Petroleum Geology

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Coursework and schedule

Introduction to petroleum geology: petroleum system and play
The Occurrence of Petroleum:composition,origin and generation
The Occurrence of Petroleum:Fluids,T,P in subsurface,oil migration
Geological Characteristics of Petroleum Systems:the reservoir
Geological Characteristics of Petroleum Systems:the reservoir
Geological Characteristics of Petroleum Systems:traps and seals
Methods of exploration and production:well drilling and production
Unconventional petroleum resources
Formation evaluation:wireline logs part 1
Formation evaluation:wireline logs part 2
Exploration Methods: Seismic interpretation and sequence stratigraphy
Unconventional resources
CCS and the future of oil industry

Selected Books

Richard C. Selley-Elements of petroleum Geology- II edition 1998- Academic press

Gluyas & Swarbrick- Petroleum Geoscience- Blackwell Publishing

Malcom Rider-The Geological Interpretation of Well Logs- II edition 2006- Rider-french consulting Ltd

Additional material will be provided during the course

The science of petroleum geology

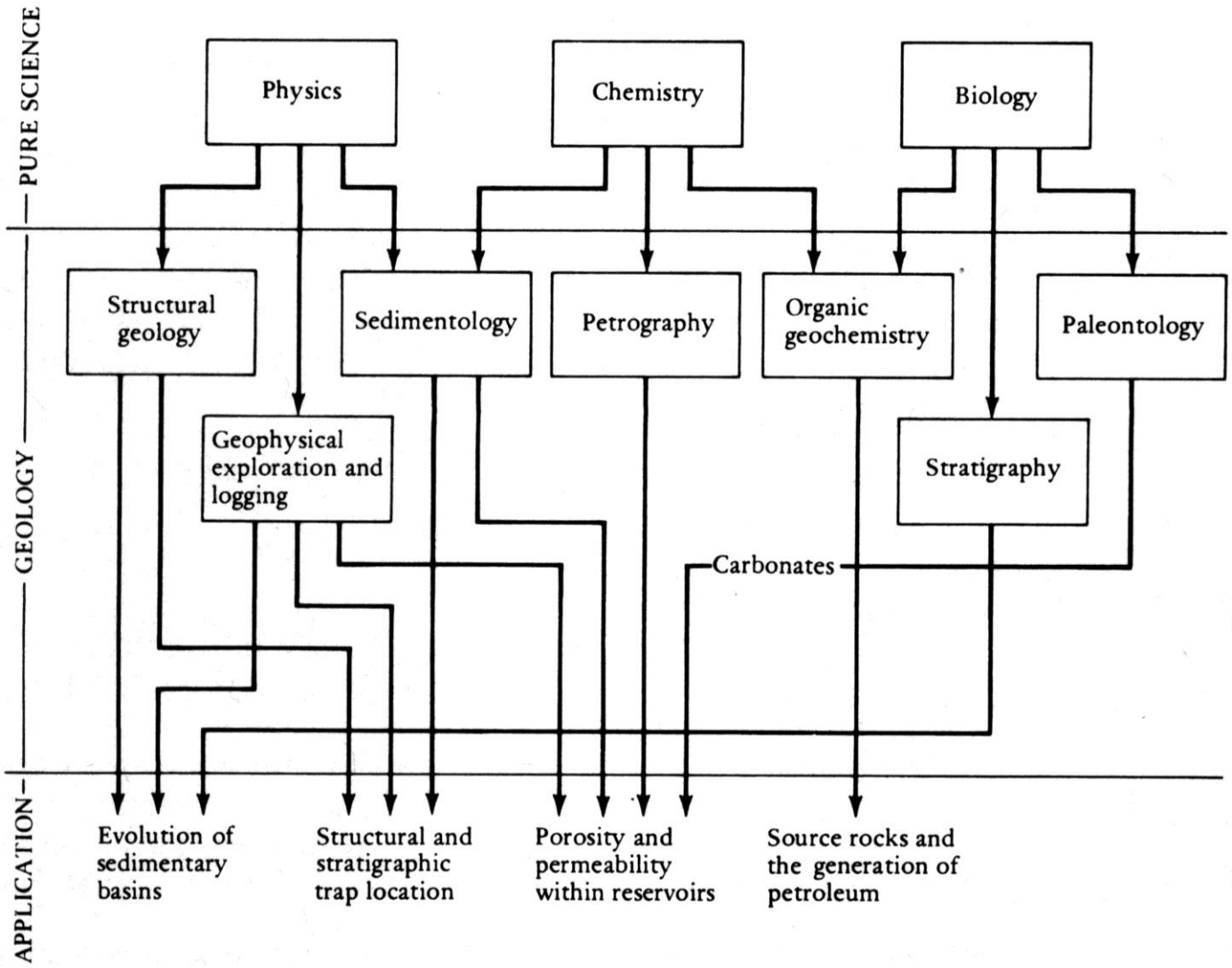
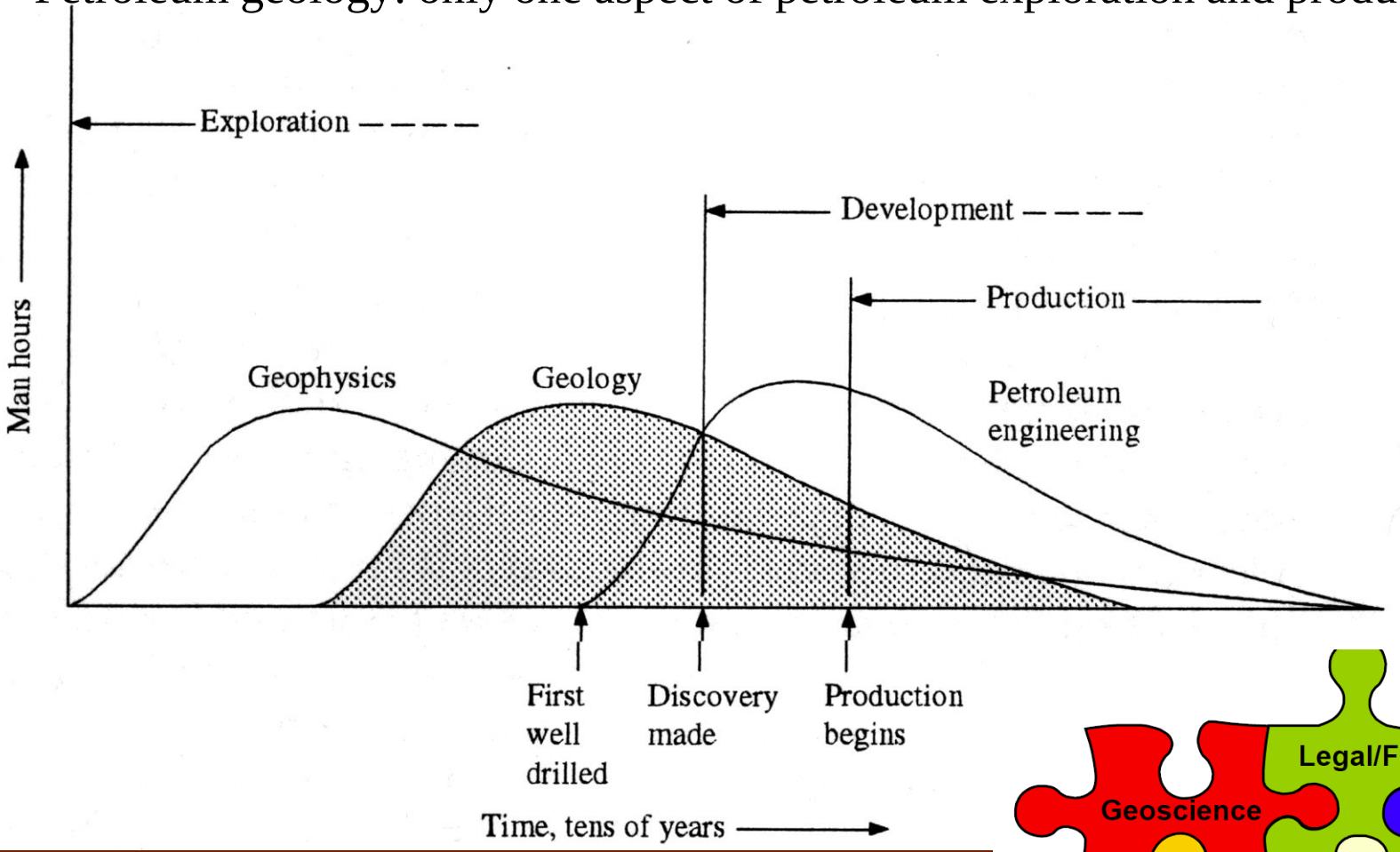
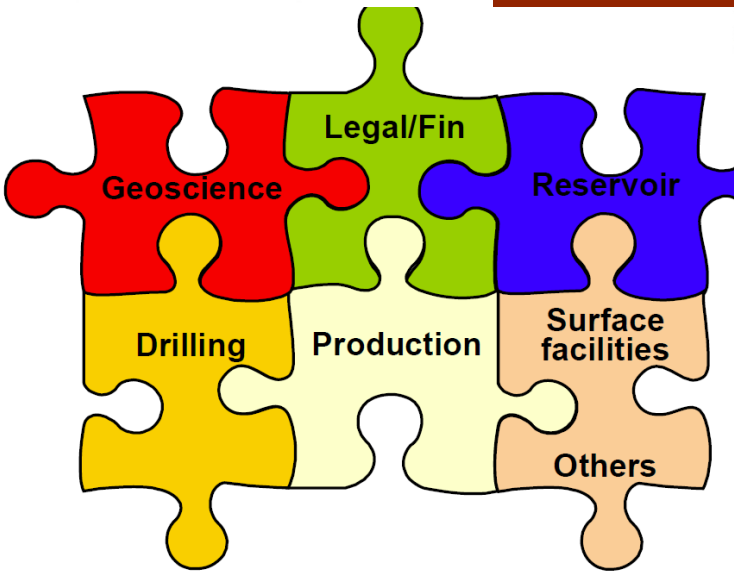


FIGURE 1.3 The relationship of petroleum geology to the pure sciences.

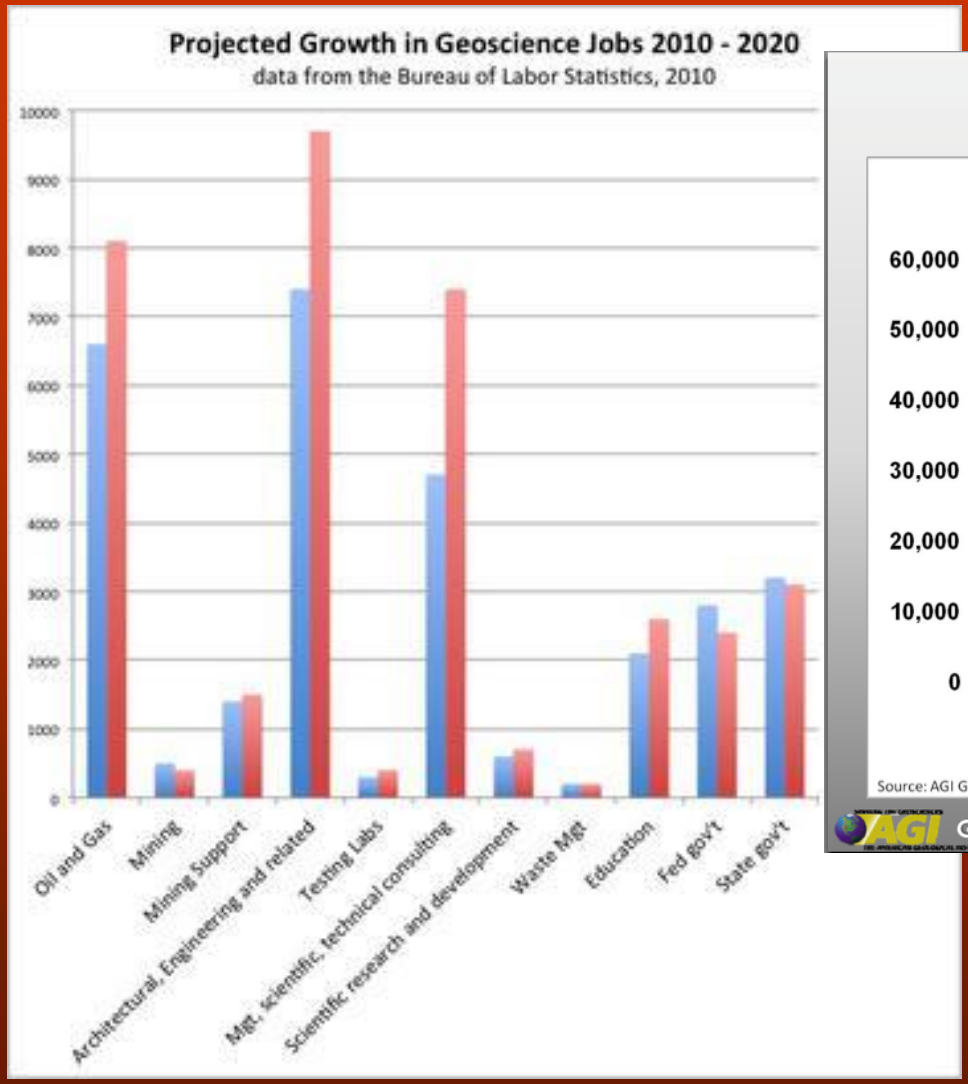
Petroleum geology: only one aspect of petroleum exploration and production

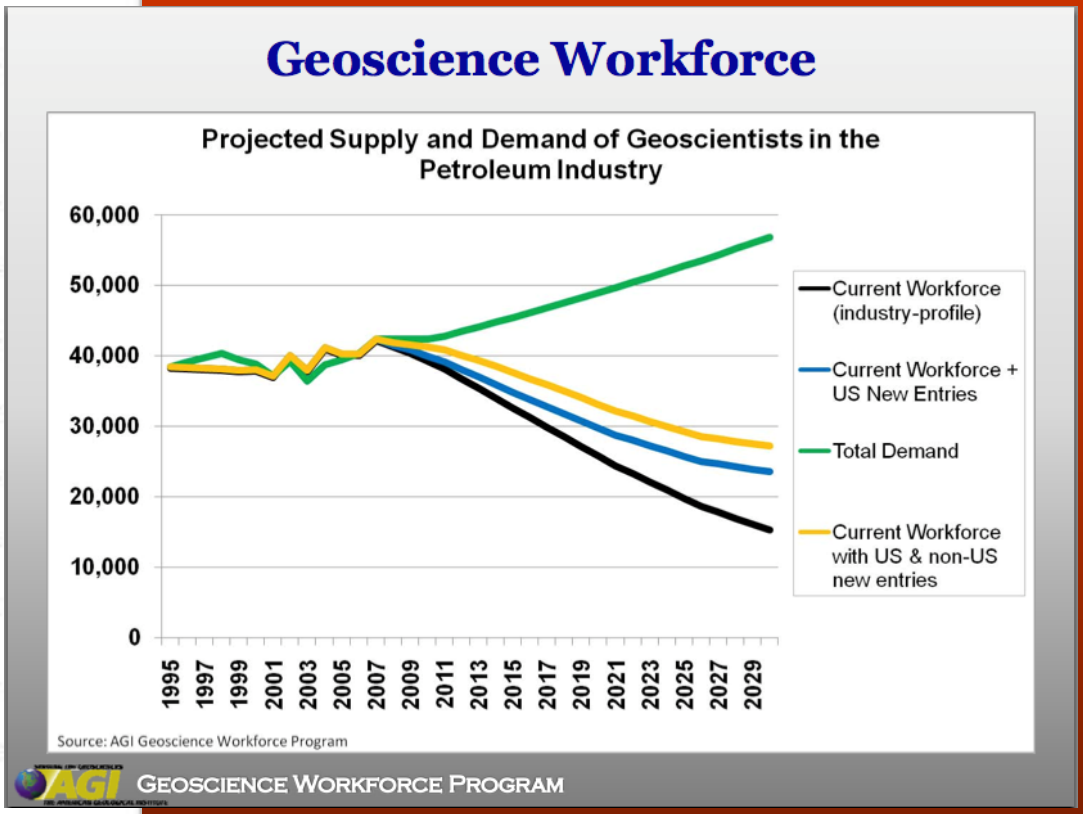


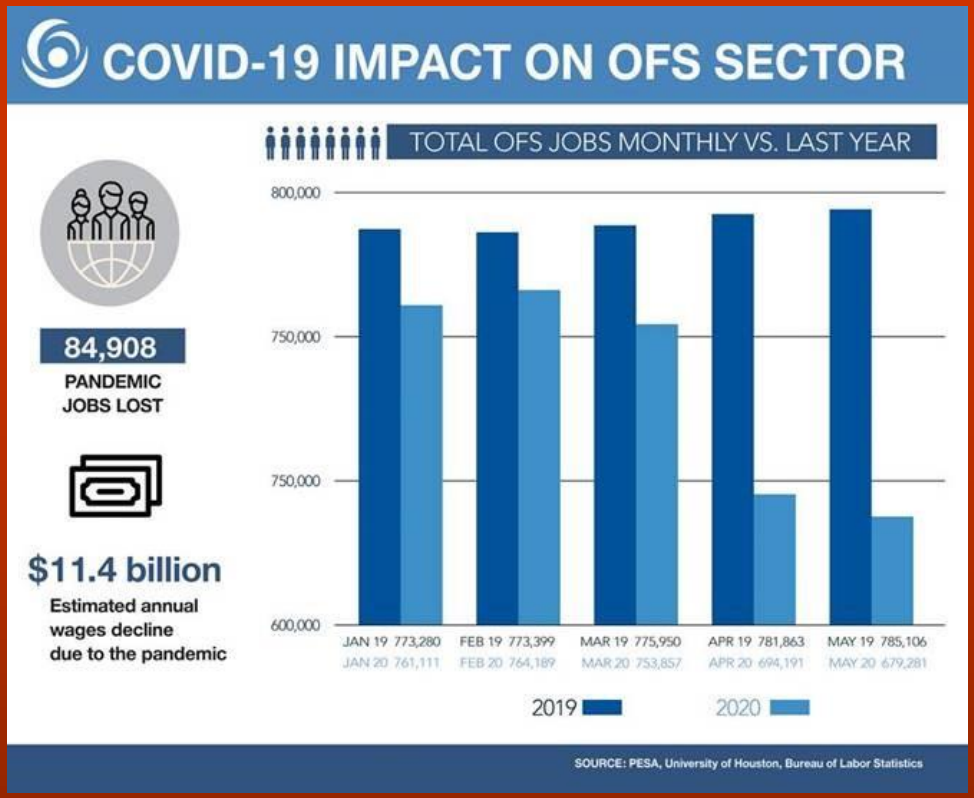
Petroleum geology is part of a continuum of disciplines employed in the exploration and production of oil and gas



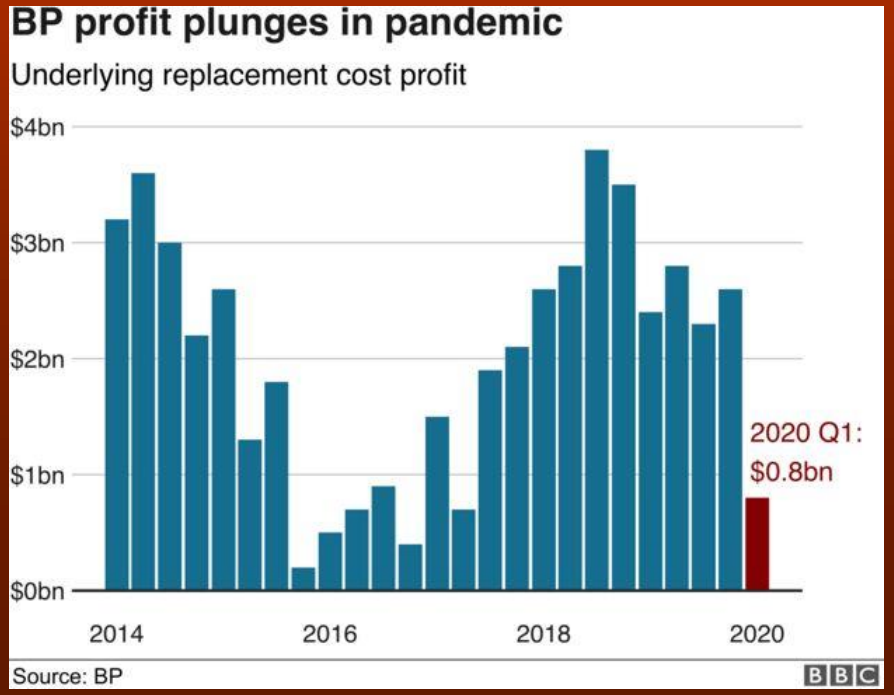
Work force as geoscientist in oil industry







Global pandemic cost oil industry 84,000+ jobs



- Main question:

  Where are there economically recoverable reserves of hydrocarbons?
- To answer this question requires understanding geologic processes in a regional context. This means that Petroleum Geology doesn't ask fundamental science questions. Instead, it uses all of the fundamental geologic (and chemical and physical) concepts and applies them to finding oil reserves

- The basic objective of petroleum geologist is to make money. This requires finding sufficient hydrocarbon reserves to be worth extracting and extracting them in the most cost-efficient way possible.

