“Classic” energy resources and geology: the present situation

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Fossil fuel (~88%)

oil (~35%)

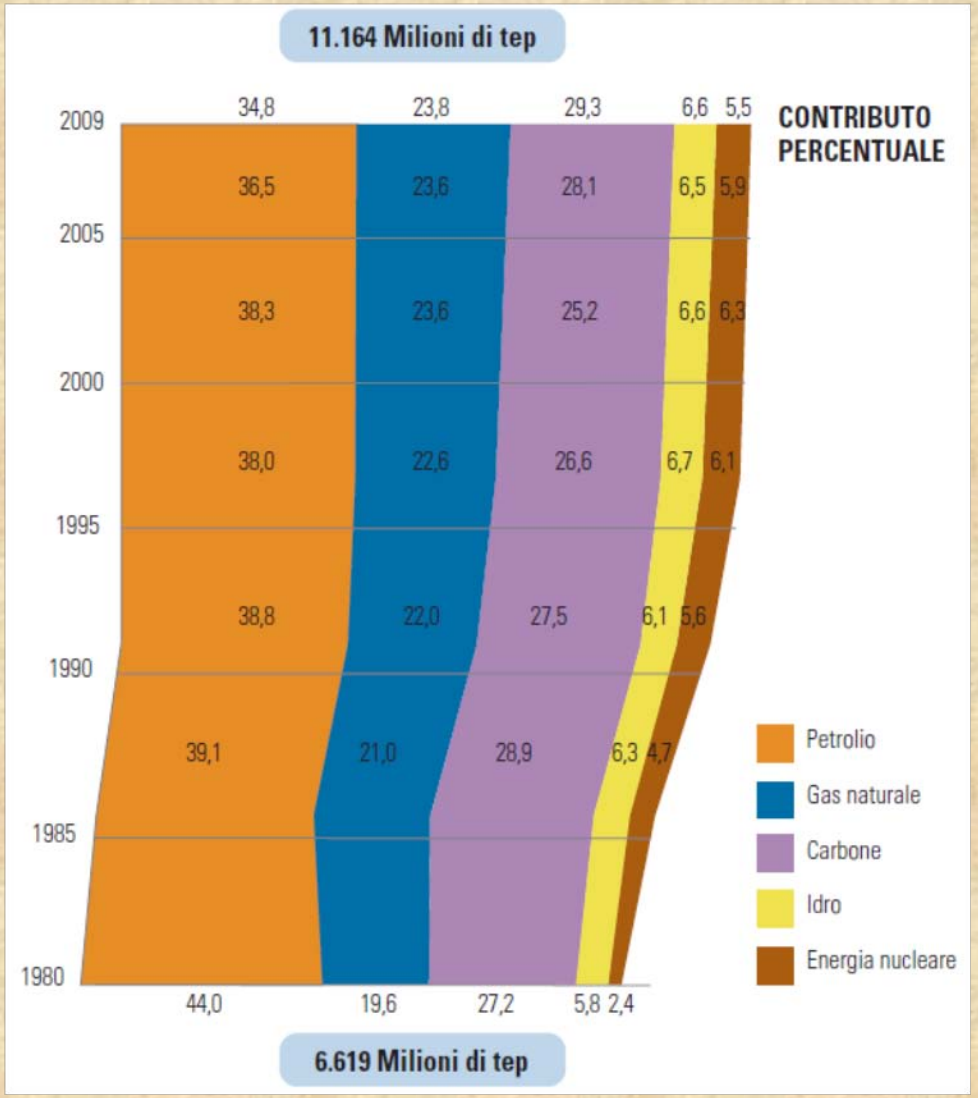
natural gas (~24%)

coal (~29%)

Hydropower, wind/solar power ~6.6%

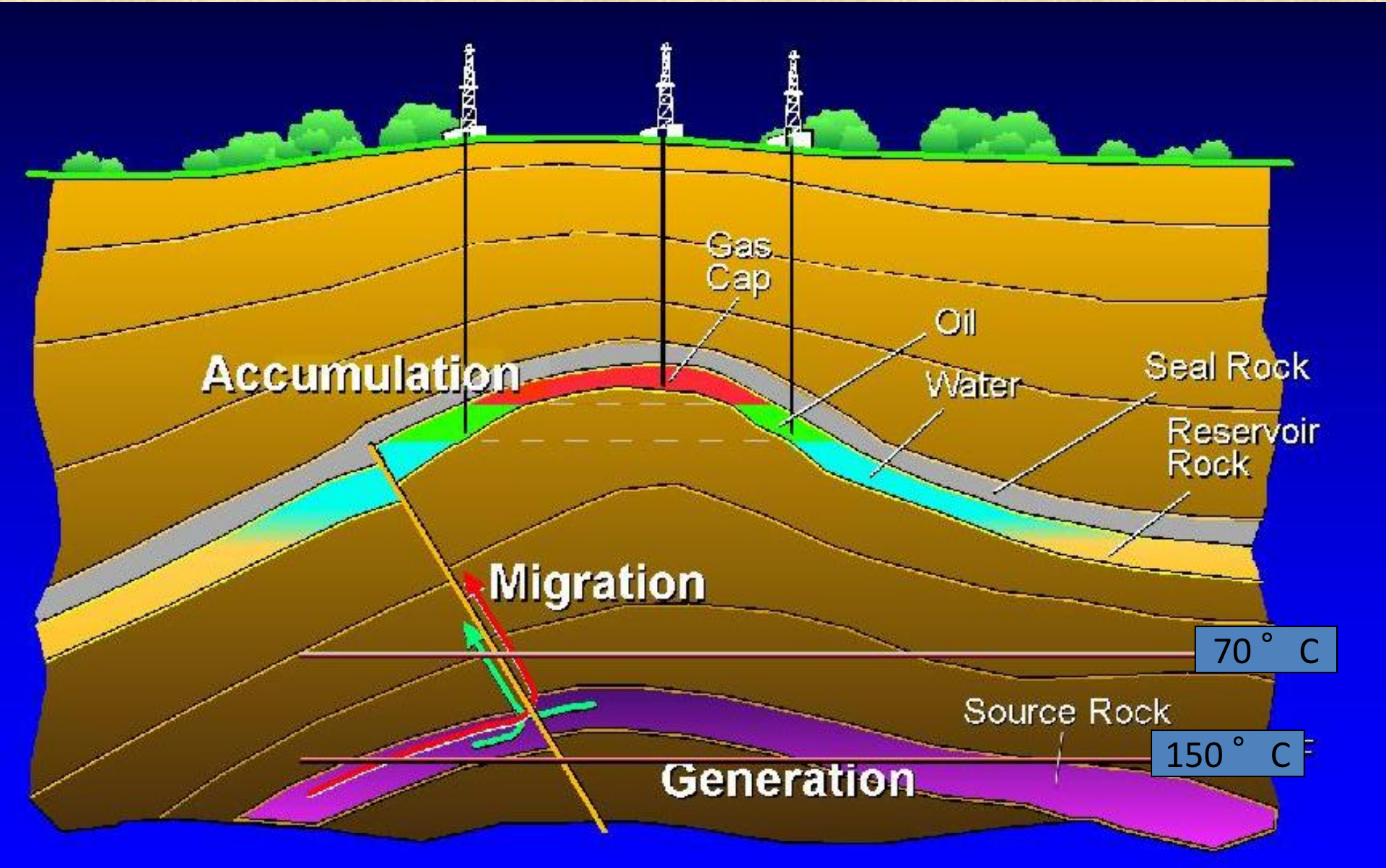
Nuclear power 5-6%

Total ~11 billions Toe/year



UP – Data Book 2011

Oil + gas: the main source, related to the "Petroleum System"



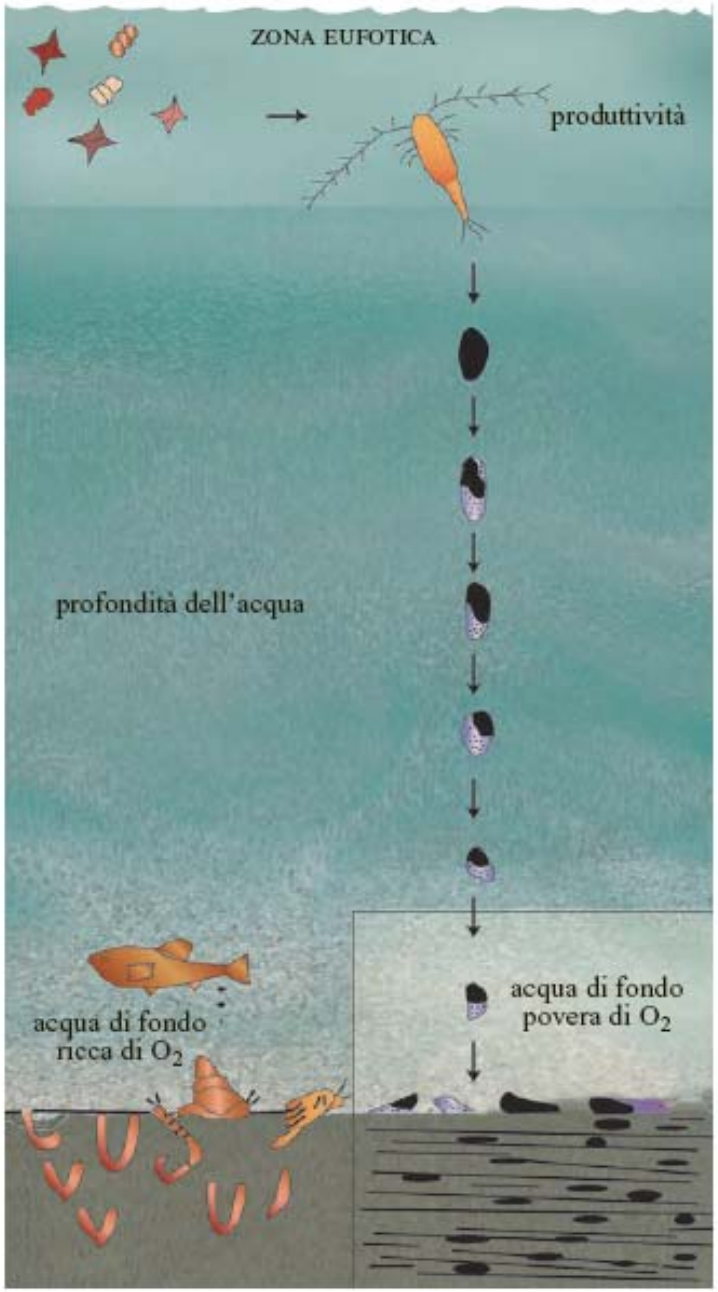
West 2009
www.soton.ac.uk/~imw/kimblack.htm.

