the Green River Formation Oil Shale and Its Main Basins



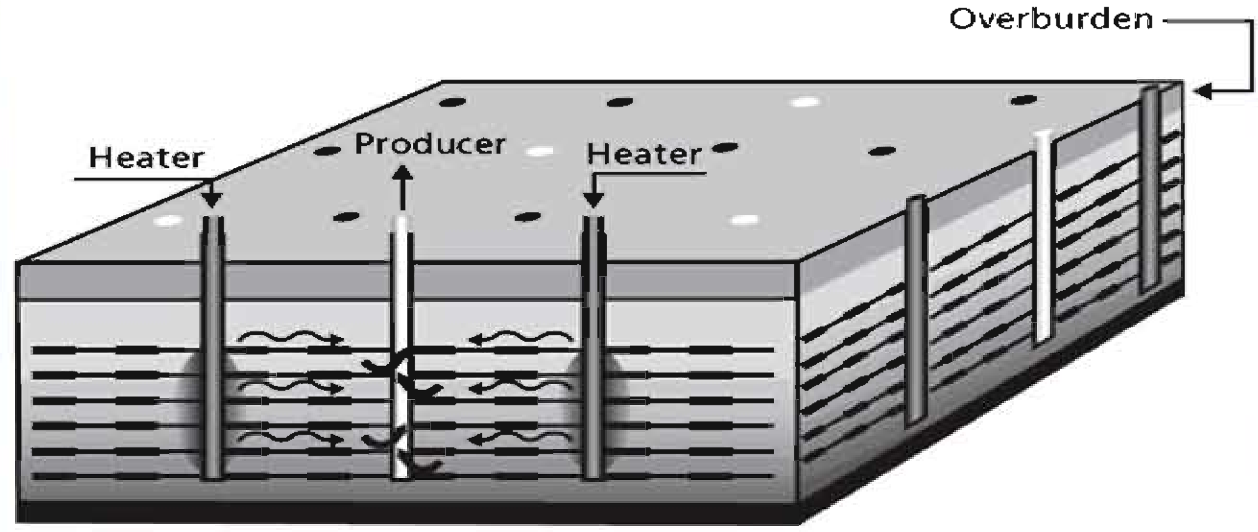
SOURCE: Adapted from Smith, 1980.

RAND *MG414-2.1*

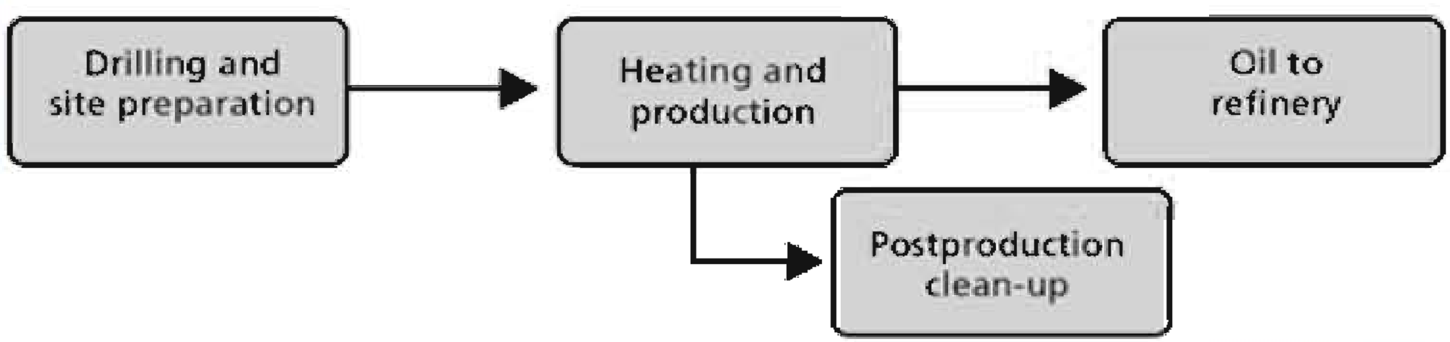
Oil shale crushed for the retorting process

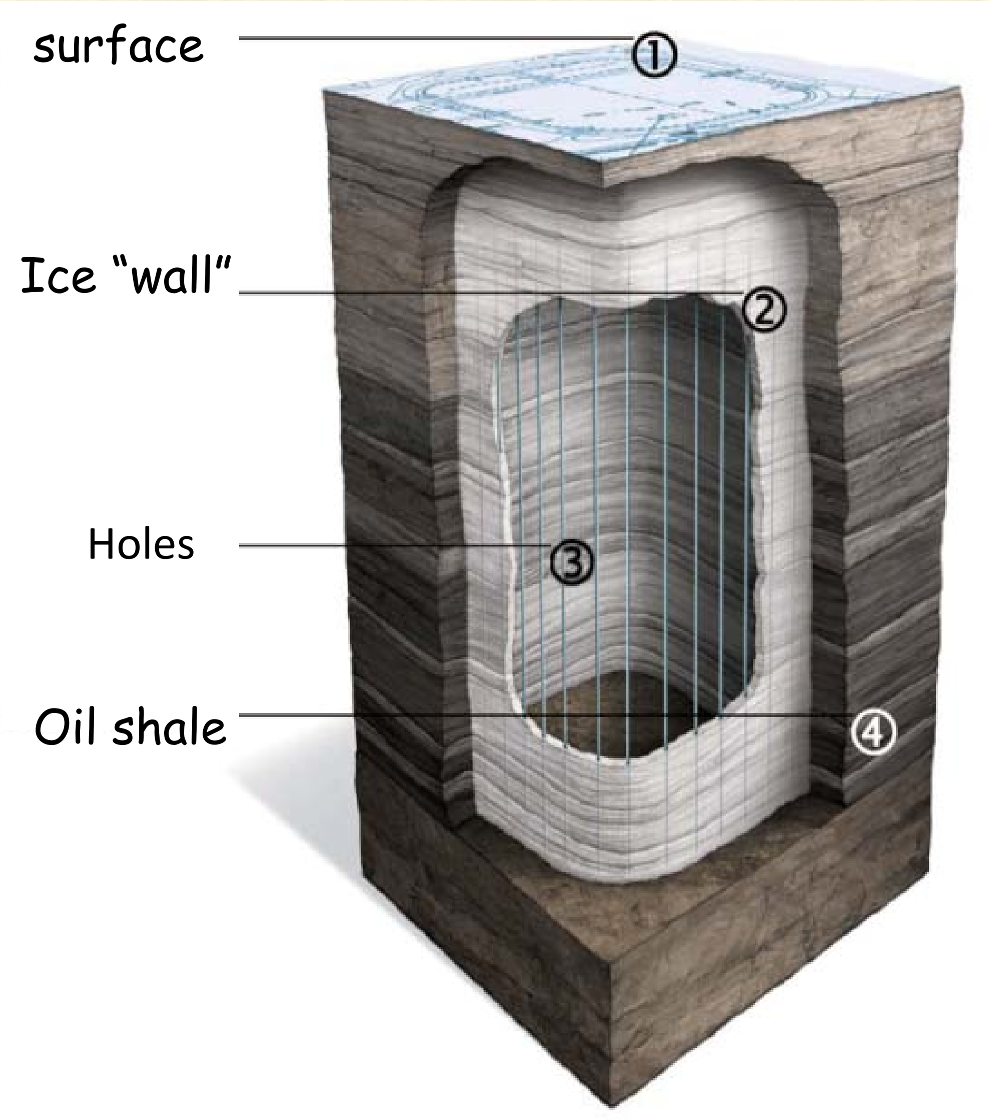


The Shell In-Situ Conversion Process



Major Process Steps in Thermally Conductive In-Situ Conversion



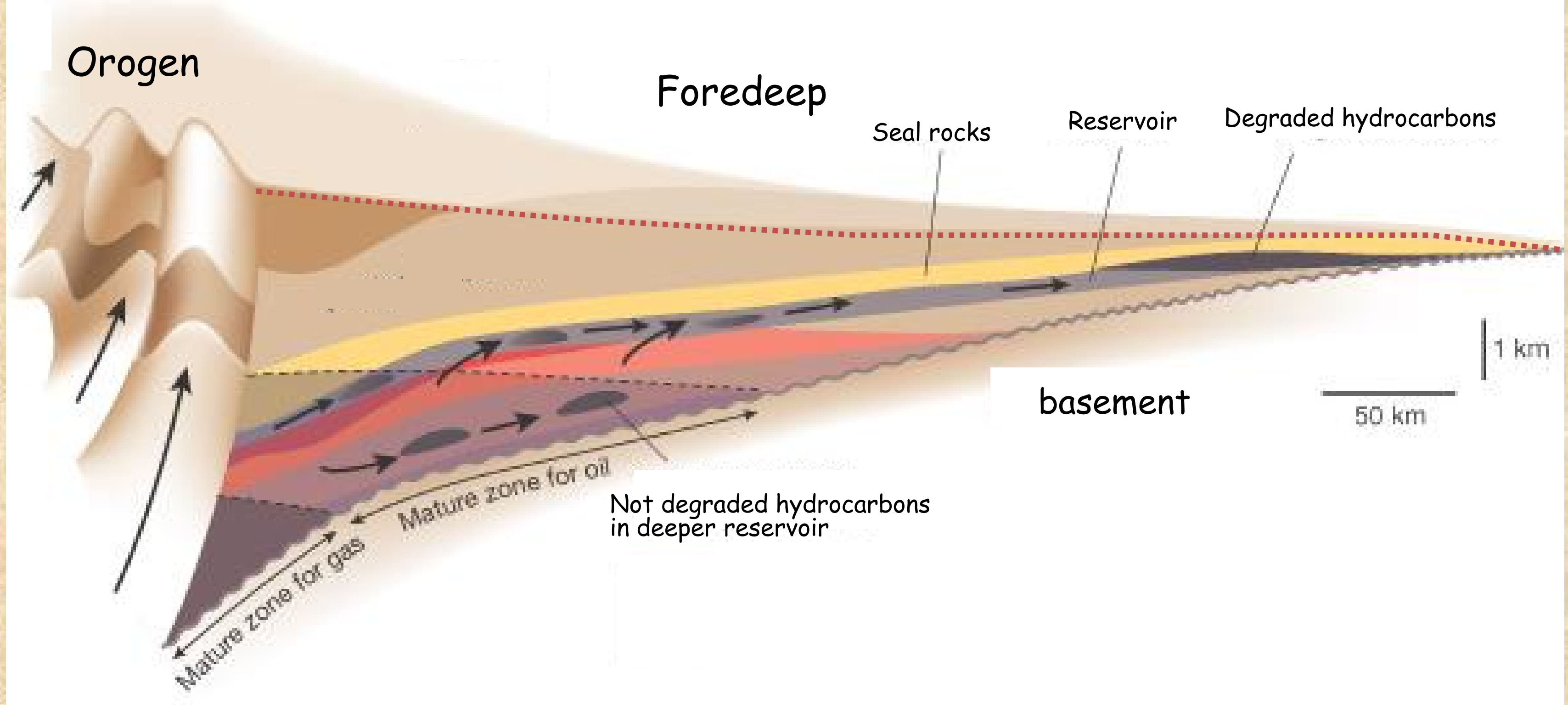


Before heating and exploitation groundwater is eliminated by creating an "ice wall"

oil: extra heavy oil / bitumen
high viscosity
high sulphur content

Main problem: low permeability of the shale

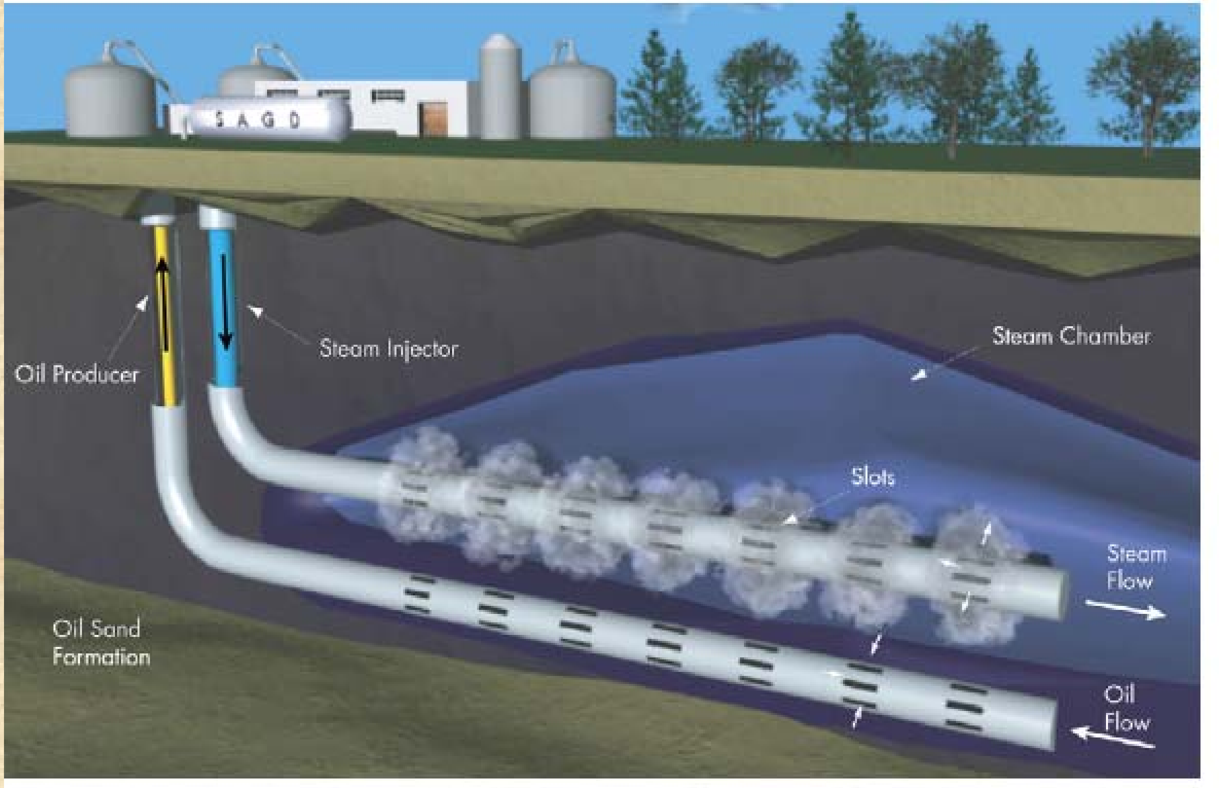

Tar sands: reservoir rocks close to surface


Orogen
Foredeep
Seal rocks
Reservoir
Degraded hydrocarbons
1 km
basement
50 km
Mature zone for oil
Not degraded hydrocarbons
in deeper reservoir
Mature zone for gas