Petroleum from Noè to OPEC

Historical Review

Petroleum
(Latin)
Petra= Rock
Oleum= Oil

Up until the mid XIX century oil, asphalt and their derivates were produced only from seepages

Rock streaked by oil. Ventura County, CA. USGS photo

Oil seeps

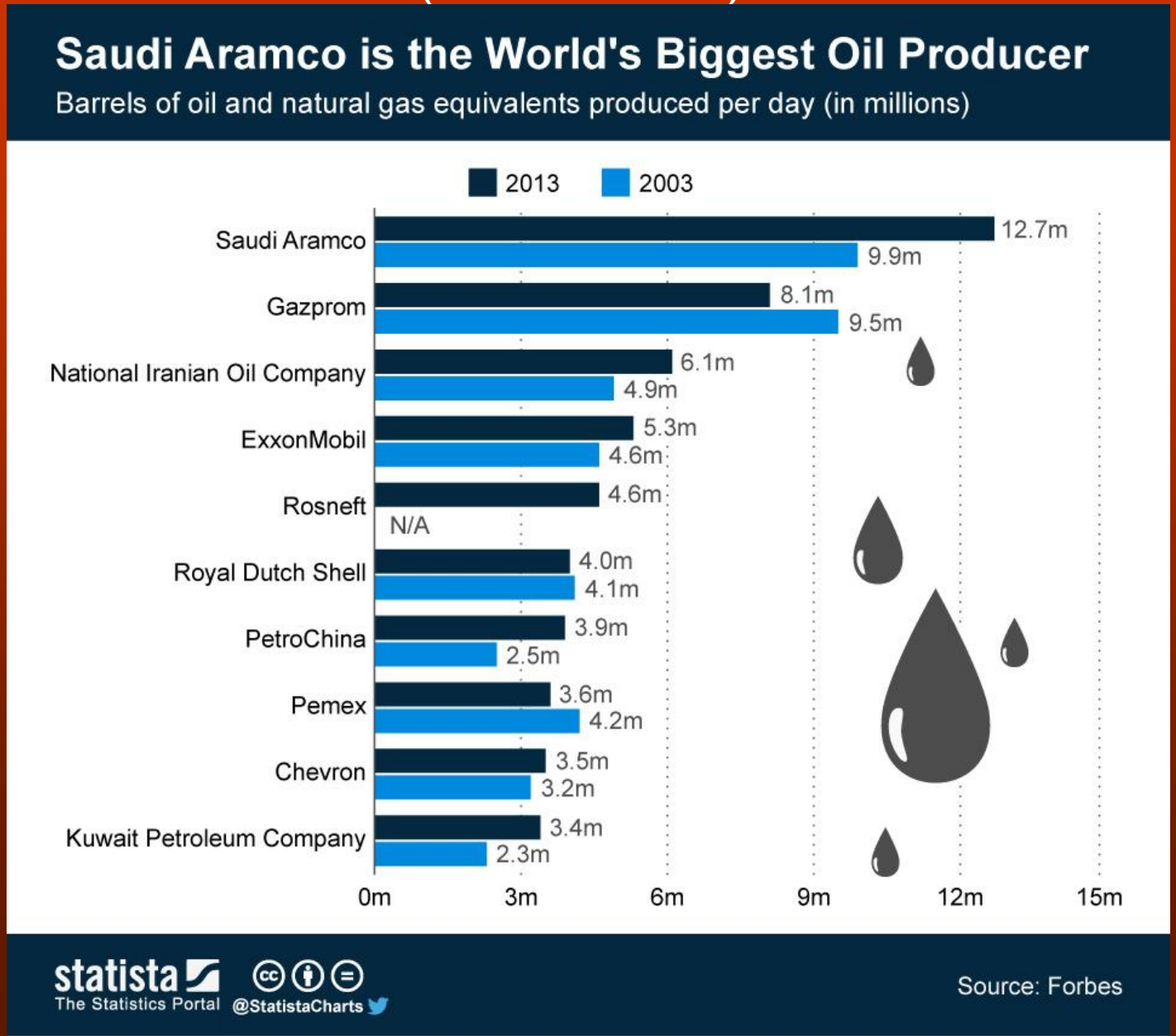
Asphaltum in Oil seep in Santa Barbara, CA. USGS Photo

The Demand for Oil Products

- Increased greatly by WWI (1914-18)
- By 1920 the oil industry dominated by the "seven sisters"
- Post WWII, oil companies began to risk profits from one productive area to explore for another.
- 1960: Organization of Petroleum Exporting Countries (OPEC) formed in Baghdad (Iraq)
  - Objective: control the power of the independent oil companies by price control & appropriation of company assets

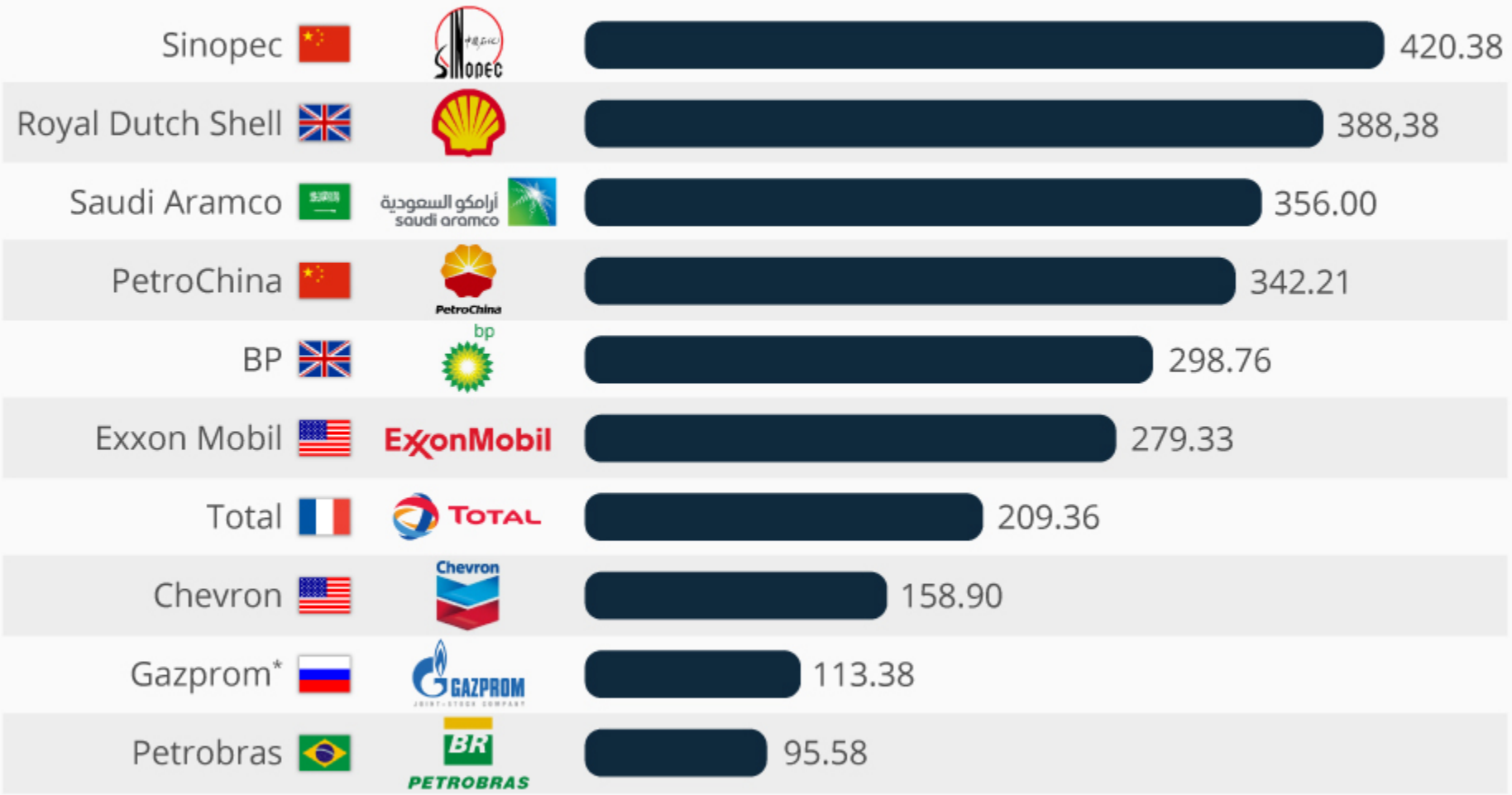
The biggest companies

(source:Forbes 2013)



The Biggest Oil and Gas Companies in the World

Revenue of the world's largest oil and gas companies in 2018 (in billion U.S. dollars)



* data from 2017

Source: company filings

Some Definitions:

- Is a naturally occurring mixture of hydrocarbon and non-hydrocarbon compounds occurring in subsurface rocks and at the surface. It may occur in the gaseous, liquid, or solid state depending on the nature of these compounds and the existent conditions of temperature and pressure. Common synonyms are hydrocarbons,oil and gas.

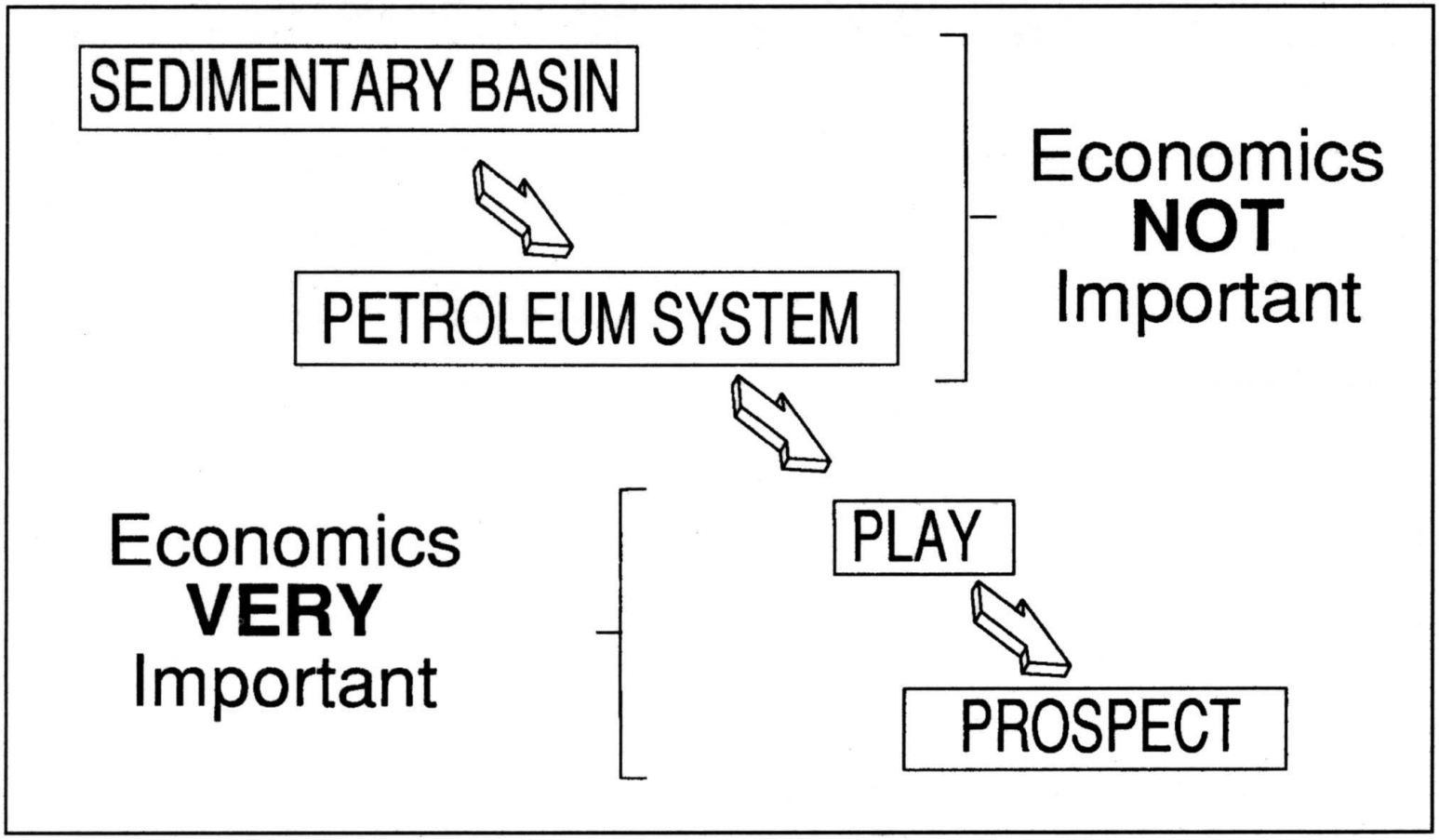
- Hydrocarbons- substance made of hydrogen and carbon (among other elements)

- Petroleum Is a mixture of HC molecules and lesser quantities of organic molecules (S,O,N)

Very generally: Oil and gas are formed from the soft part of microscopic organism preserved in certain sediments and gradually and gently cooked (matured) by exposure to the Earth's interior heat during deep burial.It is mainly the remains of marine plankton that become converted to oil and gas,although land-derived plant material can generate pure natural gas(methane)

- Grade through three states of matter: gases, liquids and solids. Petroleum exploration largely concerned with the fluids (gases and liquids).

Petroleum investigation:

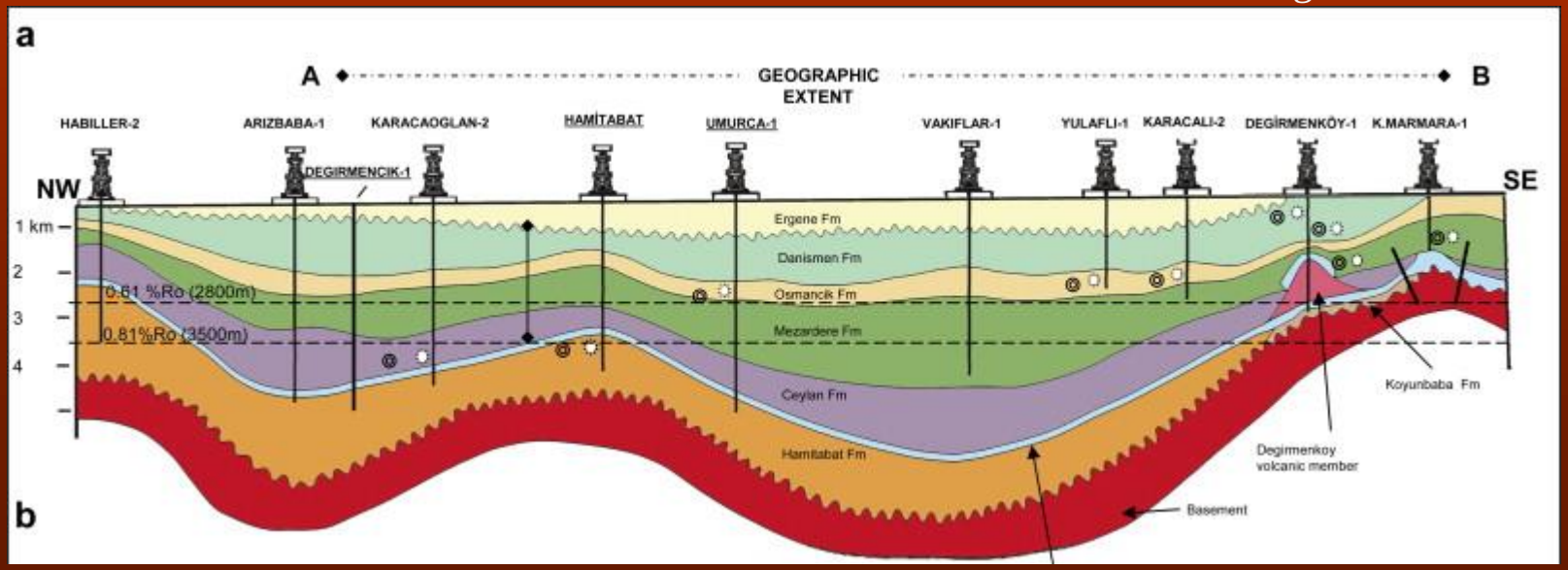


Four levels of petroleum investigation

Petroleum System Definition

„A Petroleum System is defined as a natural system that encompasses a pod of active source rock and all related oil and gas which includes all of the geologic elements and processes that are essential if a hydrocarbon accumulation is to exist.“

Magoon and Dow, 1994



PETROLEUM SYSTEM

On of the basic unit of petroleum resource assessment is the **Petroleum System**

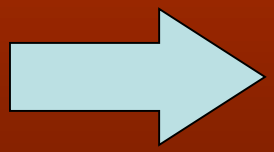
A petroleum system is a dynamic hydrocarbon system that functions in a restricted geological space and time scale.It requires timely convergence of geologic events essential to the formation of petroleum deposits

A **Petroleum System** comprises:

- A pod of mature source rock

And all of the:

- Overburden Rock
- Reservoir rocks
- Seal

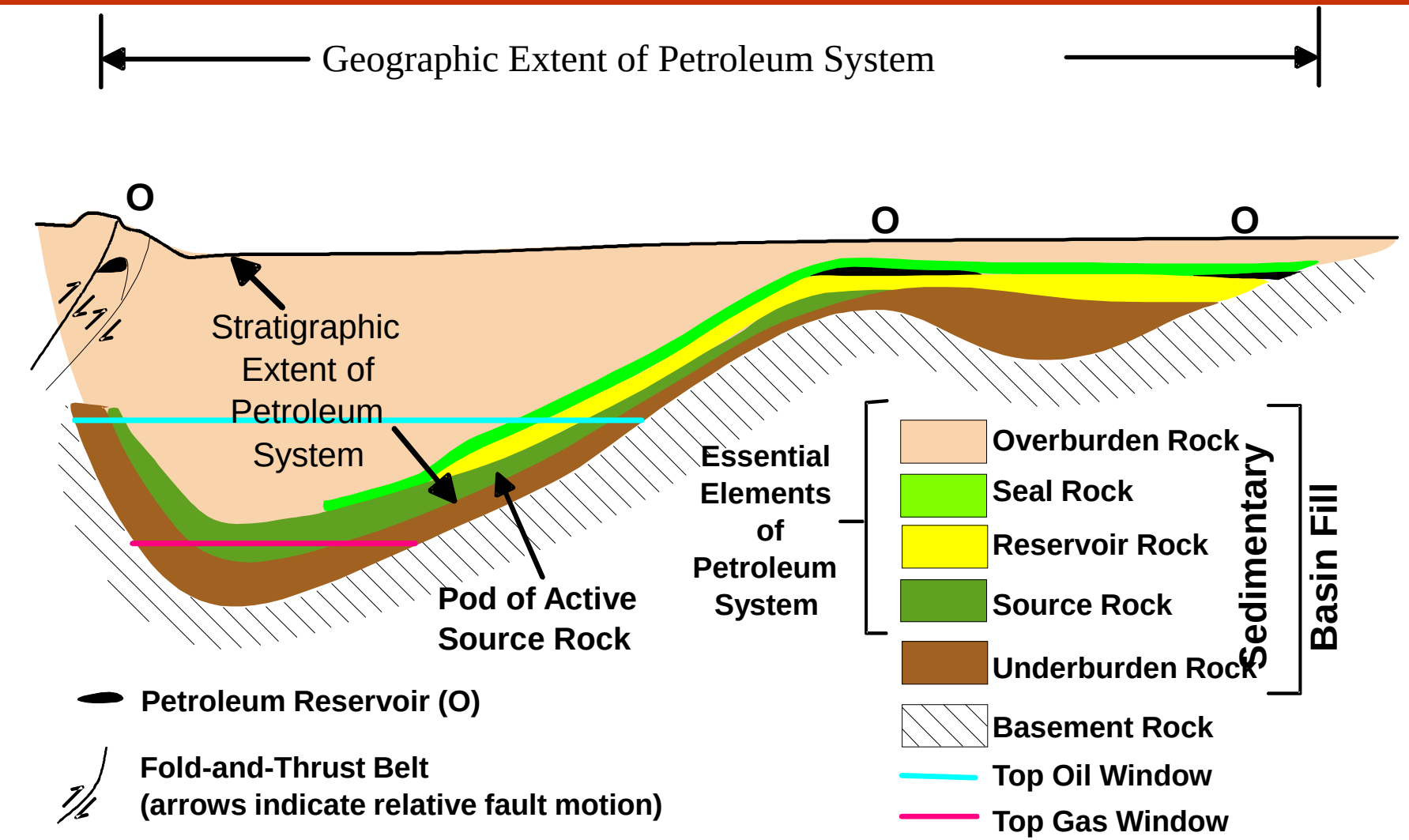


Processes

Trap formation
Generation-migration-accumulation
Preservation

It includes all the geologic (interdependent)elements and processe that are essential if an oil and gas accumulation is to exist.This concept places the source rock as the first and foremost element of the geological system required to produce a petroleum play

Cross Section Of A Petroleum System
(Foreland Basin Example)



(modified from Magoon and Dow, 1994)

VERY IMPORTANT!!!!