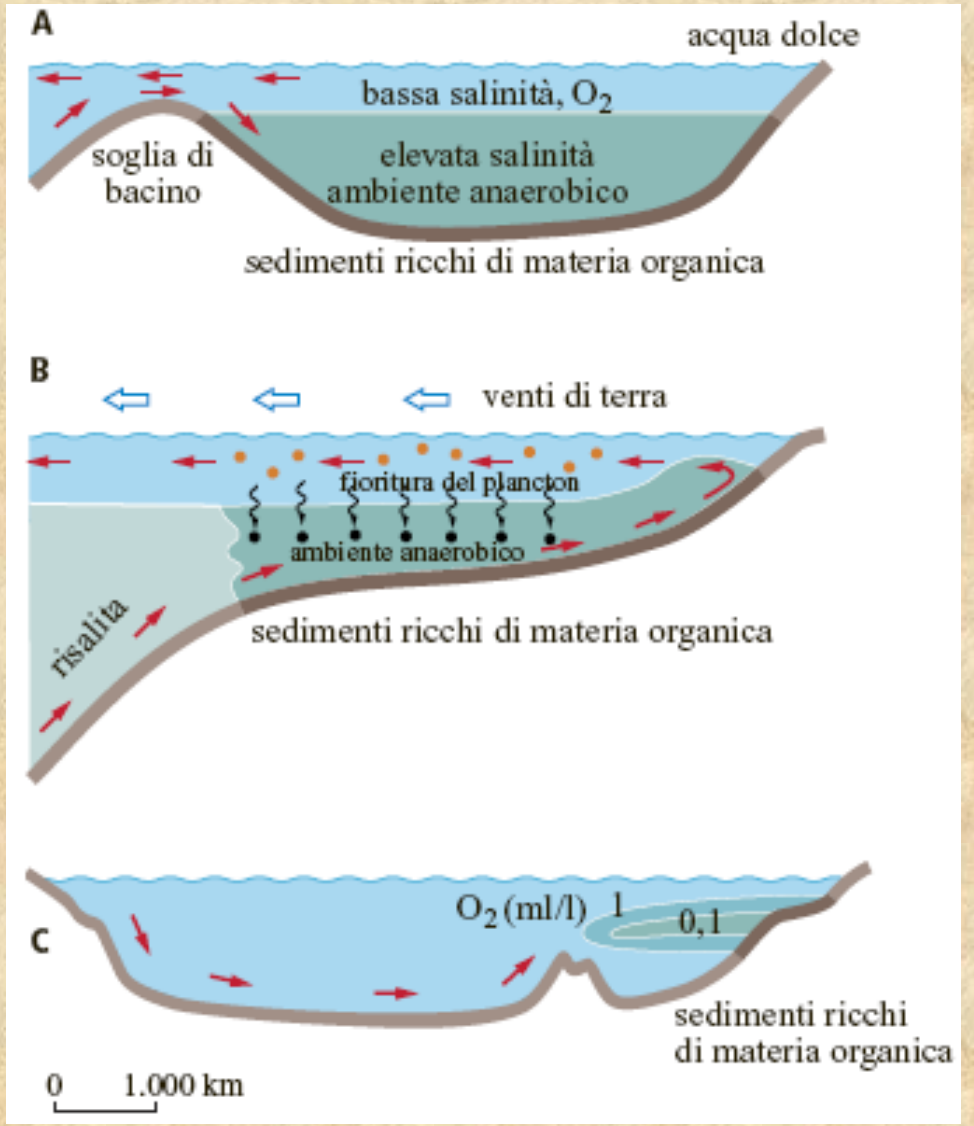
Generation

1. source rock

Kimmeridge clay 20 % organic matter

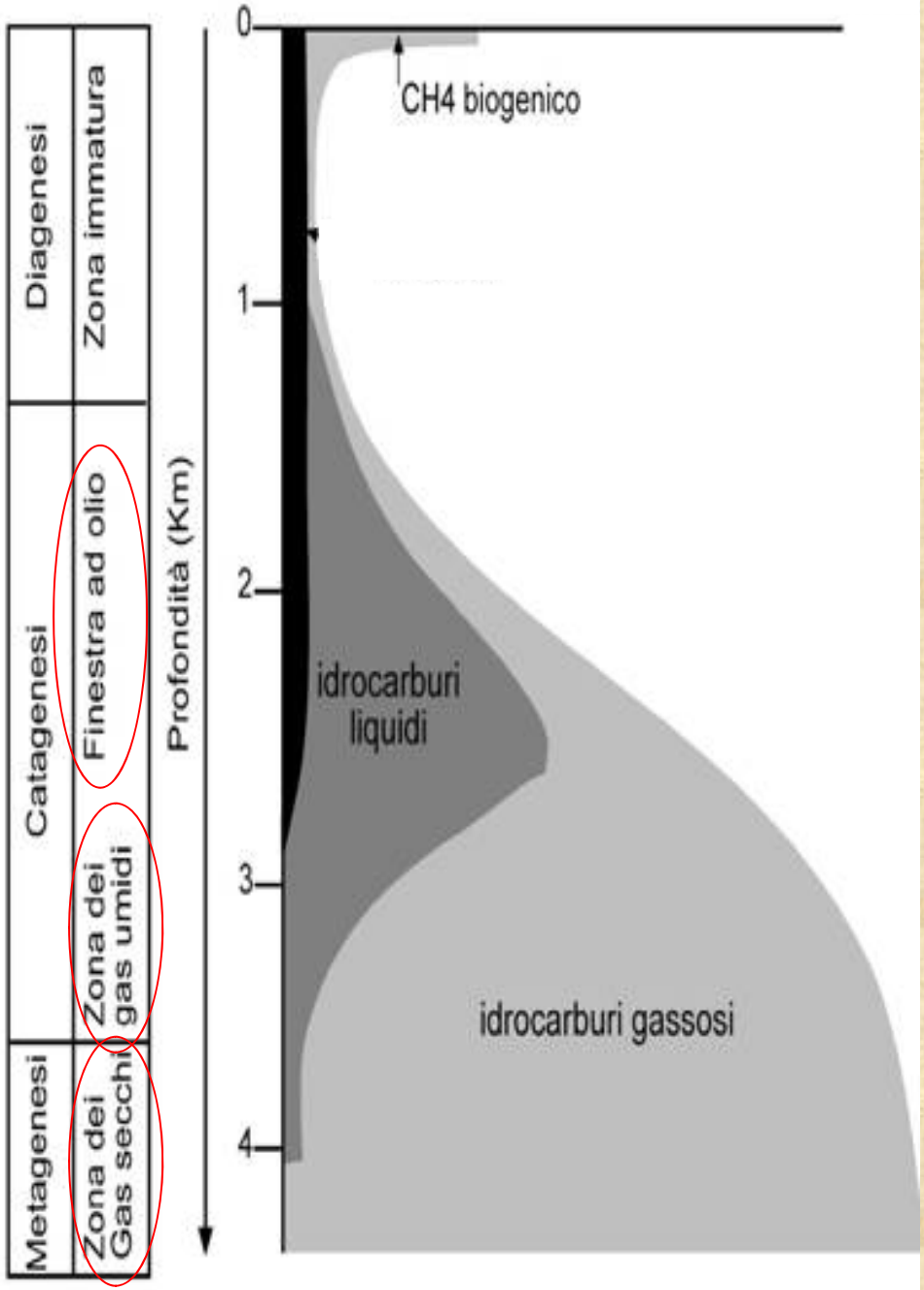
Blackstone 70 % organic matter





deposition of organic matter in anoxic environment

Huc, 2005



2. Trasformations related to burial (increase of P, T)

*Diagenesis: proteins and carbohydrates break down to form new structures that comprise a waxy material known as "**kerogen***" and a black tar like substance called "bitumen"*

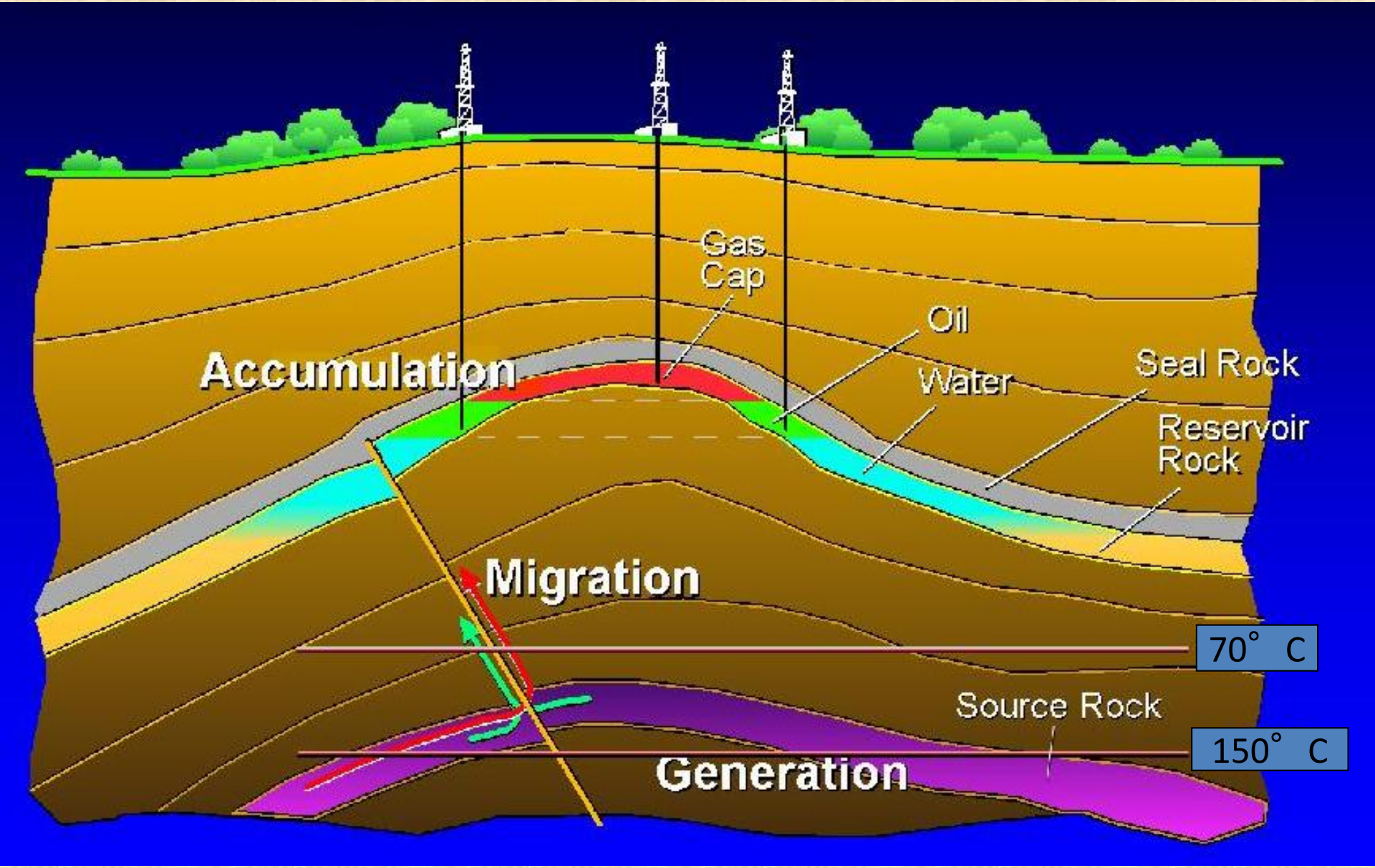
*Catagenesis: as temperatures and pressures increase (deeper burial) the process of catagenesis begins, which is the thermal degradation of kerogen to form **hydrocarbon chains***

"oil window"

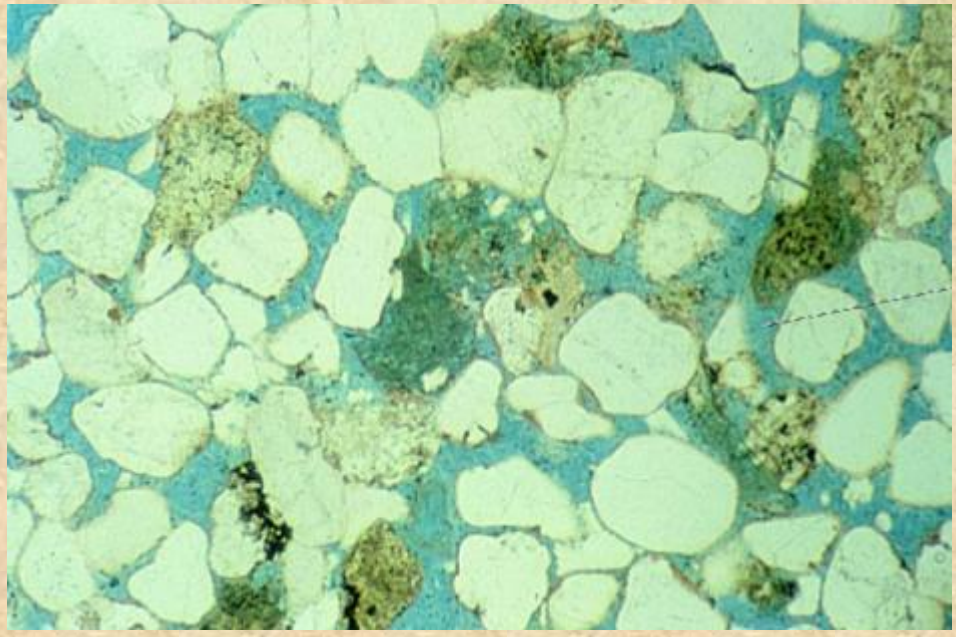
Metagenesis: "dry gas" (metano)