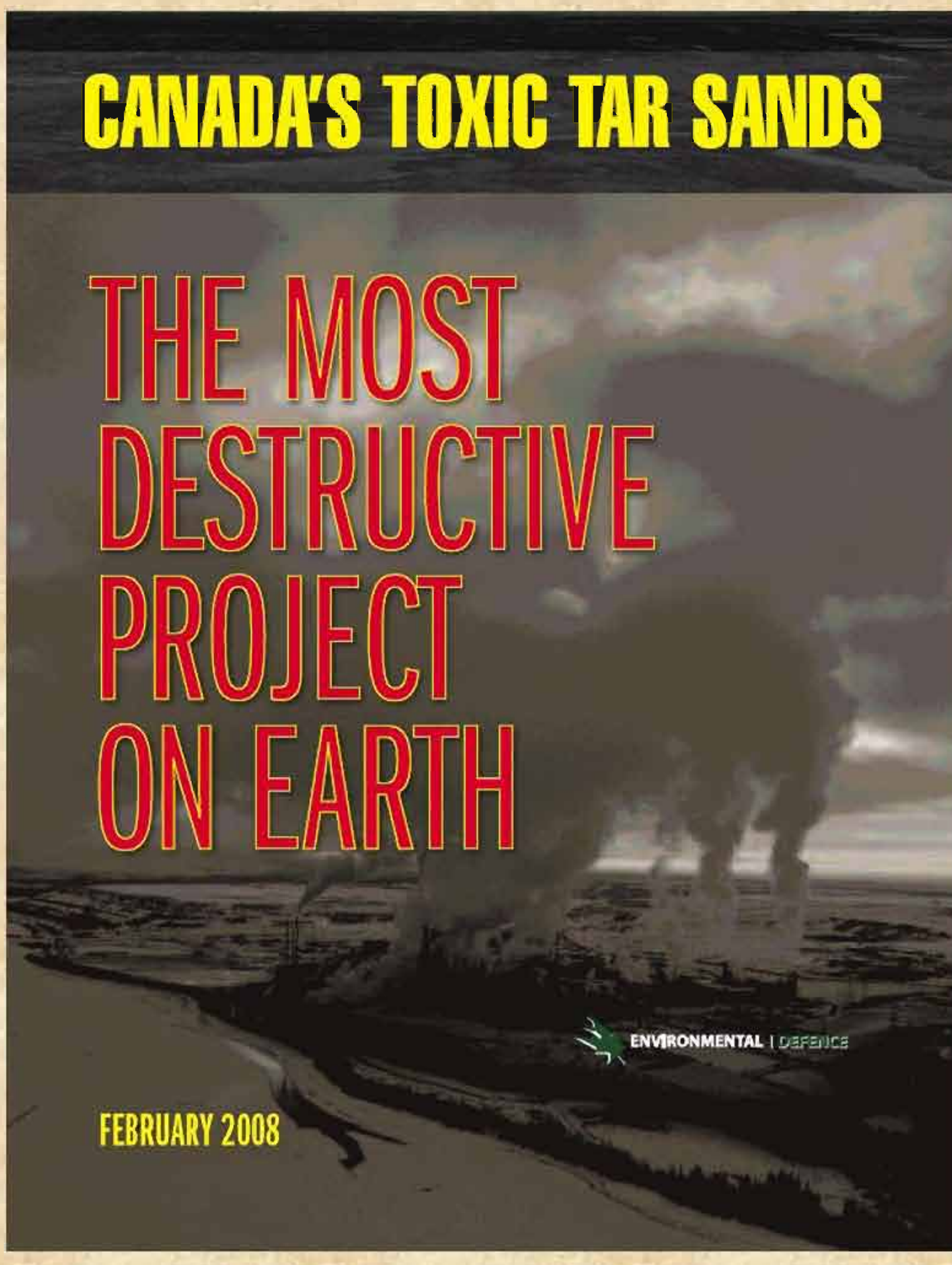
oil: extra heavy oil / bitumen
high viscosity
high sulphur content

Tar sands: >3 $\cdot 10^{12}$ barrels

Strip mining

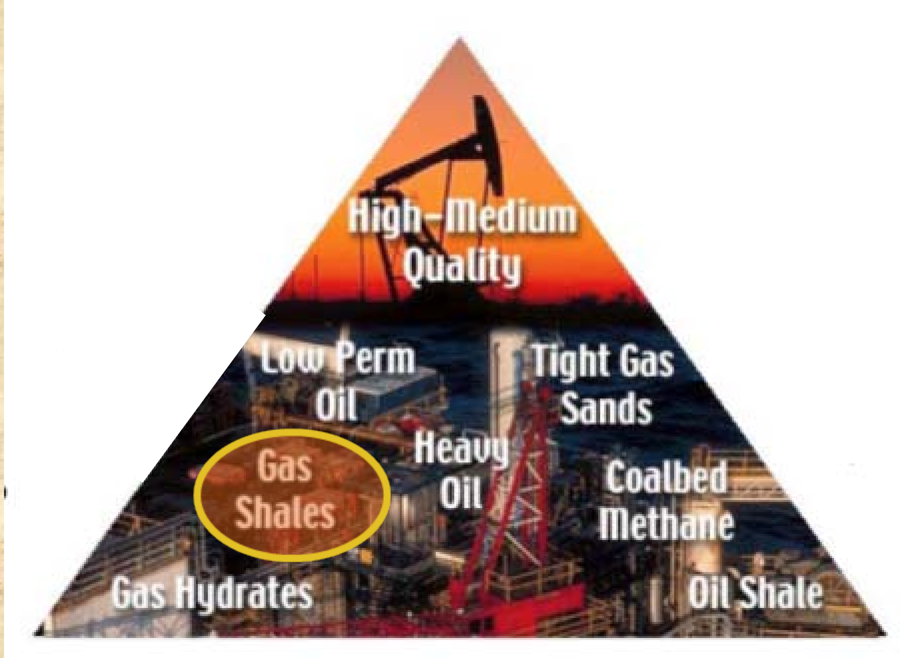


In situ exploitation:
- vapour injection
- solvents injection
- injection of oxygen and in situ combustion with production of heat


CANADA'S TOXIC TAR SANDS
THE MOST DESTRUCTIVE PROJECT ON EARTH
ENVIRONMENTAL | DEFENCE
FEBRUARY 2008

non conventional gas

- gas hydrates
- coalbed methane
- gas from shales
- gas from low permeability sand/sandstone (tight gas)

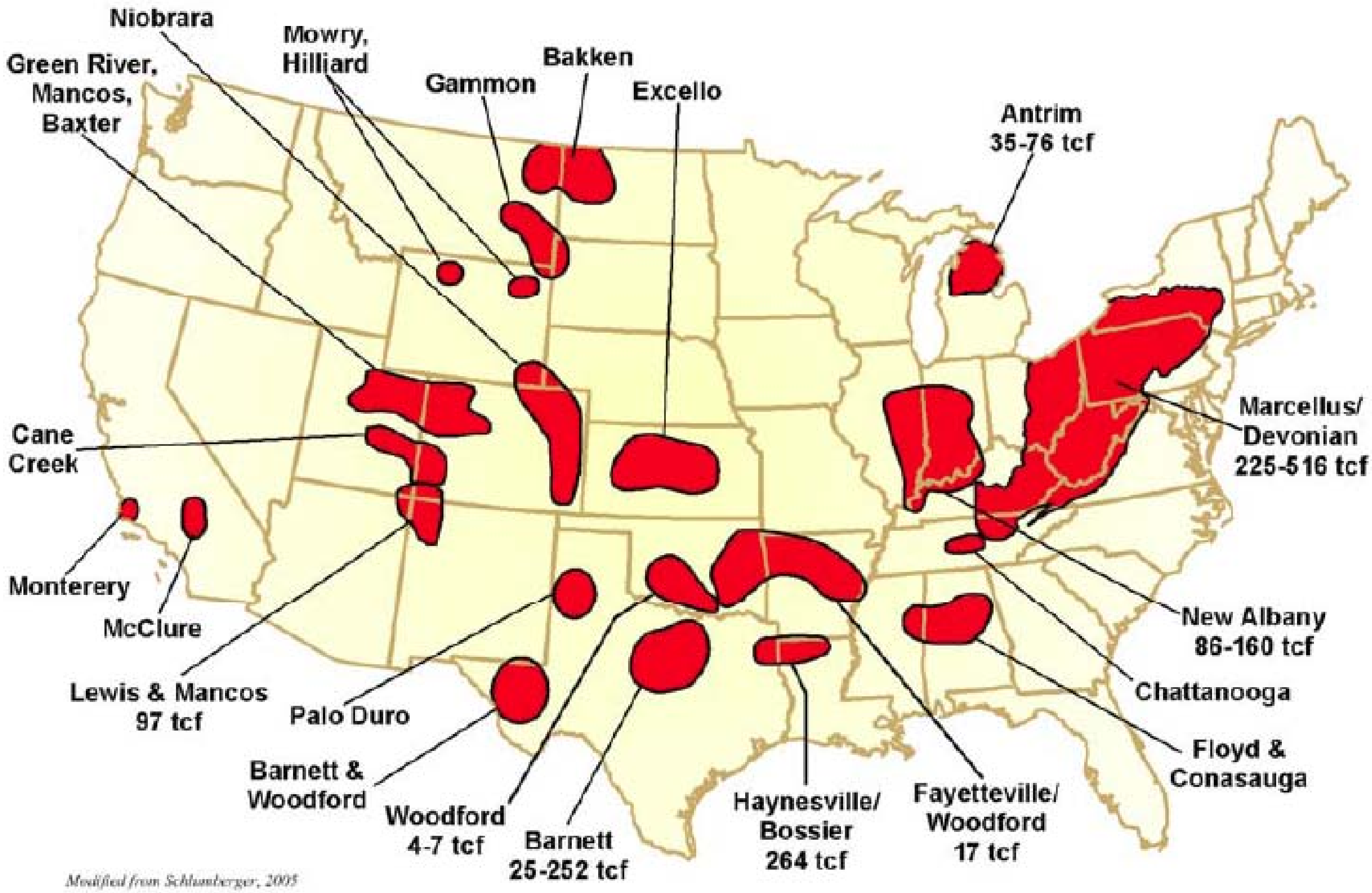


SHALE GAS

Natural gas generated and trapped in fine-grained sedimentary rocks (shale) rich of organic matter, at some km depth

-Reservoir = source-rock
-large deposits
-Very low permeability: necessary advanced drilling (horizontal drilling) and recovery (fracking) techniques

SHALE GAS


Niobrara
Mowry, Hilliard
Green River, Mancos, Baxter
Bakken
Gammon
Excello
Antrim 35-76 tcf
Marcellus/ Devonian 225-516 tcf
Cane Creek
Monterery
McClure
New Albany 86-160 tcf
Chattanooga
Lewis & Mancos 97 tcf
Palo Duro
Floyd & Conasauga
Barnett & Woodford
Woodford 4-7 tcf
Barnett 25-252 tcf
Haynesville/ Bossier 264 tcf
Fayetteville/ Woodford 17 tcf
Modified from Schlumberger, 2005

Cambriano-Ordoviciano

Siluriano

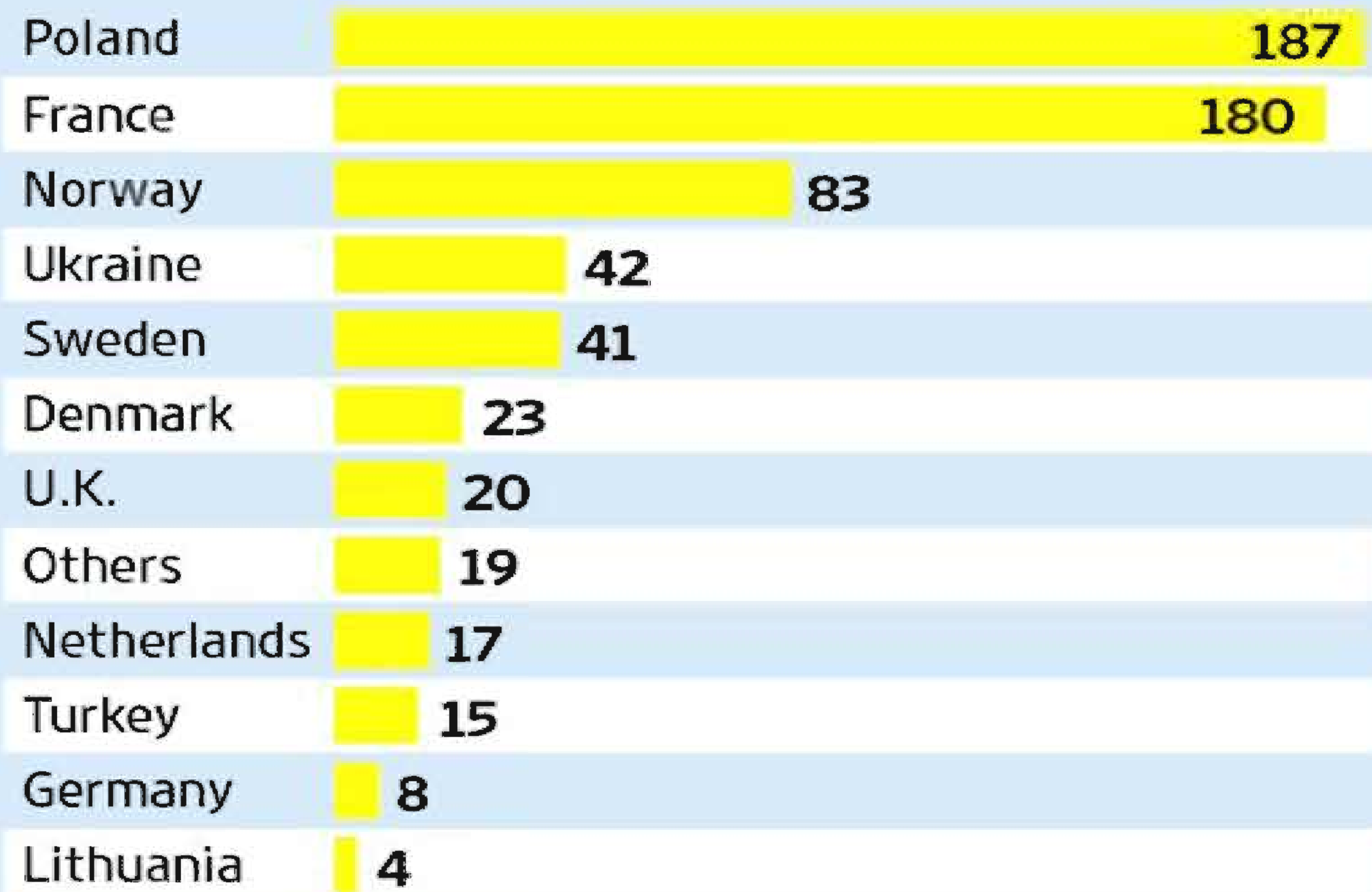
Carbonifero-Permiano

Giurassico

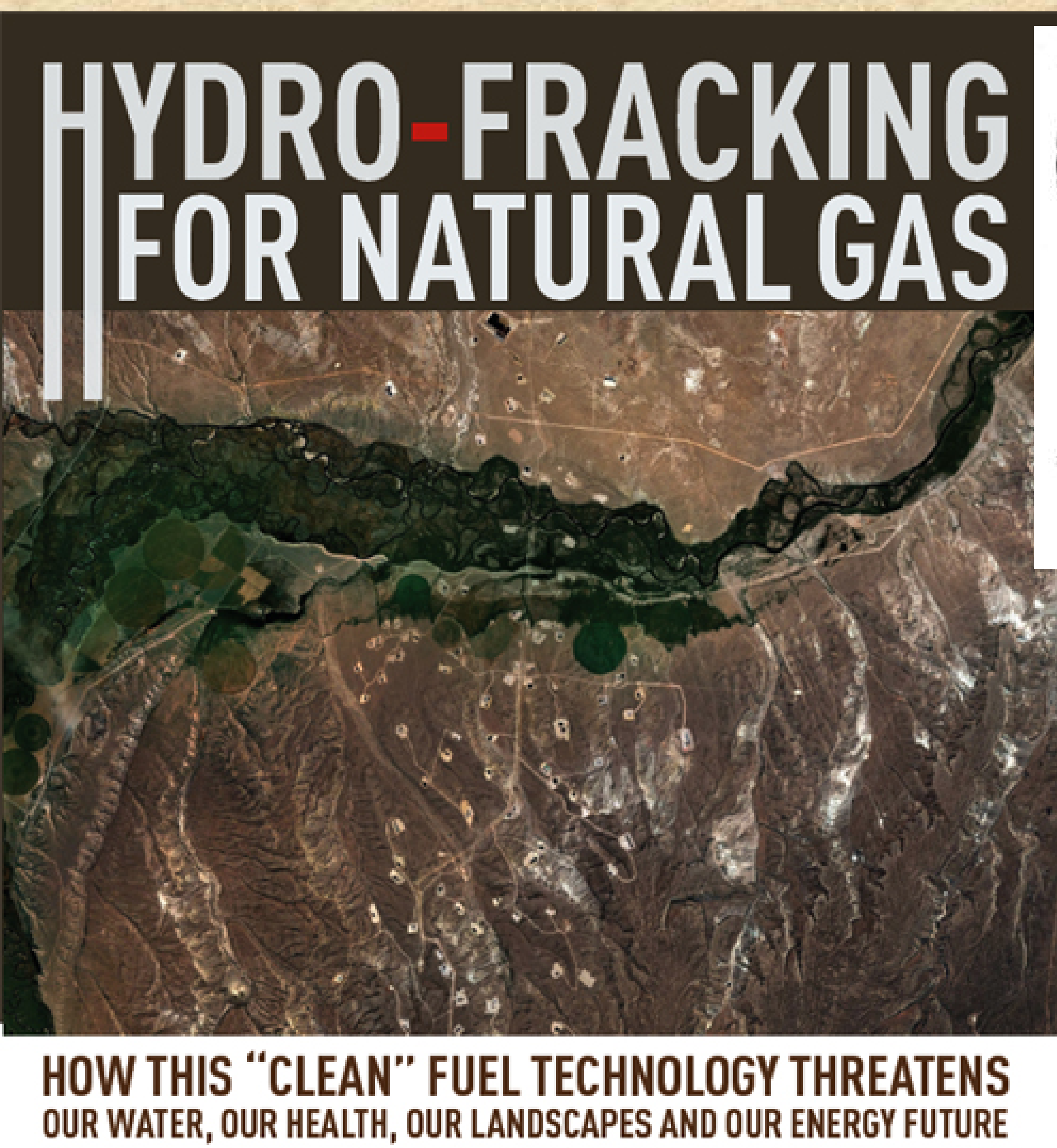
Cenozoico

Potentially productive areas in Europe

Estimated technically recoverable shale gas resources in Europe, in trillions of cubic feet