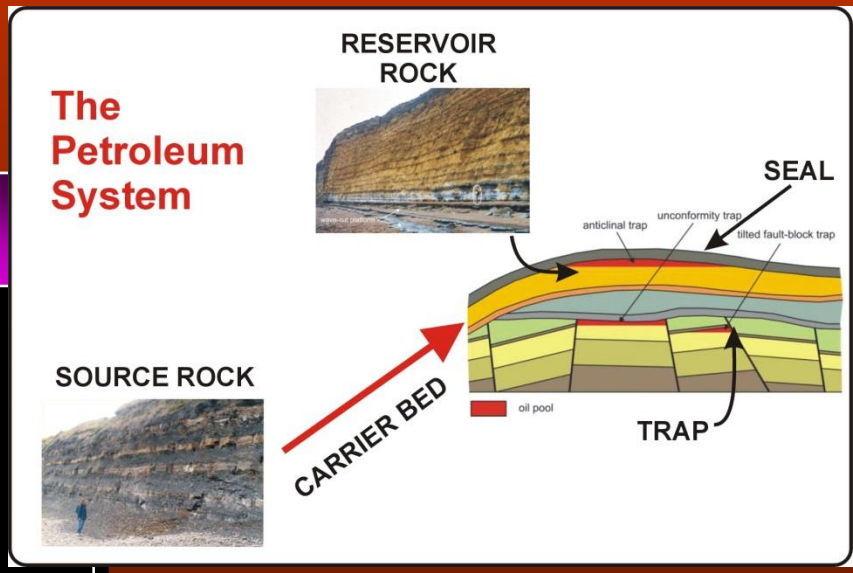
- The essential elements and processes of a petroleum system must be placed correctly in time and space so that organic matter included in a source rock can be converted into a petroleum accumulation. A petroleum system exist when these elements and processes occur or can occur

Elements

Source Rock
Migration route
Overburden Roc
Reservoir Rock
Seal Rock
Trap

Processes

Generation
Migration
Accumulation
Preservation

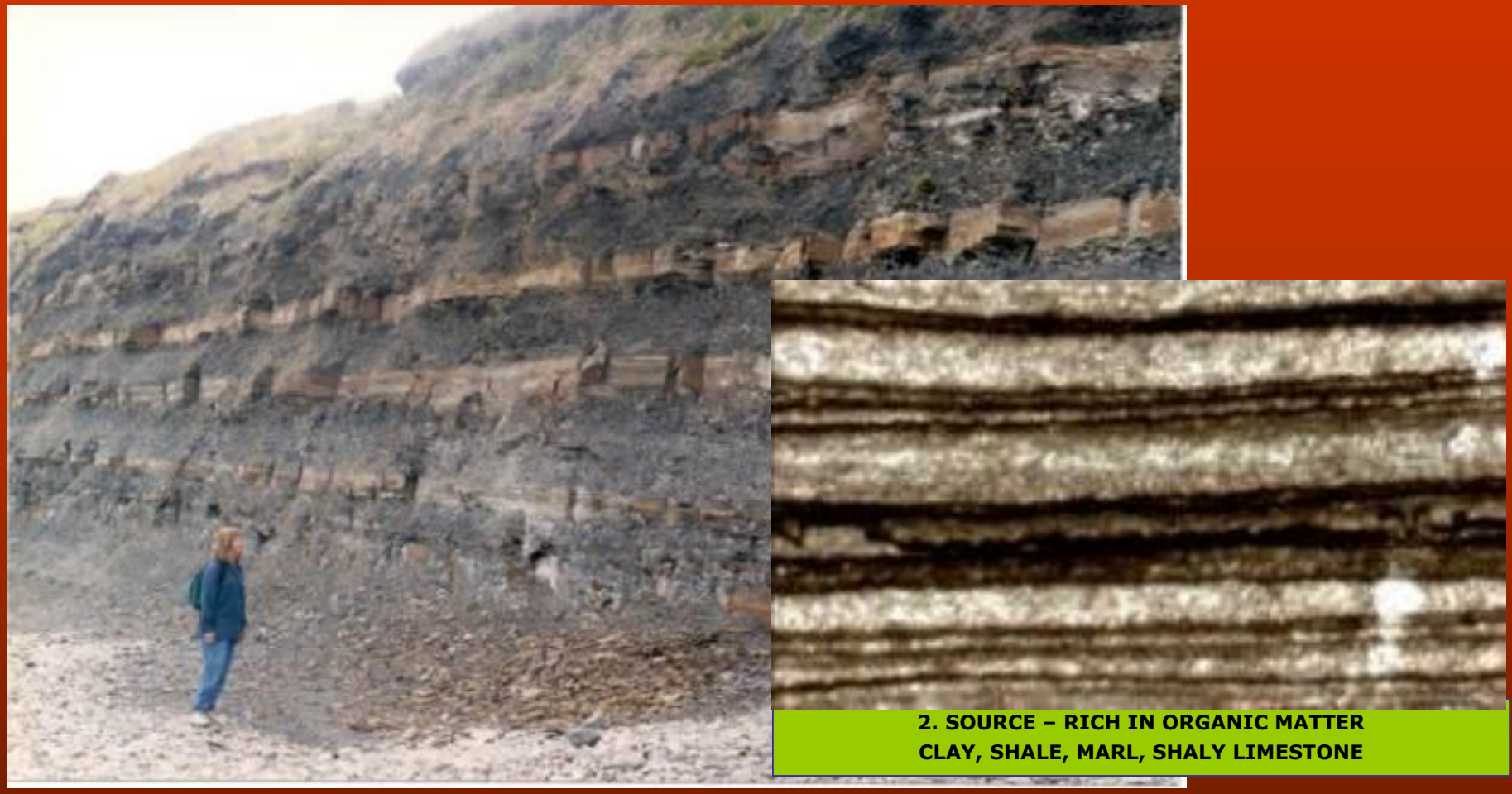


The “Magic Elements ” involved in making petroleum

1. Must be an organic-rich source rock to generate the oil/ gas-SOURCE ROCK
2. Migration route
3. There must be a reservoir to contain the expelled hydrocarbons-RESERVOIR
4. The reservoir must be sealed by an impermeable Cap Rock to prevent upwards escape of the hydrocarbons to the earth’s surface-SEAL
5. Source, reservoir and seal must be arranged in such a way that the petroleum is Trapped-TRAP

1. Petroleum Source Rocks

- Sedimentary rocks rich enough in organic matter
  - 0.5-2 weight percent organic matter
- Can be land or water based material
- Type of organic material can determine the type of petroleum generated
- To generate petroleum, the source rock must be heated for a length of time
- 65-175˚C (150-350˚F)
- Buried 2,400-5,500 m (8,000-18,000 ft)
- Millions of years



2. SOURCE – RICH IN ORGANIC MATTER
CLAY, SHALE, MARL, SHALY LIMESTONE

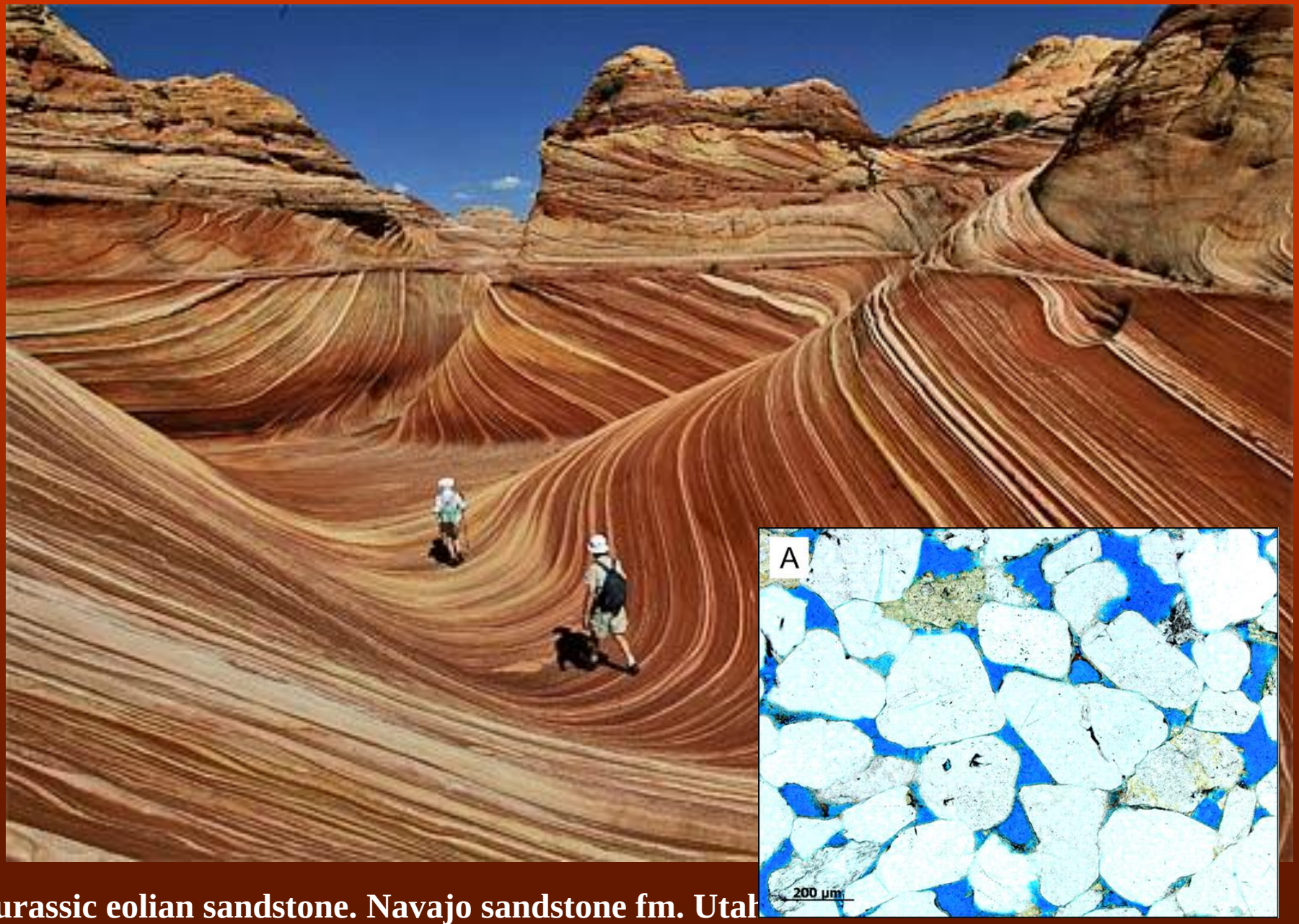
- This shale typically contains >1% of organic carbon, by weight. The shale is very widespread, underlying much of Britain and most of the North Sea, and is by far the most important source rock for the oil that has been found in the North Sea Basin.

2. Reservoir rocks

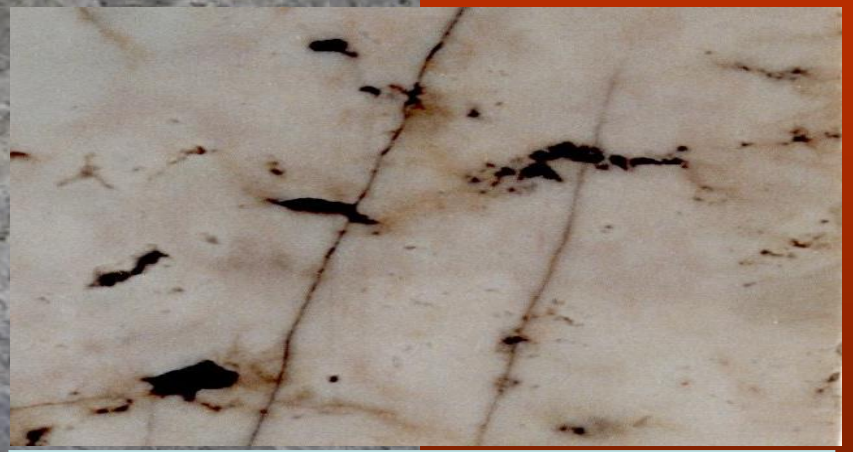
- … as petroleum is generated, pressure increases in source rock and forces the petroleum out into the fluid system of the surrounding rock.Oil is lighter than water and will rise (so called buoyancy effect)

- A good reservoir rock is **Porous** and **Permeable** so that its fluids can be **Produced**

- Often sandstone, conglomerate, and carbonate rocks (limestone)



Jurassic eolian sandstone. Navajo sandstone fm. Utah



1. RESERVOIR – POROUS, PERMEABLE
LIMESTONE, DOLOMITE, SANDSTONE

- The Cairns Formation, of Devonian age, exposed near Canmore, in the Front ranges of the Rocky Mountains, just east of Banff, Alberta. This is one of the more important reservoir units in the subsurface of Alberta.

3 The Seal

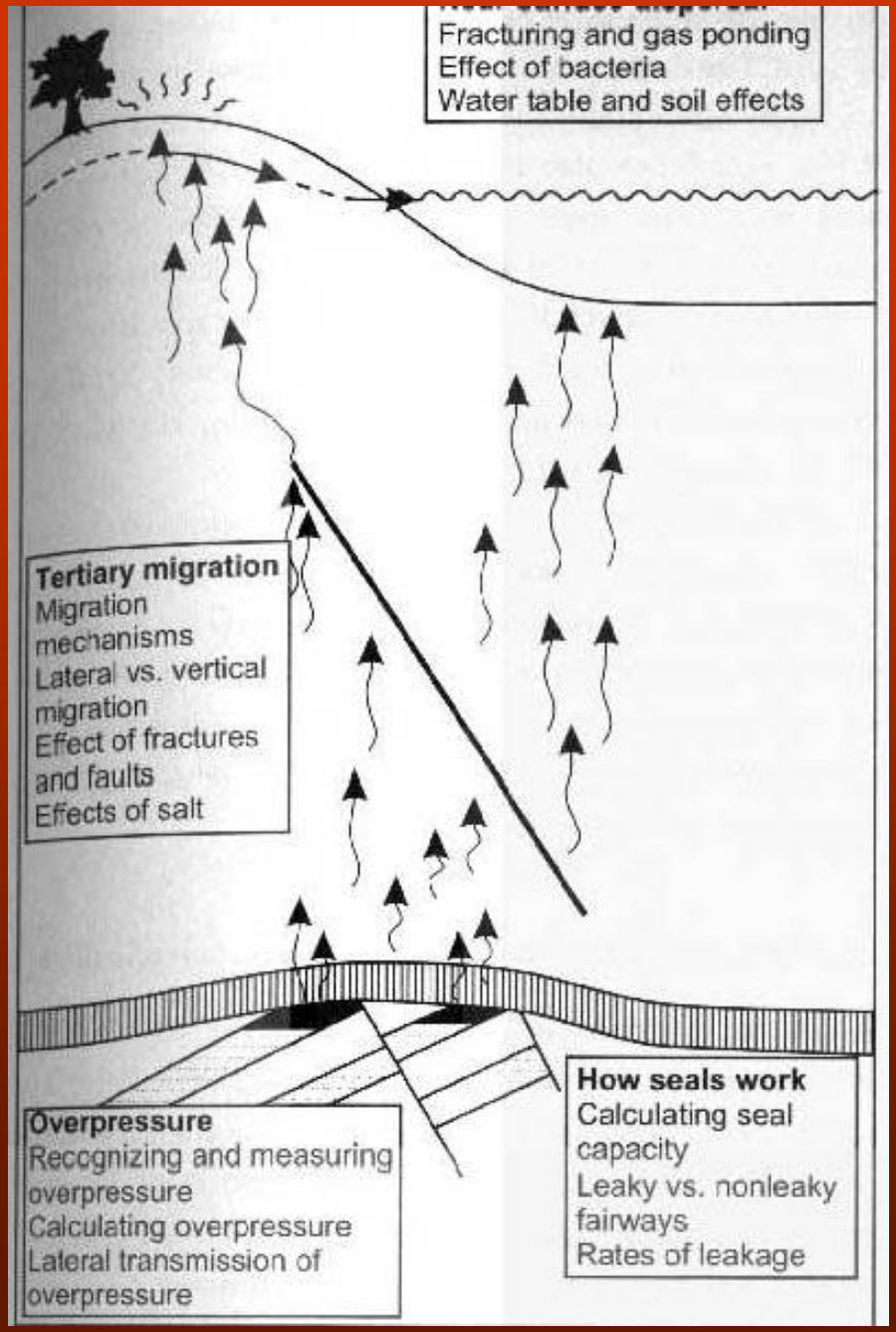
Oil and gas are less dense than water and once they migrate from the source rock they tend to rise within the sedimentary rock column.The seal tends to be a fine grained or crystallyne low-permeability rock which stops oil and gas to migrate further.

Typical seal examples include mudstone/shale,cemented limestone, chert, anhydrite and salt (halite). As such many source rocks may also be high-quality seals.

The presence of a seal or seals is critical for development of accumulations of petroleum in subsurface.In fact in absence of seals petroleum will continue to rise until it reaches the Earth’s surface where it will be destroyed by bacterial activity

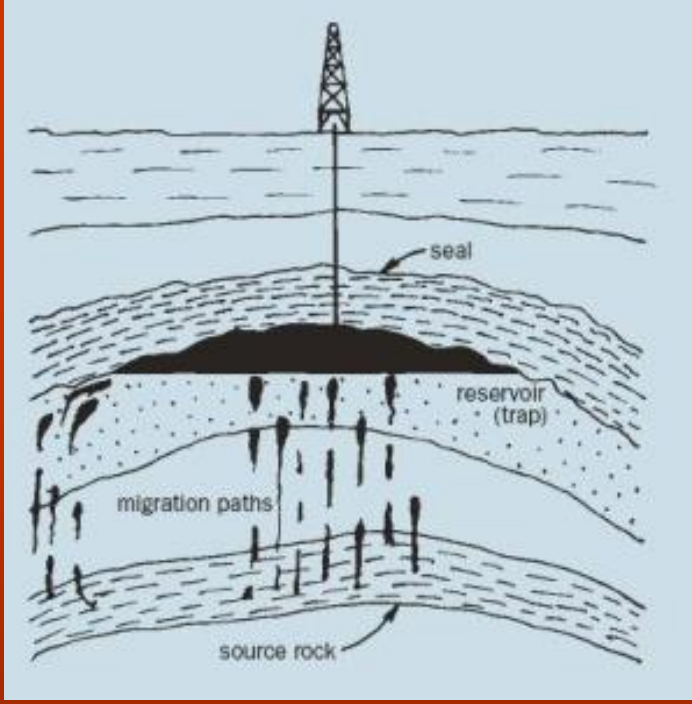
Seal and Seal failure

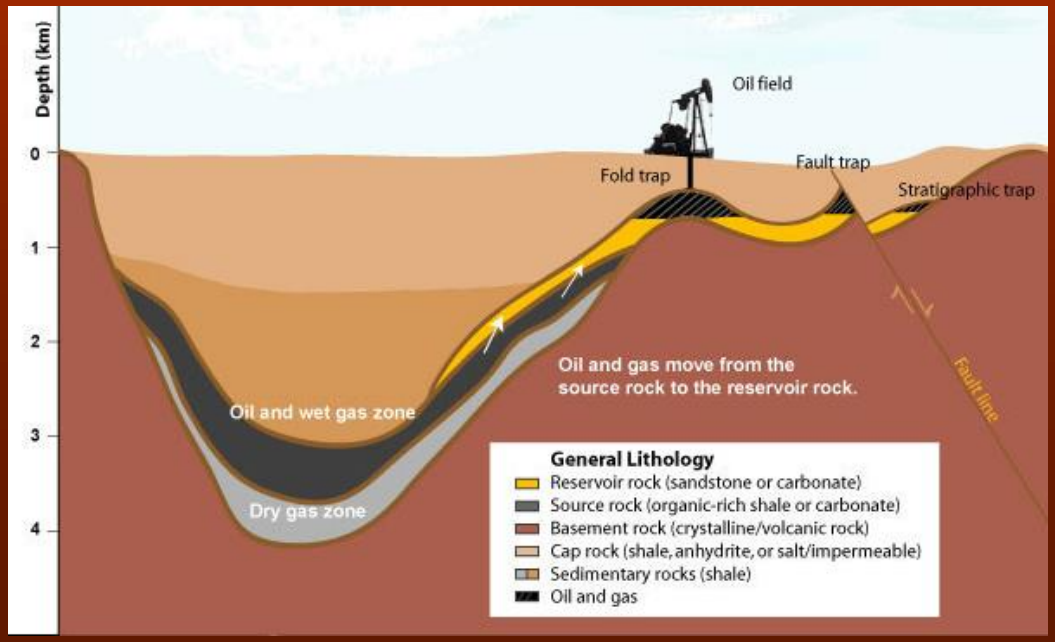
EVAPORITE S



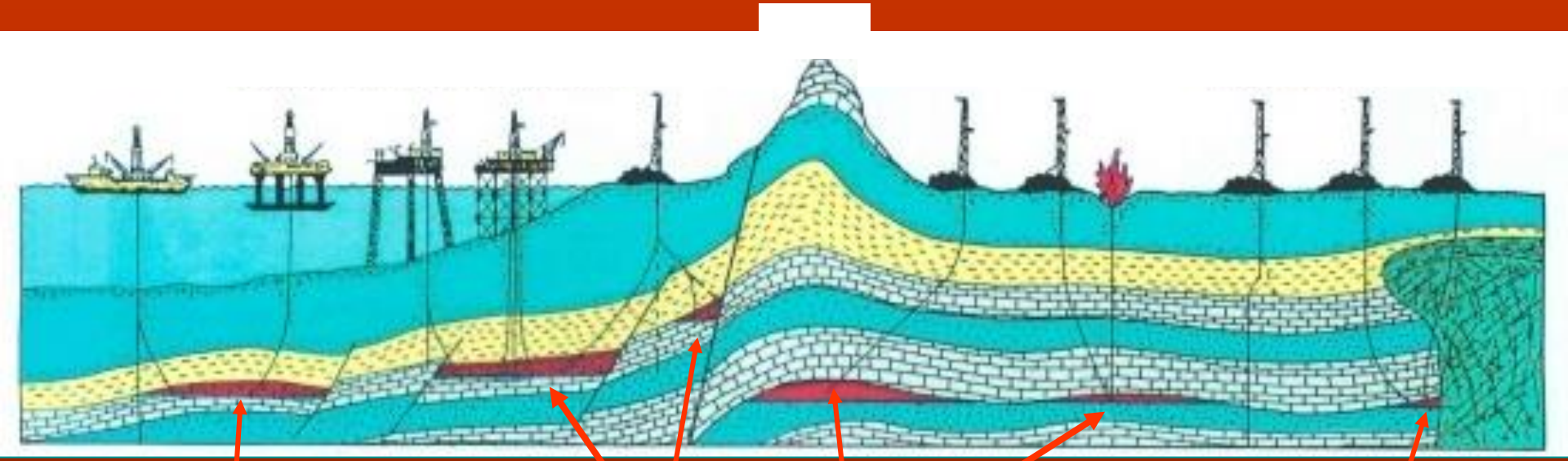
5. Traps

- The terms trap is a simply description of the geometry of the sealed petroleum bearing container:
- Structural traps: folds and faults in the rock can trap petroleum
- Stratigraphic traps: rocks that do not allow fluids to pass through them can trap petroleum