** Complex mixture of substances with high molecular weight*

Migration and Accumulation



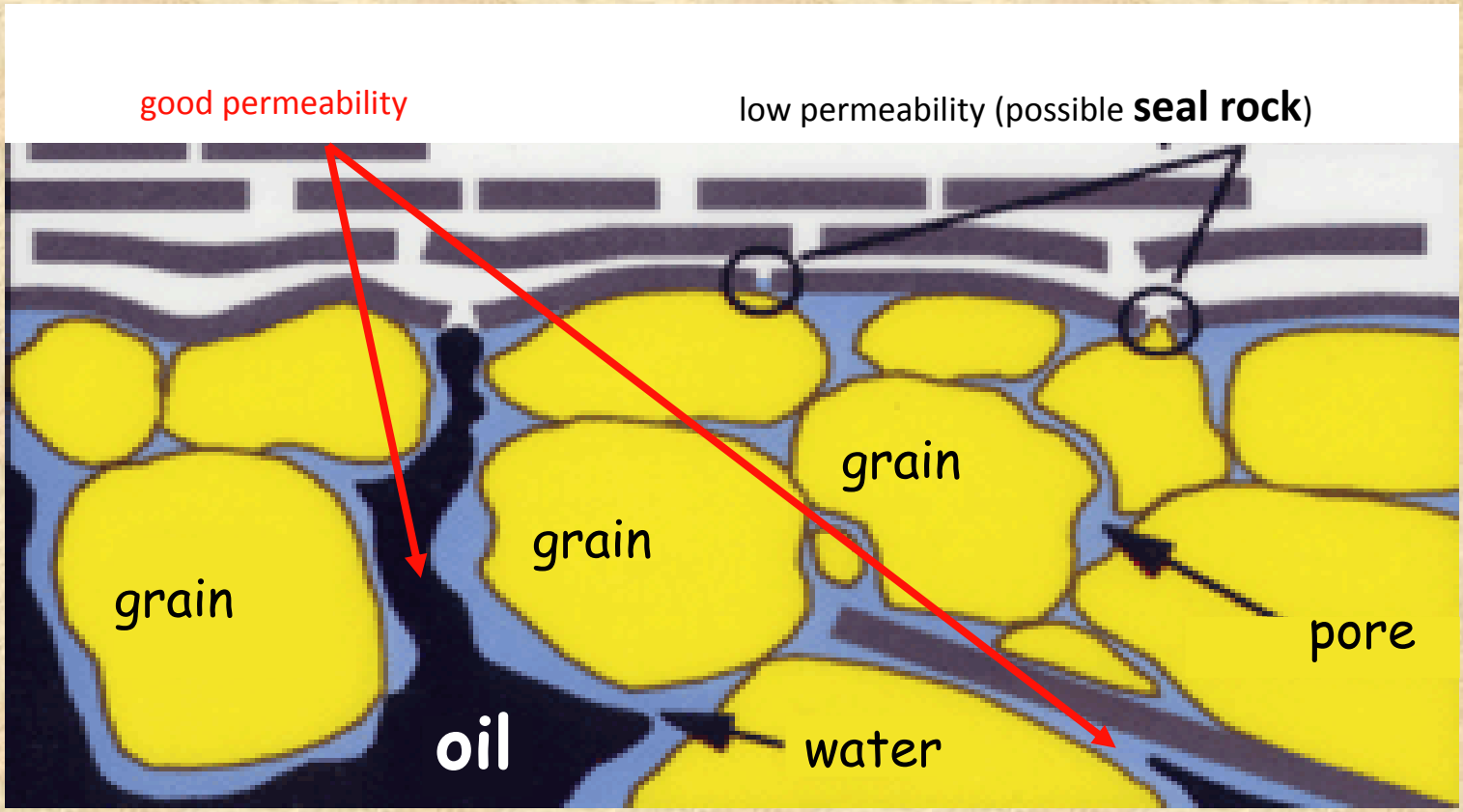
in the reservoir



“Clean” sandstone, well sorted and not cemented: a perfect reservoir rock

Clay

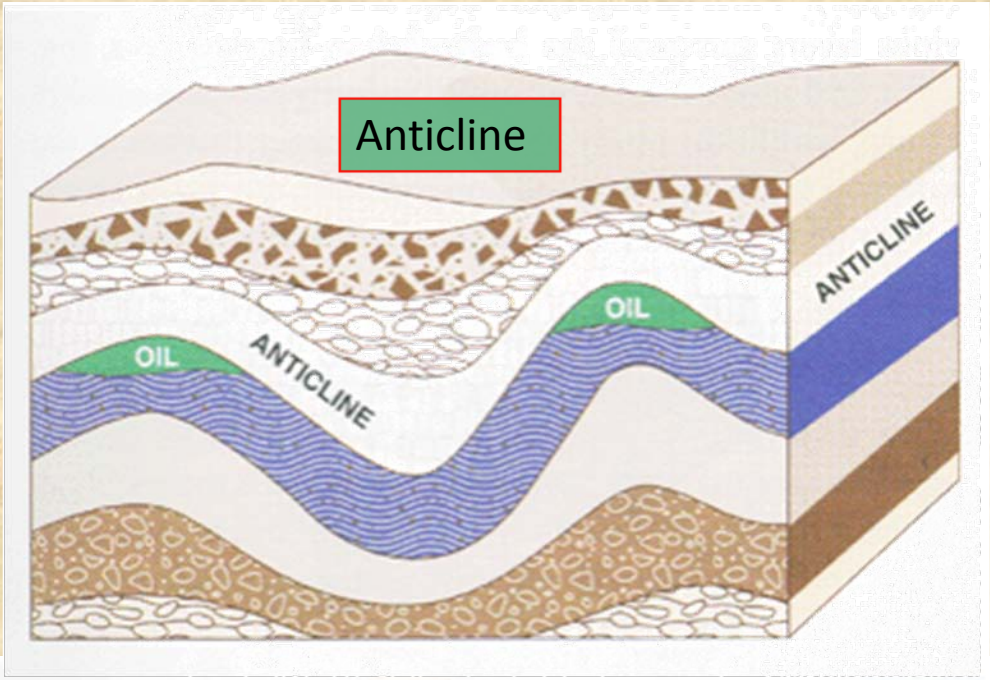
Sandstone

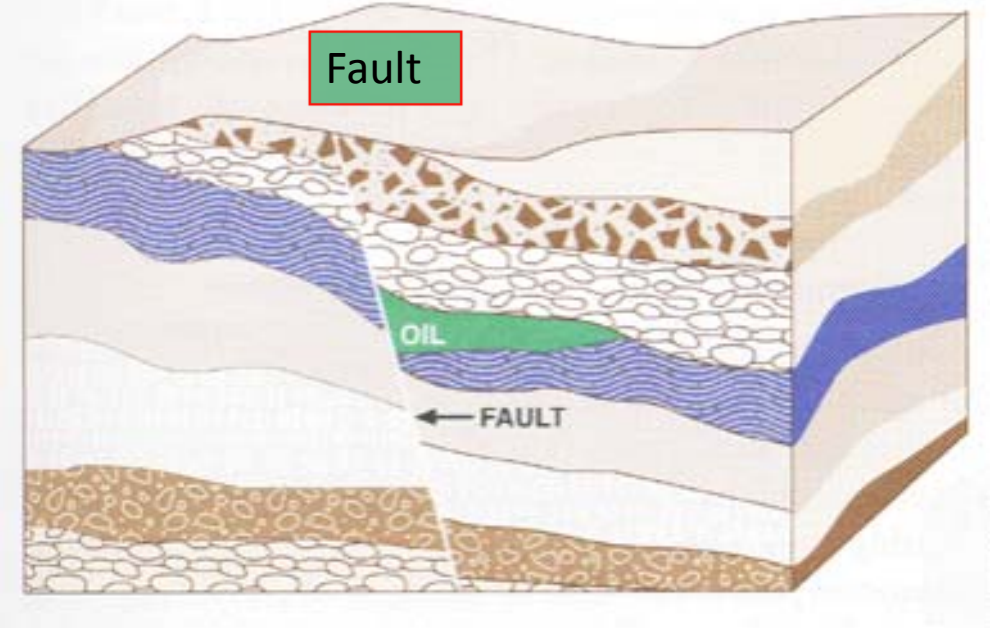


Petroleum seep in California

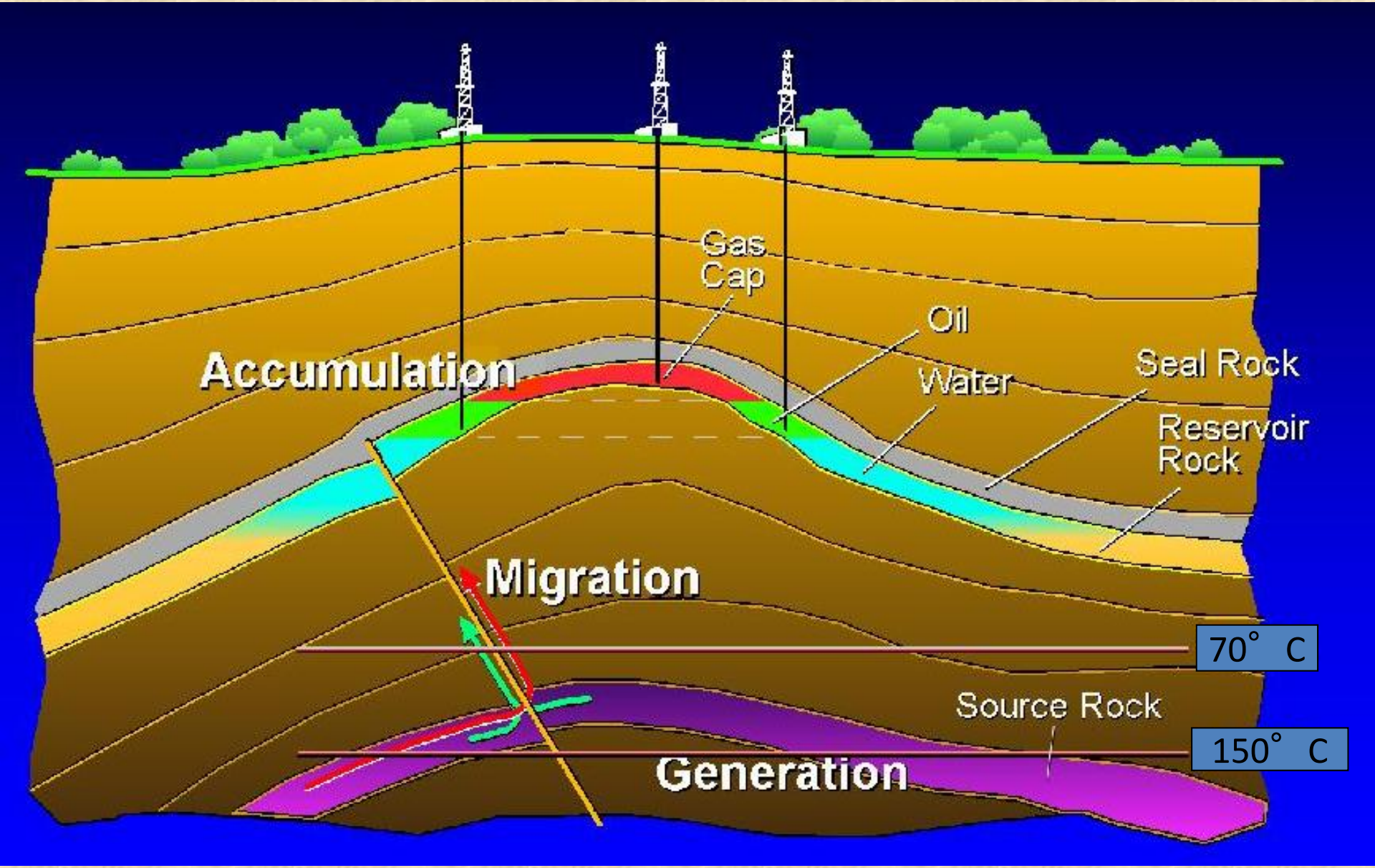
Hydrocarbons pool at Trinidad

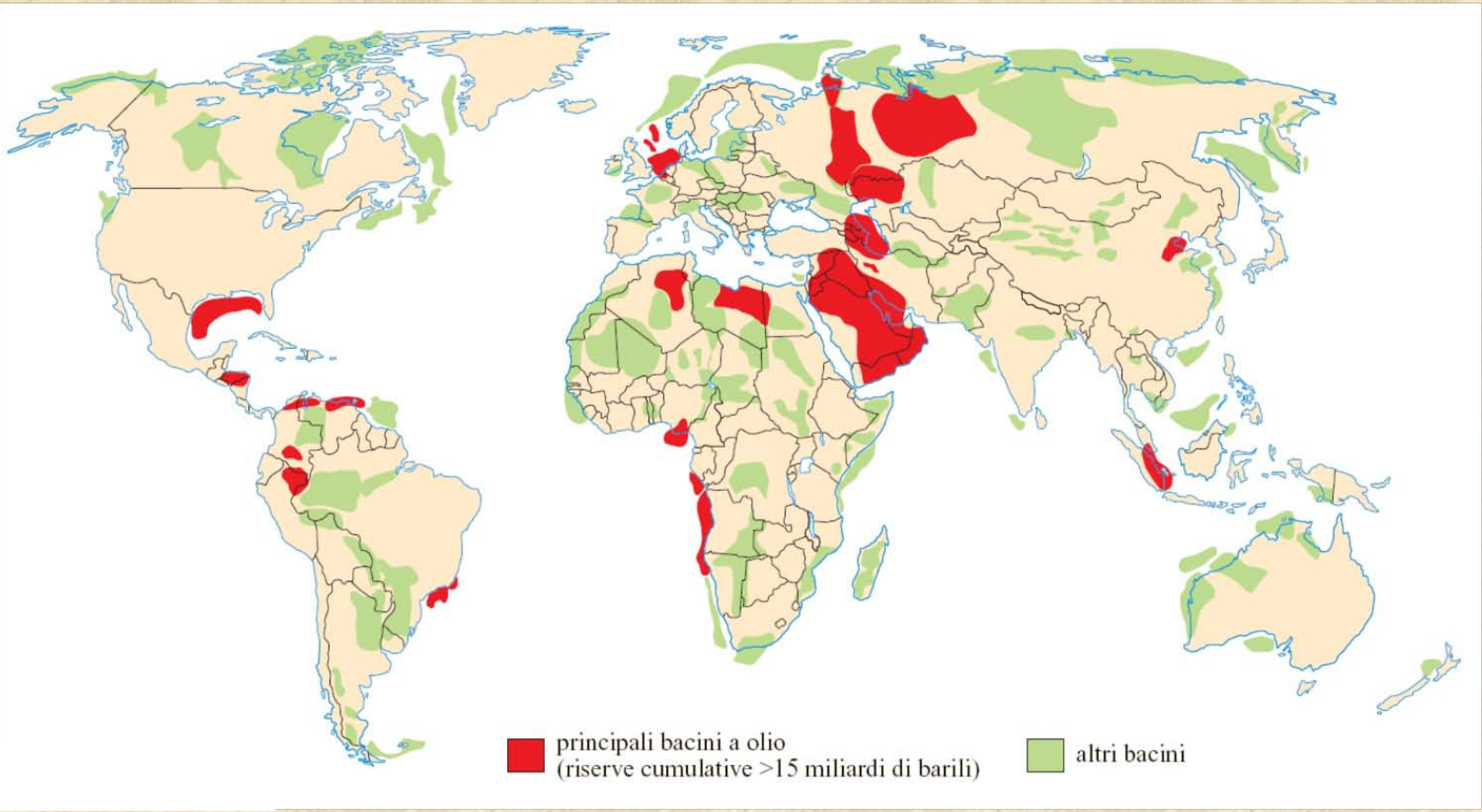
Hydrocarbons Traps





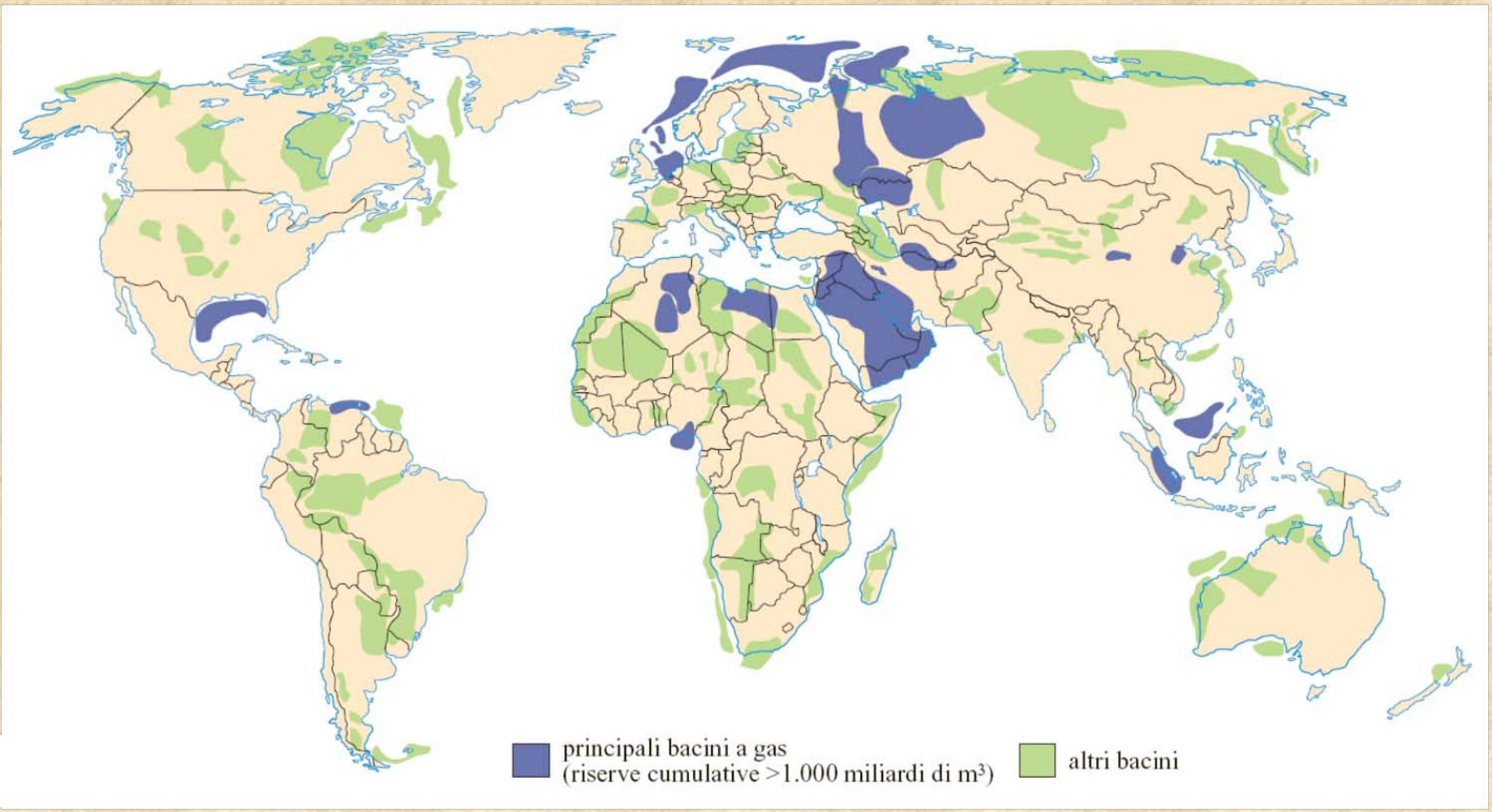
Anticline structures cropping out in Iran


Gas
Cap
Oil
Water
Seal Rock
Reservoir
Rock
Accumulation
Migration
70° C
Source Rock
150° C
Generation



Megagiant: > 50 billion barrels (= 6,8 billion t)
Supergiant: 5-50 billion barrels
Giant: da 0.5-5 billion barrels

