An ancient history, between Oil&Gas Exploration&Production and development of geo-sciences

Geology and Economy:
two of the main drivers of the society

The starting point

A

1. **Primary source** and **secondary source** of energy
2. **Renewable** and **non-renewable** energy sources
3. The **use of oil and gas** in the modern society
4. Fundamentals of **Petroleum Geology**:
    1. Petroleum system
    2. Exploration
    3. Resources/Reserves classification
    4. Volumetric calculation
    5. Development & Economics

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1. When the **first well** has been drilled in USA? And in Italy?
2. The evolution of the **knowledge**
3. How much Oil&Gas has **still to be discovered**?
4. **Economic** and **Energy scenarios**: World, Europe, Italy

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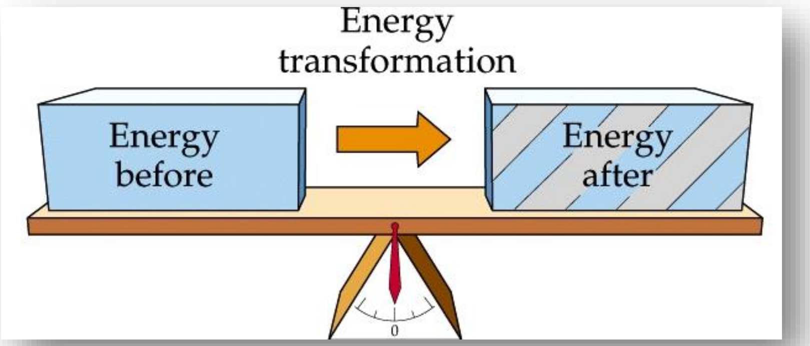
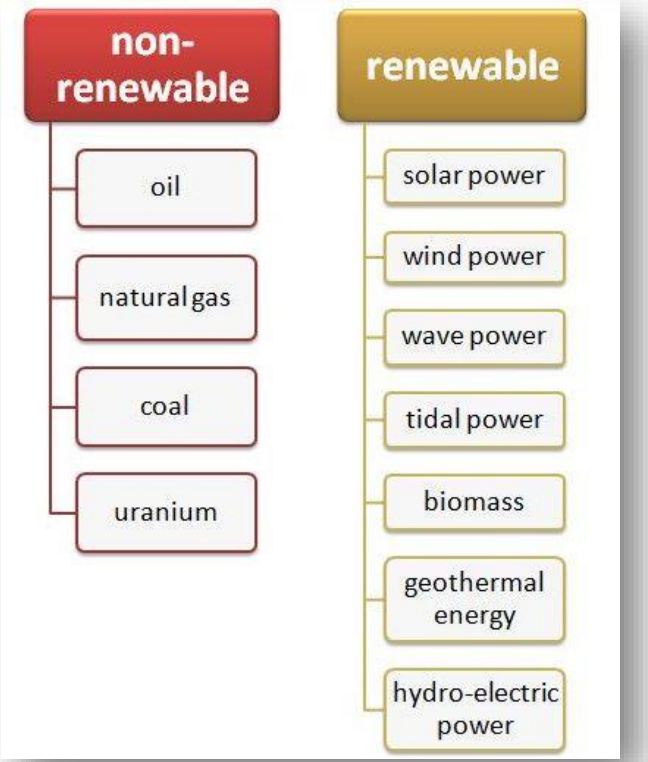
First law of thermodynamics
"In an isolated System energy is neither created nor destroyed, but is transformed from one form to another"