TRAPS, MORPHOLOGY AND WELLS



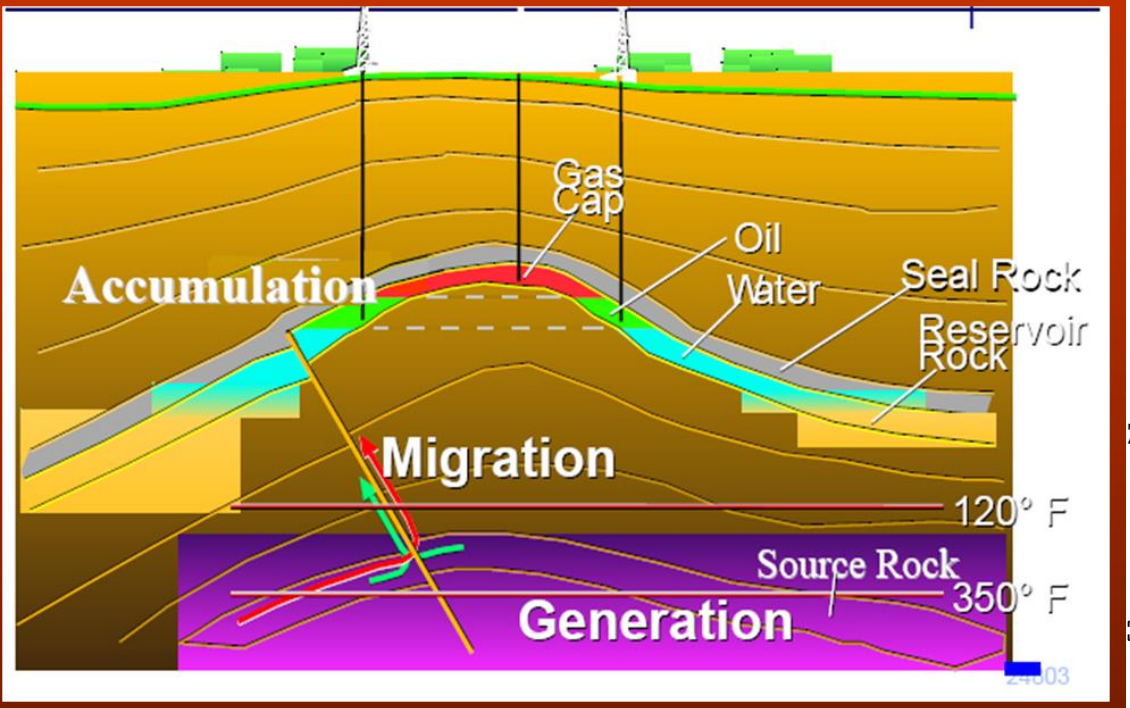
Anticline

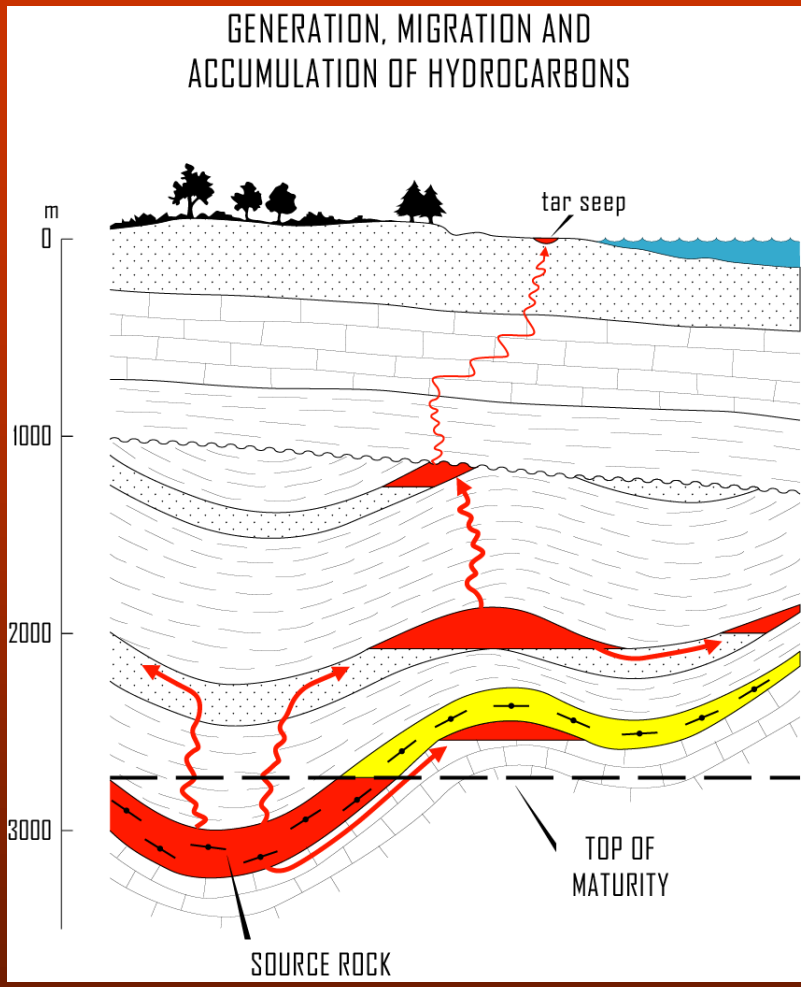
Closure against fault

Anticline

Closure against salt dome

...Summarizing





PETROLEUM SYSTEM

A Petroleum System helps to describe and predict:

- The abundance
- The stratigraphic and geographic distribution
- The habitat of hydrocarbon reserves in a basin

Its stratigraphic extent

Is the span of lithological units which encompass the essential elements within the geographic extent of a petroleum system.

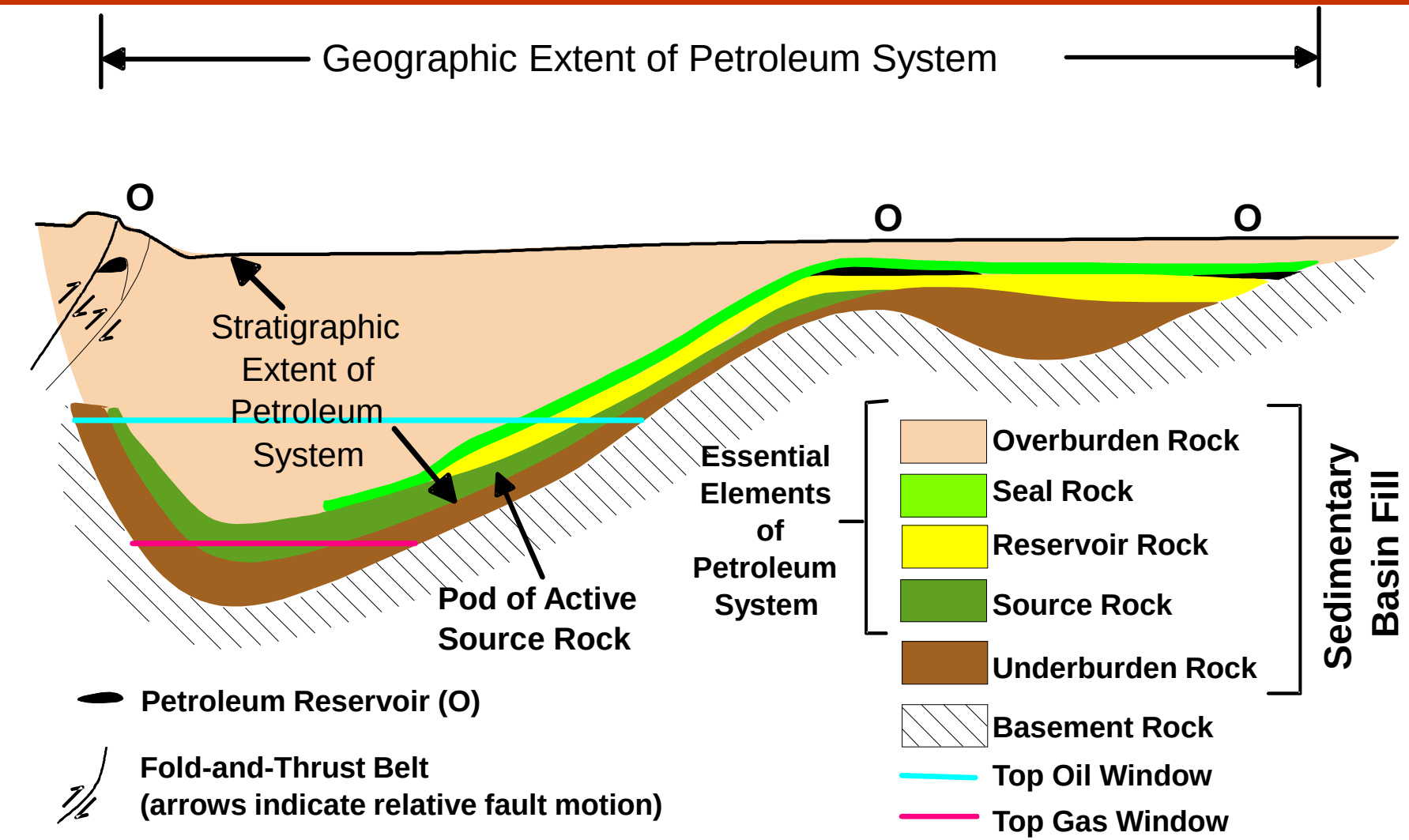
Its geographic extent

is the area over which the PS is known to occur .It is defined in map view by a line on the earth s surface that circumscribes the pod of active source rock together with the associated discoveries and seeps

Its temporal extent

illustrated by a burial history chart and events chart.It shows the age of the essential elements and processes,the preservation time and the critical moment (time at which most of hydrocarbons were generated,migrated and accumulated in the primary trap type)

Cross Section Of A Petroleum System
(Foreland Basin Example)

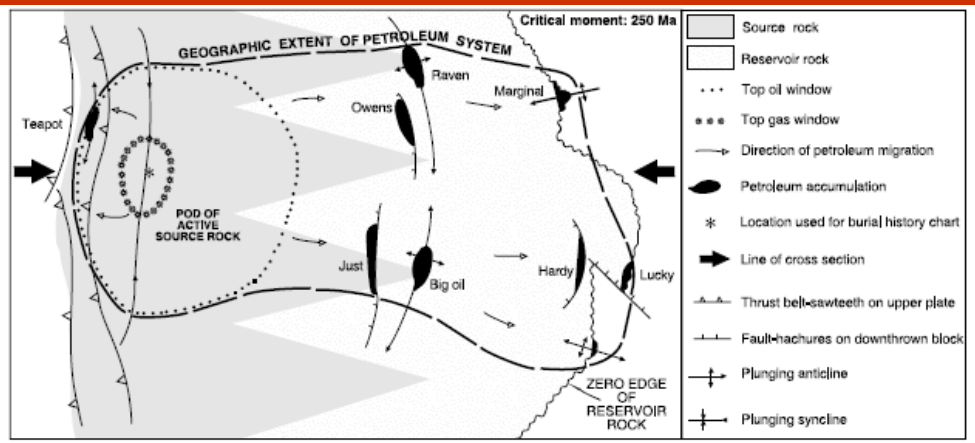


(modified from Magoon and Dow, 1994)

PETROLEUM SYSTEM

A Petroleum System has 3 important Temporal aspects

- Petroleum System Age : is the time required for the process of generation-migration-accumulation
- Critical moment:is the time that best depict the G-M-A of HC in a petroleum System
- Preservation time-begins immediately after the G-M-A pocess and exted to present day.It encompasses any changes to the petroleum accumulations during this period (remigration,degradation,destruction)



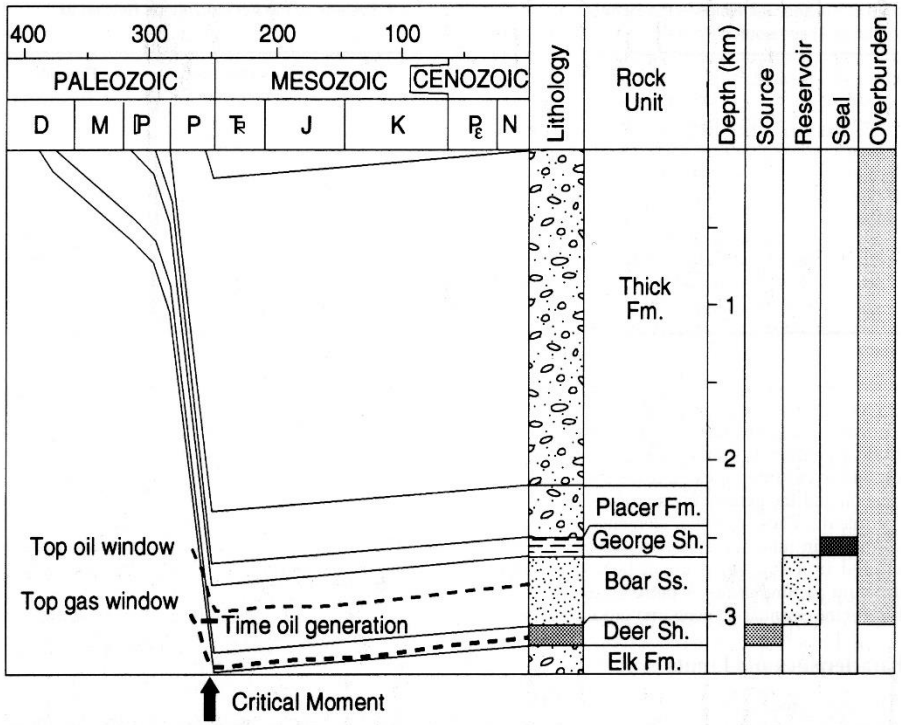


Figure 1.2. Burial history chart showing the critical moment (250 Ma) and the time of oil generation (260–240 Ma) for the fictitious Deer–Boar(.) petroleum system. This information is used on the events chart (Figure 1.5). Neogene (N) includes the Quaternary here. All rock unit names used here are fictitious. Location used for burial history chart is shown on Figures 1.3 and 1.4. (Time scale from Palmer, 1983.)

- Timing between petroleum generation, migration, and trap formation is vital

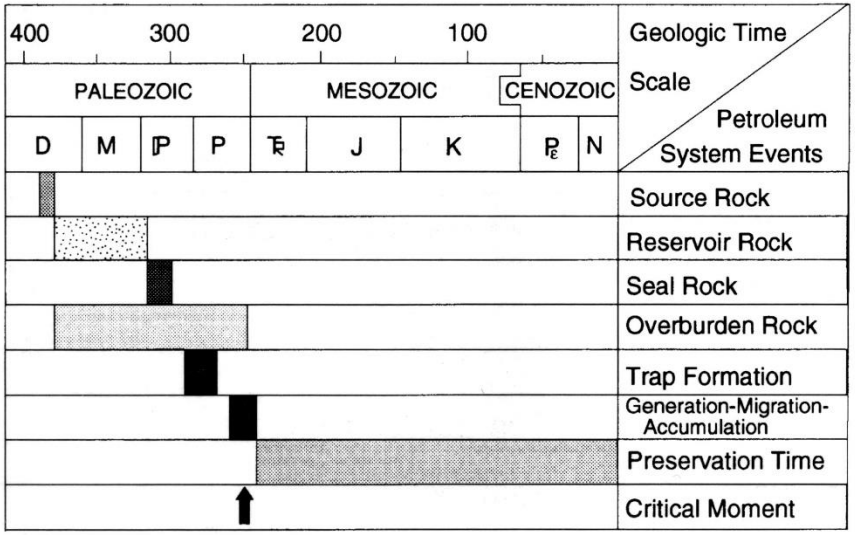


Figure 1.5. The events chart showing the relationship between the essential elements and processes as well as the preservation time and critical moment for the fictitious Deer–Boar(.) petroleum system. Neogene (N) includes the

@ 250 Ma -> Critical Moment:

- **generation started**
- **traps exist**
- **migration possible**

PETROLEUM SYSTEM

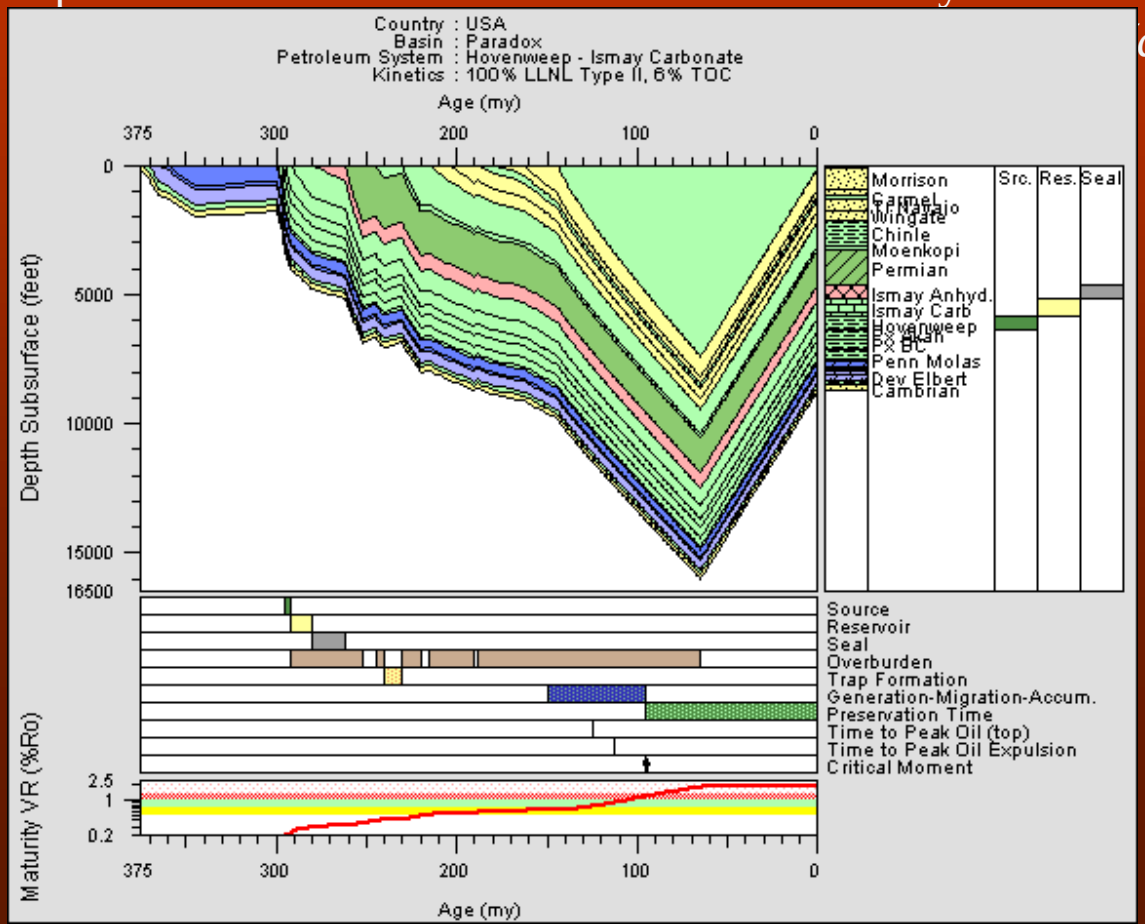
Burial History Chart

A burial history curve or geohistory diagram summarizes the sedimentological and paleontological evidences in the overburden rock used to reconstruct the burial or thermal history of the source rock. This allow to show the time over which hydrocarbon generation occurs. Depicts the essential elements and the critical moment for the petroleum system.

Events Chart

A chart for a petroleum system showing when the essential elements and processes took place as well as the preservation time and critical moment of the system.

after Magoon and Dow, 1994)



PLAY and PROSPECT

PLAY: A play is a set of known or postulated oil and (or) gas accumulations sharing similar geological,geographic and temporal properties such as source rock,migration patterns,timing,trapping mechanism and HC type

A **Petroleum Play** helps to define a part of a basin in which the petroleum could be trapped

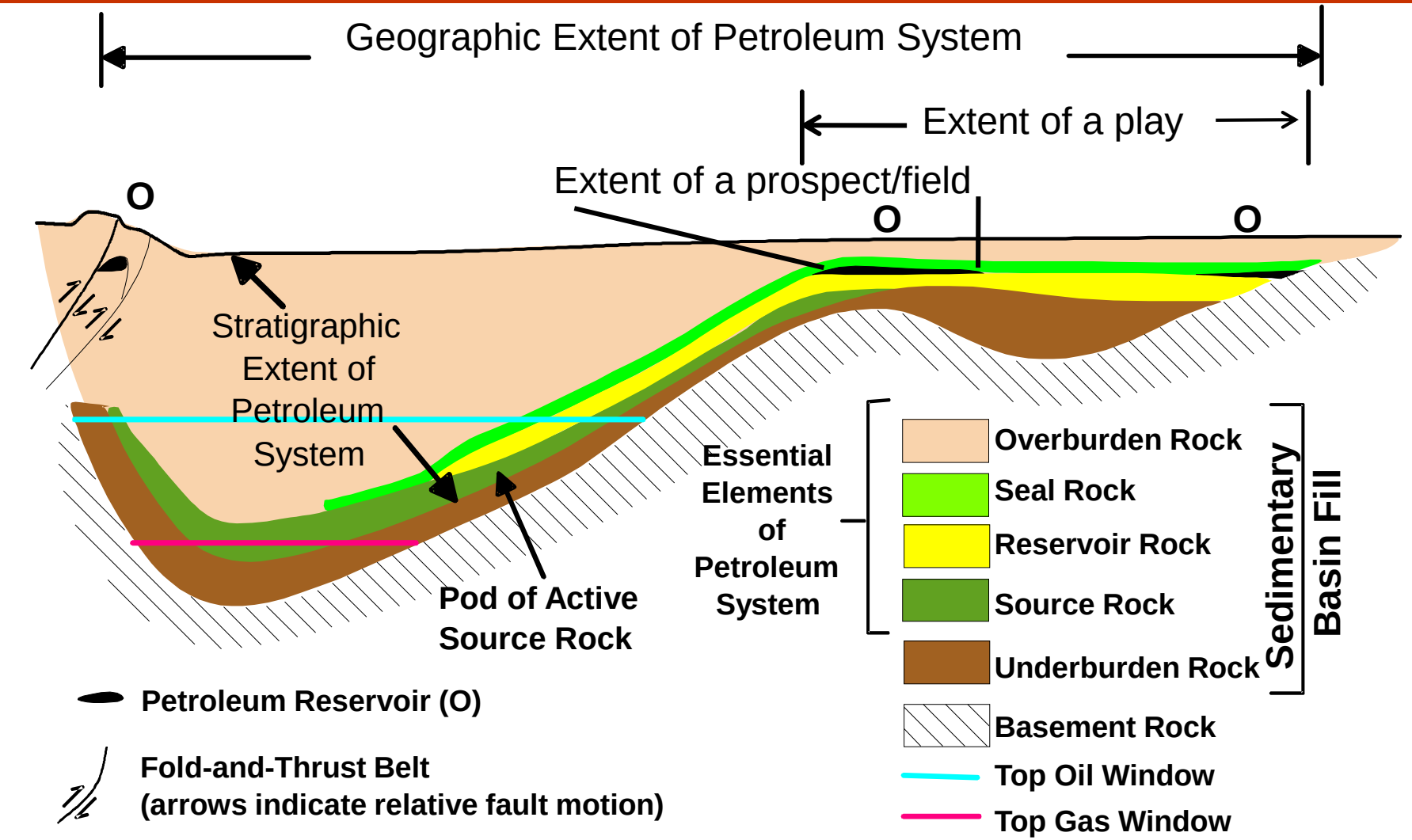
A **Play** can be:

Proven: if at least one oil- or gas field exists with the defined seal and reservoir.