Prato, 2005

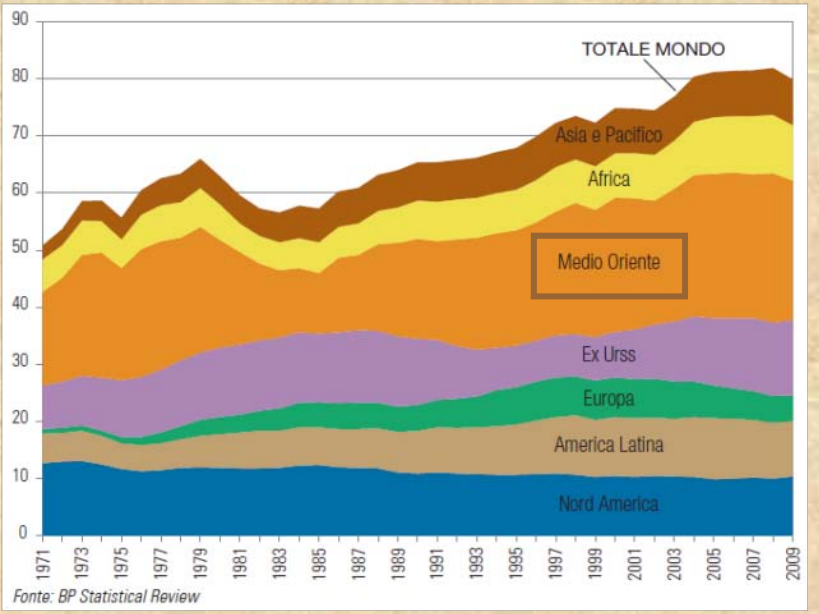


Supergiant: > 850 billion m^3
Giant: 85-850 billion m^3
Major: 17-85 billion m^3

Prato, 2005

World production

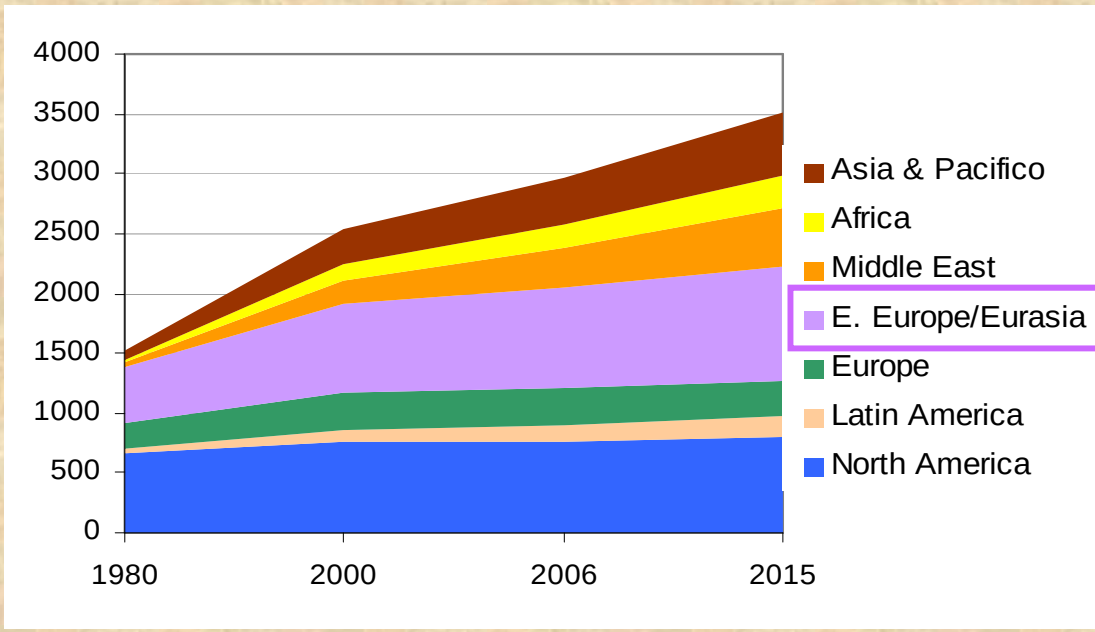
oil



Million barrels/day

UP data book 2011

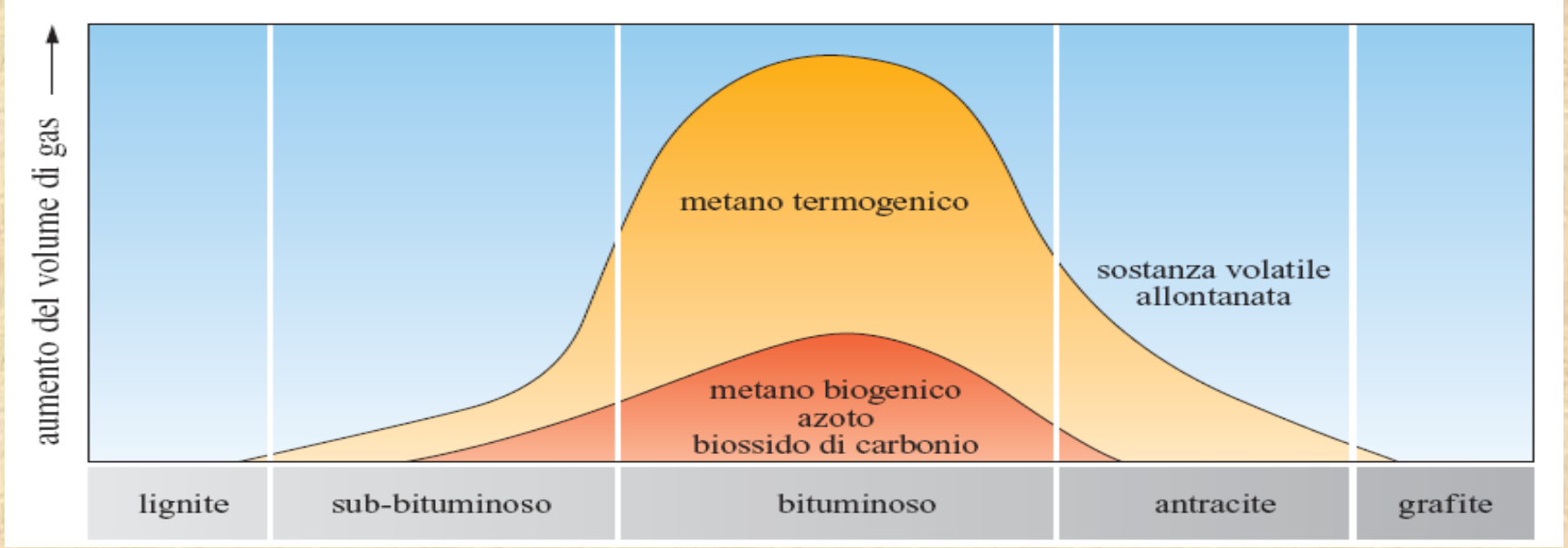
gas

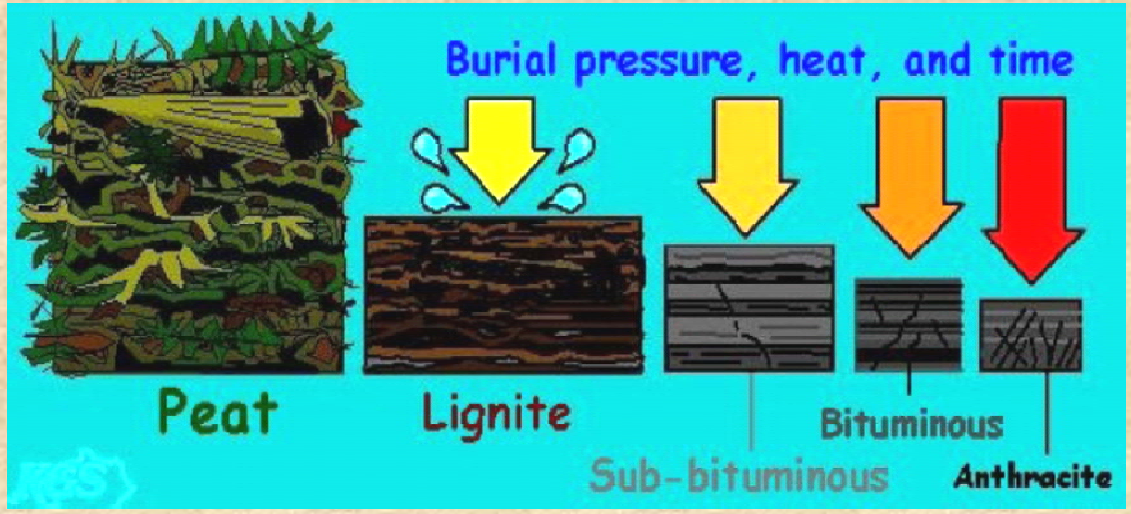


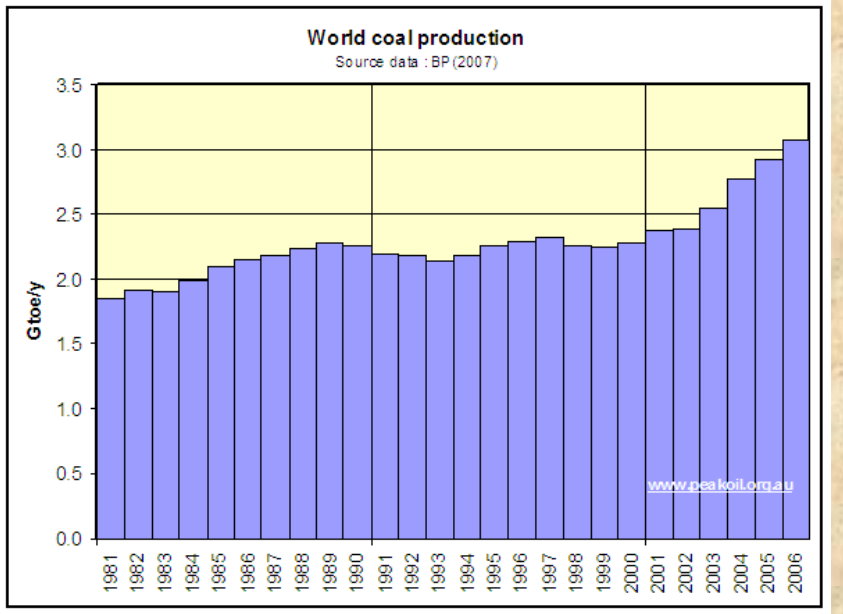
Billion cubic metres

drawn from World Energy Outlook 2008

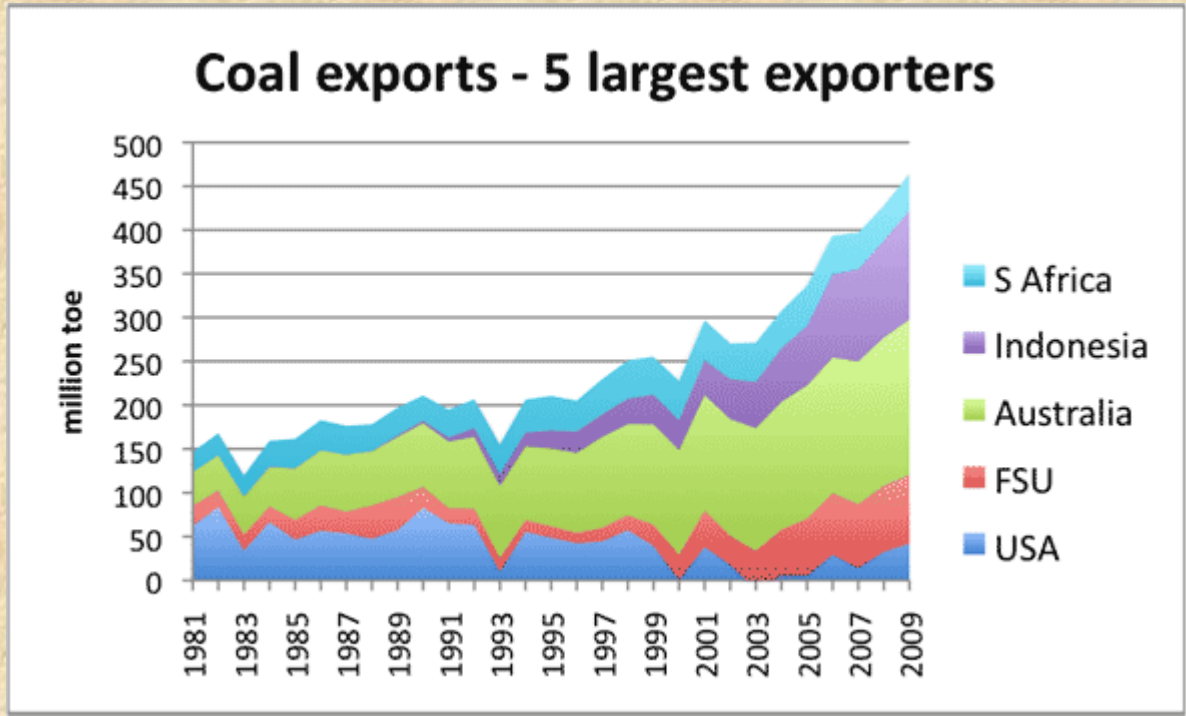
Absaloko coal mine, Montana


aumento del volume di gas
metano termogenico
sostanza volatile allontanata
metano biogenico
azoto
biossido di carbonio
lignite
sub-bituminoso
bituminoso
antracite
grafite


Burial pressure, heat, and time
Peat
Lignite
Sub-bituminous
Bituminous
Anthracite



Anderson et al., 2003




Uranium

Primary Uranium source:

Acidic magmatic rocks (e.g., granite-rhyolite)

	Basalt	Andesite	Rhyolite	Alkaline magma	Kimberlite	Clarke*
U	0.1–0.6	0.8	5	10	–	2.7
Th	0.2	1.9	26	35	–	7.2

data in ppm

Uranium concentrations

- Acidic magmatic differentiates/hydrothermal solutions

Rossing, Namibia

Uranium in nature:	quadrivalent uranous ion, **U^{4+}** hexavalent uranyl ion, **U^{6+}**