Source: U.S. Energy Information Administration


HYDRO-FRACKING
FOR NATURAL GAS
HOW THIS "CLEAN" FUEL TECHNOLOGY THREATENS
OUR WATER, OUR HEALTH, OUR LANDSCAPES AND OUR ENERGY FUTURE

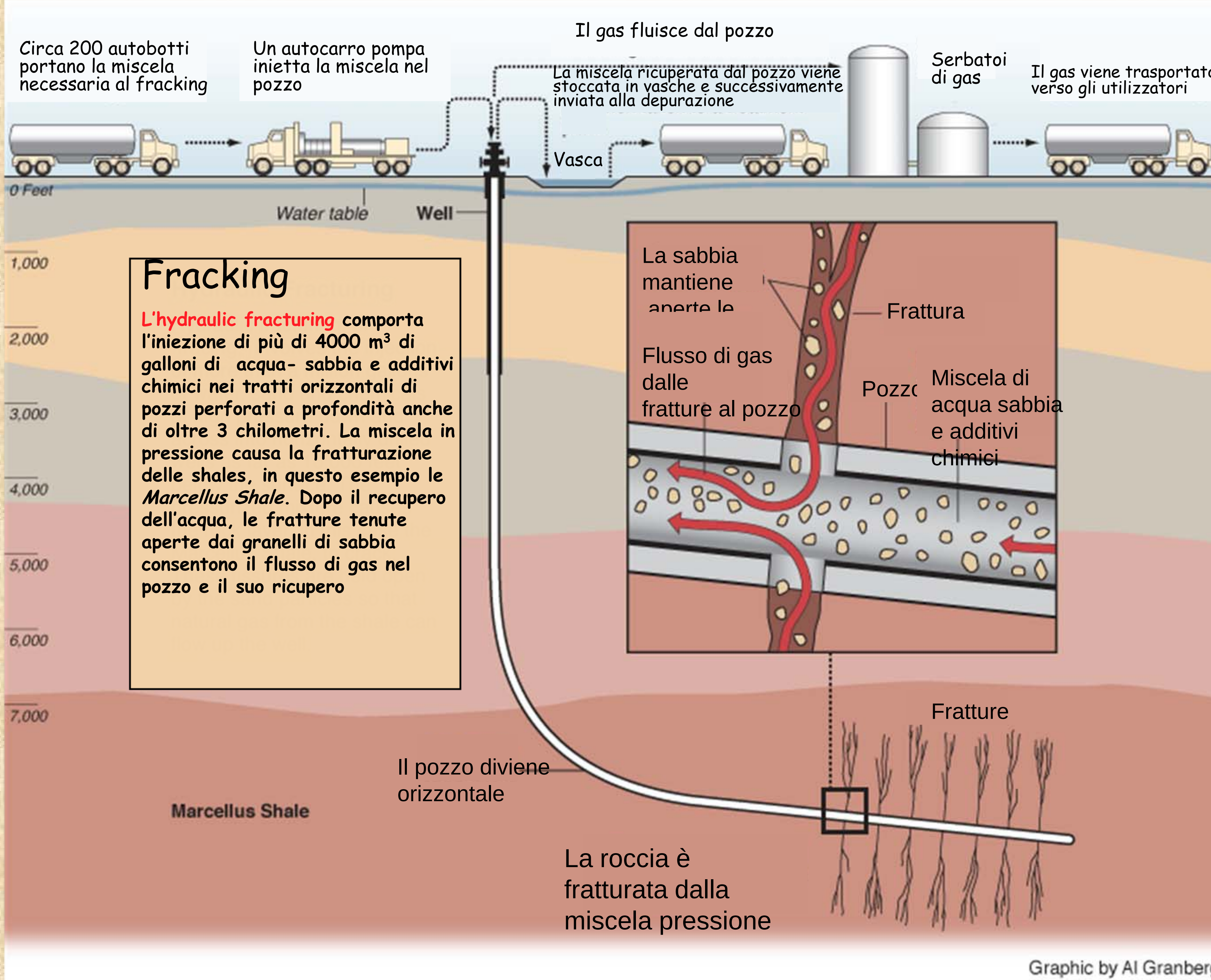

Hydrofracking explained:
Basically, we inject chemicals into the ground, corrupting the water supply while extracting natural gas.
Hydrofracking politics explained:
Basically, we inject money into politicians' pockets, corrupting the democratic process while extracting corporate profits.
Courtesy MARQUIL @ EmpireWire.com

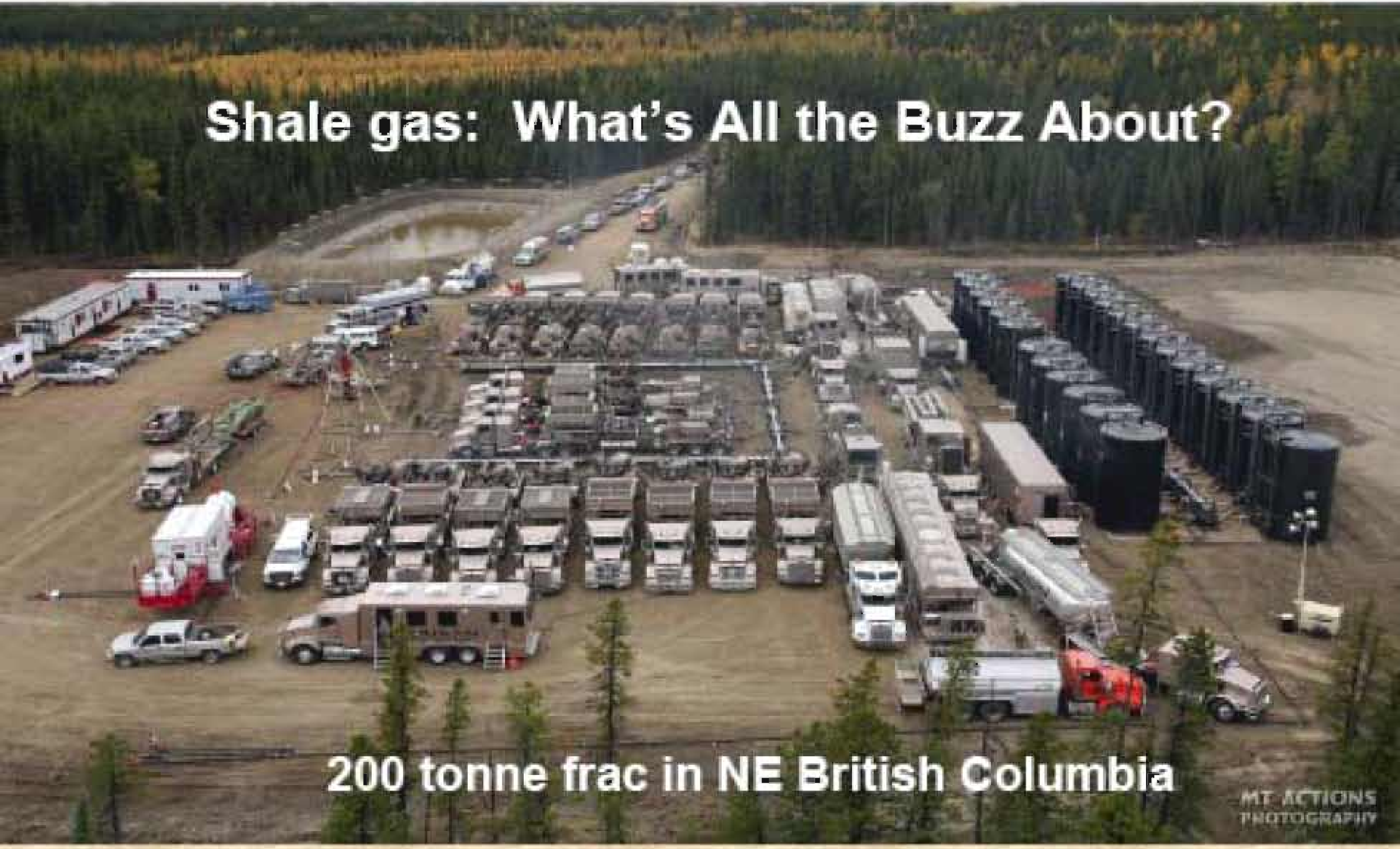

STOP
FRACKING!
with our water

fracking ?

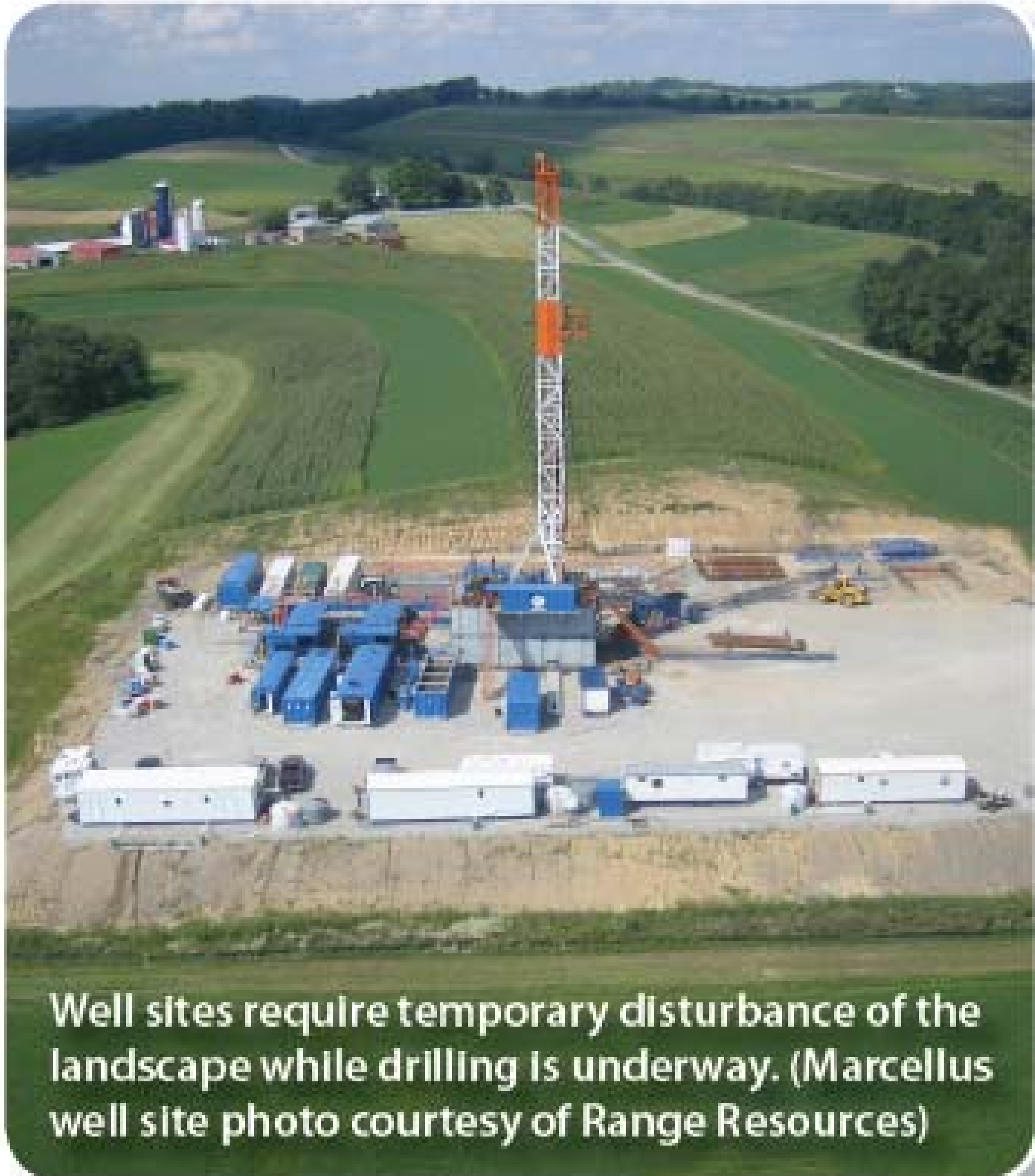
Fracking

L'hydraulic fracturing comporta l'iniezione di più di 4000 m^3 di galloni di acqua- sabbia e additivi chimici nei tratti orizzontali di pozzi perforati a profondità anche di oltre 3 chilometri. La miscela in pressione causa la fratturazione delle shales, in questo esempio le *Marcellus Shale*. Dopo il recupero dell'acqua, le fratture tenute aperte dai granelli di sabbia consentono il flusso di gas nel pozzo e il suo ricupero




Shale gas: What's All the Buzz About?
200 tonne frac in NE British Columbia
MT ACTIONS
PHOTOGRAPHY


marcellus-shale.us



Well sites require temporary disturbance of the landscape while drilling is underway. (Marcellus well site photo courtesy of Range Resources)