Hypothetical: if there is the possibility of hydrocarbons accumulations in the play but these have yet to be found.

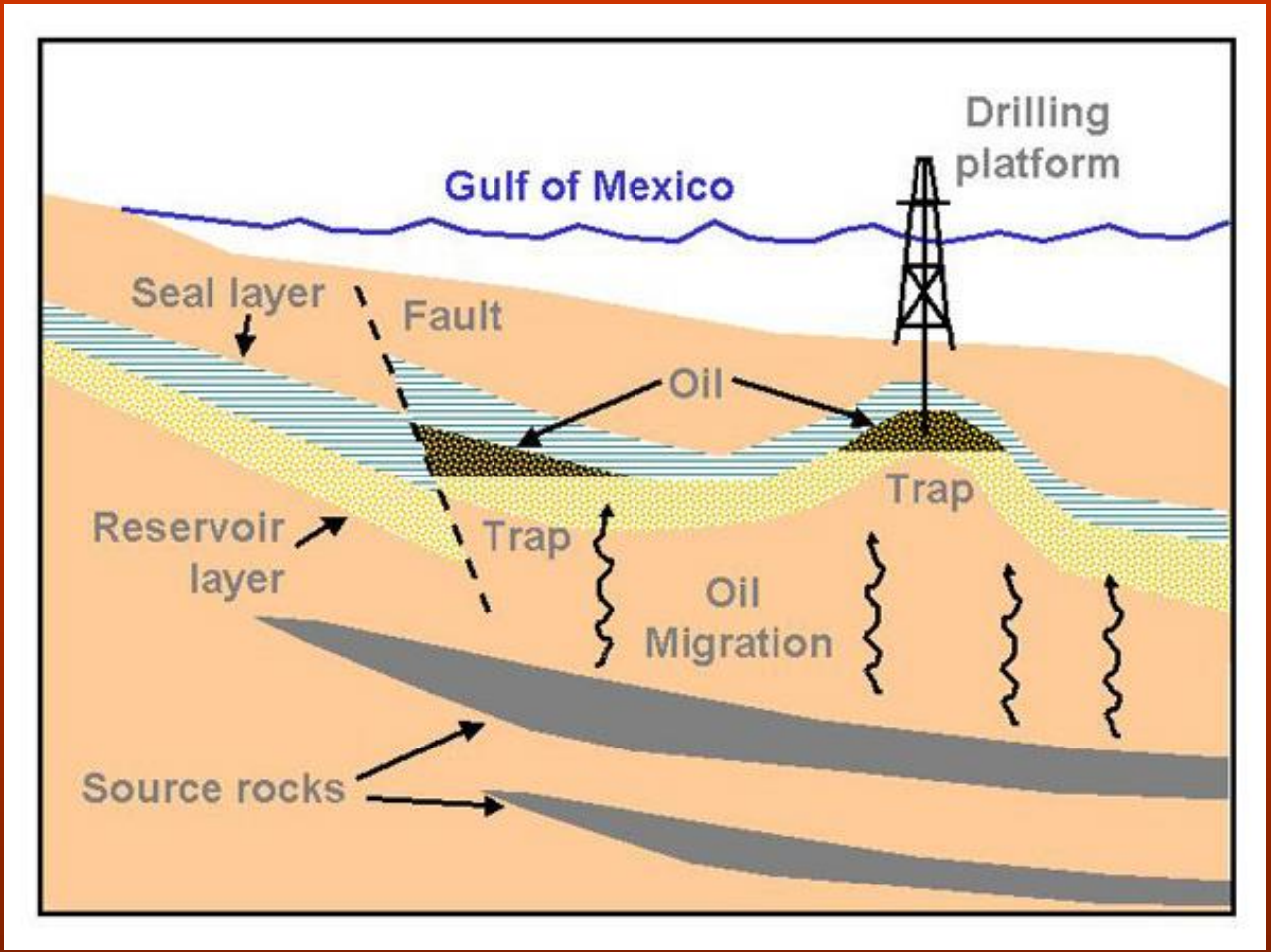
The play consist of one or more geologically related prospecs and a prospect is a potential trap that must be evaluated by drillind to determine wheter it contains commercial quantities of petroleum.Once drilling is complete the term is dropped and the site becomes a dry hole or a producing field

Cross Section Of A Petroleum System
(Foreland Basin Example)



(modified from Magoon and Dow, 1994)

PLAY



Plays are defined generically as groups of geologically similar reservoirs and prospects within a common geographical area. **Geological similarity is essential to ensure that each group is homogenous**. Geological similarity is defined primarily by stratigraphy (the reservoir formation) and the trapping mechanism. Secondary characteristics used to define plays include depositional environment, reservoir lithology, fluid type, and petroleum source.

Prospect and probabilities

Prospect: A volume of rock that are believed, but not proven, to contain hydrocarbons. It is a potential trap defined on the basis of geological and geophysical information but has not been drilled yet.

The two aspects of prospect evaluation are geology and economics.

Is the well likely to find oiland/or gas?
If so are the economics such that it would be commercial viable?

The probability of a well finding petroleum ranges from 1.0 (petroleum certain to be present) to 0.0.

..so the probability of a prospect containing oil or gas will be given by (P1xP2xP3xP4xP5), where P1 to P5 are the five magic elements(parameters) that must be present for oil or gas to occur

- A Source rock
- A reservoir
- A cap rock
- A trap
- Sufficient heat to generate oil or gas

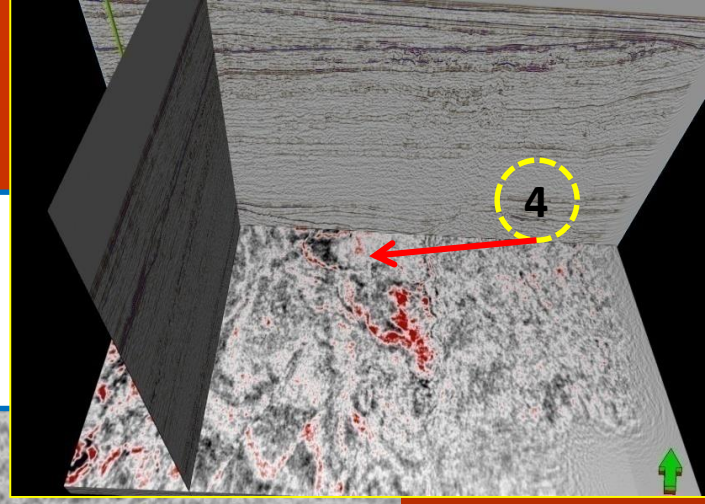
Prospect and probabilities

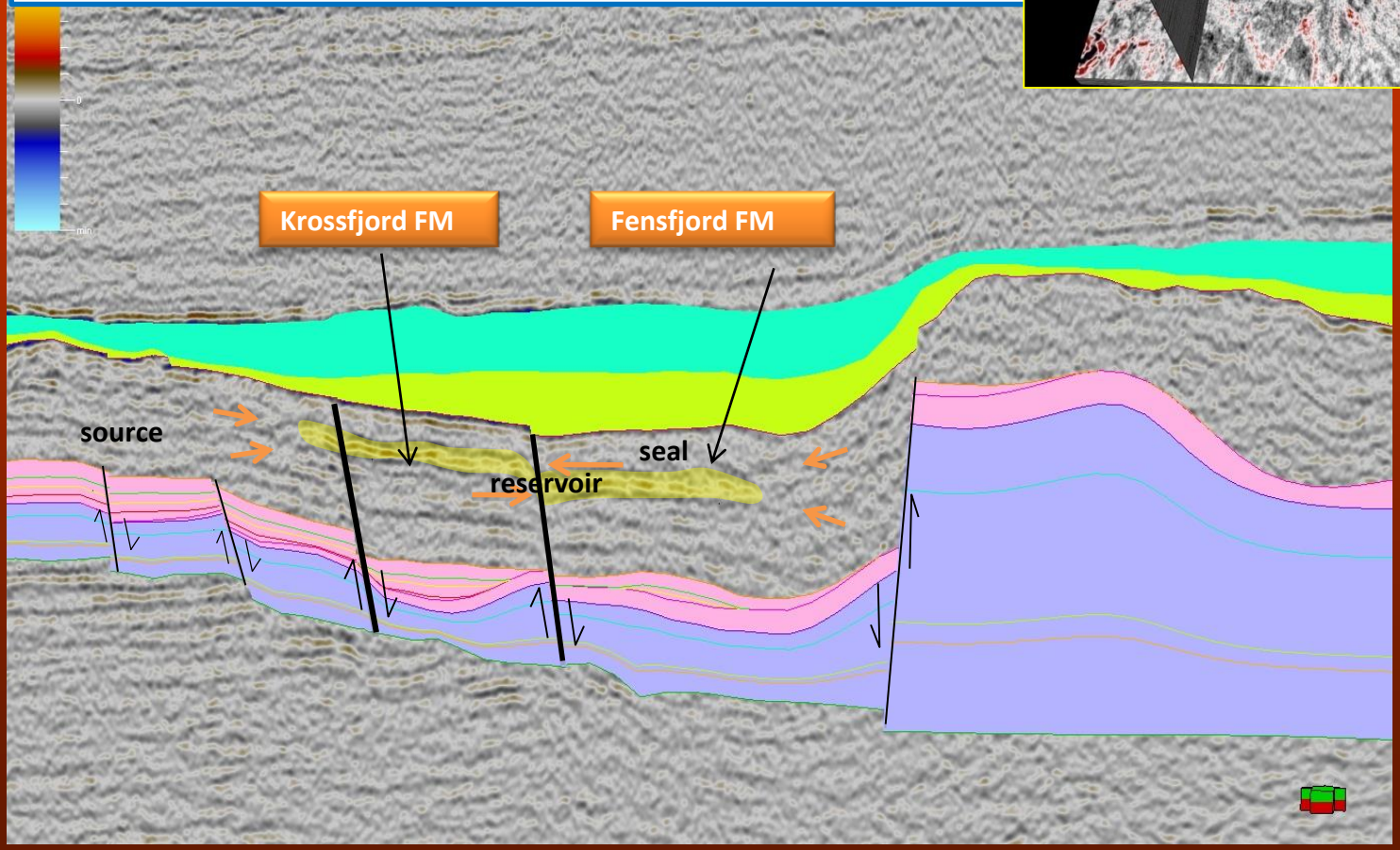
TABLE 10.1 Matrix for Calculating the Probability of Success for Four Prospects

	Prospects			
Probabilities	**A**	**B**	**C**	**D**
Probability of a source rock	0.9	0.6	0.7	0.3
Probability of a reservoir	1.0	0.7	0.5	0.4
Probability of a trap	0.7	0.6	0.5	0.6
Probability of a seal	0.8	0.5	0.6	0.0
Probability of correct maturation level	0.6	0.4	0.4	0.1
PROBABILITY OF SUCCESS	0.302	0.050	0.042	0.000
	→ Decreasing probability of success			

Prospect

Play: Upper Jurassic Trap: (Structural)/Stratigraphic
Migration:Lateral,Upward Source: Heather FM
Reservoir: Heather Sand Seal: Draupne FM Major risk: Spatial distribution of sands





Exploration Strategy

1-Global basin Analysis

Complete Basin Studies

Acquire new exploration licences

2-Develop play concept

3-Define exploration play areas

4-Evaluate prospect

Compile full lead & Prospect inventory

5-Identify Drillable prospects

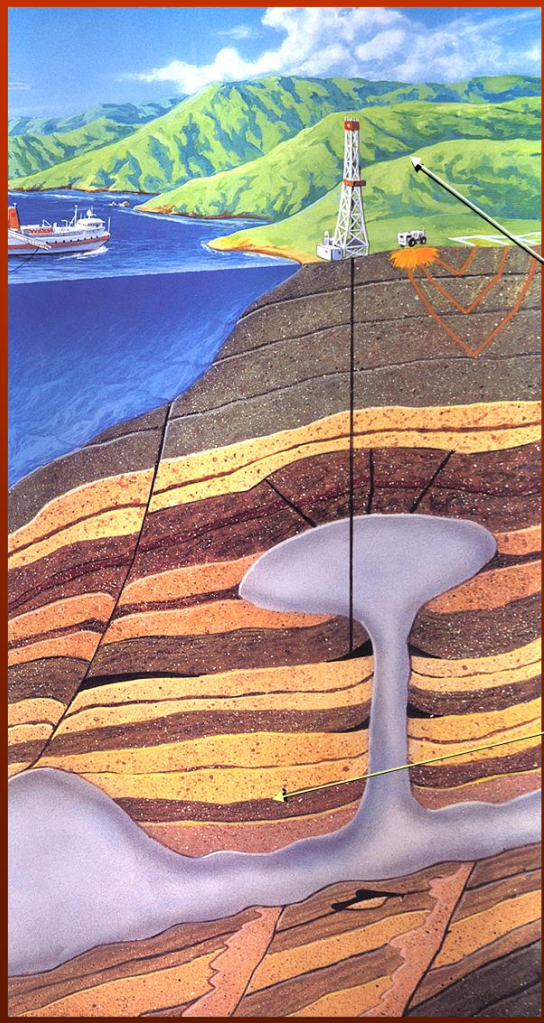
Drillable prospects well proposal

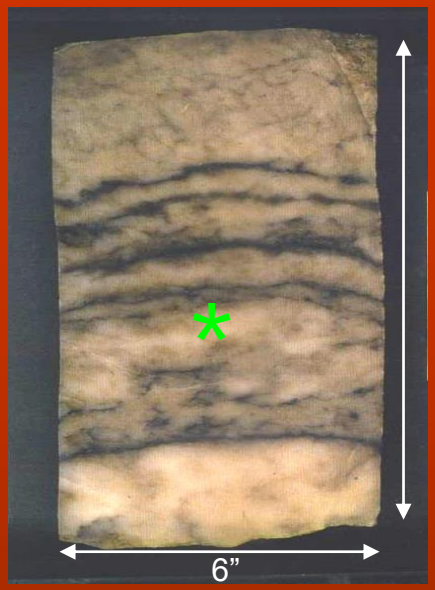
6-Drill exploration wells

=NEW RESOURCES

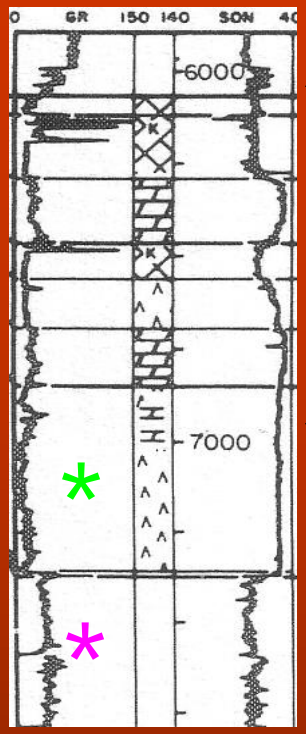
Petroleum Exploration

- Surface and subsurface geological studies
  - Stratigraphy
  - Structure
  - Paleontology
  - Geochemistry
- Seismic surveys
- Gravity and magnetic surveys
- Well logs