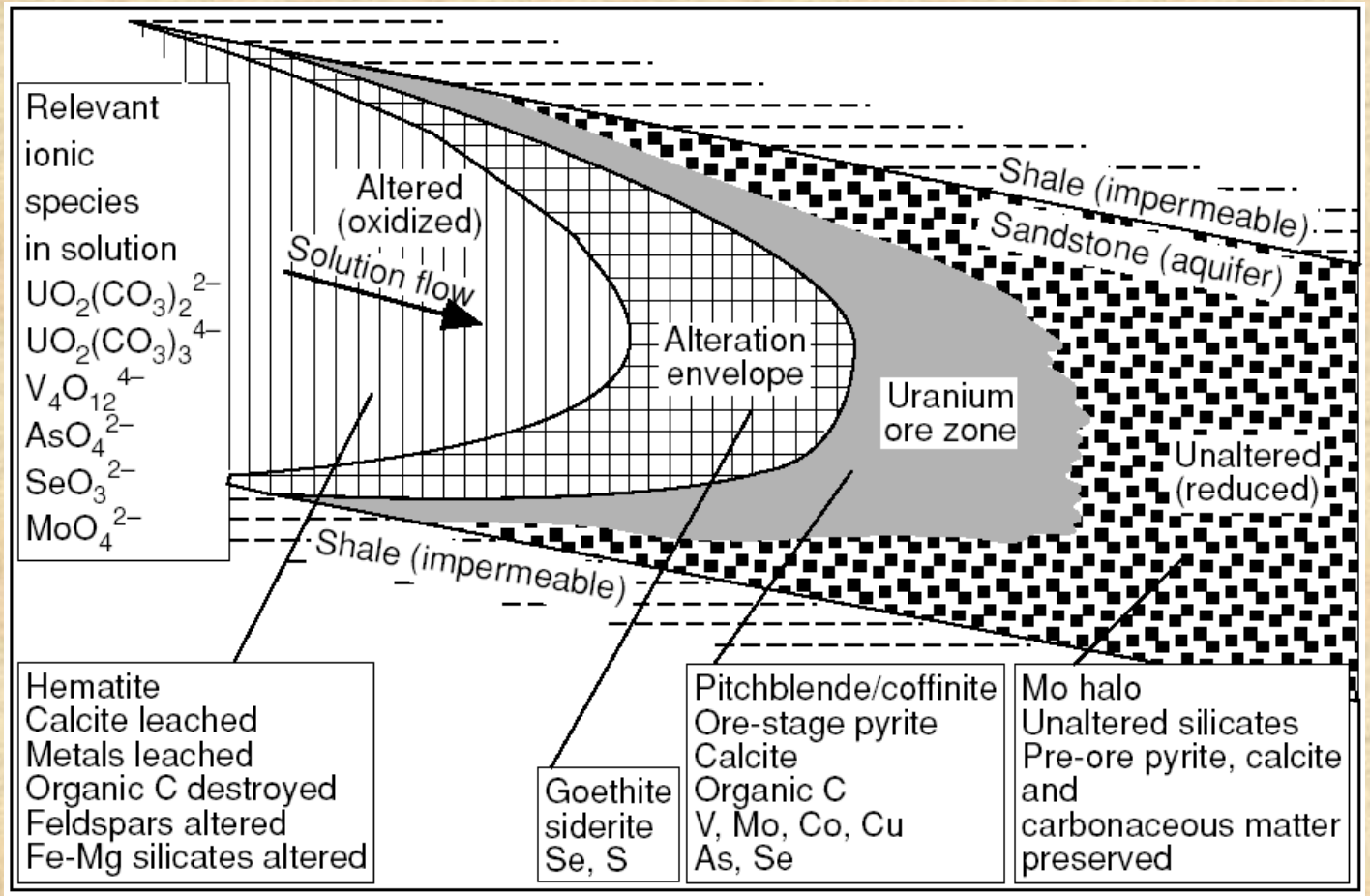
The uranous ion (U_4^+) is generally characterized by very low solubilities in aqueous solutions and most fluid-related transport takes place as U^{6+}.

Most Uranium deposits occur **within sedimentary rocks**
deriving from weathering/erosion of magmatic rocks

Due to the strongly different behaviour of U^{4+} and U^{6+}, uranium strongly concentrates when a change of oxidation state occurs.

Uranium is easily taken to solution as U^{6+}; solubility drops down when reducing conditions are met.

Redox fronts behave, therefore, as **geochemical barriers and uranium traps**



Typical redox front, which behaves as a uranium trap, in sandstone ("roll-front uranium deposit")


ox
red

Calcrete (caliche) (= calcified soils in arid climate) – hosted superficial deposits

Uranium minerals: pitchblende, uraninite U_3O_8

coffinite $U(SiO_4)_{1-x}(OH)_{4x}$

carnotite $K_2(UO_2)_2(V_2O_8)\ 3H_2O$

Uranium mining

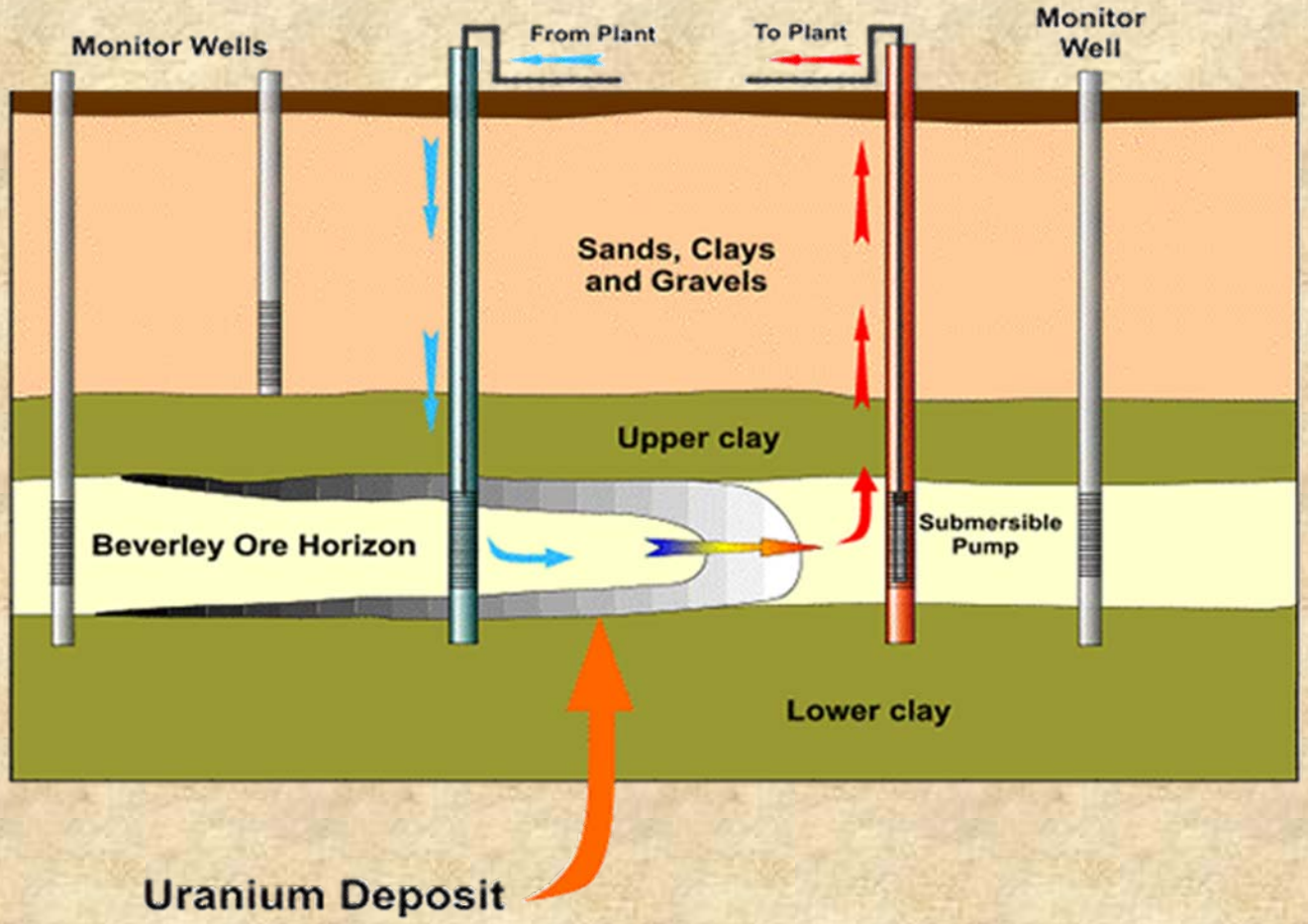
Open-pit mining

Underground mining

Problem: radon gas

Heap leaching

In-situ leaching (ISL)
solution mining
in-situ recovery (ISR)



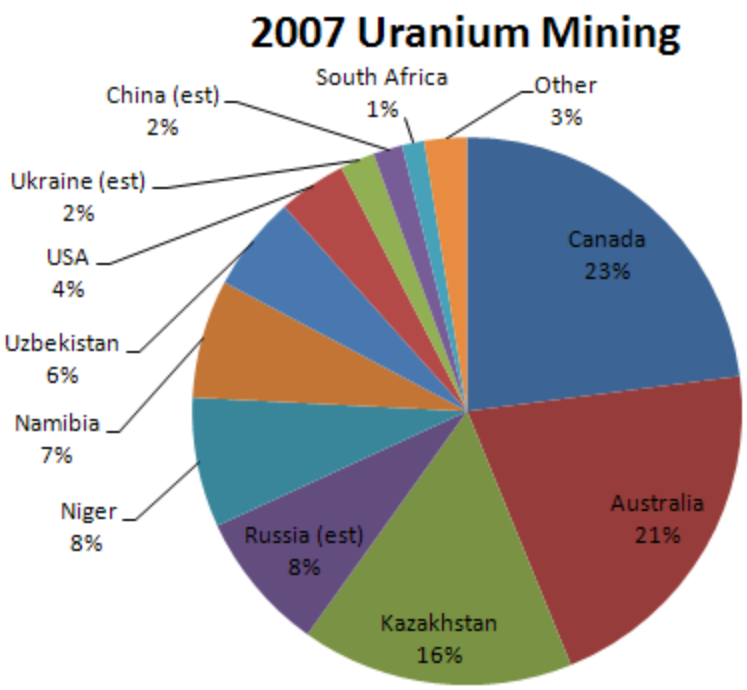
Recovery from seawater (?)