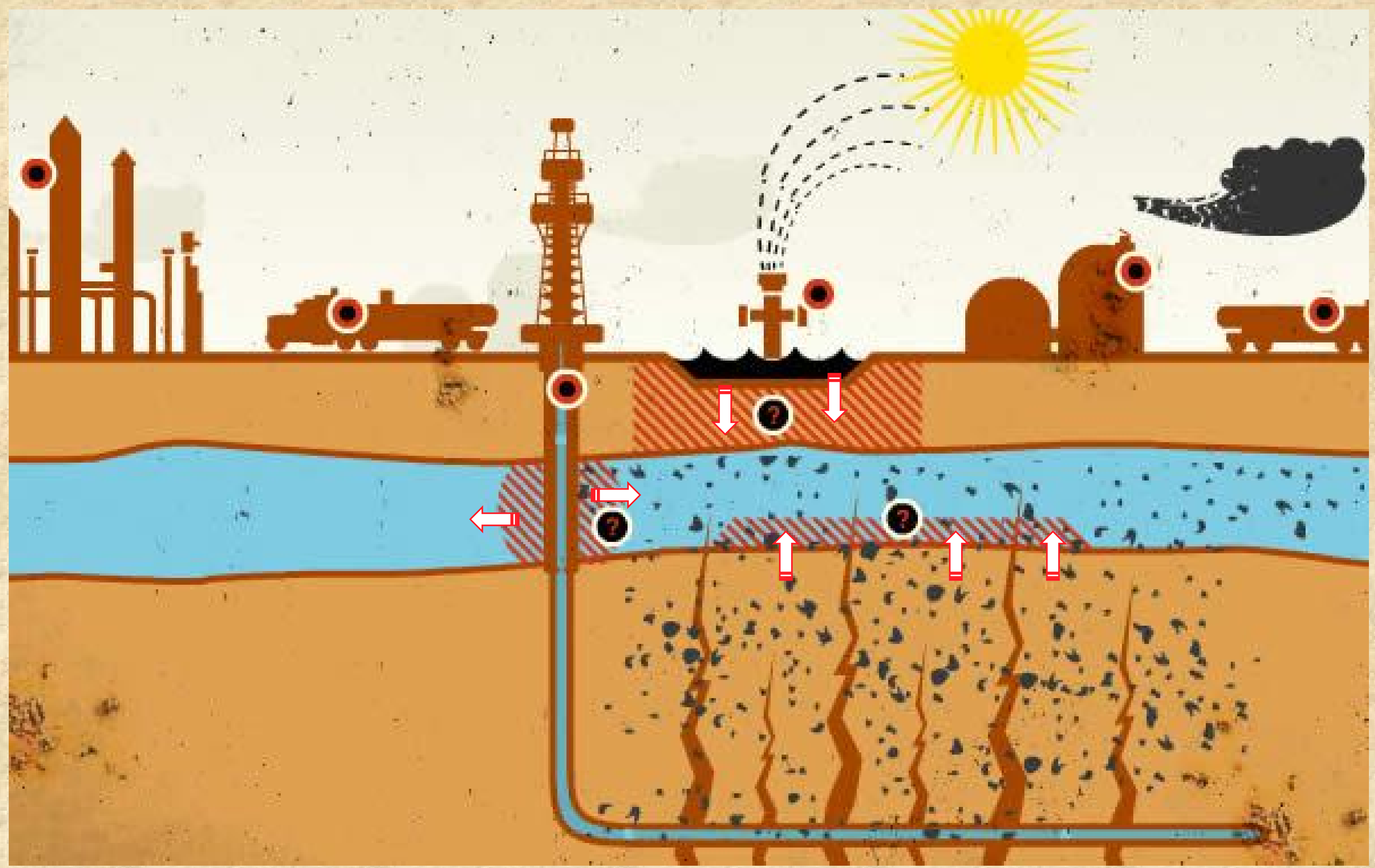
Secondo le compagnie che ricercano e producono lo shale gas l’impatto sul territorio di questo tipo di produzione è limitato nello spazio alle zone di perforazione dei pozzi e nel tempo alla durata della perforazione e messa in opera del pozzo


MARCELLUS AIR © www.marcellus-shale.us

Vasca di decantazione della miscela del fracking "a riposo"

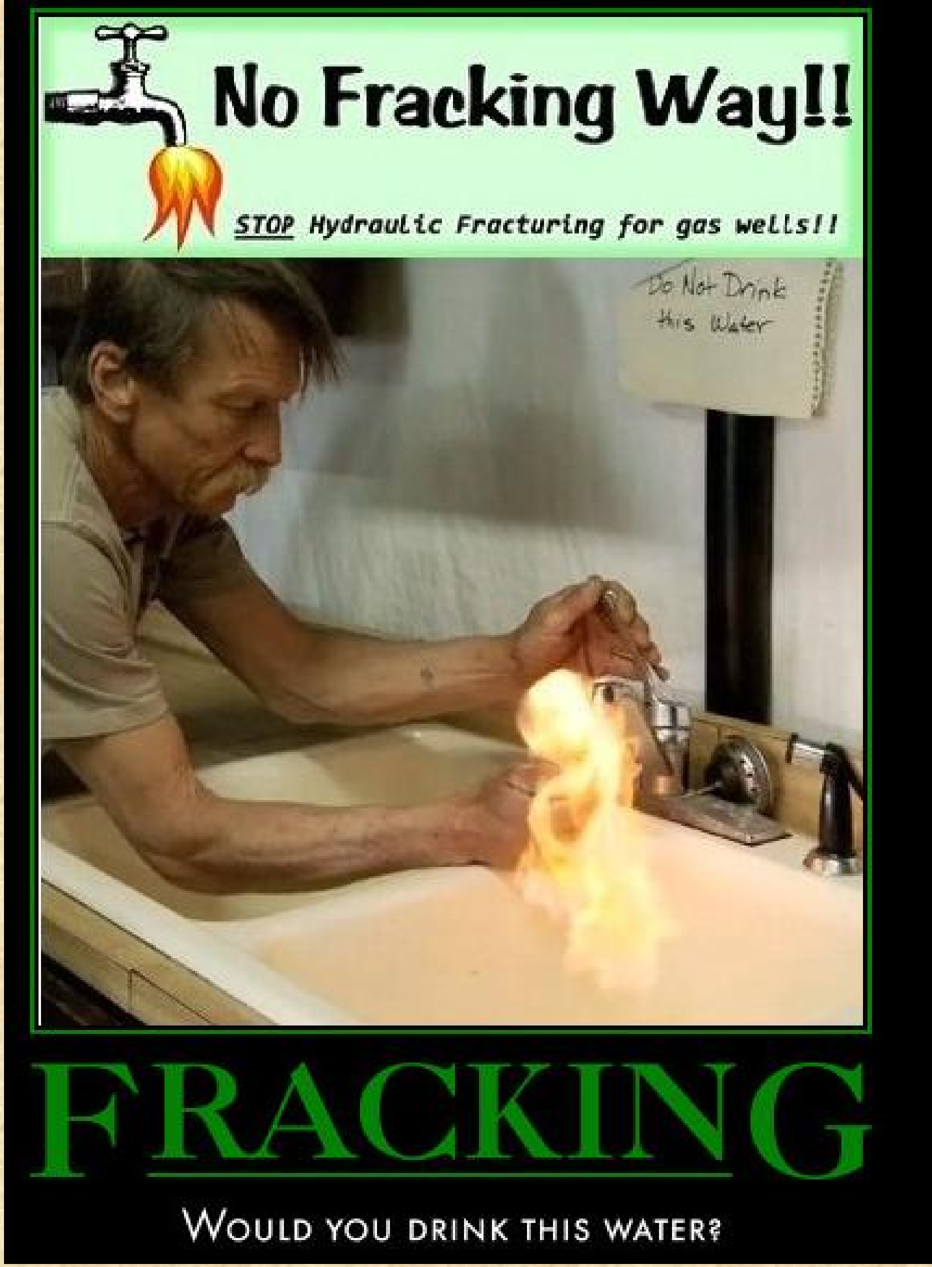
Vasca di decantazione della miscela del fracking in attività

Garfield County Colorado

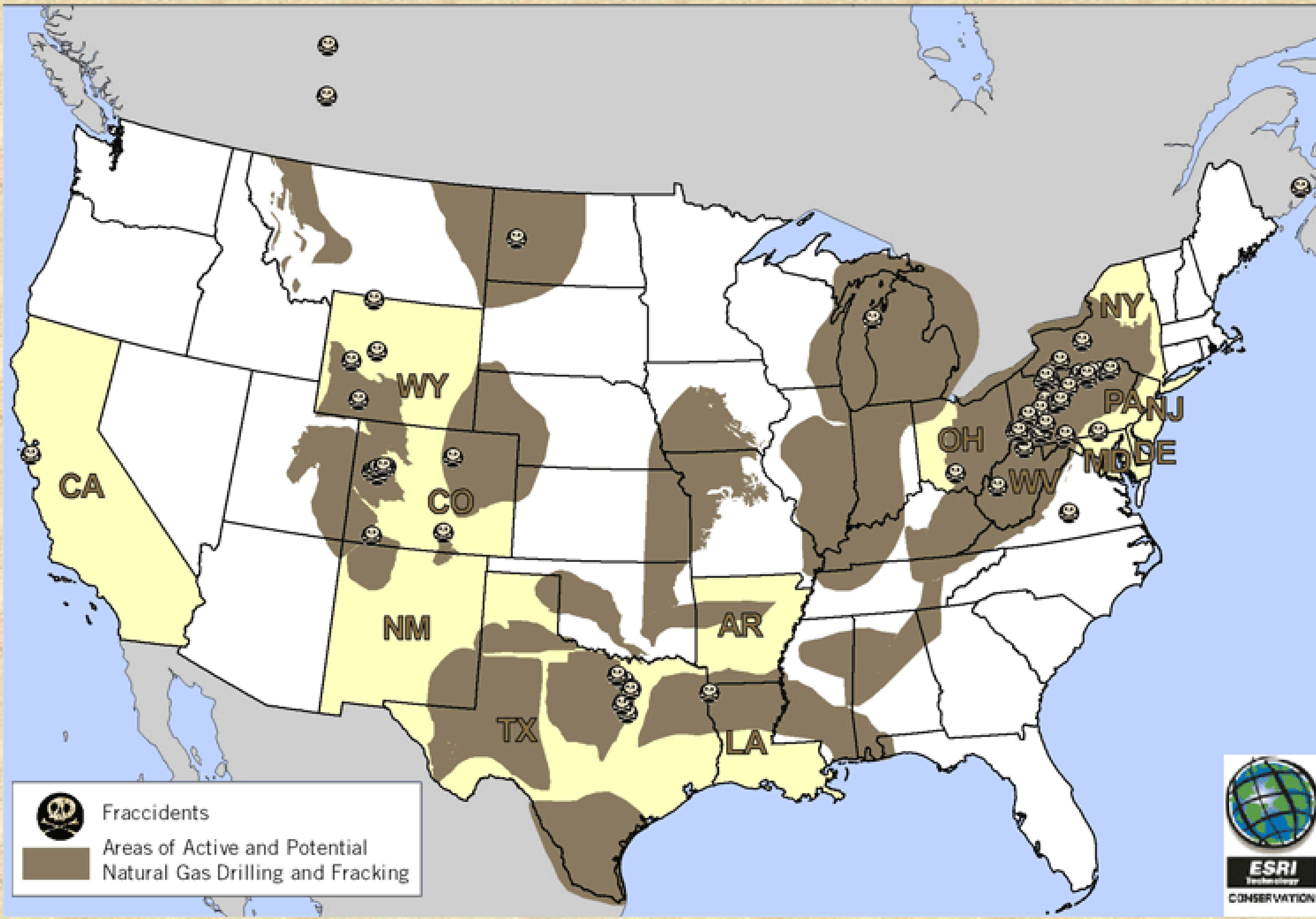


Possibili inquinamenti del sottosuolo e in particolare delle falde idriche in conseguenti alle attività di sfruttamento dello shale gas

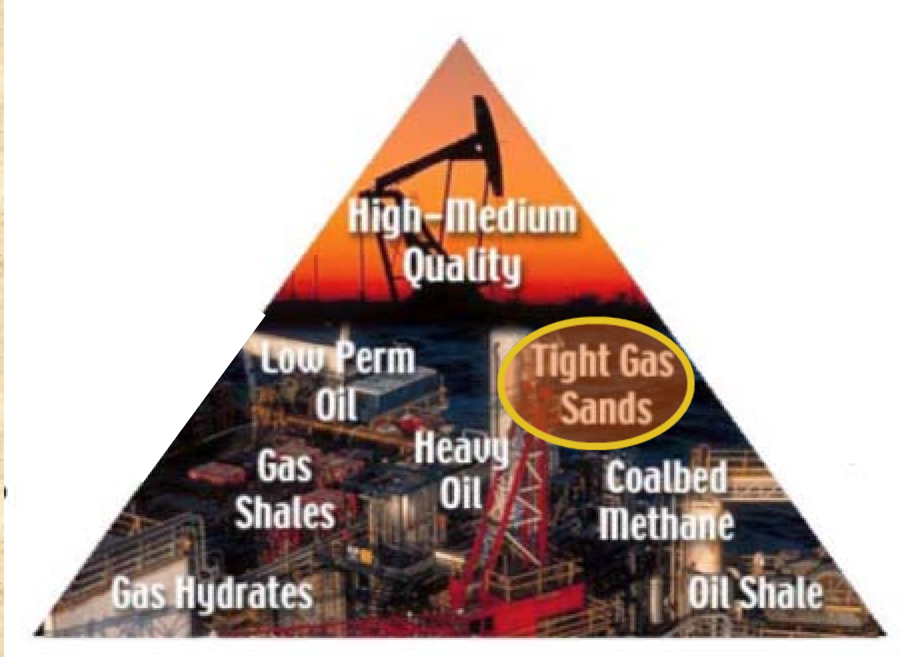
Gli stessi pericoli sono associati anche allo sfruttamento del CBM e del Tight gas



Immagini tratte dal documentario GASLAND di Josh Fox dedicato ai pericoli ambientali derivanti dalla ricerca e dallo sfruttamento dello shale gas negli Stati Uniti



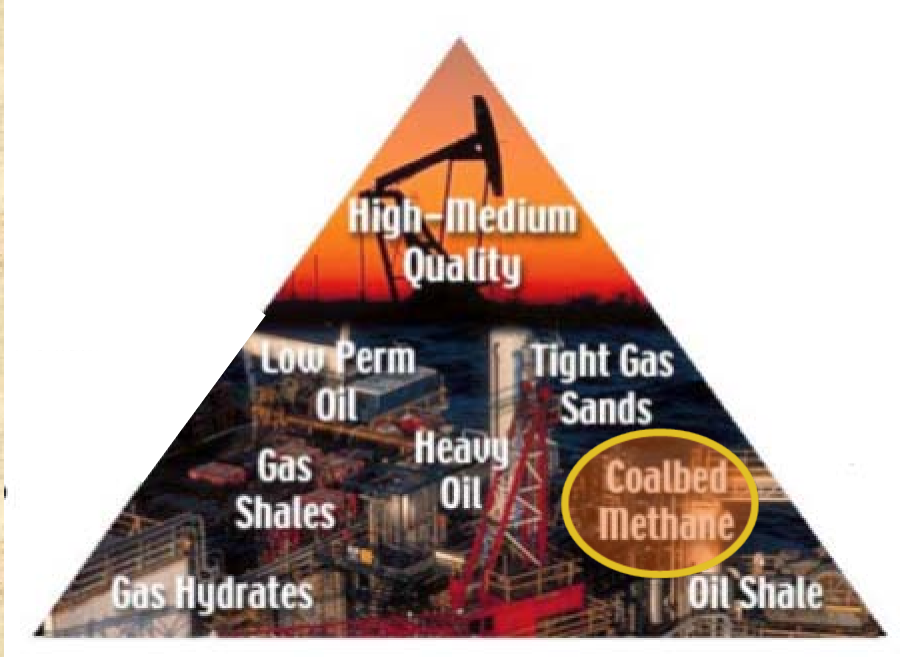
Mappa degli incidenti e inquinamenti verificatisi nella zone oggetto di sfruttamento delle gas shale