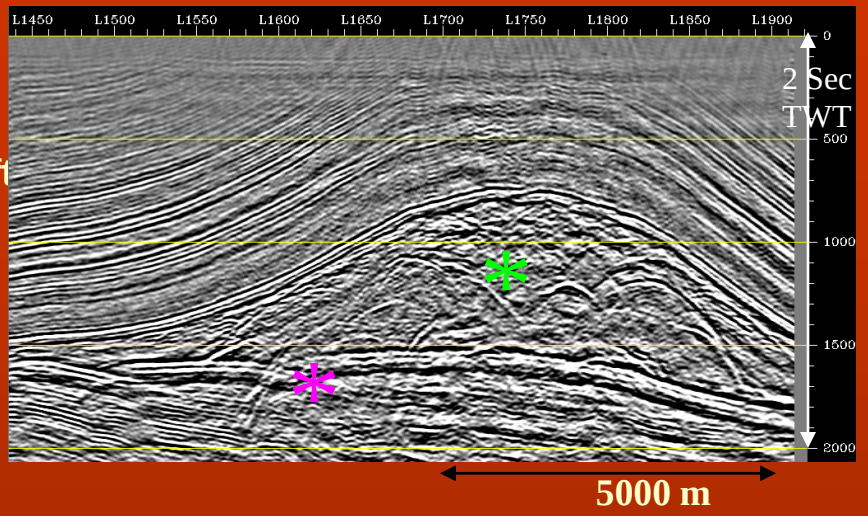




a) Core from well



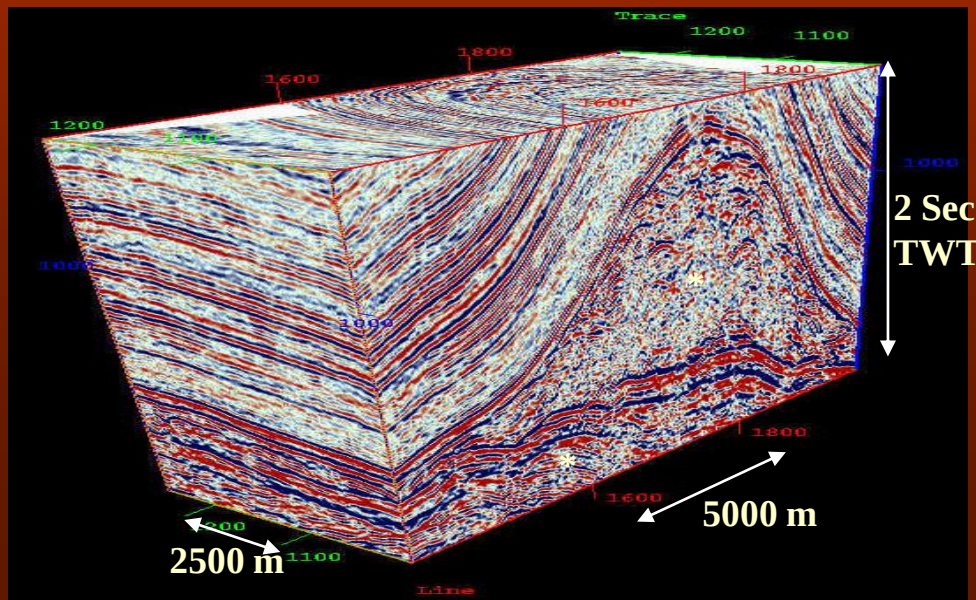
b) Electric wireline well logs



c) 2D Seismic Line

* Salt

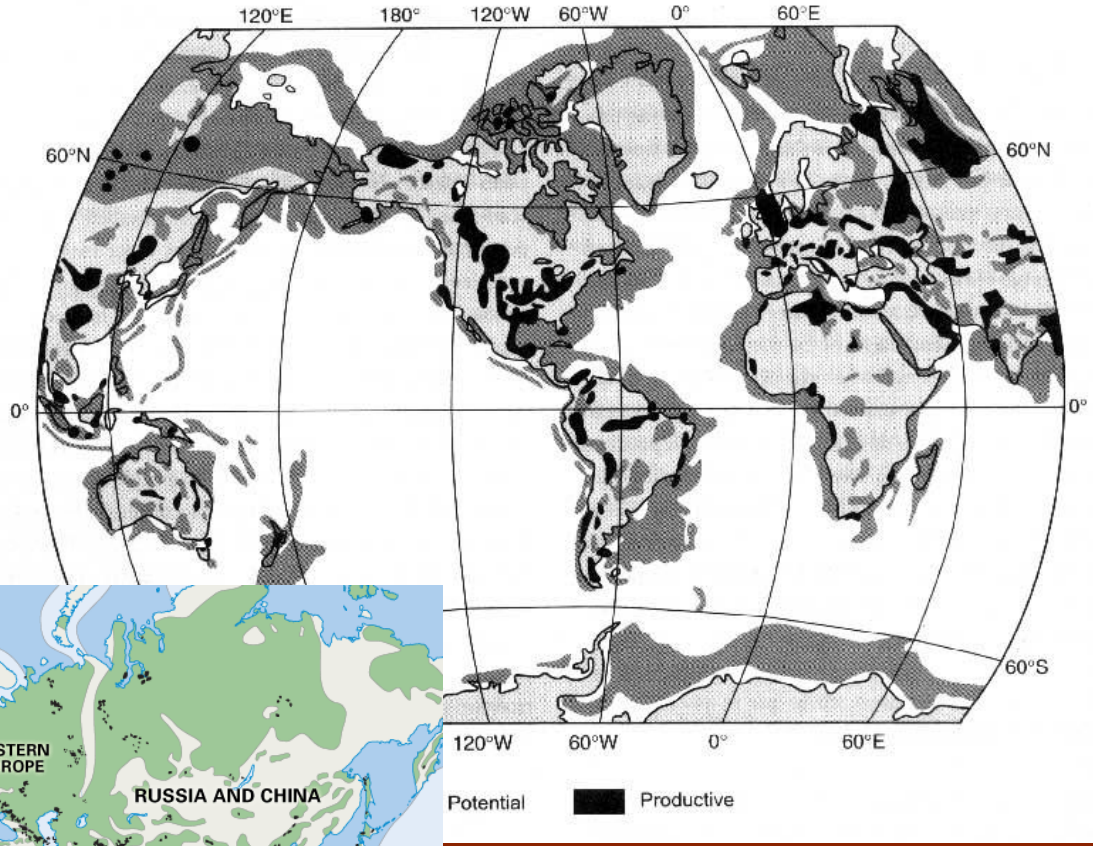
* Sandstone



d) 3D Seismic Volume

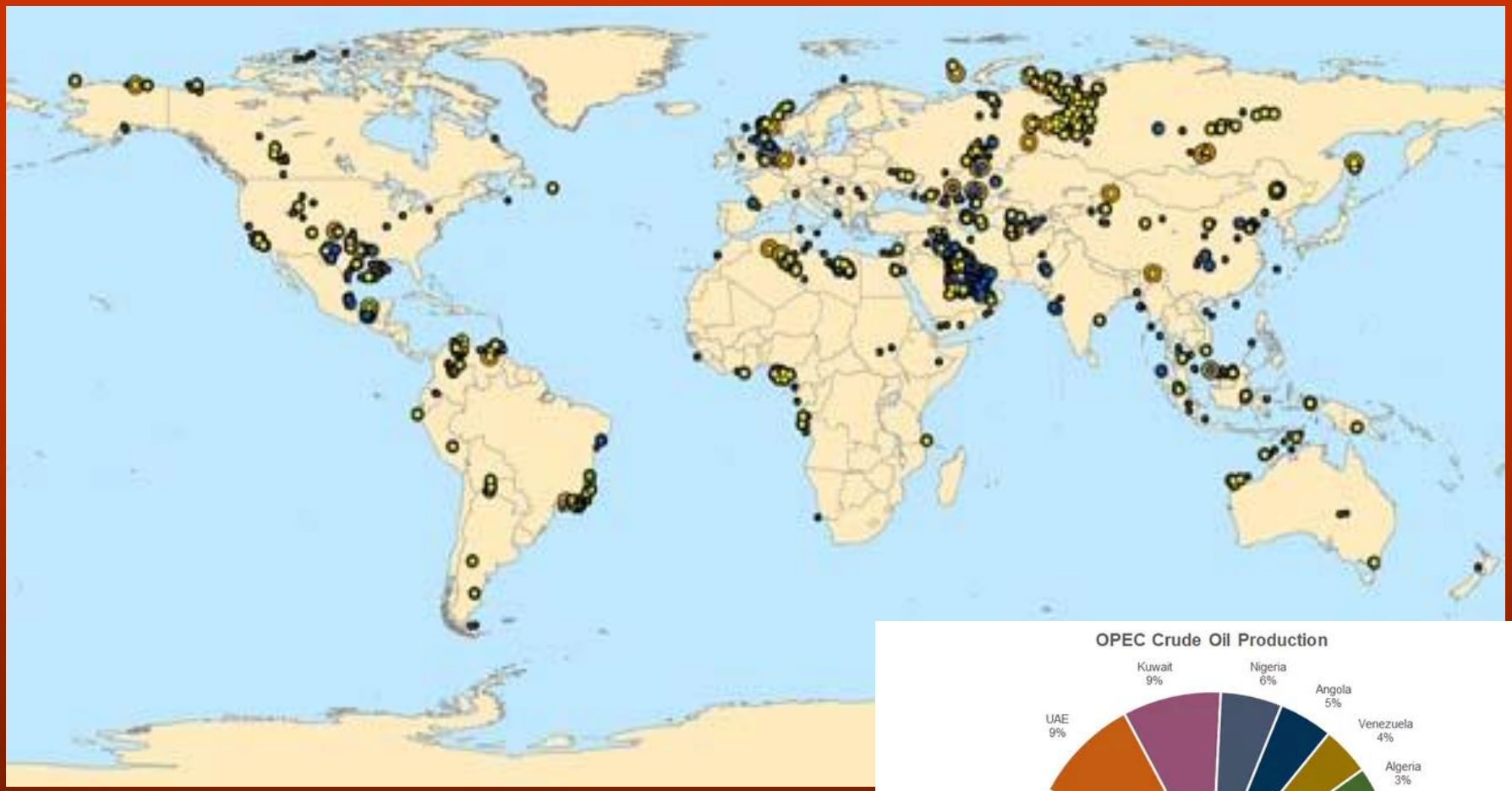
The Black Gold

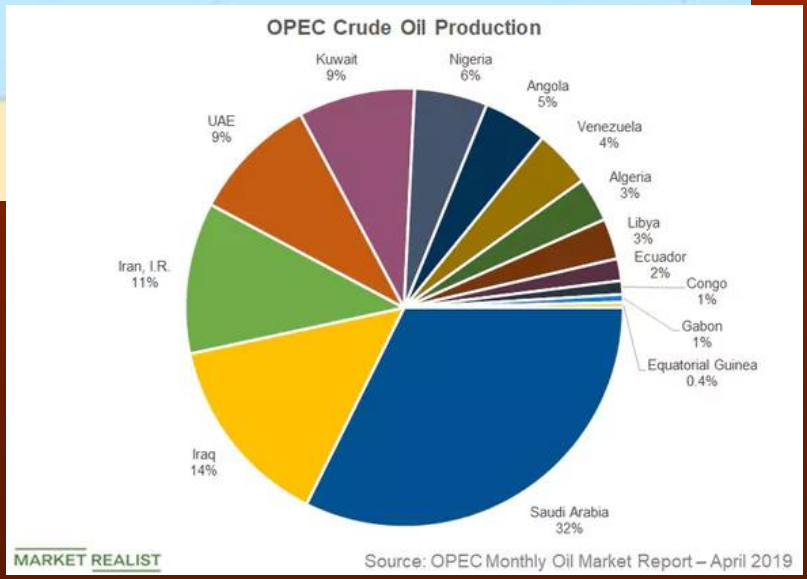
The Major petroleum basins of the world



From Halboury 1986

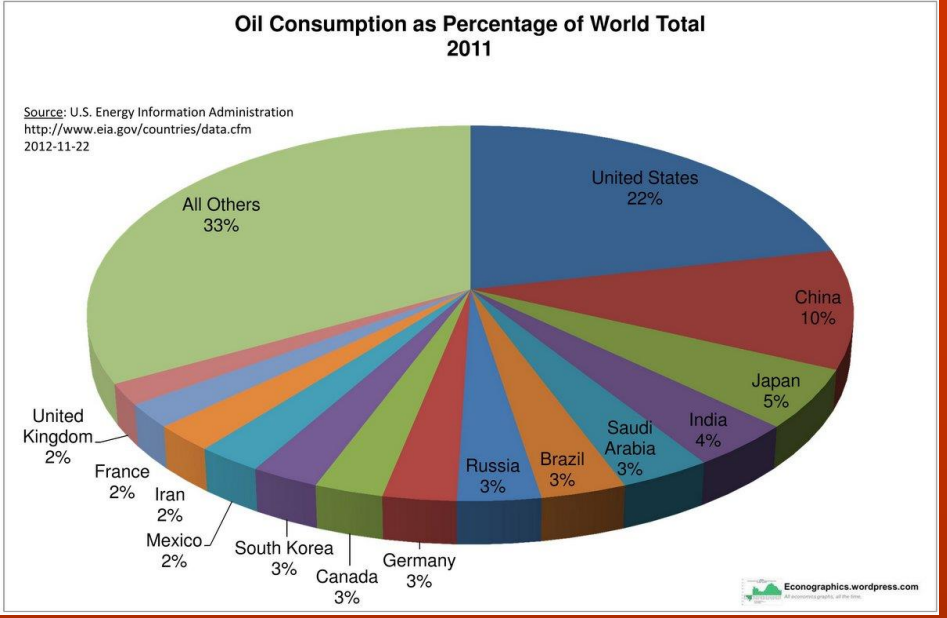
Giant Oil and Gas Fields of the World

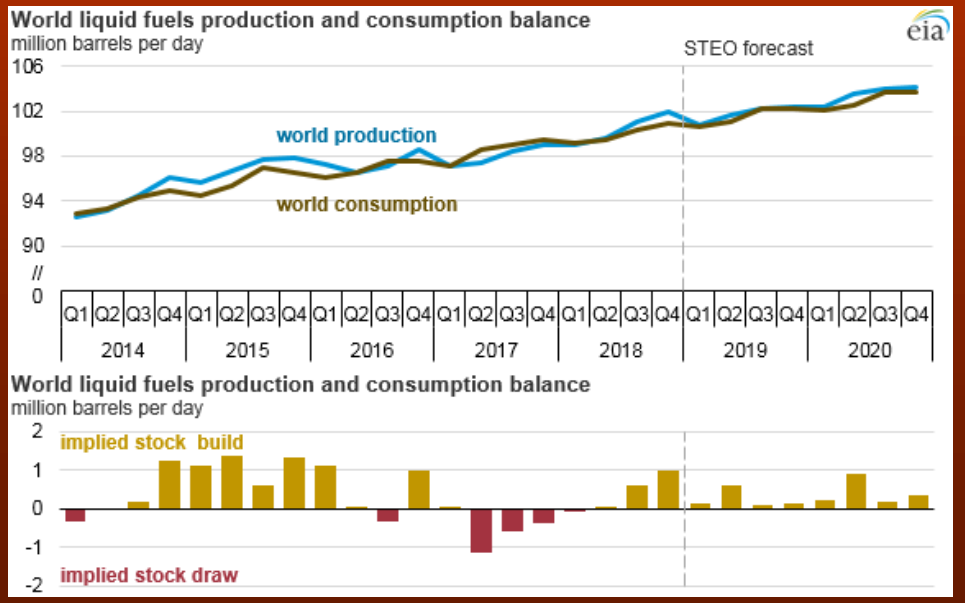




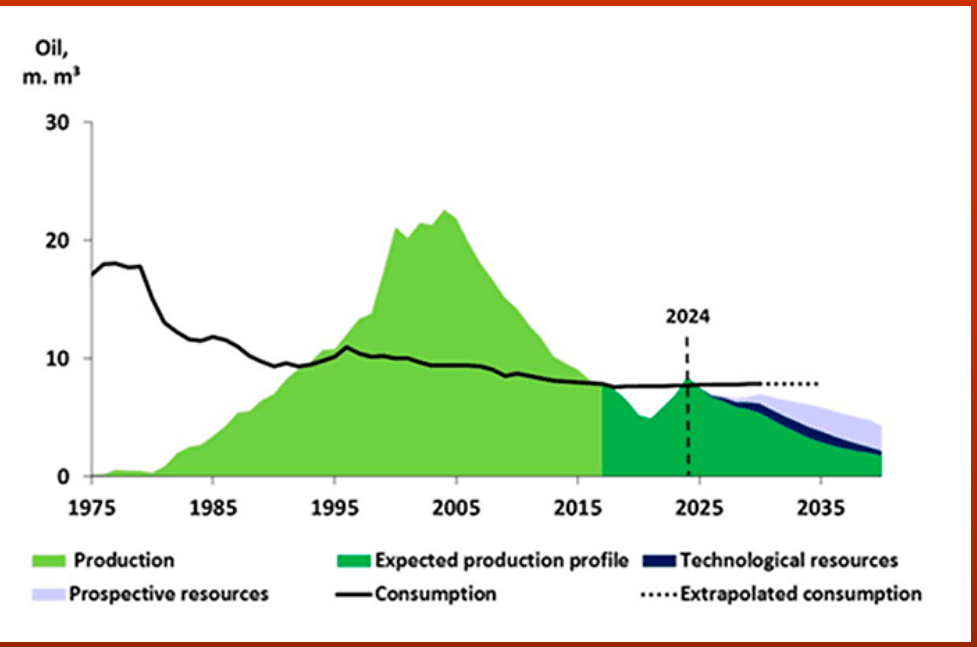
Oil consumption

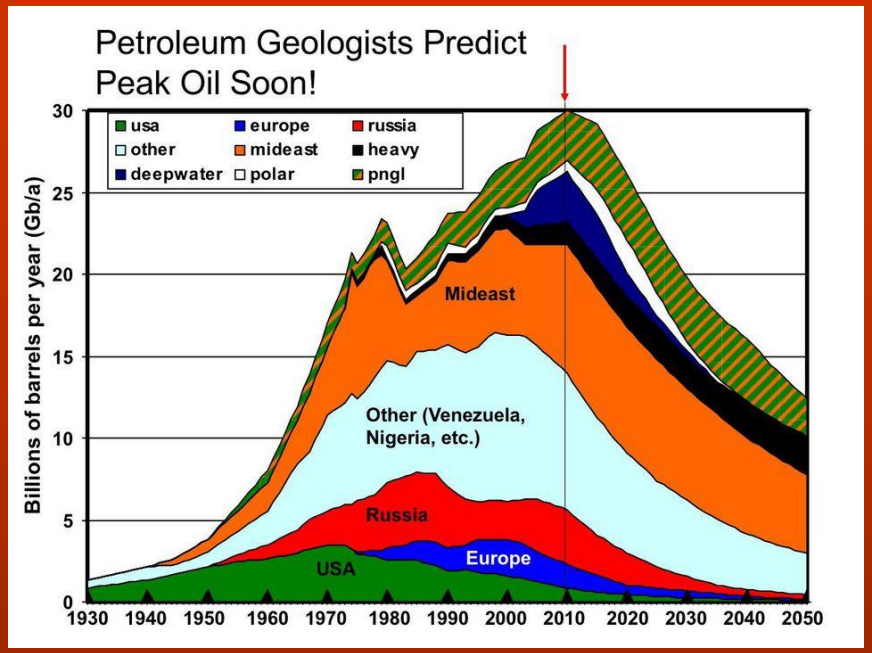
Peak Oil is when we reach the maximum rate of oil production and the demand for oil outstrips the capacity to produce it.

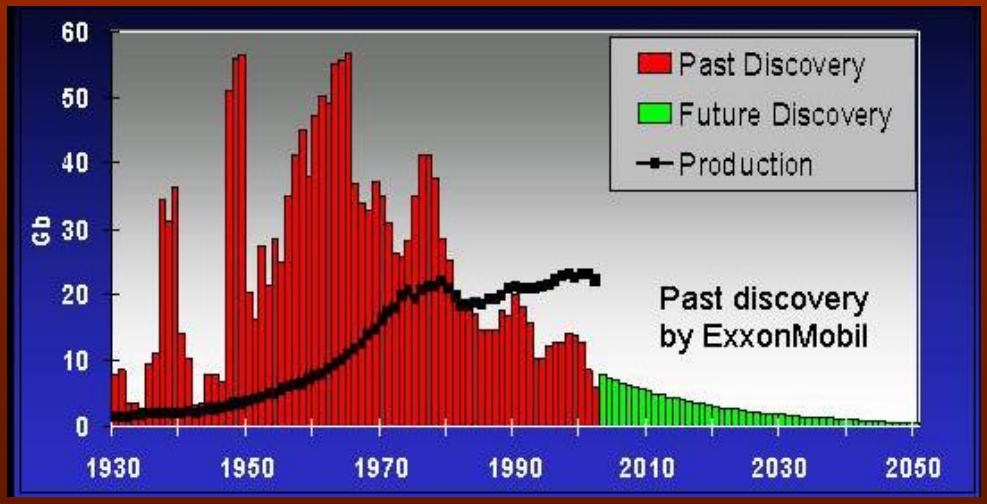


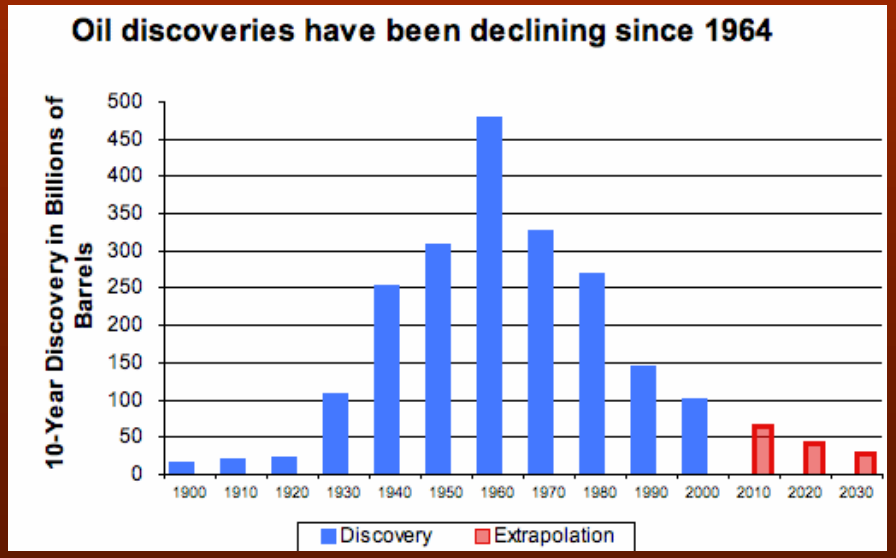


Oil peak and discoveries









Reserves and resources

Oil reserves are the estimated quantities of crude oil that are claimed to be recoverable under existing economic and operating conditions.
Resources are estimated quantities of petroleum to be potentially recoverable but not yet considered mature for comercial development.

The total amount of oil in an oil reservoi is known as oil in place.However only the oil that can be brought to the surface is cosidered to be reserves
The ratio of reserves to oil in place for a given field is refered as the recovery factor

Resources:

Resources are those quantities of hydrocarbons estimated, as of a given date, to be potentially recoverable from accumulations, but the applied project(s) are not yet considered mature enough for commercial development.

Reserves= F (Price,world economics,availability,cost,salaries,technical or fiscal measures,political boundaries,speculations etc.)

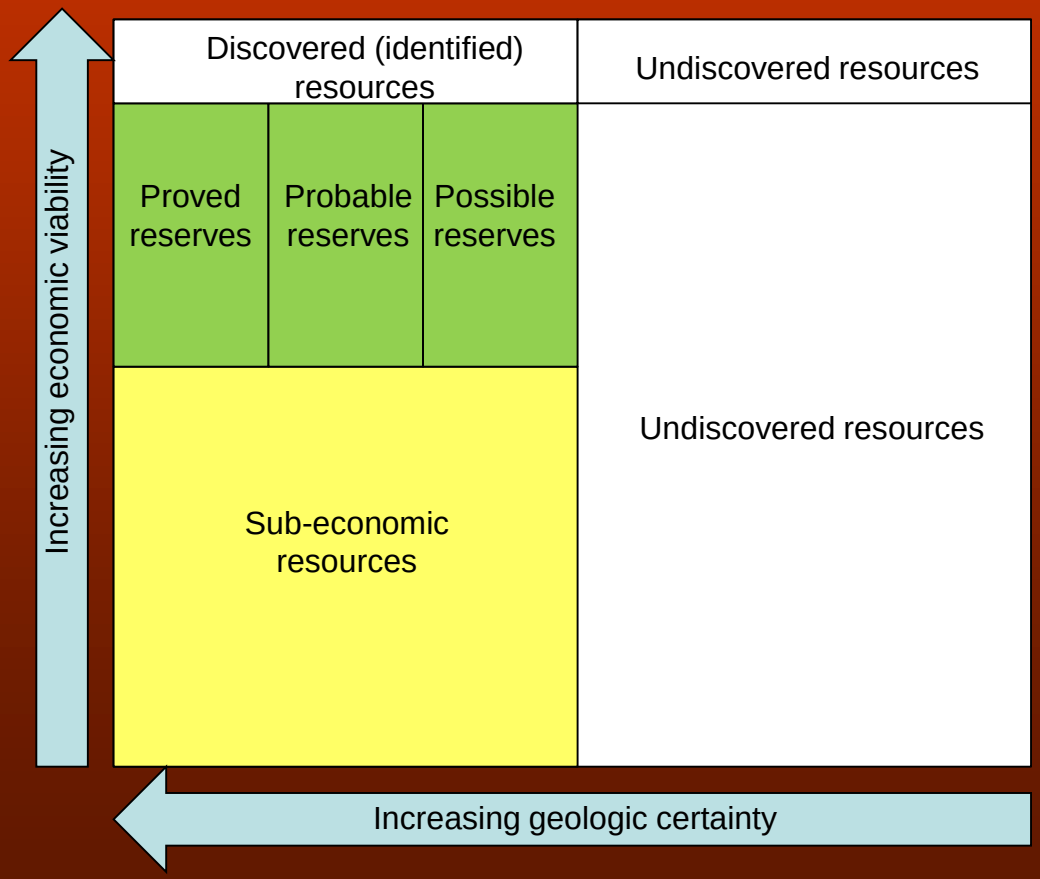
Reserves can be

Proved (reasonable certainty of being recoverable)