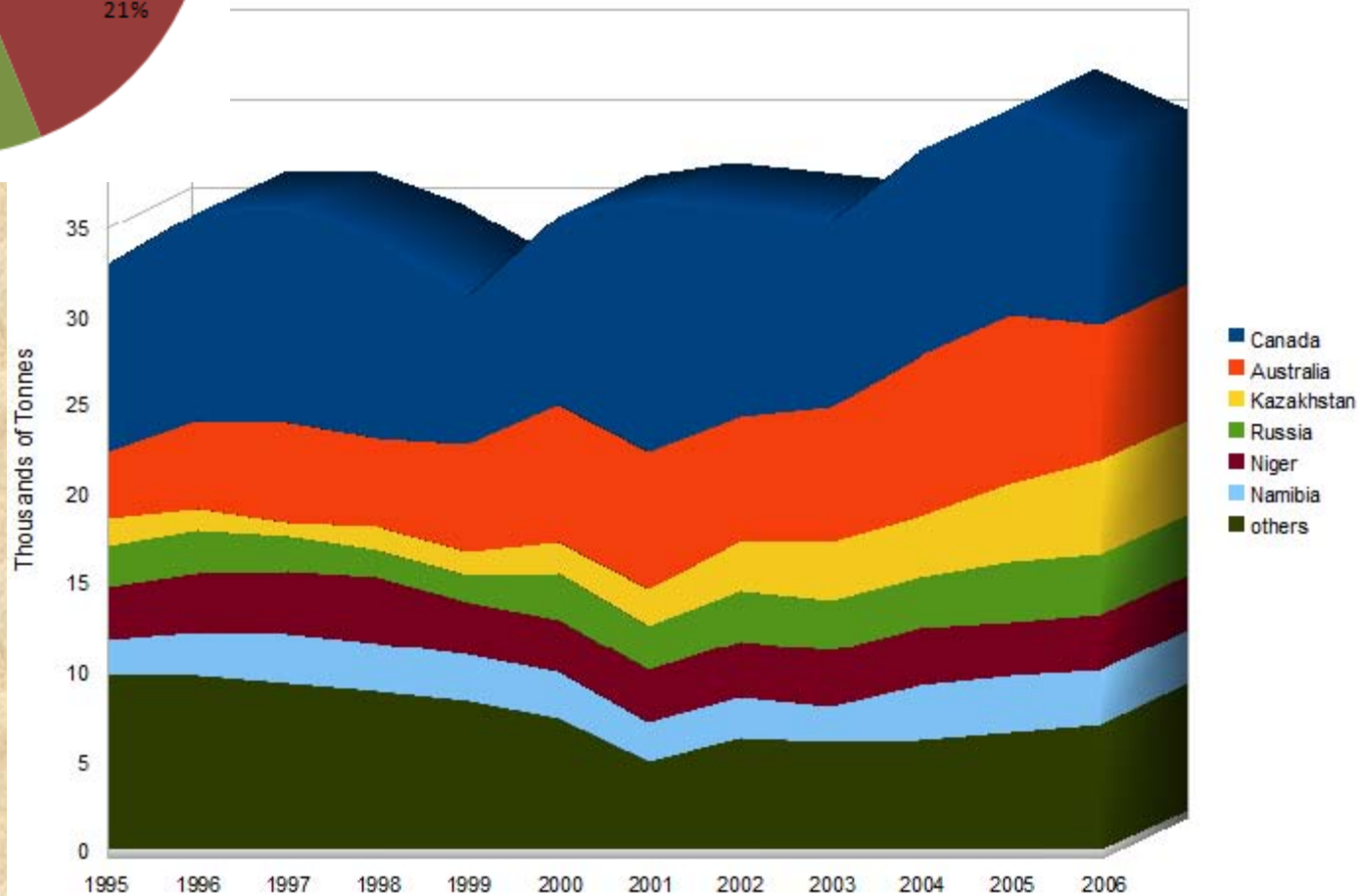
U in seawater: ca. 3.3 ppb

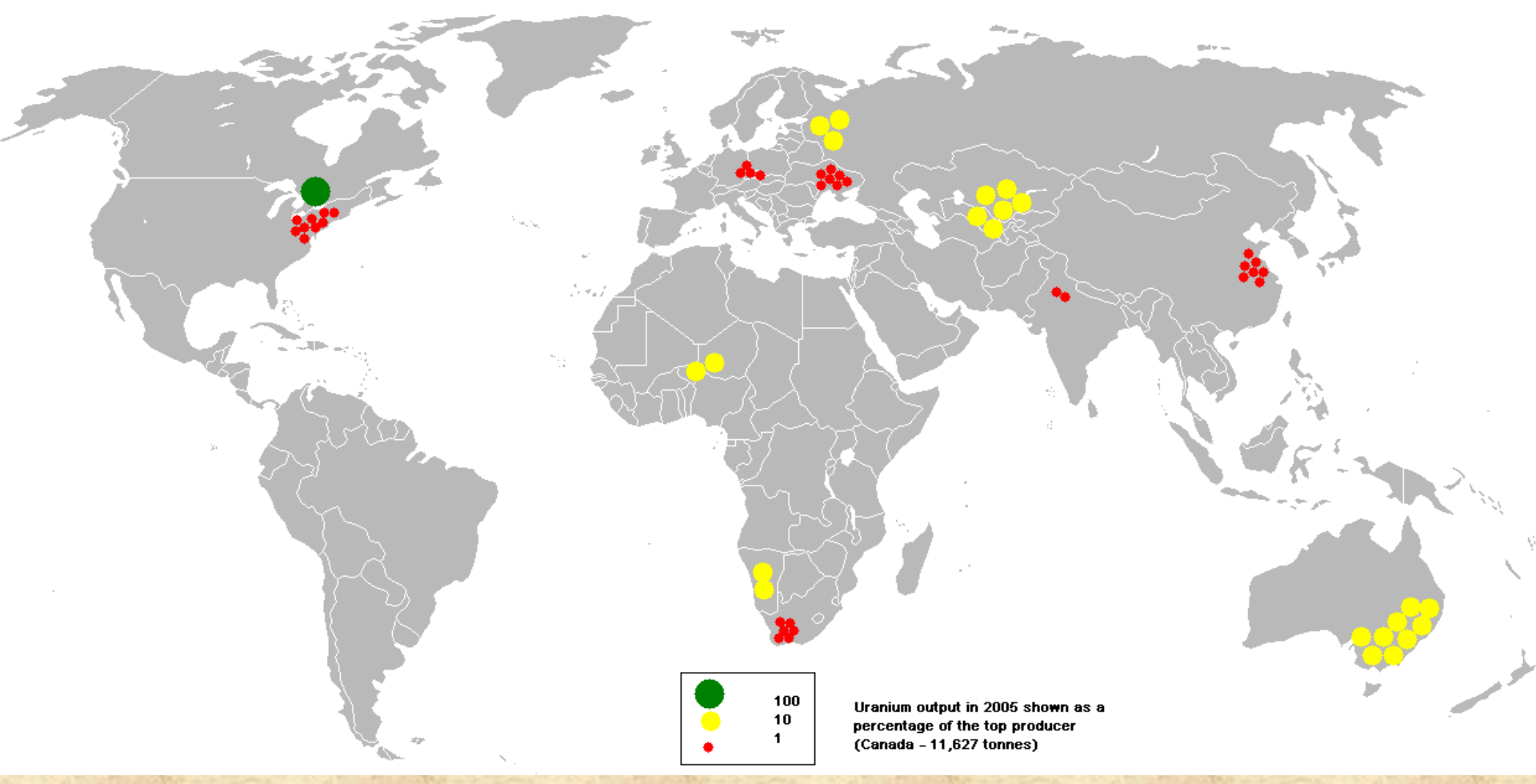
recovery of U by inorganic adsorbents such as titanium oxide or polymer fiber adsorbents?

After mining, ore is processed by grinding the ore material to a uniform particle size and then treating the ore to extract the uranium by chemical leaching.

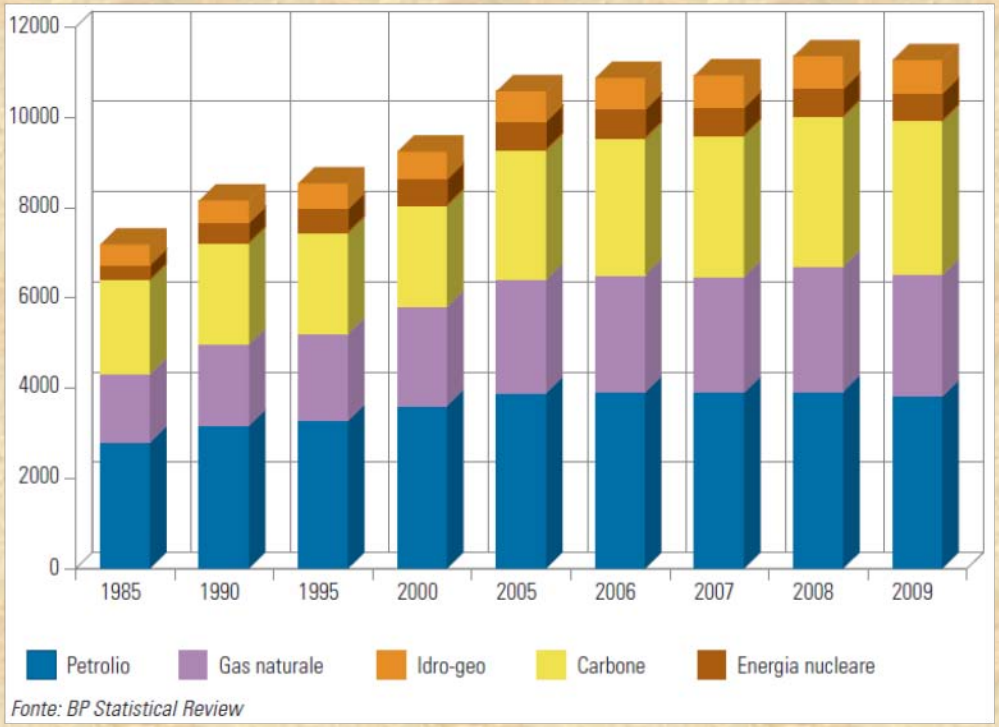
The milling process commonly yields dry powder-form material consisting of natural uranium, **yellowcake**, which is sold on the uranium market as U_3O_8.