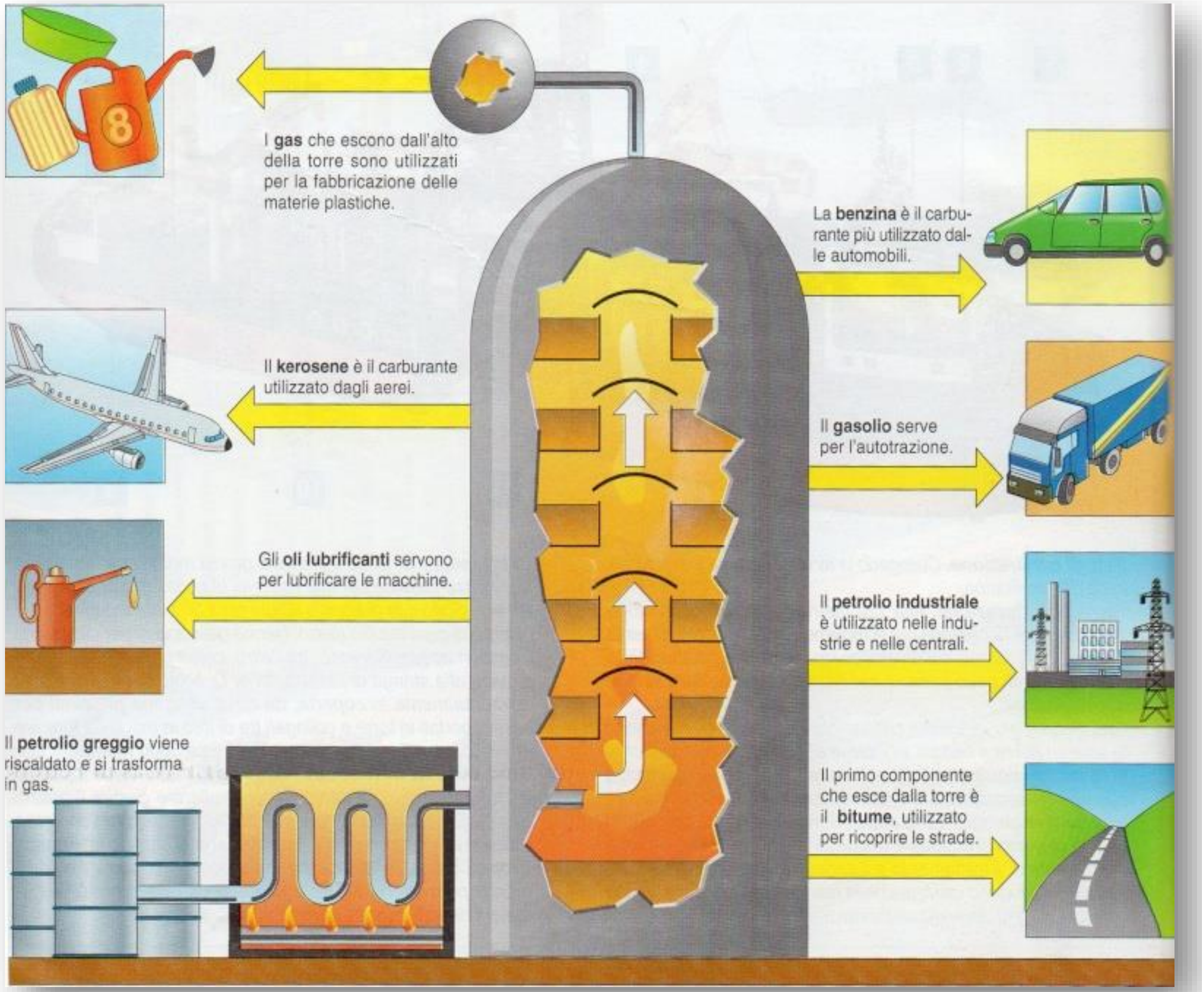


Energy sources:

- **Primary** if it is present in nature and usable as it is. Energy does not derive from the transformation of another source
  - **Renewable source**: solar, wind, hydroelectric, geothermal, from biomass
  - **Non-renewable source**: fossil sources that can be used as such (raw fuels, natural gas, coal, nuclear)
- **Secondary** if it can be used only through its transformation (petrol, electricity, hydrogen)



OIL –its use after refinery



- Artificial hearts and sanitary prostheses
- Aspirin
- Balloons
- Bende
- Blenders
- Cameras
- Candles
- CD players
- garments
- CD / DVD
- Computer
- Televisions
- Mobile phones
- Containers
- Colored crayons
- Credit cards
- Dentures
- Deodorants
- Digital watches
- Dyes
- Fertilizers
- Food preservatives
- Soccer balls
- Furniture
- Shaving foam
- Soft contact lenses
- Surfboards
- Telephones
- Tents for camping
- Toothpastes
- Toys
- Umbrellas
- Garbage bags
- Glasses
- Glue
- Golf balls
- Hairdryer
- Hang gliders
- Paints
- Ink
- Insecticides
- Life jackets
- Rossetti
- Suitcases
- Medical appliances
- Medicine
- MP3 players
- Tights
- Protective structures for patio / veranda
- Scents
- Photographic films
- Photos
- Piano keys
- Rollerblade
- Roof covers
- Shampoo
- ...