TIGHT GAS

Gas naturale intrappolato in livelli di rocce sedimentarie arenaceo pelitiche poco permeabili (tight sands)

Caratteristiche:
- le rocce serbatoio sono poco permeabili
- i giacimenti sono complessi, poco prevedibili, e molto variabili lateralmente
- per lo sfruttamento sono necessarie tecniche speciali di perforazione (horizontal drilling) e di ricupero (fracking)

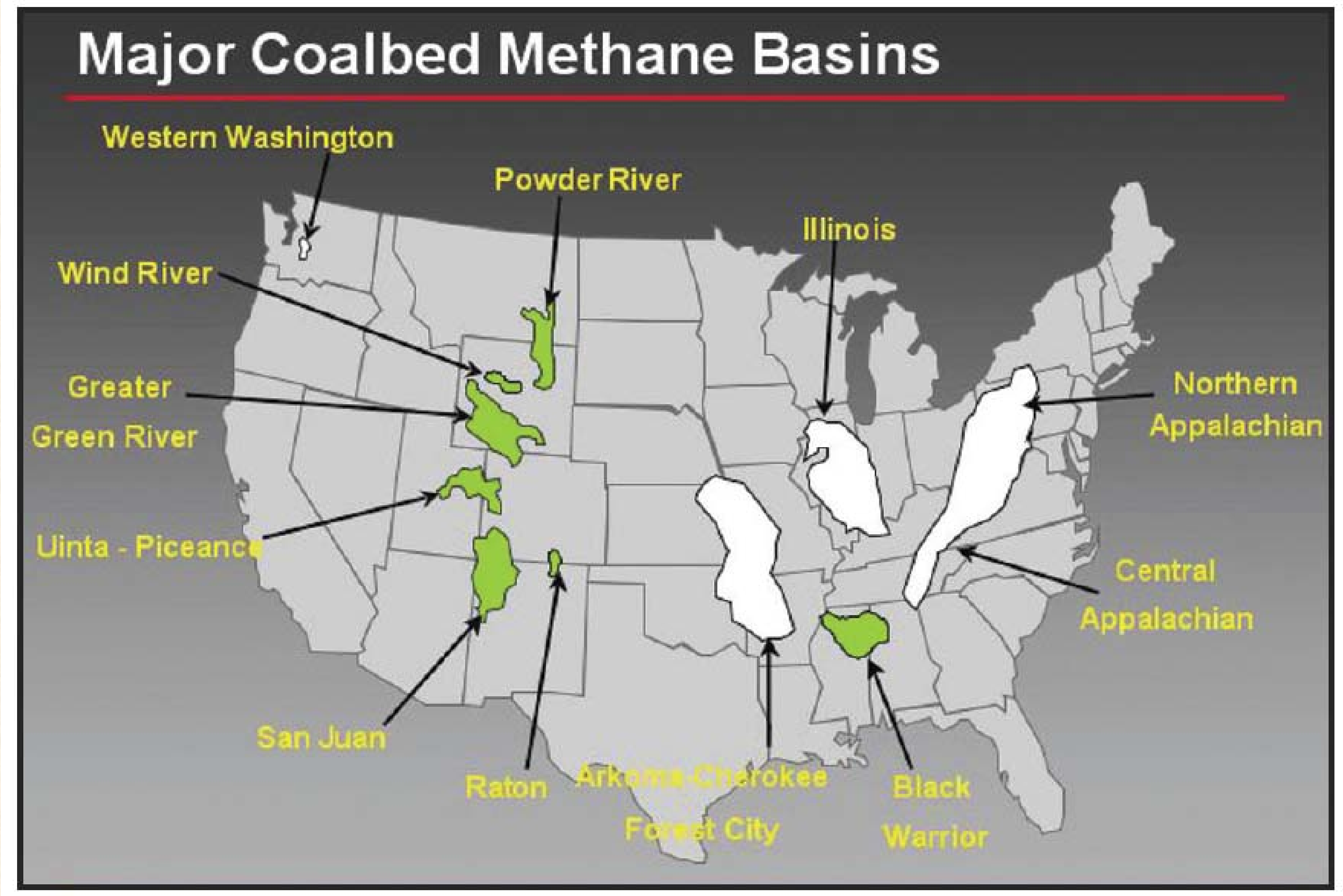


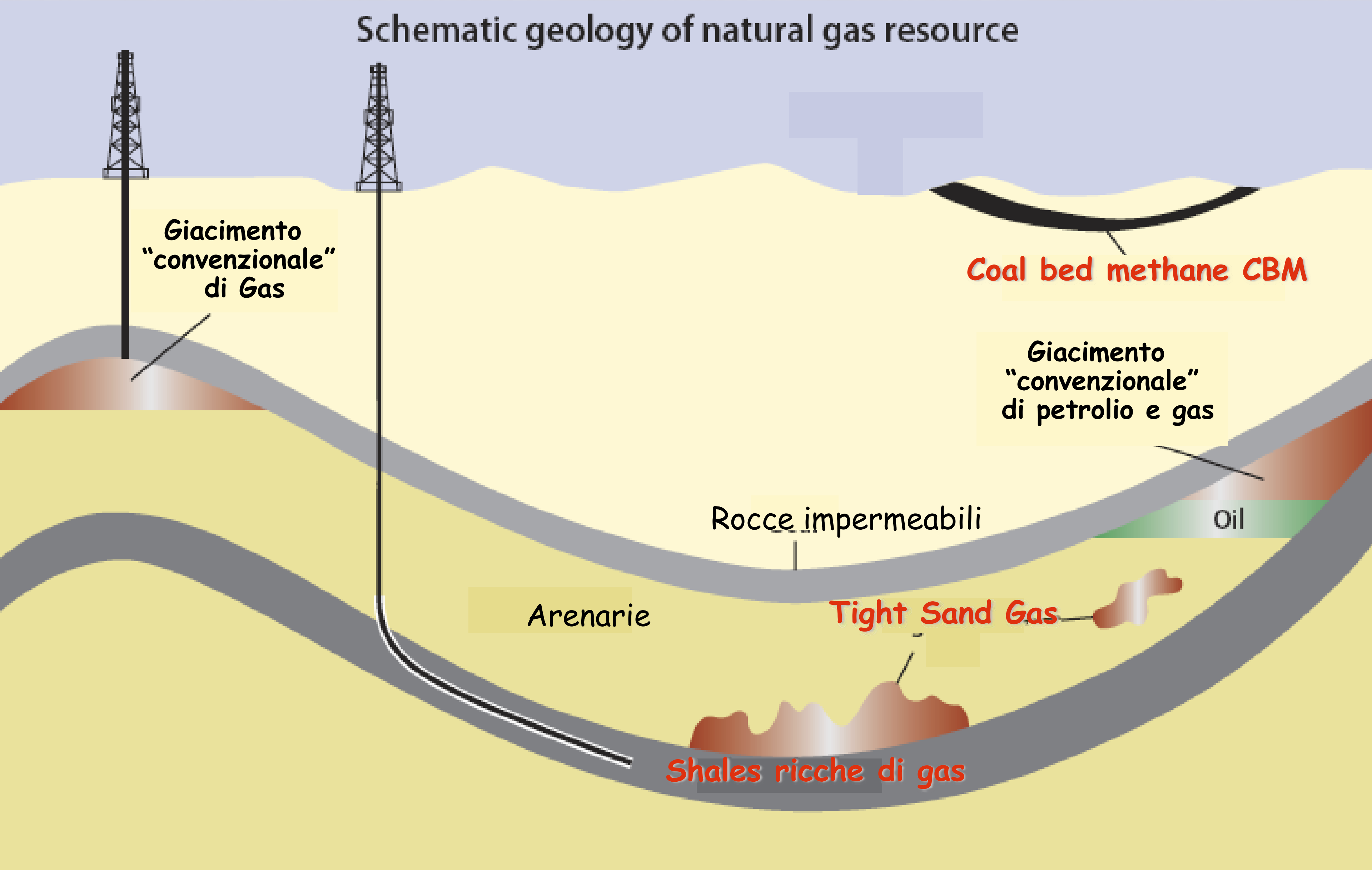
COAL BED METHANE CBM

Gas naturale (95%metano) generato e intrappolato in livelli carbone sepolti a profondità poco elevate <1500m

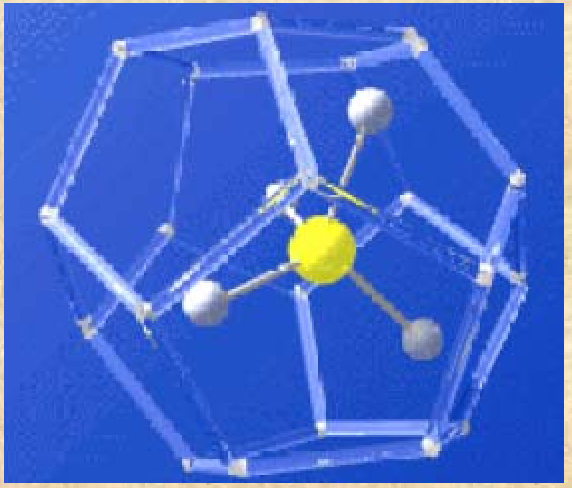
Caratteristiche:
- il gas è adsorbito nella struttura molecolare del carbone e mantenuto in loco dalla pressione dell'acqua
- la matrice è attraversata da una fittissima rete di fratture (cleats) che, una volta eliminata l'acqua, permettono il fluire del gas verso il pozzo di estrazione
- per lo sfruttamento è necessario eliminare l'acqua e sono spesso utilizzate anche in questo caso tecniche speciali di perforazione (horizontal drilling) e di recupero (fracking) per elevare la resa

COAL BED METHANE CBM




Schematic geology of natural gas resource
Giacimento "convenzionale" di Gas
Coal bed methane CBM
Giacimento "convenzionale" di petrolio e gas
Rocce impermeabili
Oil
Arenarie
Tight Sand Gas
Shales ricche di gas

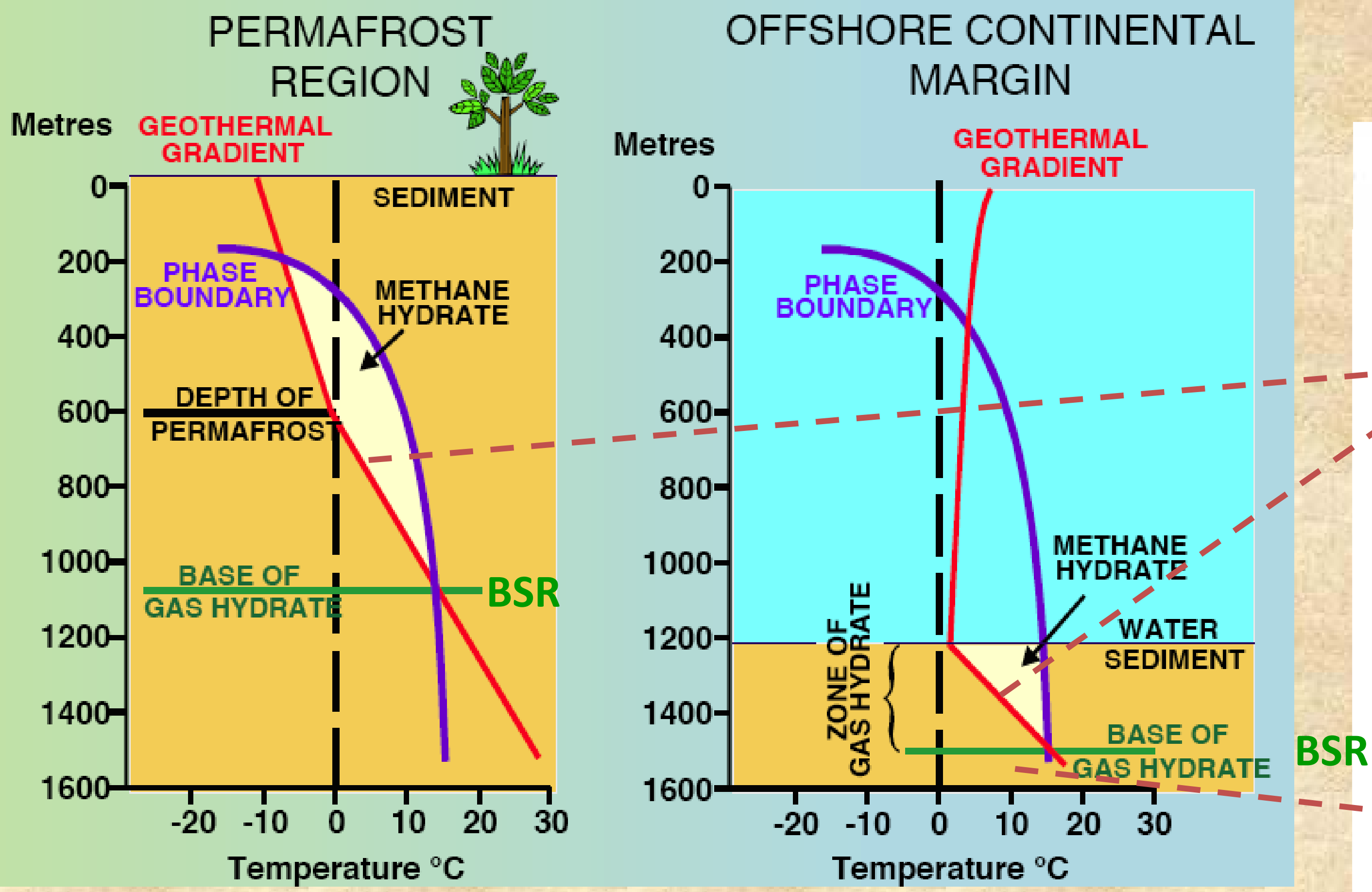
Gas hydrates, clathrates

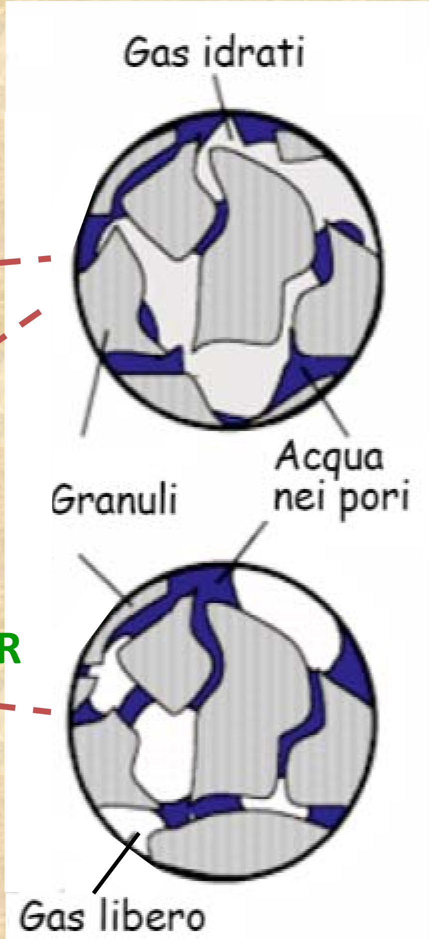


Crystalline water-based solids in which small non polar molecules (typically gases: methane, CO_2…) are trapped inside “cages” of hydrogen bonded water molecules