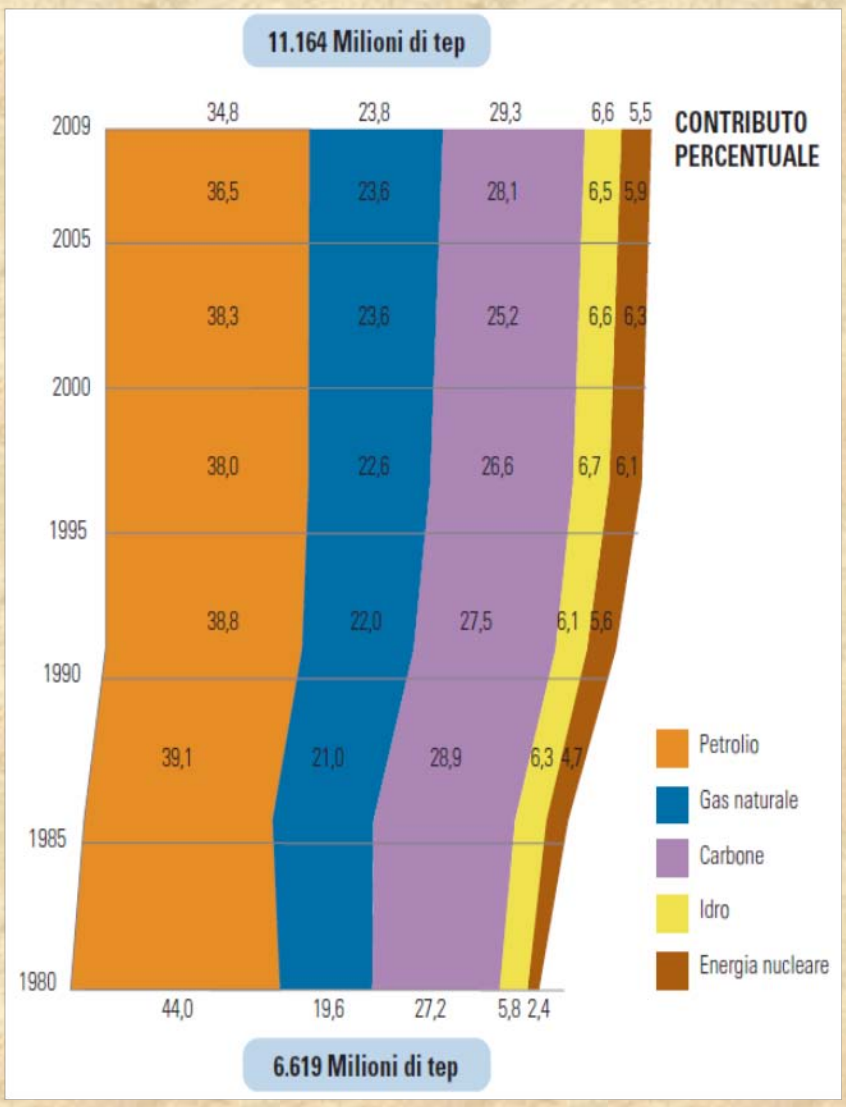

2007 Uranium Mining
China (est) 2%
South Africa 1%
Other 3%
Ukraine (est) 2%
USA 4%
Uzbekistan 6%
Namibia 7%
Niger 8%
Russia (est) 8%
Kazakhstan 16%
Australia 21%
Canada 23%


Thousands of Tonnes
0
5
10
15
20
25
30
35
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Canada
Australia
Kazakhstan
Russia
Niger
Namibia
others


100
10
1
Uranium output in 2005 shown as a percentage of the top producer (Canada – 11,627 tonnes)

The overall consumption



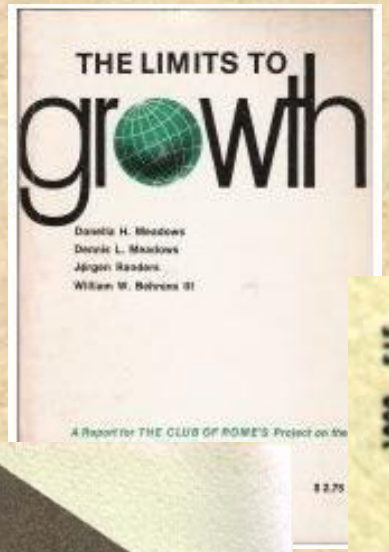


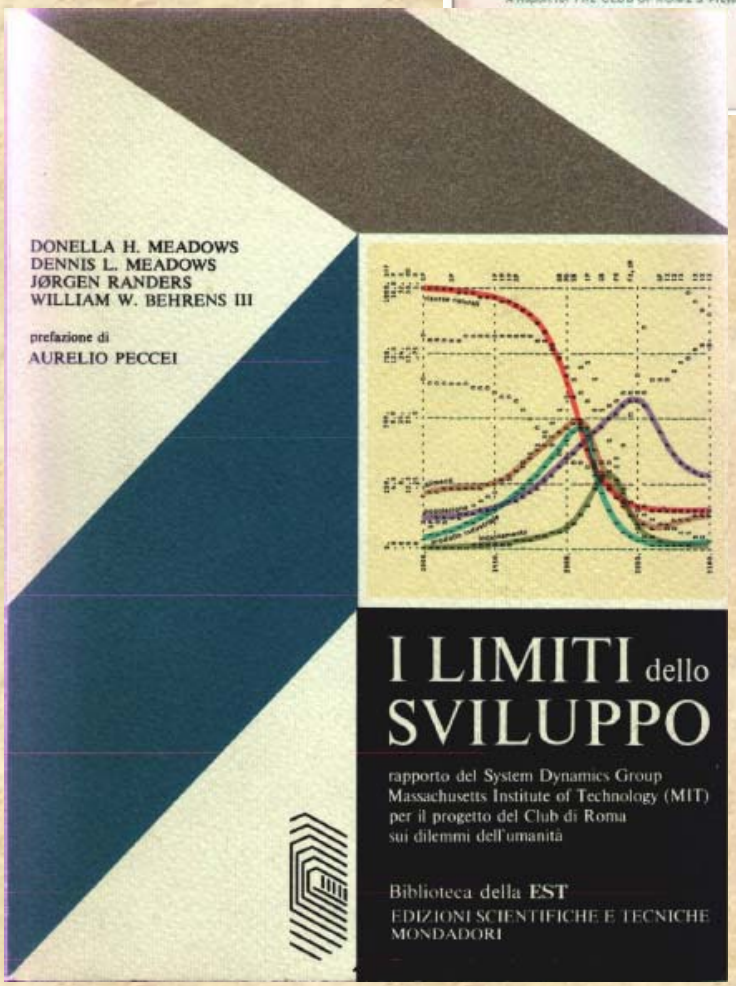
2009: ~11.3 milions toe

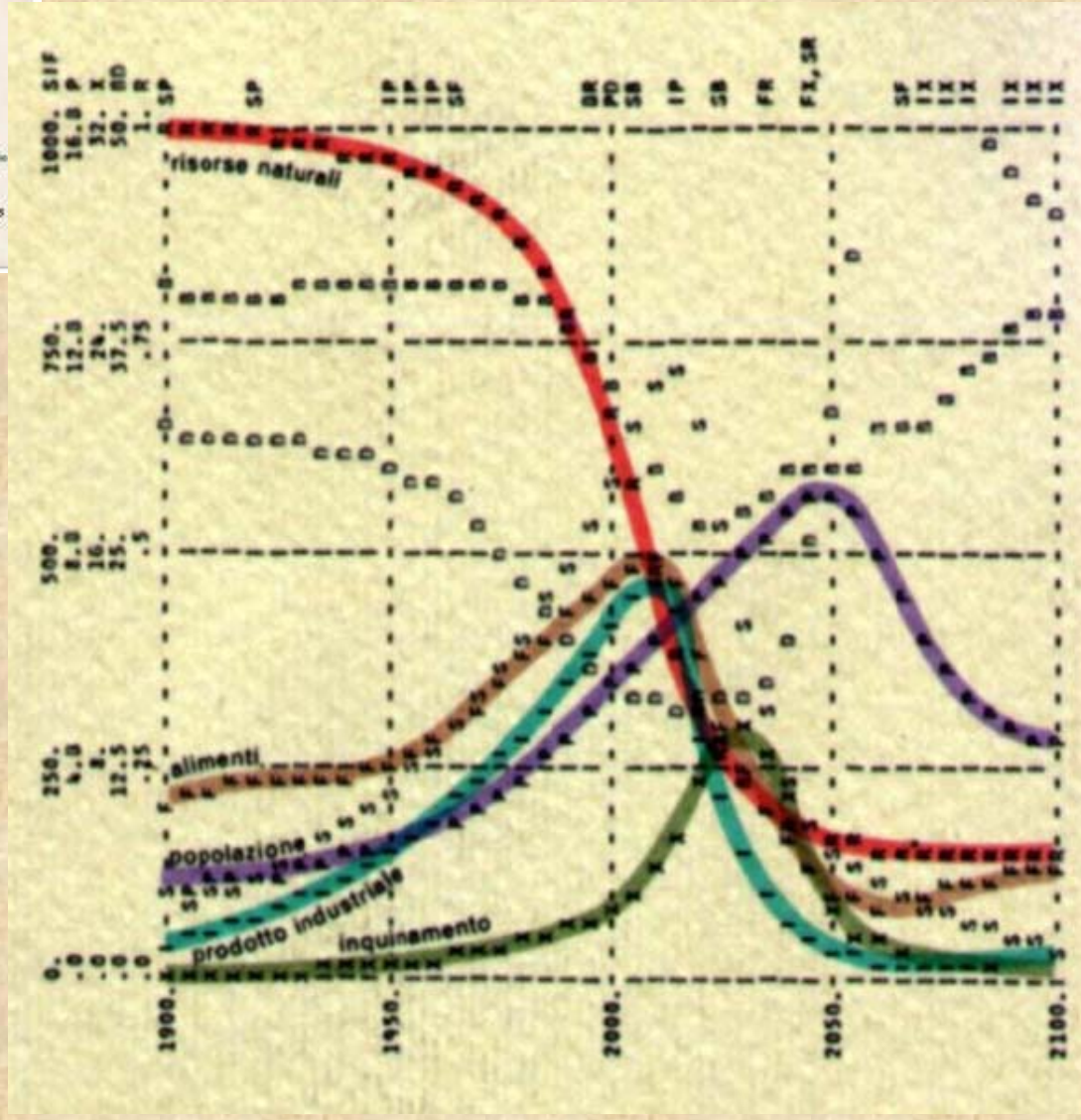
da UP data book 2011

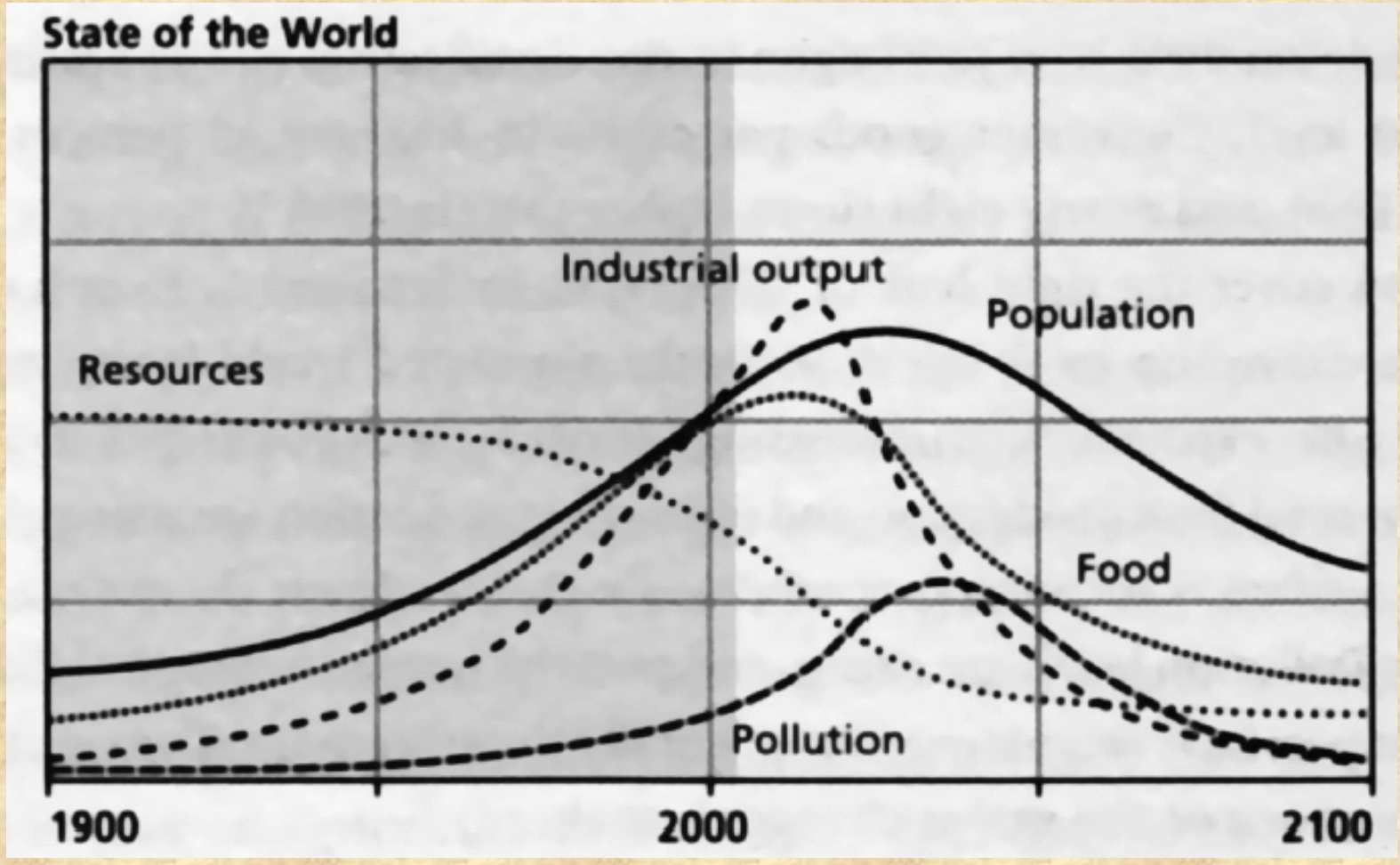
What are the reserves?