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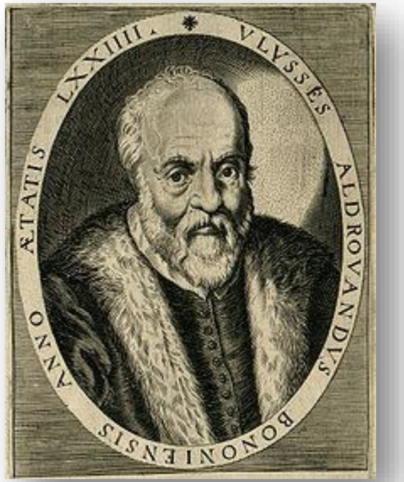
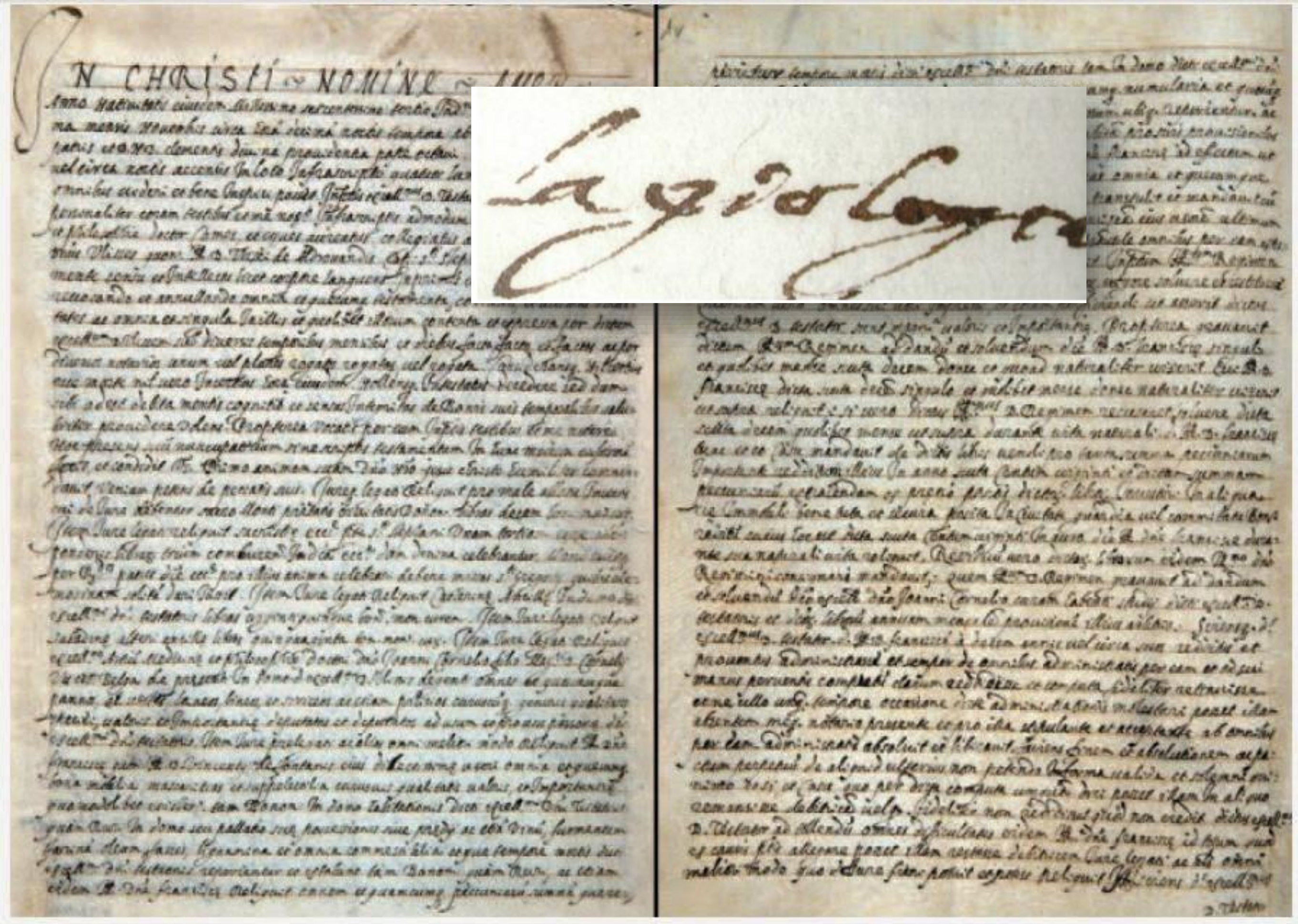
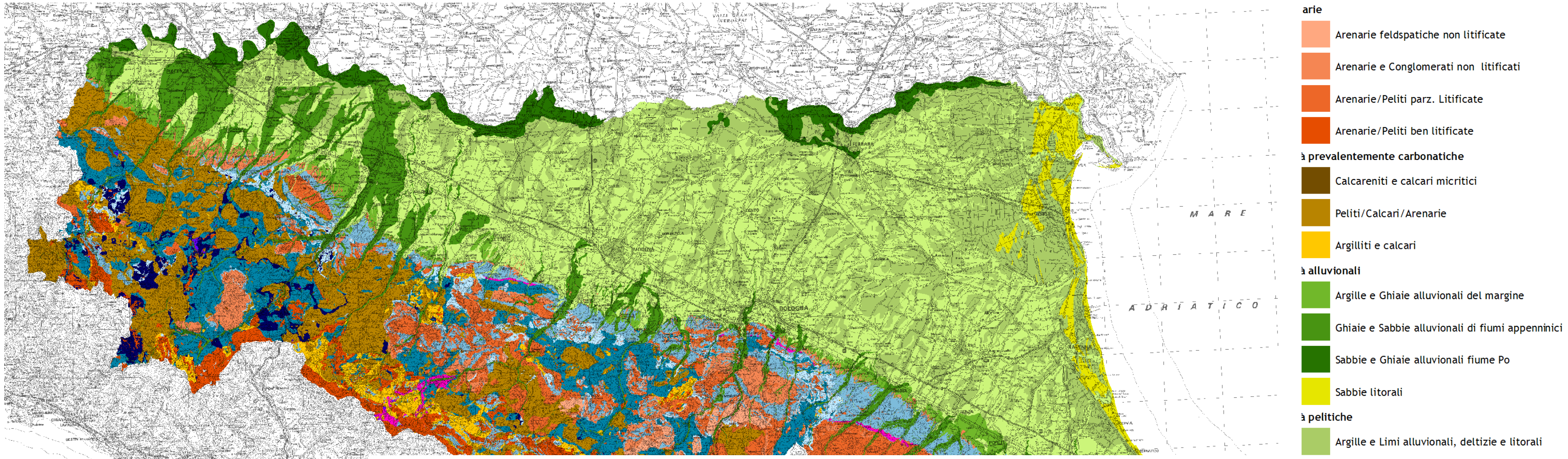
GEOLOGY (from the Greek γῆ, gê, "earth" and λόγος, logos, "study") is the branch of Earth Sciences that studies the Earth and the processes that shape it and change it