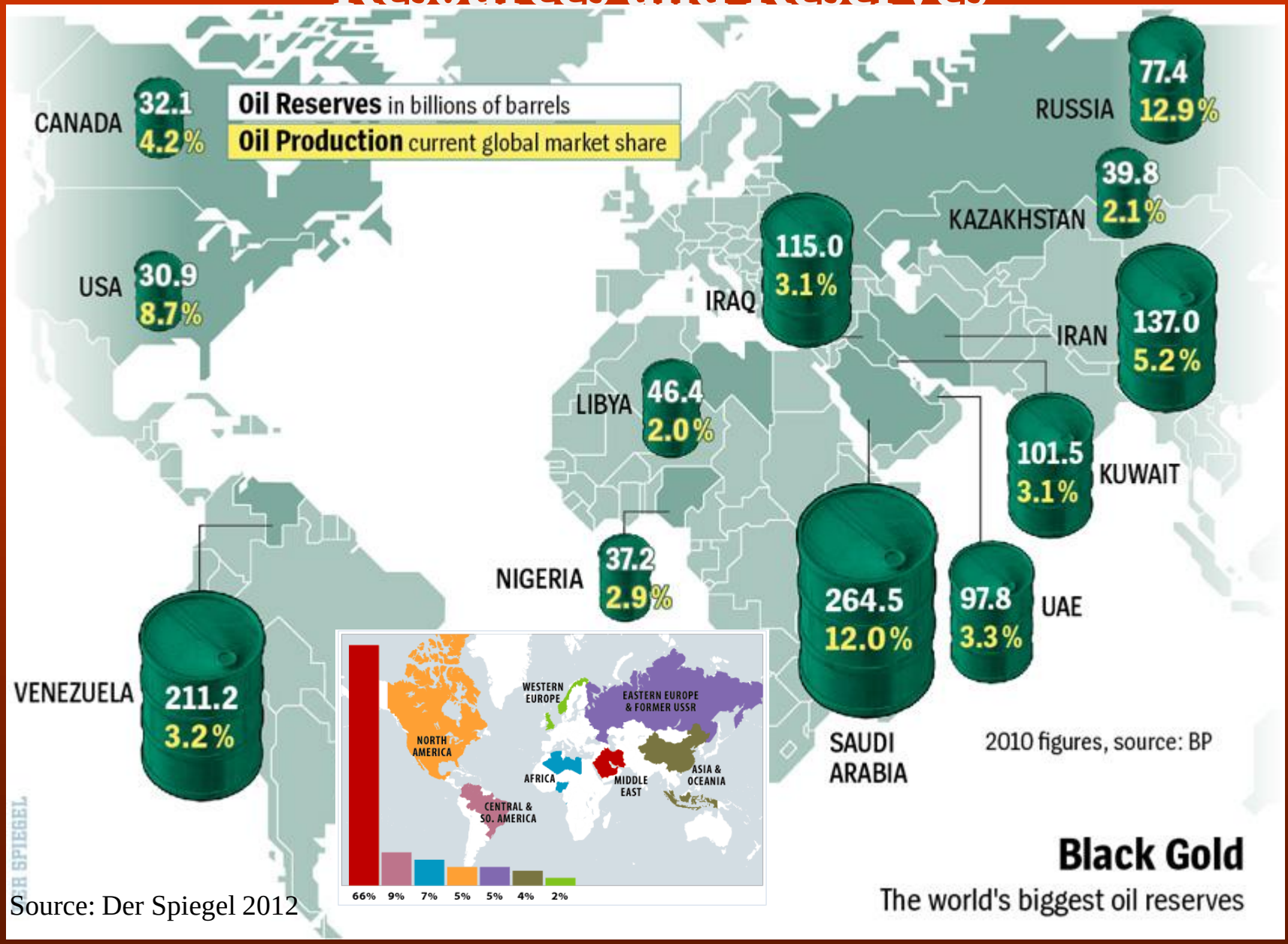
Probable

Possible

Unproved



Resources and Reserves

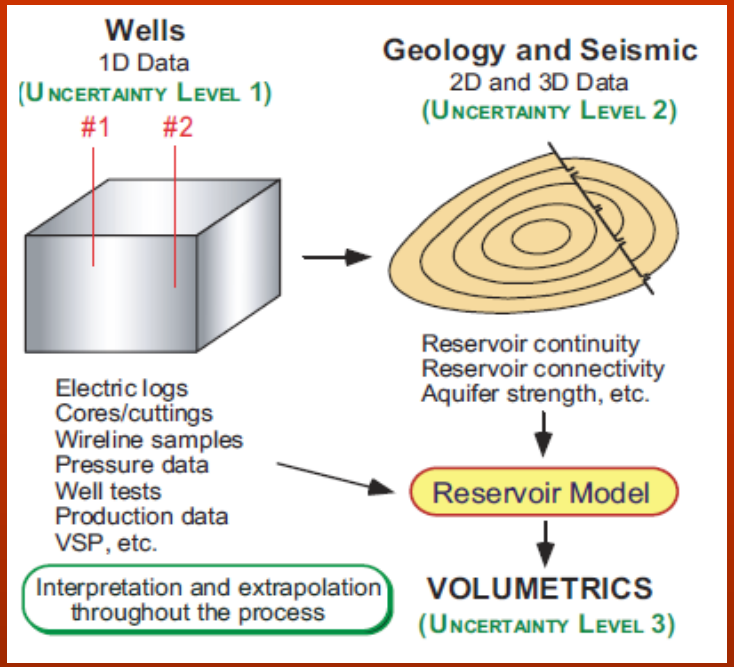


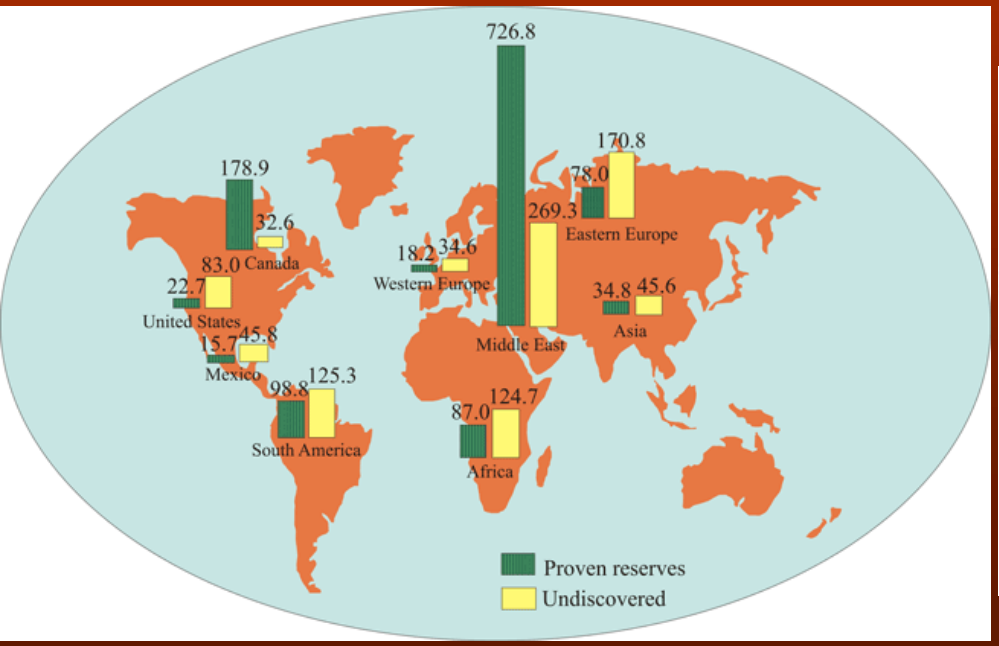
Source: Der Spiegel 2012

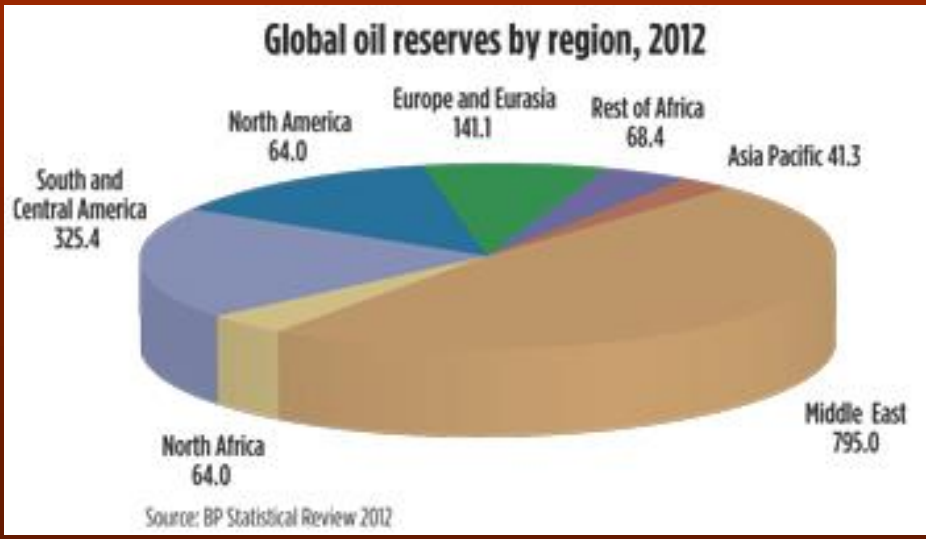
Most oil reserves are in a few large fields.

Warning: All reserve estimates involve uncertainty,depending on the amount of reliable geologic and engineering data available and the interpretation of those data.

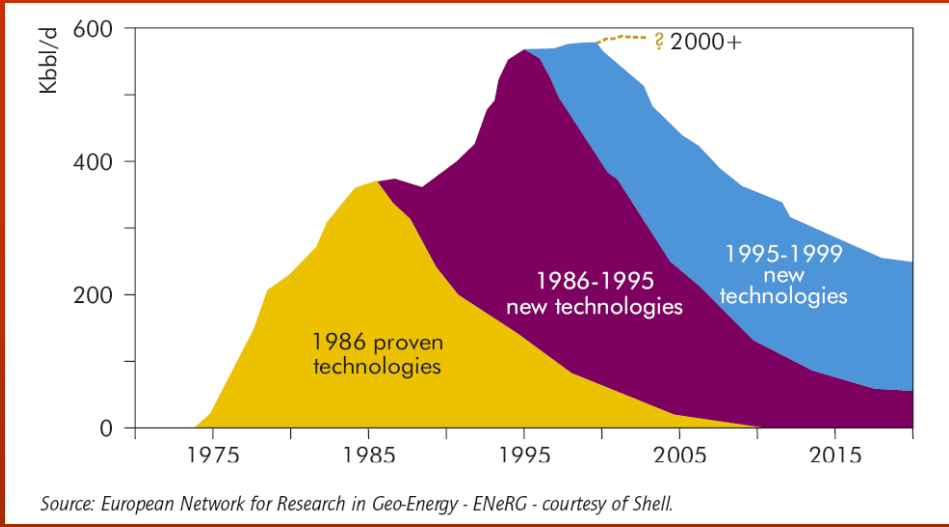
Oil Recovery Factors:
1979: 20%
2000: 35 %
> 2000: 50%
Average increase of the RF : 0,2 – 1% / year
1% Increase = Annual consumption



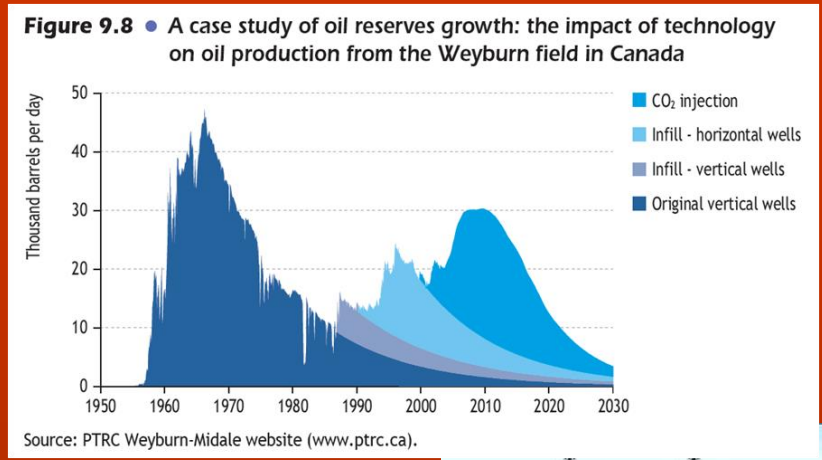


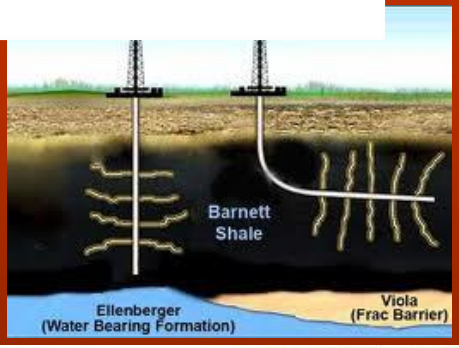


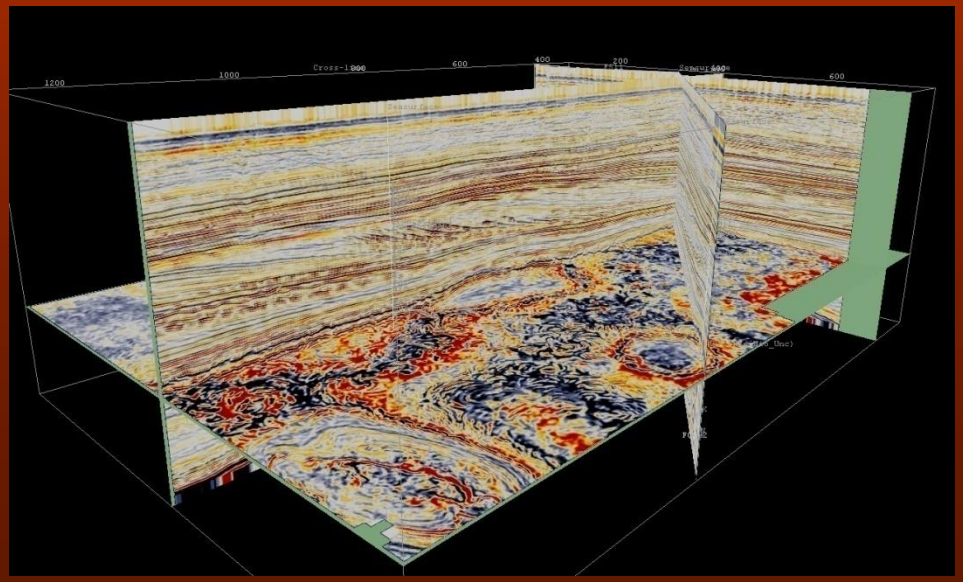
New Technologies

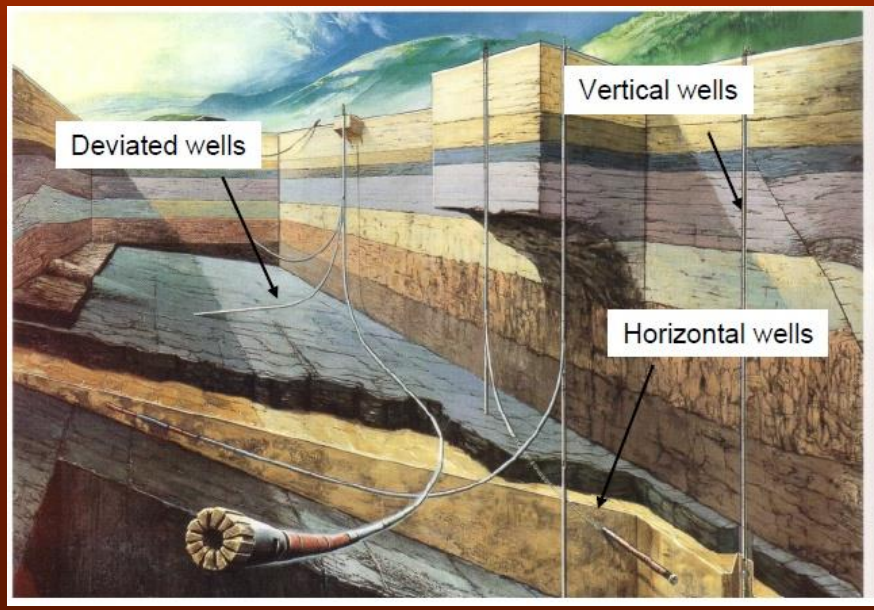


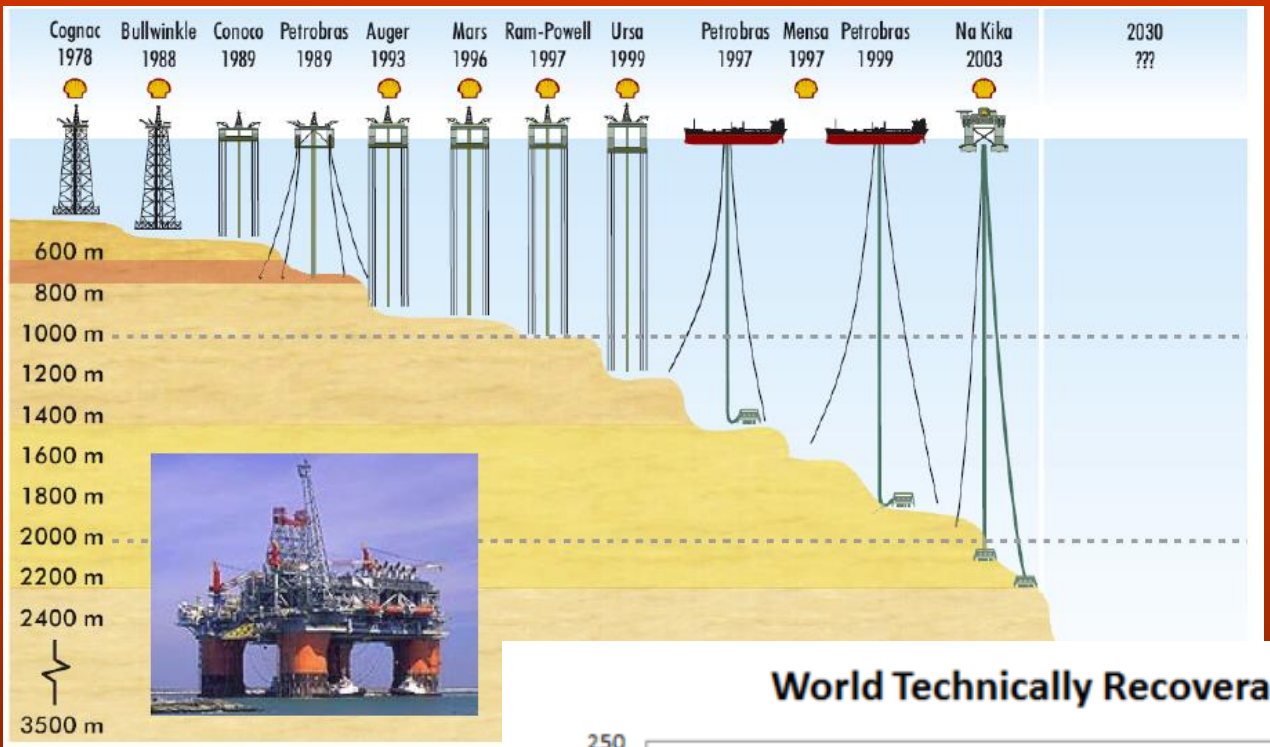
Source: European Network for Research in Geo-Energy - ENeRG - courtesy of Shell.



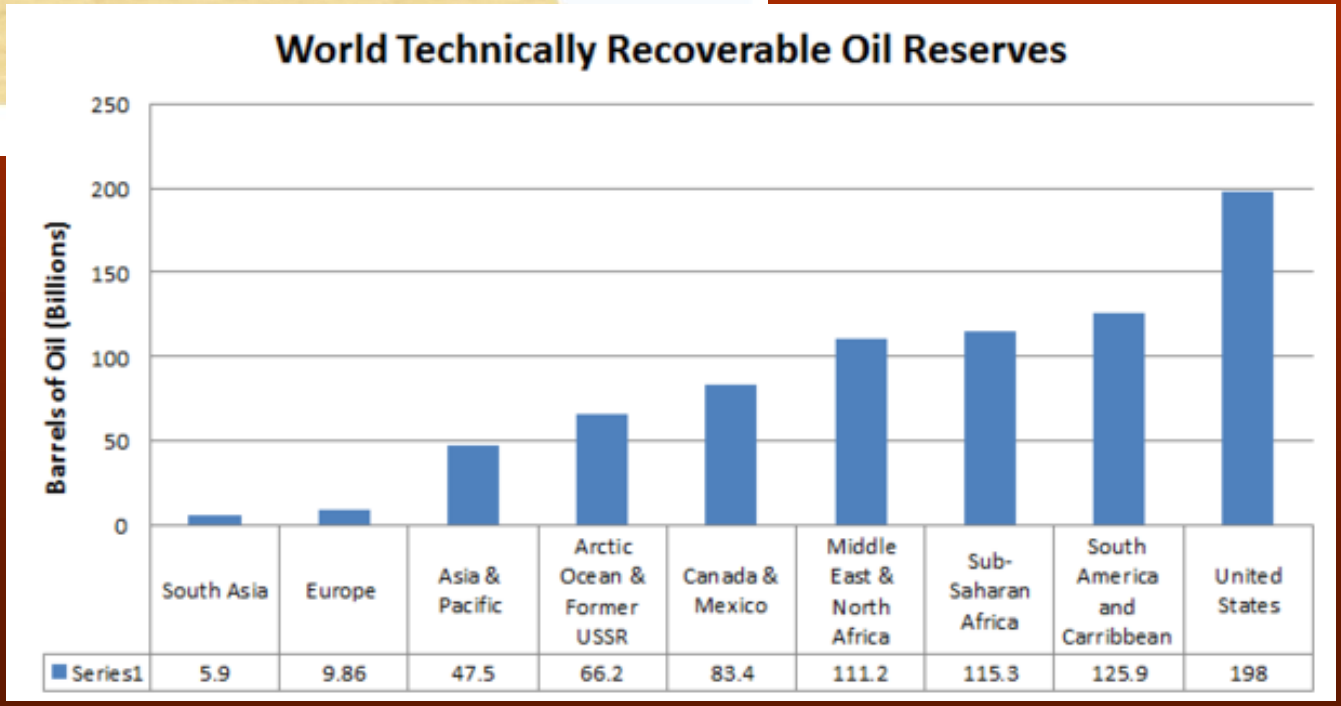








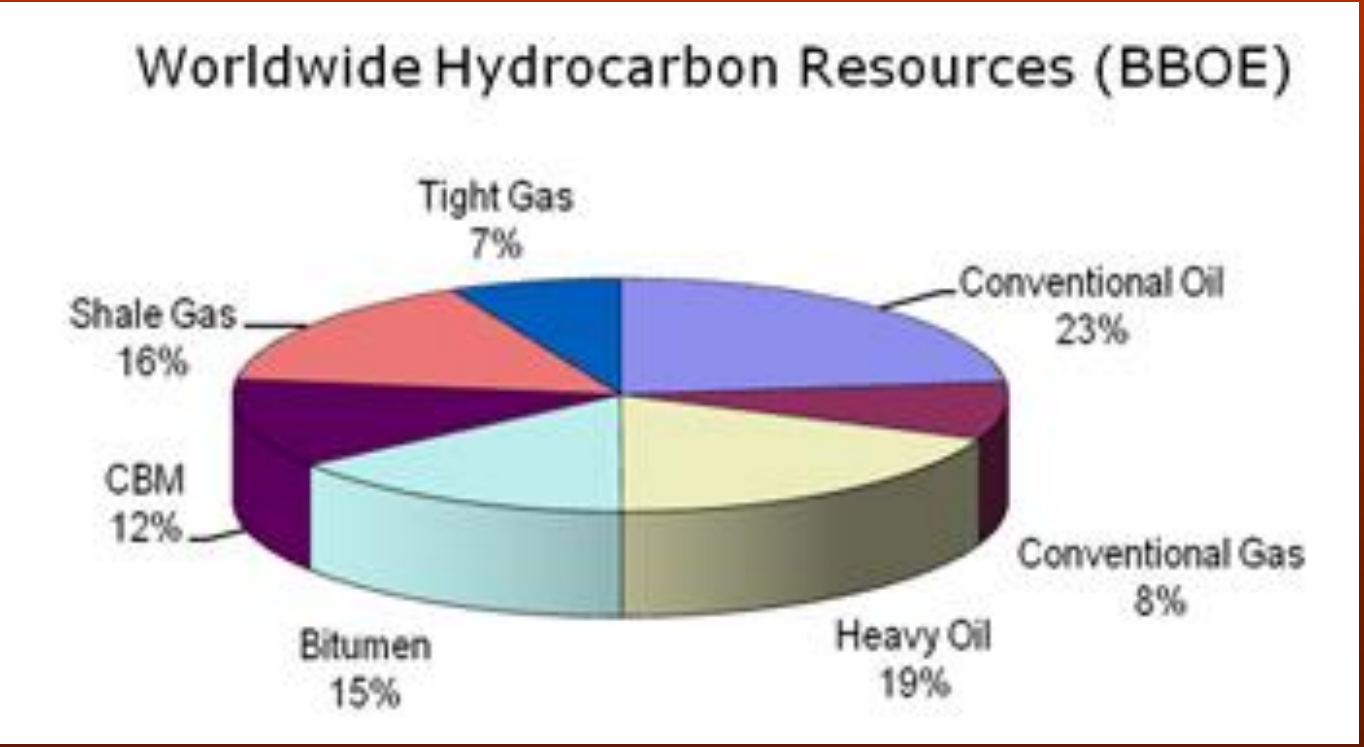
Courtesy of Shell.