1972: Club di Roma: “The limits to growth”

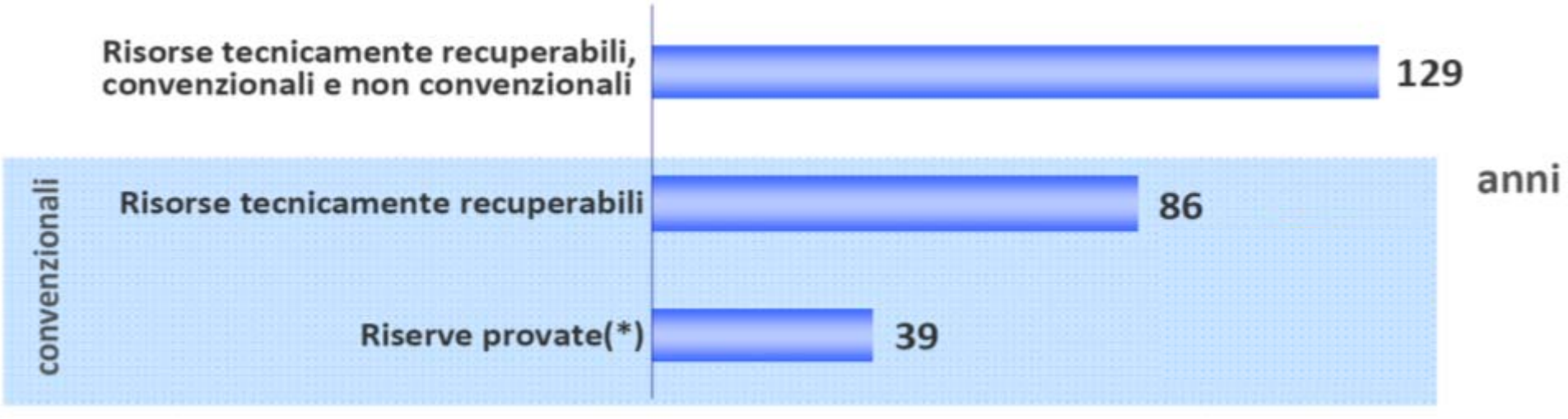


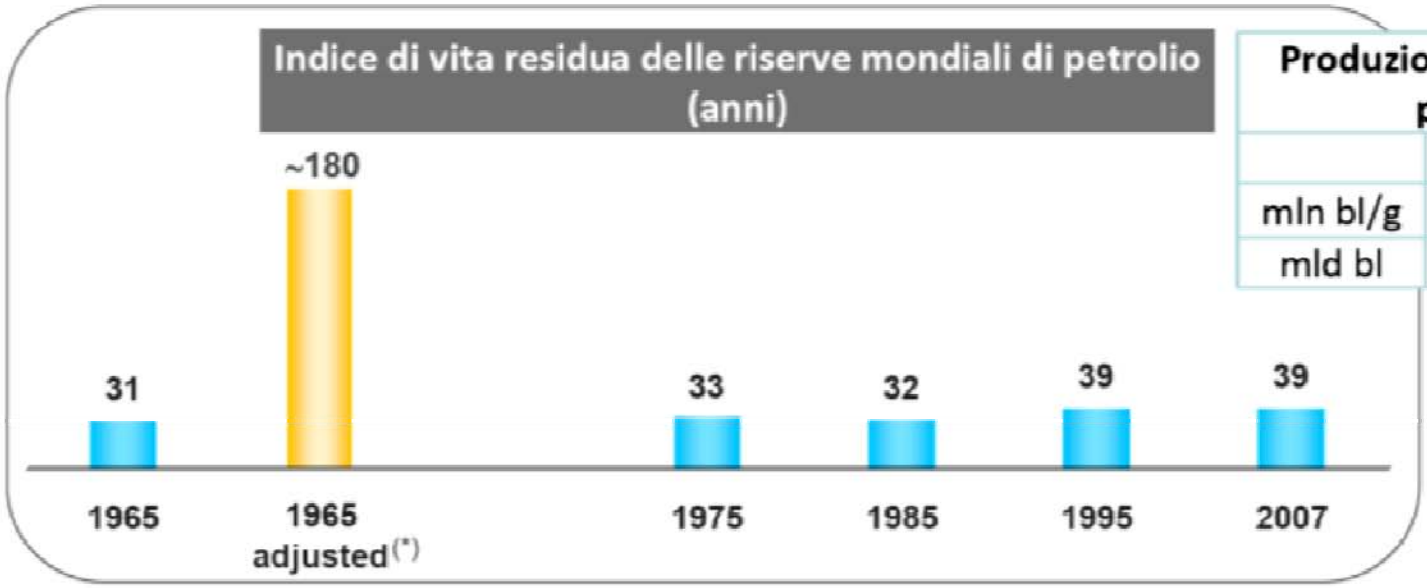





State of the World
Industrial output
Population
Resources
Food
Pollution
1900
2000
2100

Reserves estimates: Oil



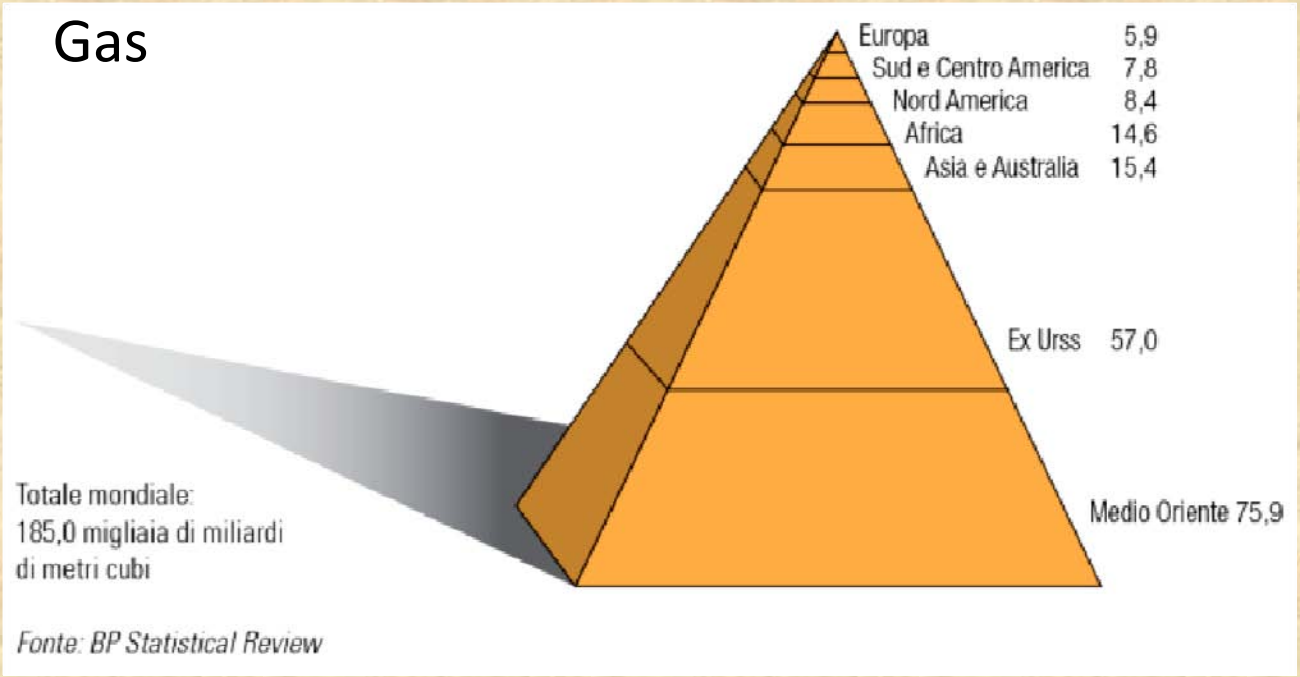


Produzione mondiale di petrolio	1965	2007
mln bl/g	32	83
mld bl	12	31

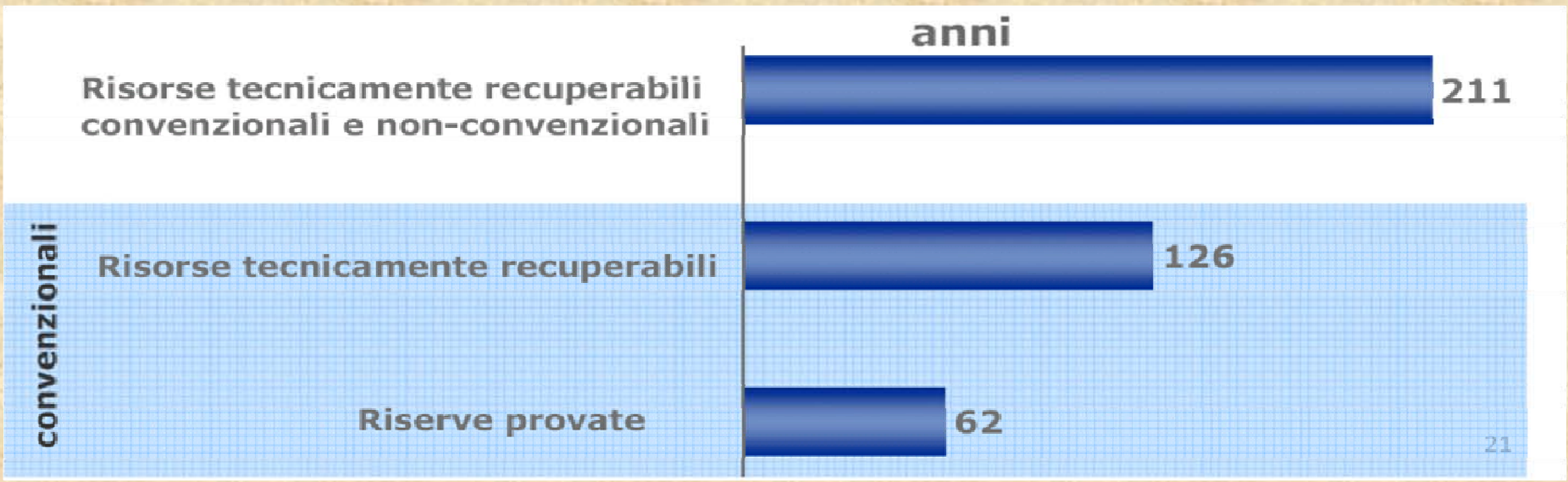
(*) Calcolato sommando alle riserve di fine 2007 la produzione cumulata dal 1966 a oggi

mod. da Pino 2010

Gas



da UP data book 2010

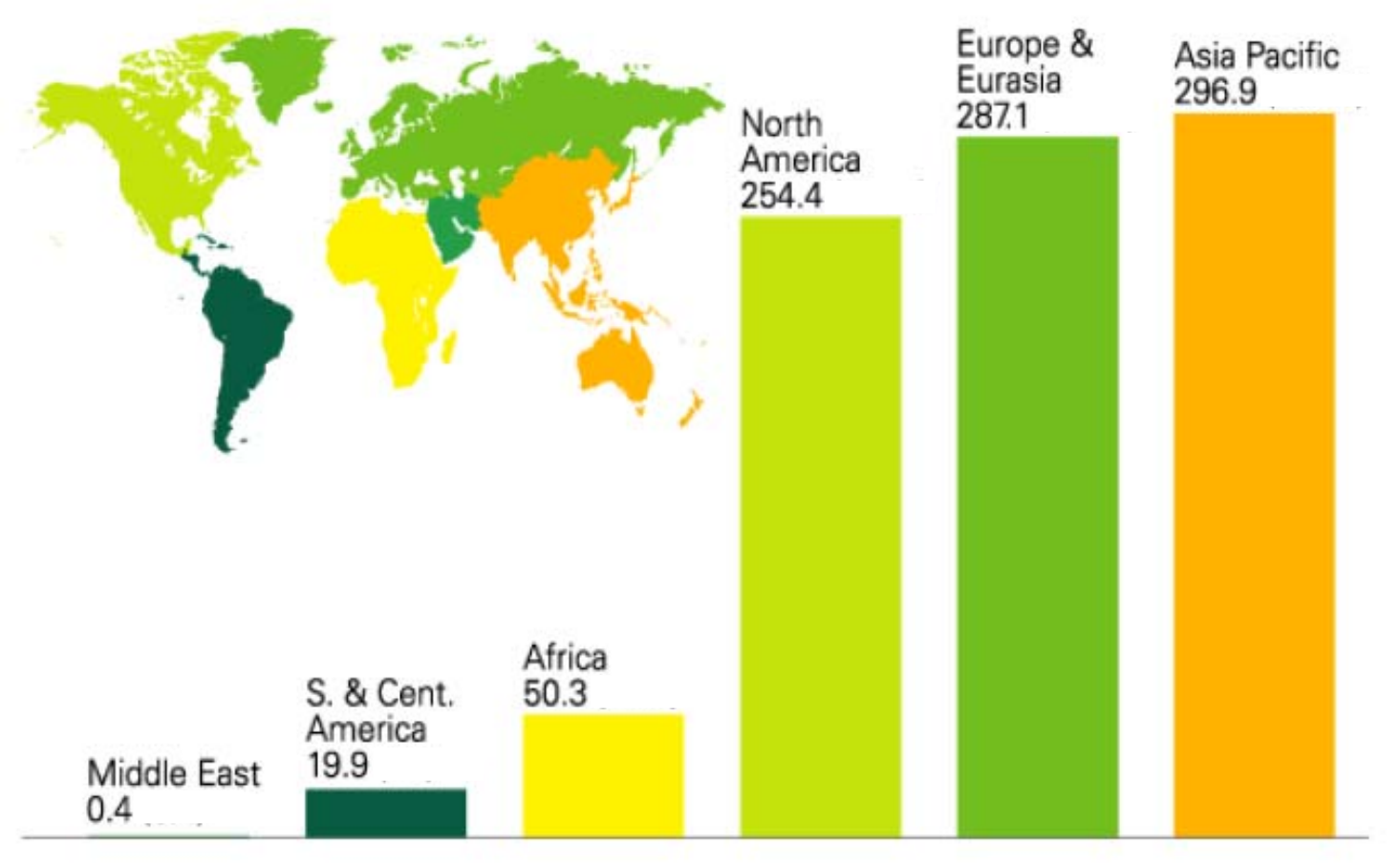


Proven reserves ~180 trillion cubic metres. Three countries – Russia, Iran, Qatar - hold 56%

Pino, 2010

Coal

Reserves ~ 220 years



$t \cdot 10^9$

data 2009 mod. from Energy & Resourse Institute

IAEA, www. iaea.org

Uranium?