The most common are methane clathrates

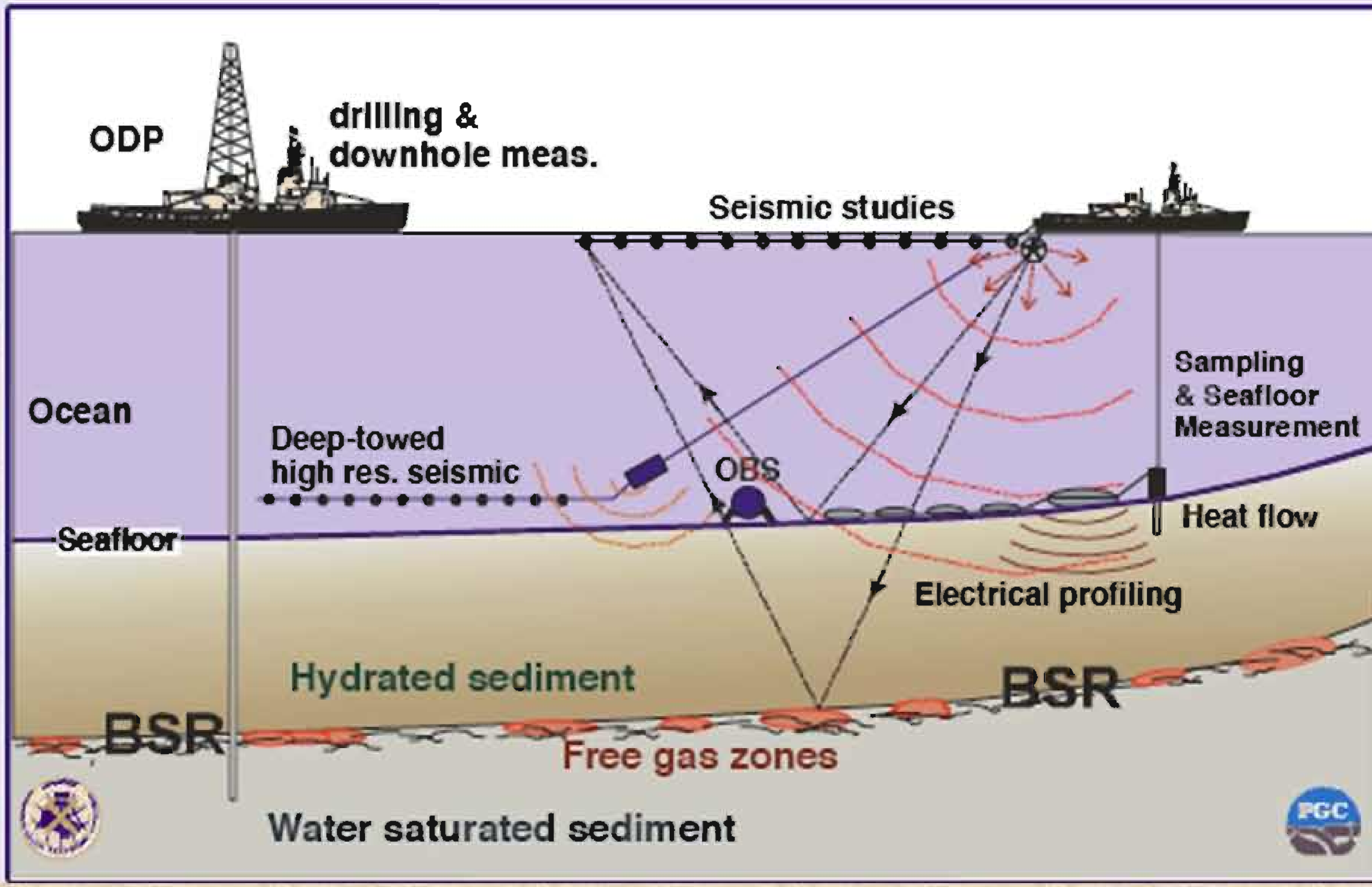
Depths & Temperatures where Gas Hydrates are Stable

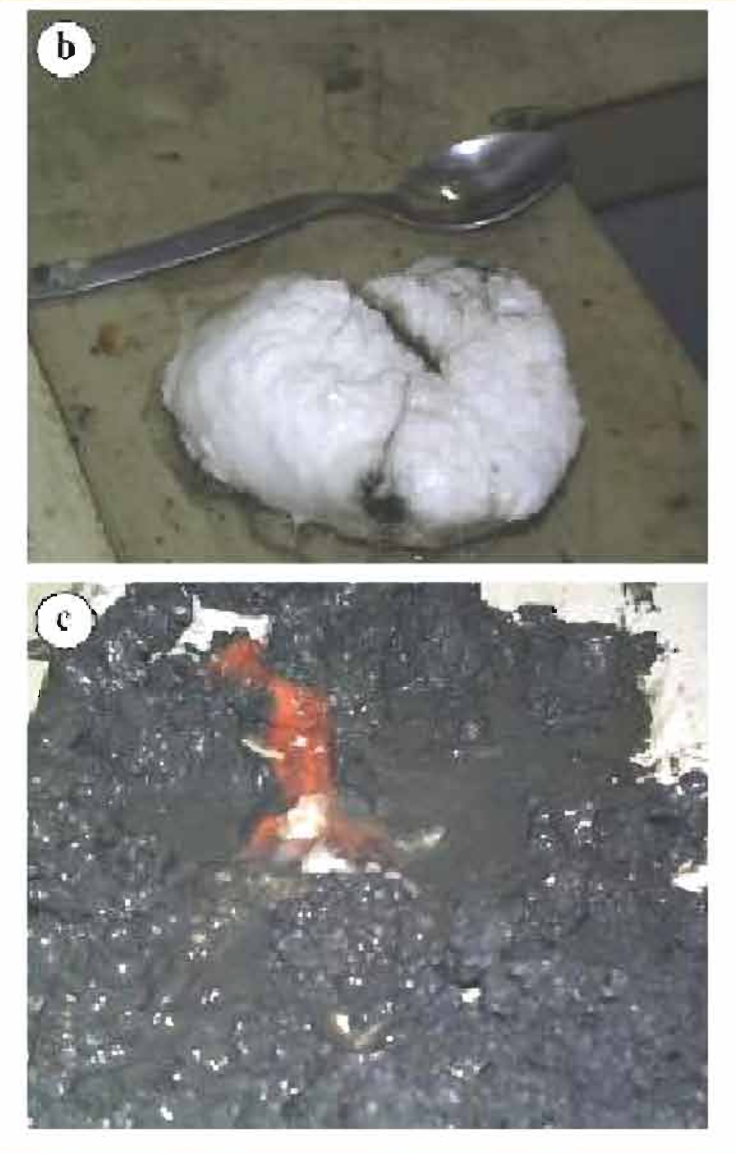


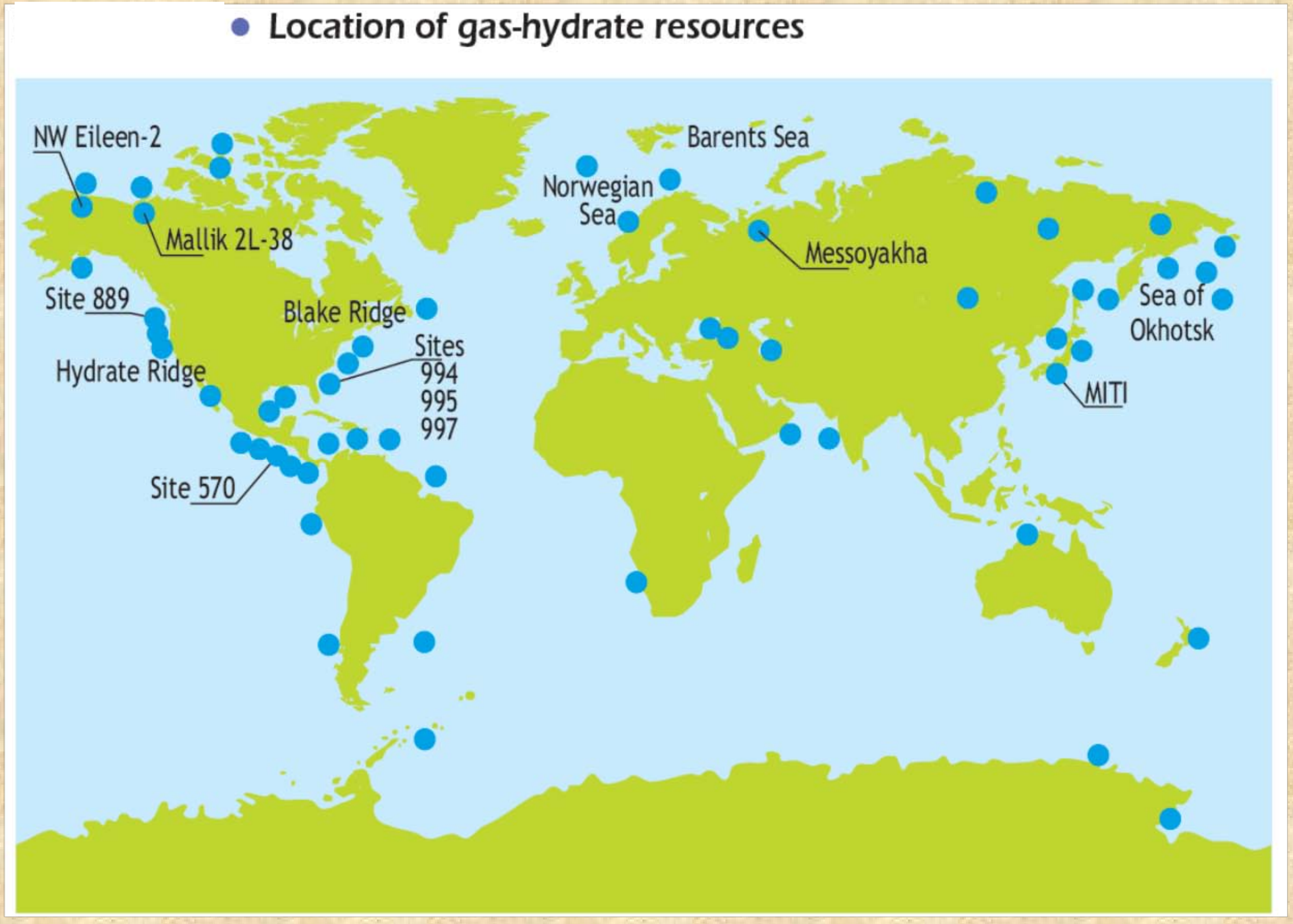


BSR: Bottom Simulating Reflector

Marine Gas Hydrate Studies




b
c



World Energy Outlook 2008

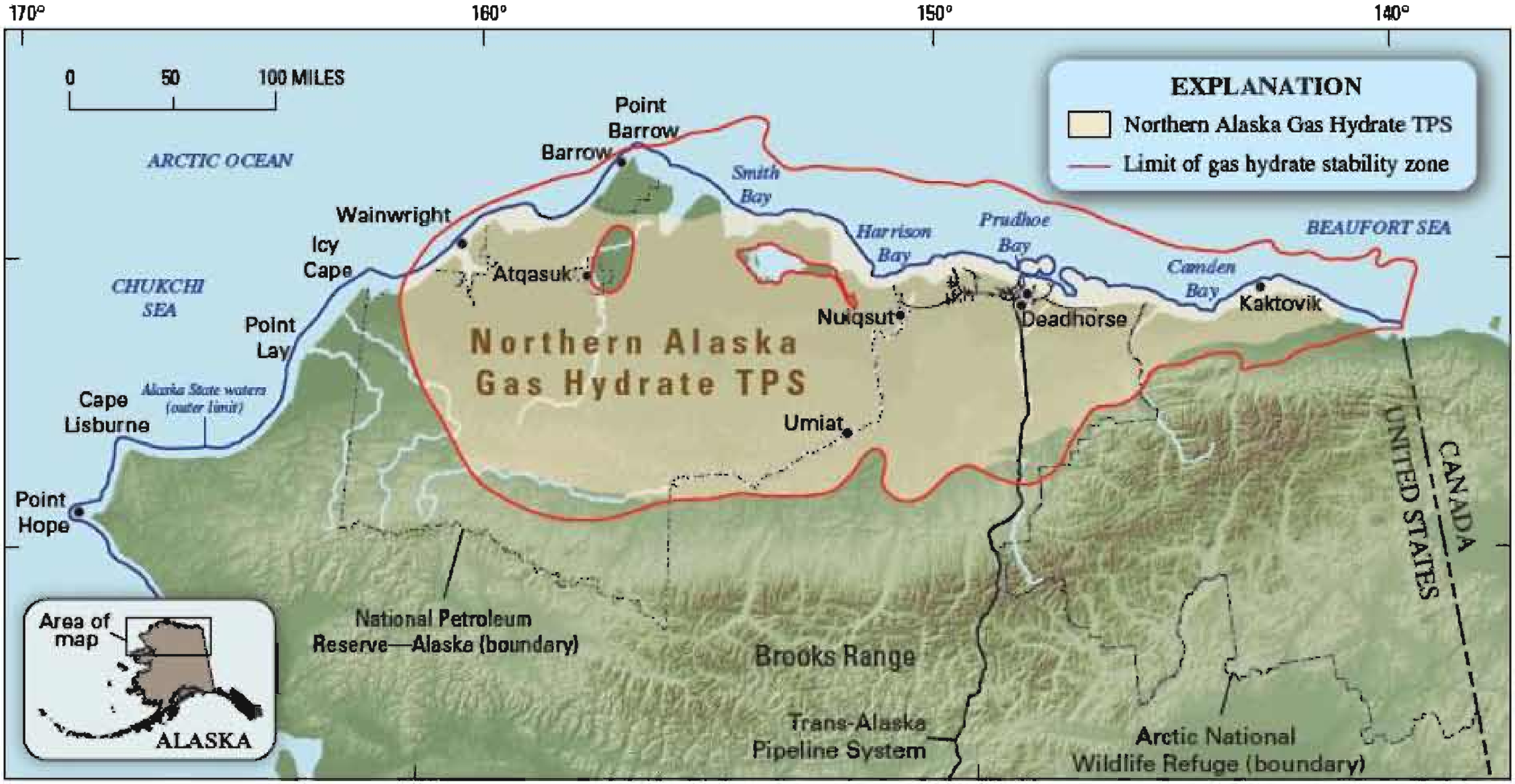


Figure 1. The Northern Alaska Gas Hydrate Total Petroleum System (TPS) (shaded in tan), and the limit of gas hydrate stability zone in northern Alaska (red outline).