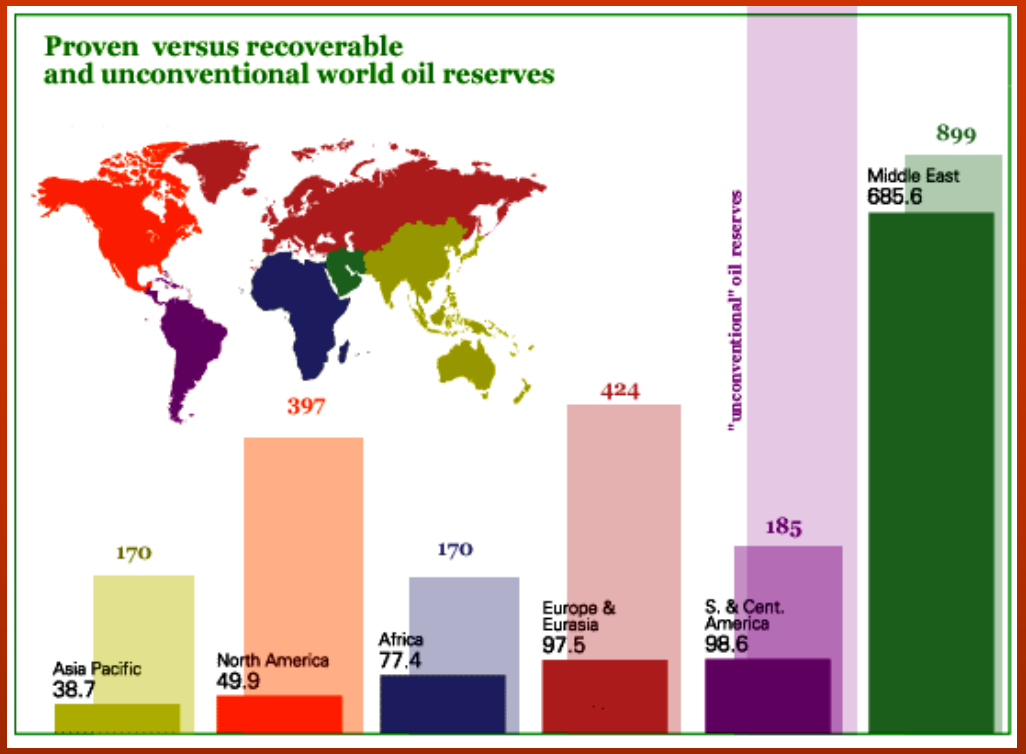


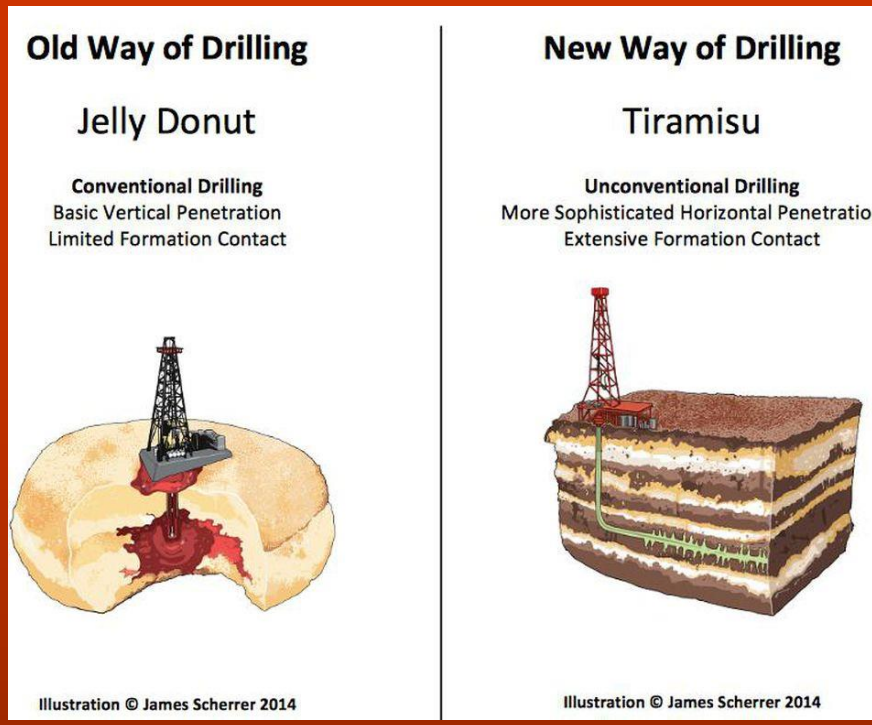
Unconventional resources

Examples include oil/gas shale deposits, extra heavy oil, natural bitumen. Unlike conventional resources, in which the petroleum is recovered through wellbores and typically requires minimal processing prior to sale, unconventional resources require specialized extraction technology to produce. to develop.

For example, steam and/or solvents are used to mobilize bitumen for in-situ recovery. Moreover, the extracted petroleum may require significant processing prior to sale (e.g., bitumen upgrades). The total amount of unconventional HC resources in the world considerably exceeds the amount of conventional oil reserves, but are much more difficult and expensive





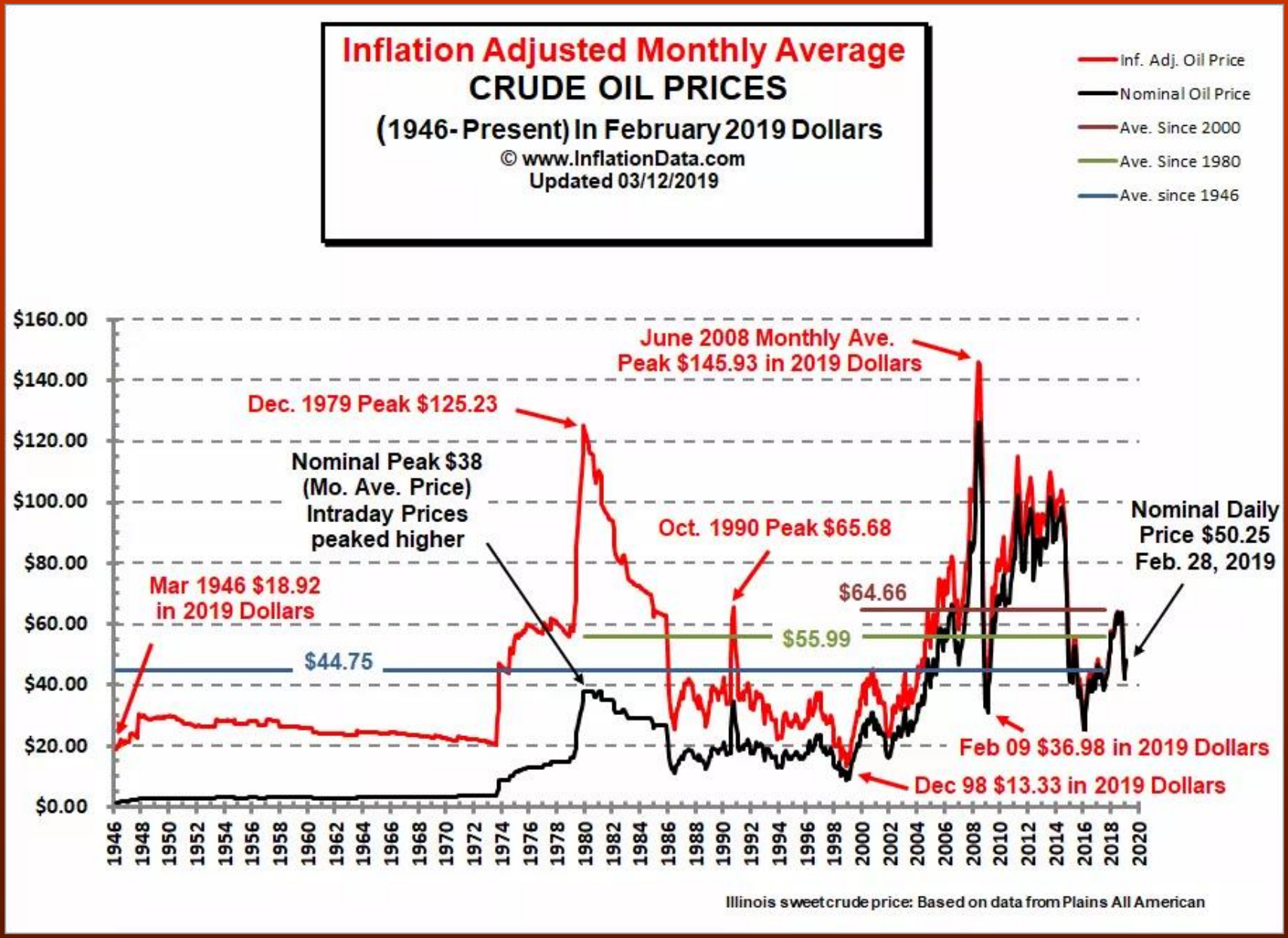


But... Never forget the minuses on the Unconventional HC developmentProblems with

Upside	Downside
• Low exploration risk	• Expensive drilling and completion
• Long-life reserves	• Oil upgrading is capital intensive
• Stable, predictable production	• Low energy return on investment
• Assembly-line development	• Large greenhouse gas emissions
• Long project life provides: - opportunity to improve recovery - opportunity to improve efficiency - security of supply	• High oil recovery requires large amounts of water
• Gas decline rates decrease with time	• High gas recovery requires high well density
	• Potential for groundwater contamination

Crude oil prices 1946-2019

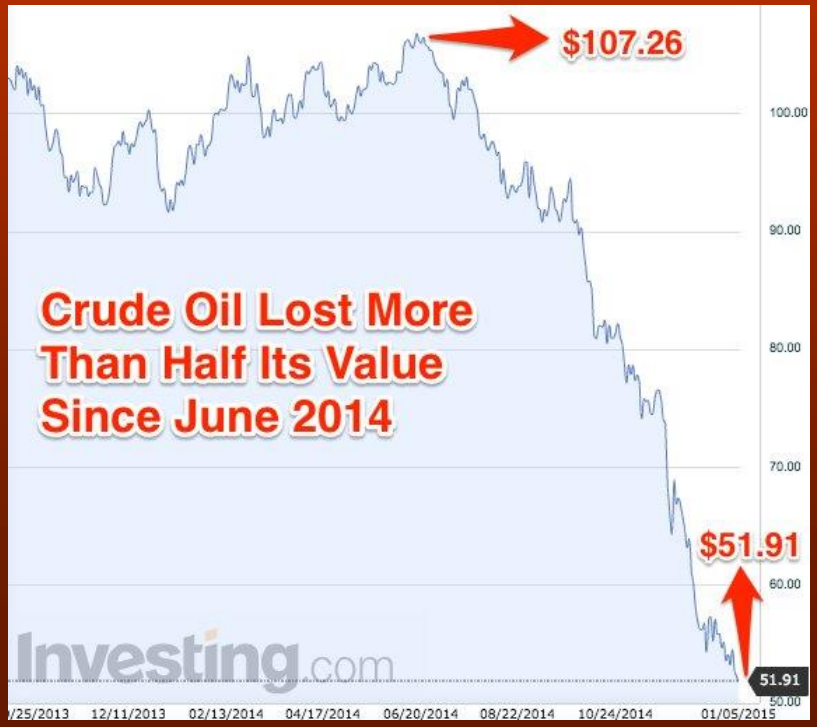
US dollars per barrel

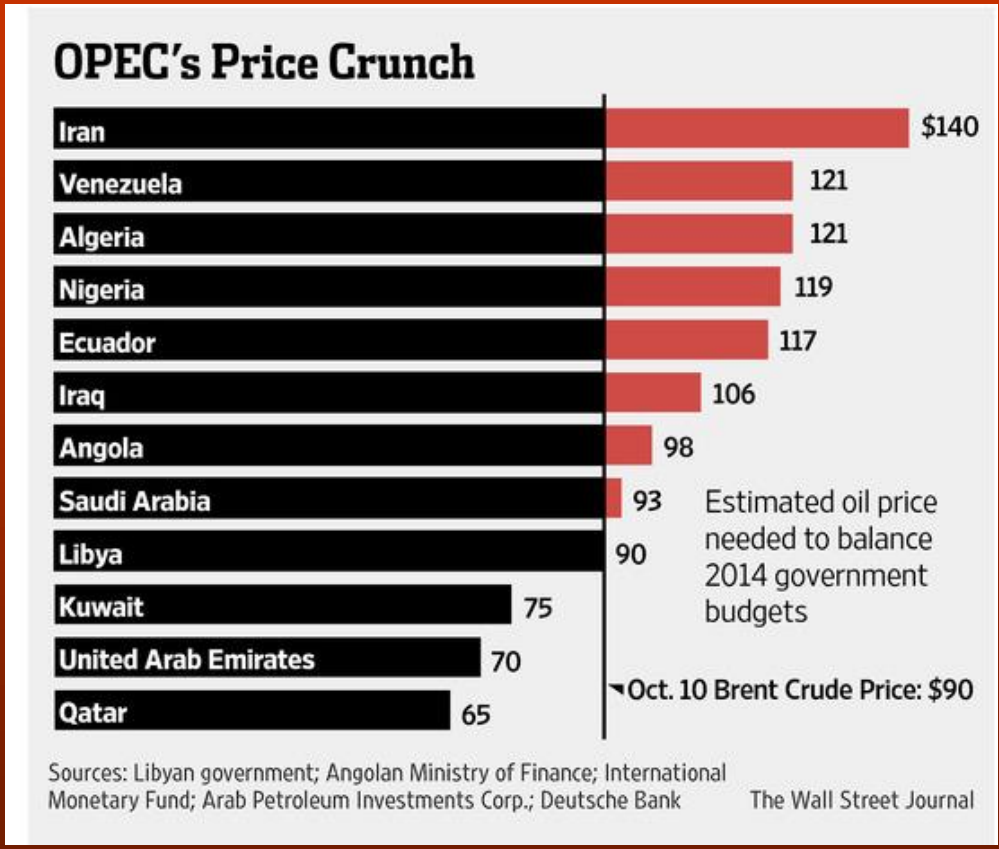


BUT…

Oil prices dropped dramatically from 2014 reaching now the lowest prices since 2009

But..why??? Mainly due to political reasons!!





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Crude Oil Nov 2018

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OPEN

$72.22

▲0.10 0.14%

Last Updated: Sep 28, 2018 at 5:01 a.m. EDT
- Delayed quote

Advanced Charting | 1D | $ | % | VOL

$72.50
$72.25
$72.00
8pm

SETTLEMENT PRICE 09/27/18

$72.12

43.26% VS AVG.

VOLUME: 57.3K | 65 Day Avg. - 132.4K

OPEN: 72.2

72.11

OVERVIEW | CHARTS | HISTORICAL QUOTES

KEY DATA | RECENT CONT

OPEN | 52 WEEK RANGE

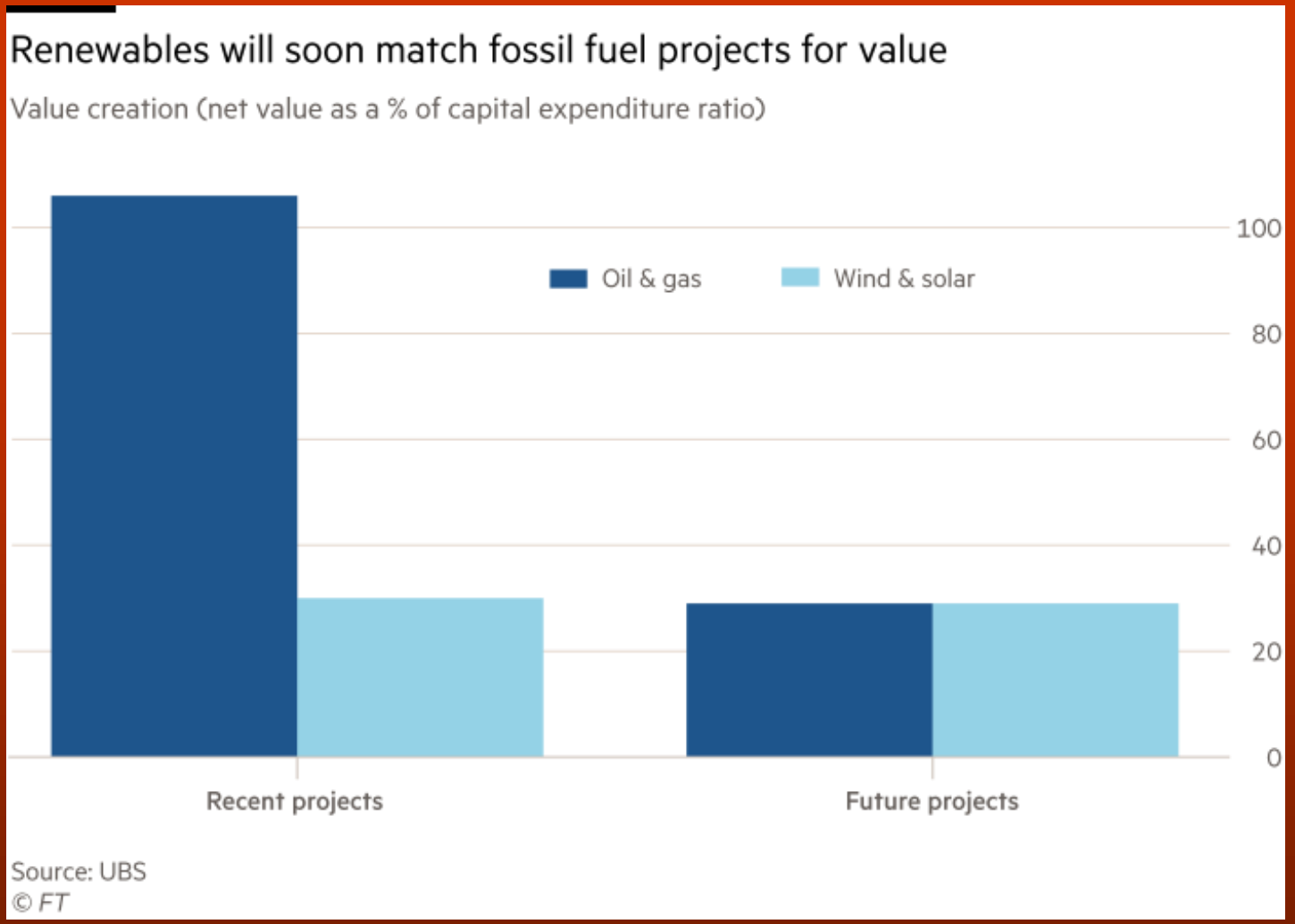
Oil price hits 18-year low

Brent crude, US dollars per barrel

Source: Bloomberg, 30 March 2020, 08:30 GMT

BBC

Crude oil Price….today 40.96 $



Further reading:

https://www.ft.com/content/99fc40be-83aa-11ea-b872-8db45d5f6714

https://phys.org/news/2020-09-pandemic-oil-gas-industry.html

https://www.woodmac.com/news/editorial/renewable-energy-hunt-for-best-returns/