Japan's Commitment to Production Leads International Gas Hydrate Research

- Japan: USDOE estimates $50 Million USD each year of research.
- United States: H.R. 1753, authorizes $165 Million USD over five years for new research.
- India: $16 Million USD/year in a total budget of $56 Million USD over five years.
- Canada: $2.02 Million USD over the next four years.
- Korea – expected annual expenditure in near term up to $6 Million USD/year
- Primarily government and research

Canada

the ENERGY lab

Fire in the Ice

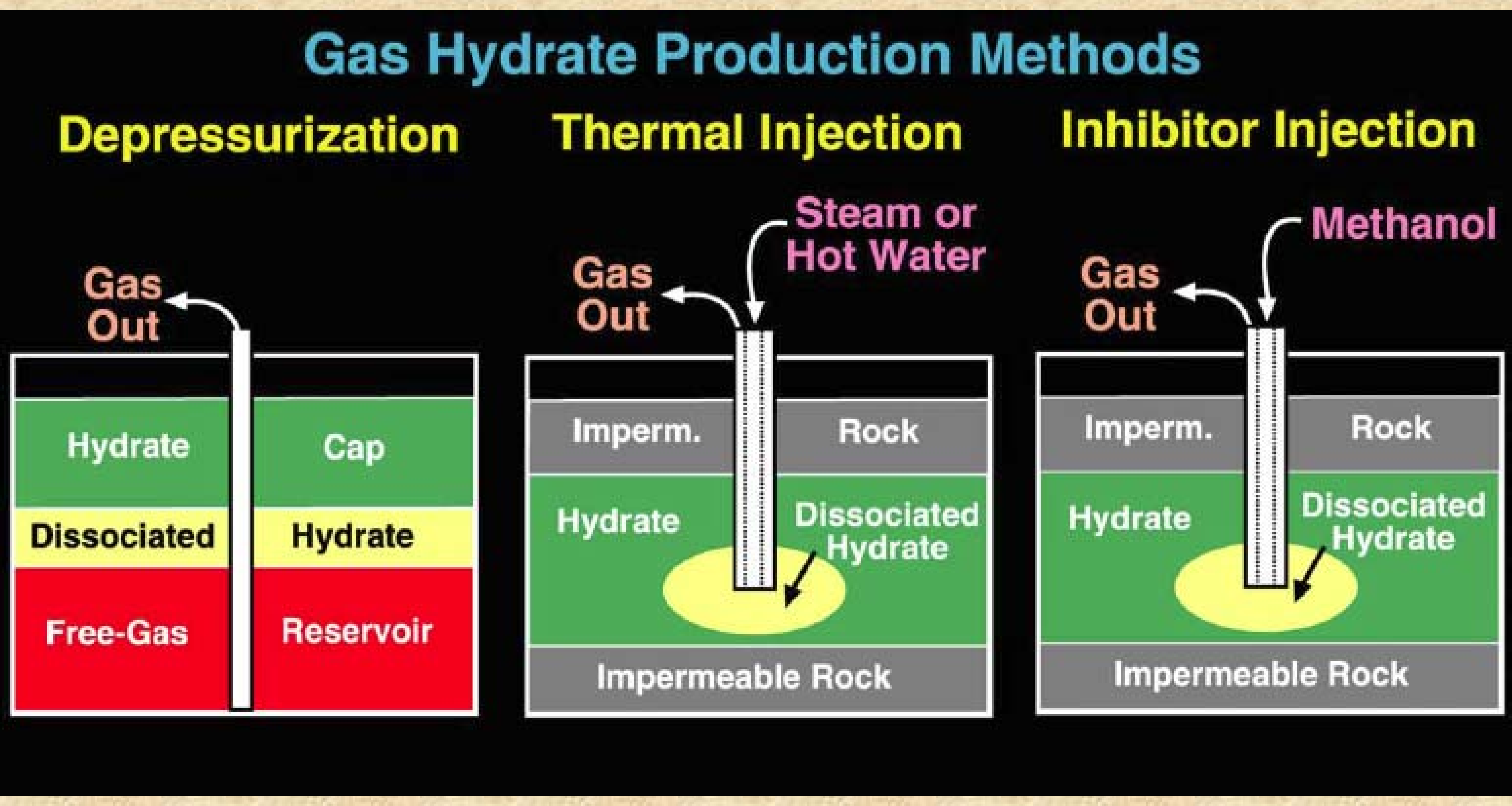
Summer 2009 Methane Hydrate Newsletter

NETL

Joint Industry Project Leg II Discovers Rich Gas Hydrate Accumulations in Sand Reservoirs in the Gulf of Mexico

Energy

Gas Hydrate Resource: Smaller But Sooner



Possible methods for exploitation of gas hydrates

- Depressurization
- Heating : hot water, vapour, microwaves…
- Injection of chemical inhibitors in order to dissociate ("melt") the gas hydrates

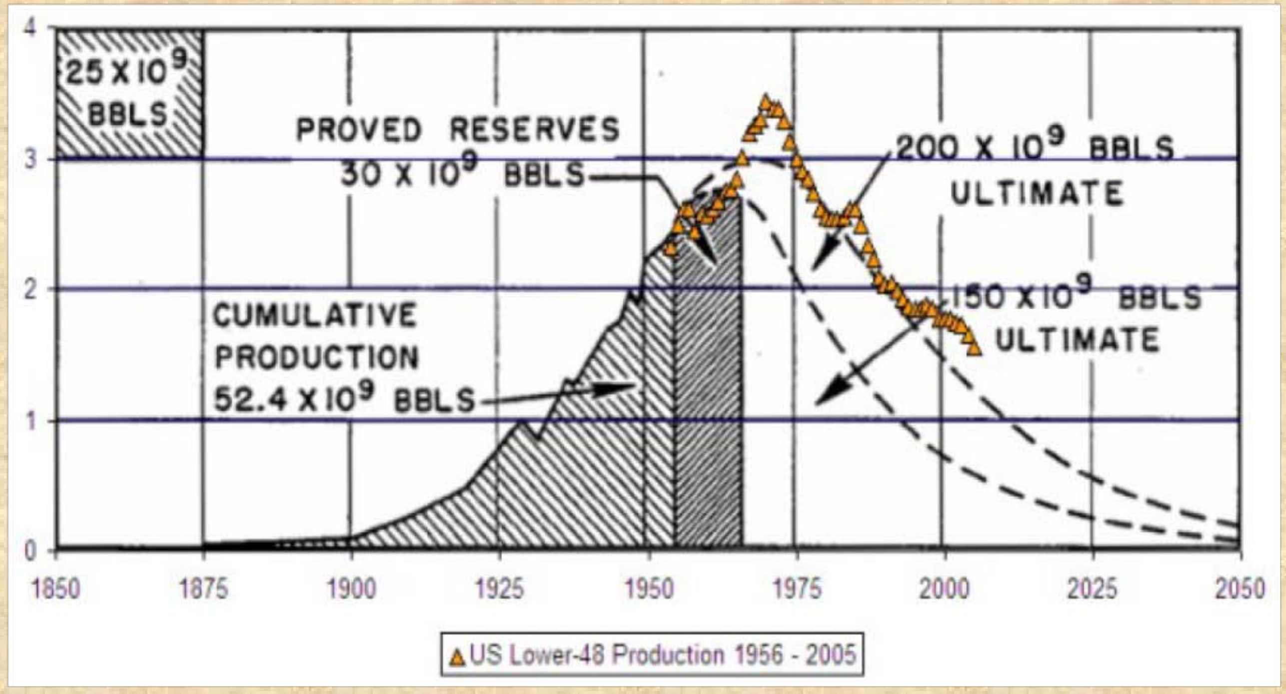
…but the situation **is not** that simple

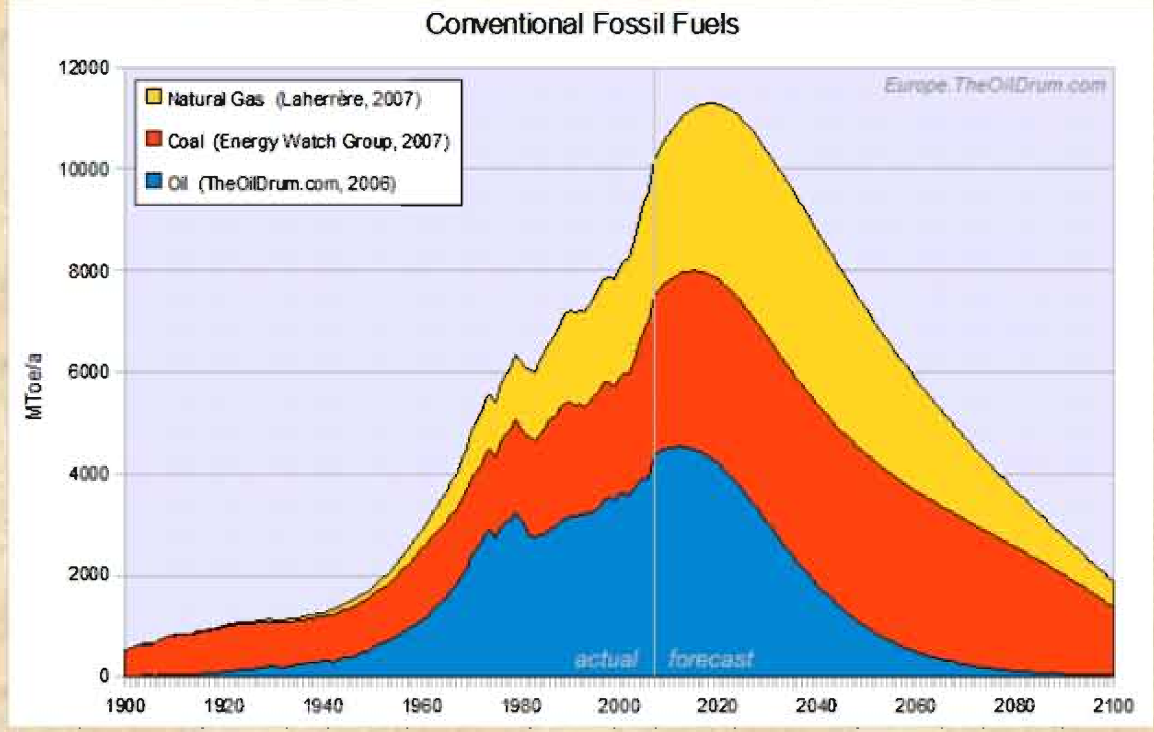
“Hubbert’s theory” (1956):

Fossil fuel production in a given region over time follows a roughly bell-shaped curve (*Hubbert curve*).

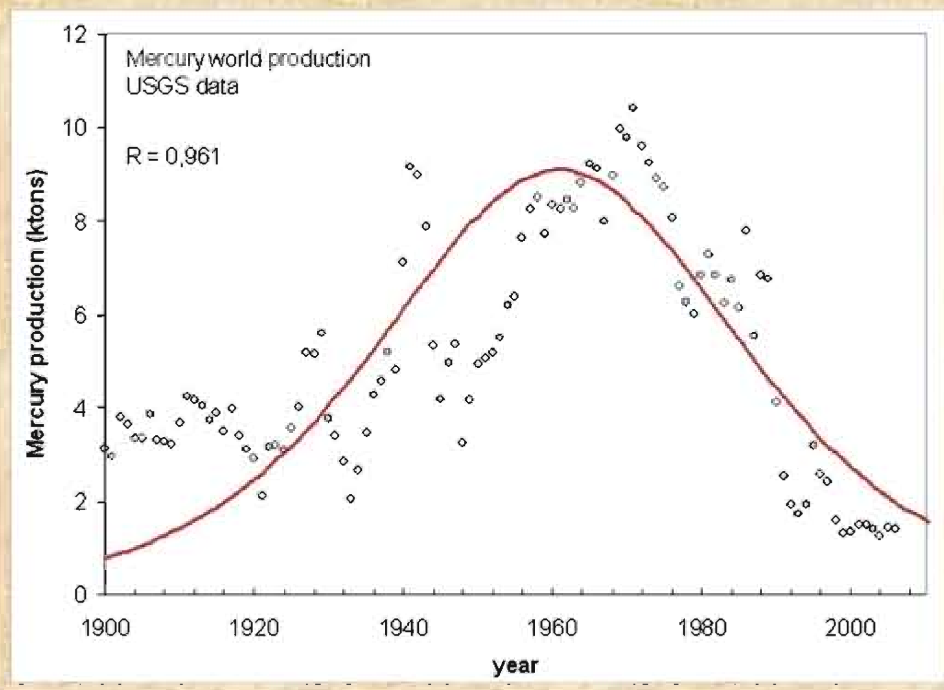
After fossil fuel reserves are discovered, production at first increases approximately exponentially, as more extraction commences and more efficient facilities are installed.

At some point, a peak output is reached, and production begins declining until it approximates an exponential decline.



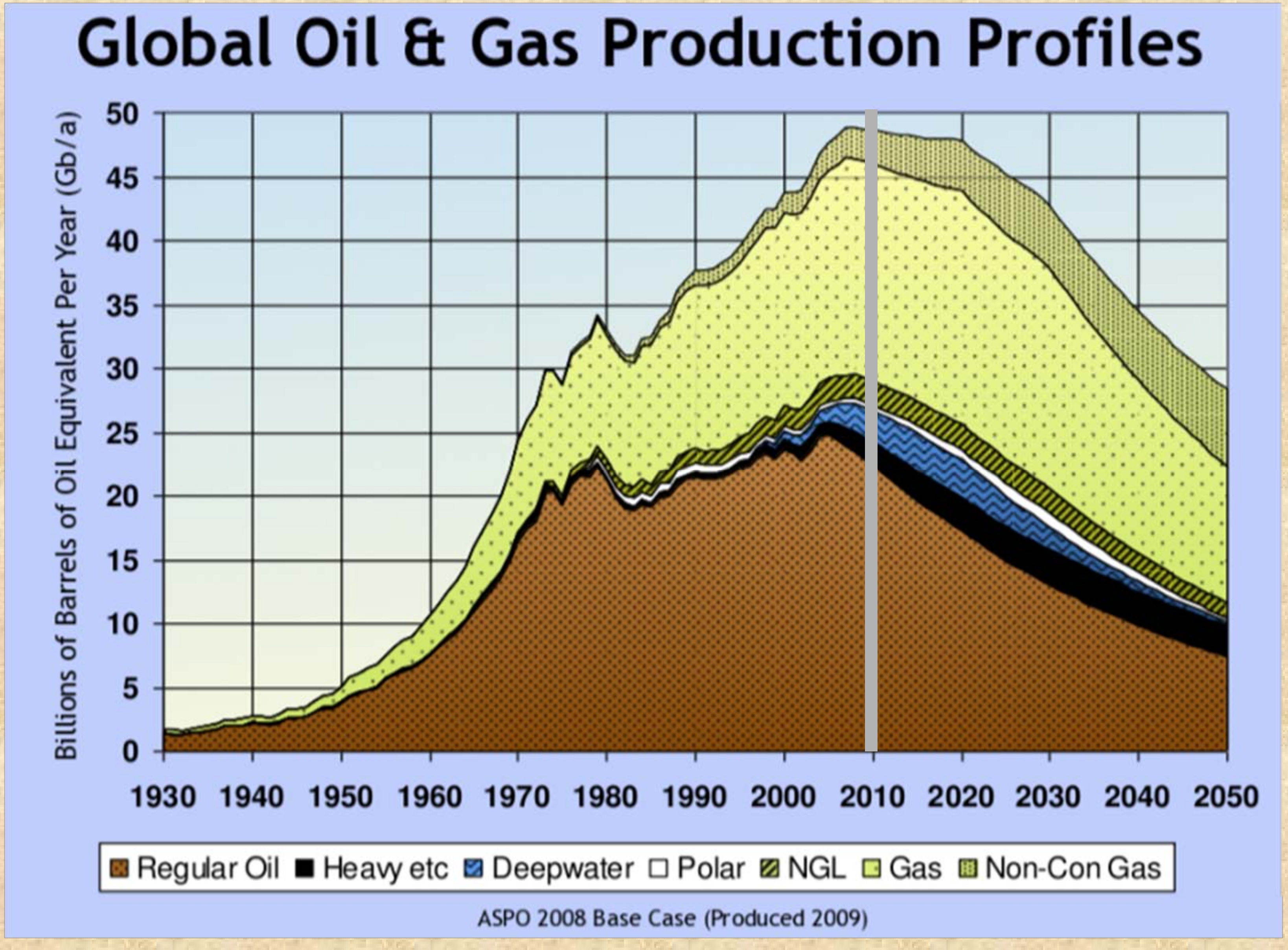


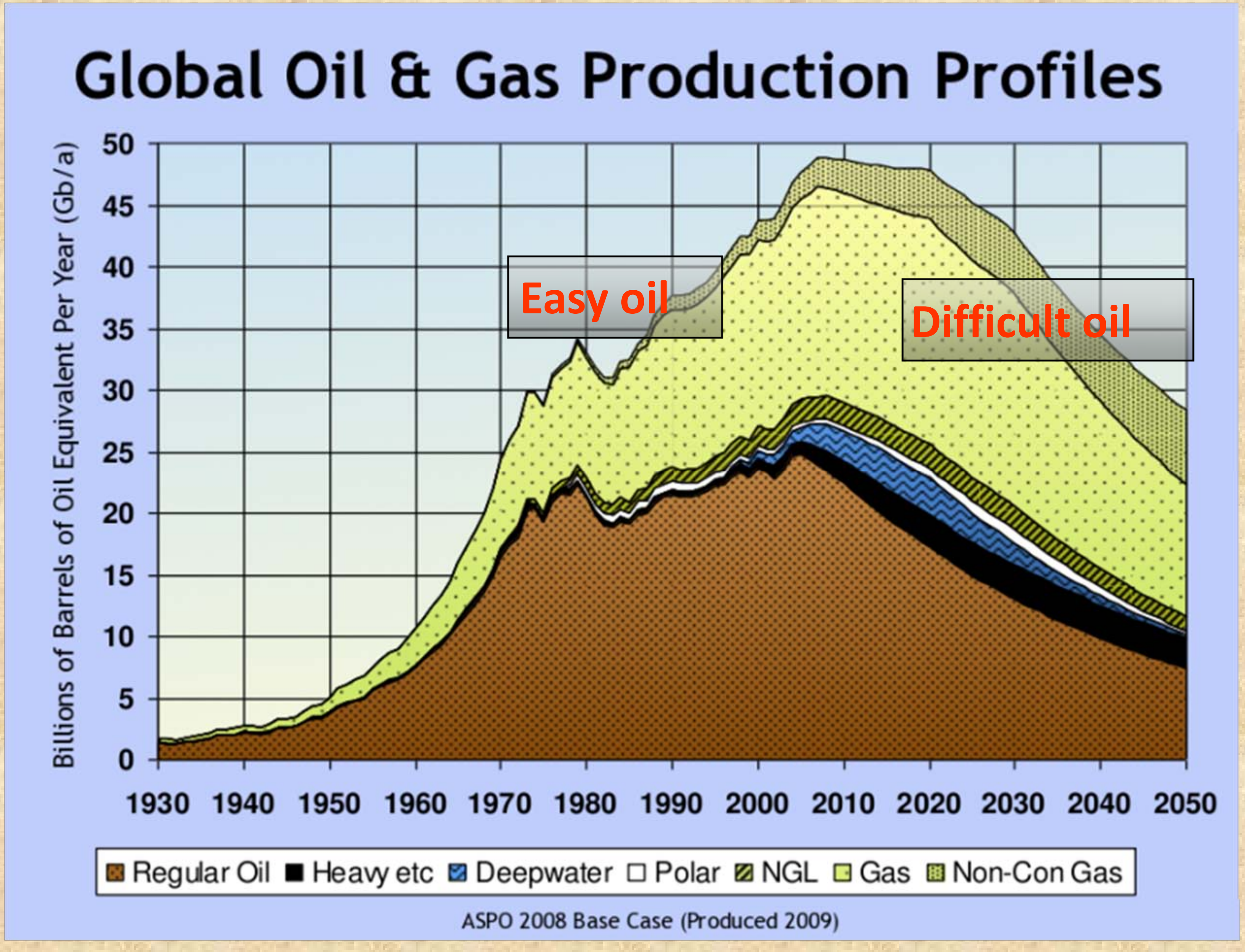
Conventional Fossil Fuels
Natural Gas (Laherrère, 2007)
Coal (Energy Watch Group, 2007)
Oil (TheOilDrum.com, 2006)
Europe.TheOilDrum.com
MToe/a
actual
forecast
0
2000
4000
6000
8000
10000
12000
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100



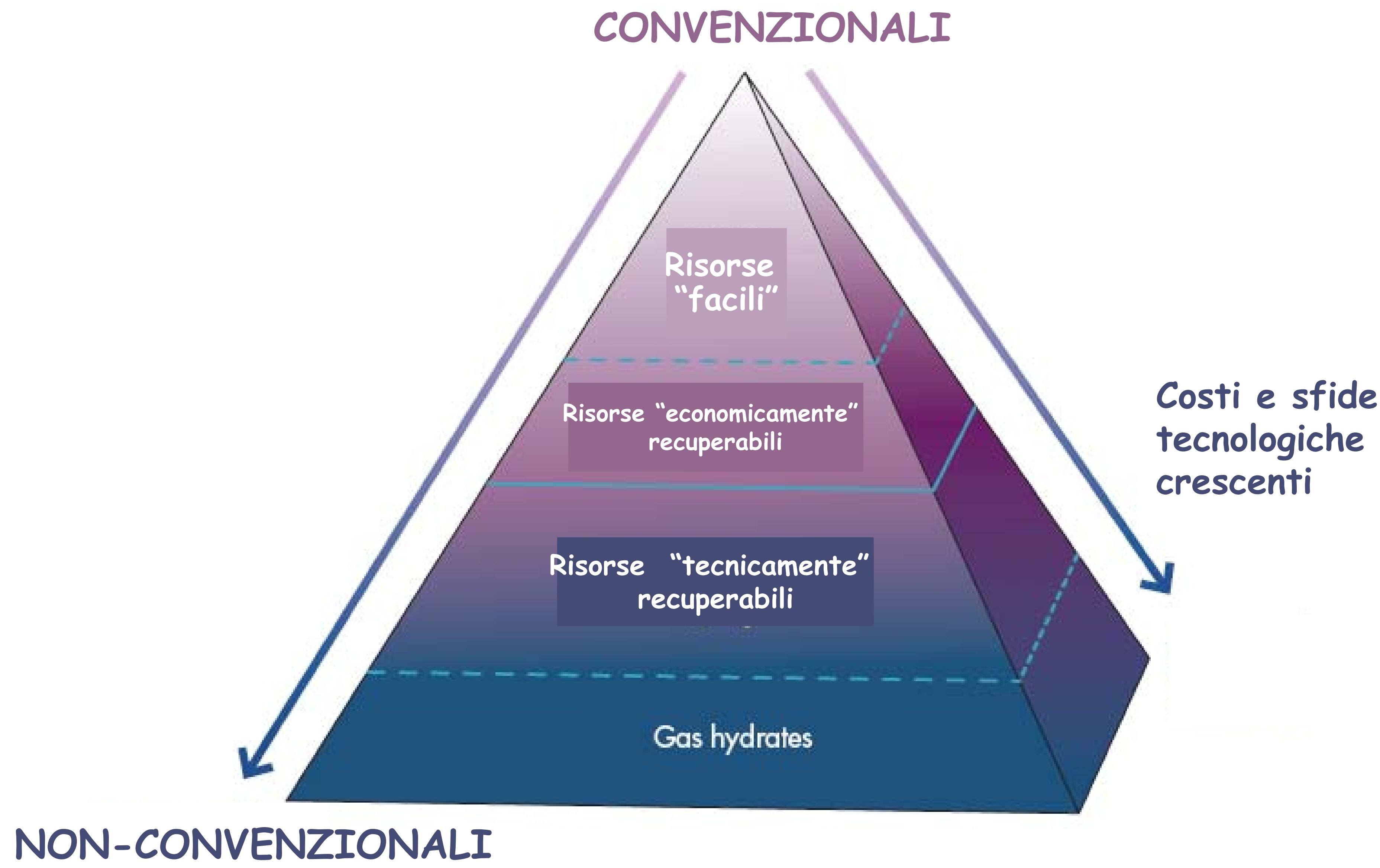
Mercury world production
USGS data
R = 0,961
Mercury production (ktons)
year
0
2
4
6
8
10
12
1900
1920
1940
1960
1980
2000

Are we at the "petrol peak"?





Global Oil & Gas Production Profiles
Easy oil
Difficult oil
Billions of Barrels of Oil Equivalent Per Year (Gb/a)
0
5
10
15
20
25
30
35
40
45
50
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Regular Oil
Heavy etc
Deepwater
Polar
NGL
Gas
Non-Con Gas
ASPO 2008 Base Case (Produced 2009)


CONVENZIONALI
Risorse "facili"
Risorse "economicamente" recuperabili
Risorse "tecnicamente" recuperabili
Gas hydrates
Costi e sfide tecnologiche crescenti
NON-CONVENZIONALI

- **deeper and deeper deposits, in remote areas**

-IOR/EOR techniques

- exploitation of non conventional often poor-quality deposits; hydrocarbons recovery with complex, expensive methods, which often imply a strong impact on the environment

→ increasing costs; environmental concern

- climate change: greenhouse effect, CO_2 emissions

- nuclear: other types of problems

21 april 2010 – The Deepwater Horizon rig

the “dome”

- deeper and deeper deposits, in remote areas

-**IOR/EOR techniques**

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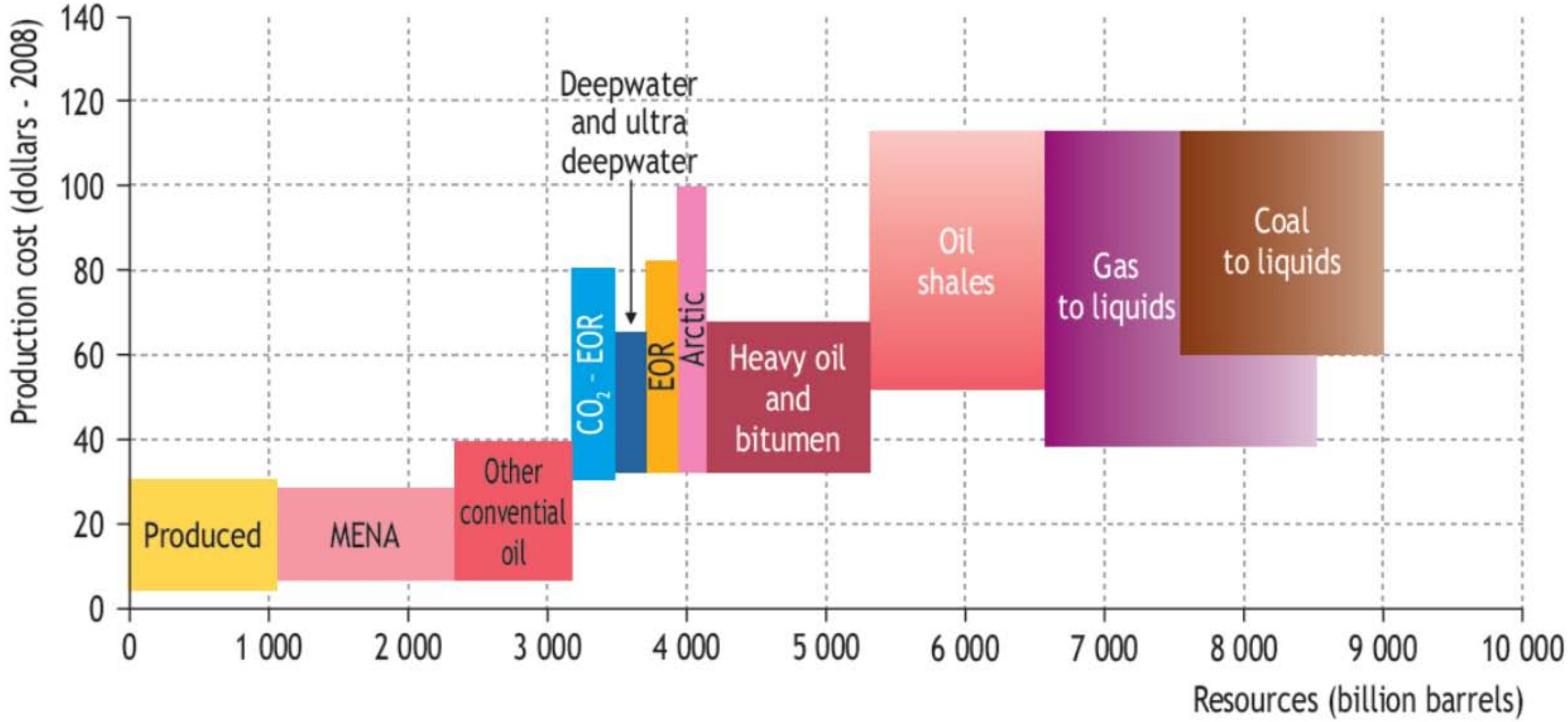
→ increasing costs; environmental concern

- climate change: greenhouse effect, CO_2 emissions

- nuclear: other types of problems

Long-term oil-supply cost curve



Note: The curve shows the availability of oil resources as a function of the estimated production cost. Cost associated with CO_2 emissions is not included. There is also a significant uncertainty on oil shales production cost as the technology is not yet commercial. MENA is the Middle East and North Africa. The shading and overlapping of the gas-to-liquids and coal-to-liquids segments indicates the range of uncertainty surrounding the size of these resources, with 2.4 trillion shown as a best estimate of the likely total potential for the two combined.

NGL: Natural gas liquids, obtained during the natural gas processing: ethane, propane, butanes, pentanes…

World Energy Outlook 2008

Coal to liquid: Coal transformed to liquid, generally by adding hydrogen

- deeper and deeper deposits, in remote areas

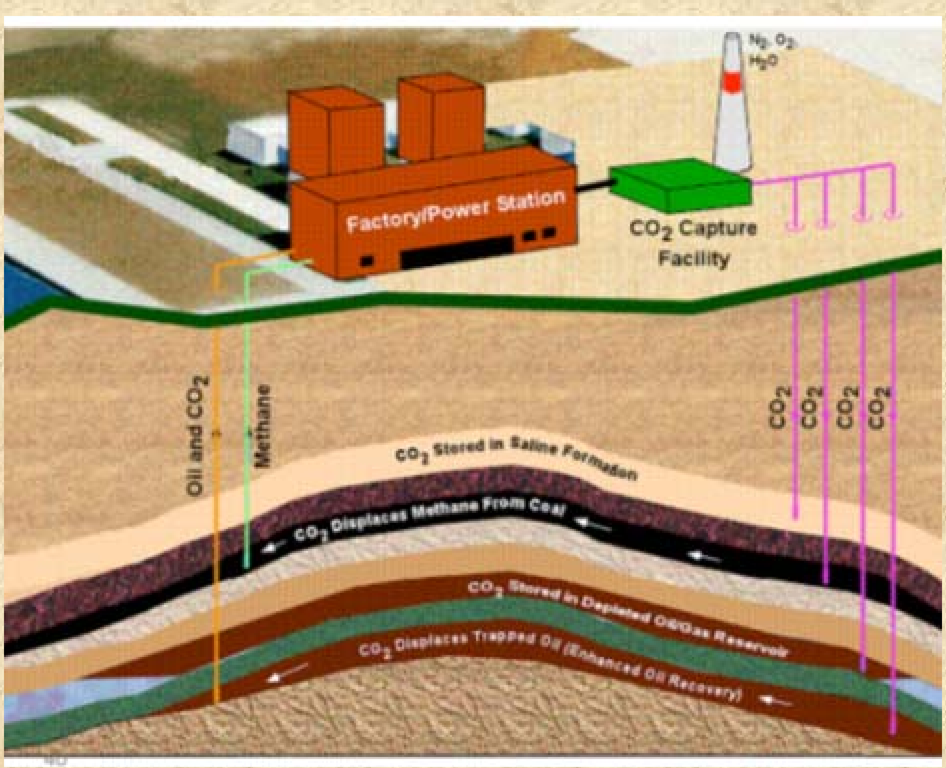
-IOR/EOR techniques

- exploitation of non conventional often poor-quality deposits; hydrocarbons recovery with complex, expensive methods, which often imply a strong impact on the environment

→ increasing costs; environmental concern

- **climate change: greenhouse effect, CO_2 emissions** as an example **coal**: the **cheapest** energy source

is surely **incompatible** with the environment (global warming),
unless **CCS** (Carbon Capture and Storage) technologies are adopted…
but in this case probably it is **not anymore** a cheap source



Sleipner, attivo dal 1996