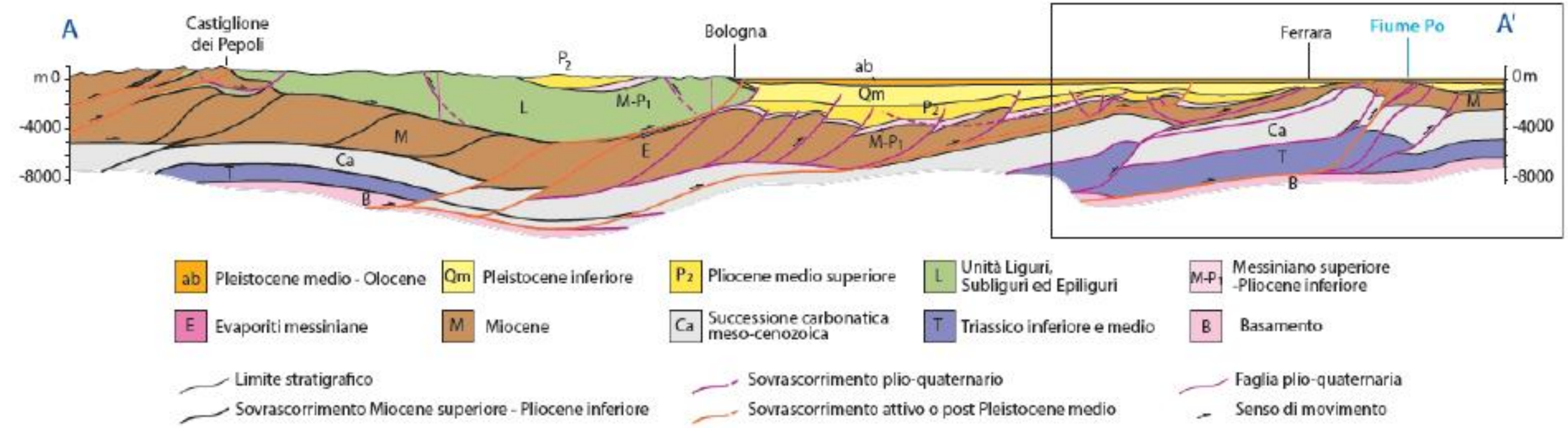


The term "geology" was used for the first time in 1603 by the naturalist Ulisse Aldrovandi (Bologna, 1522; 1605) in his will, in which he has his books and his collections of "Giologia, Botanologia & Zoologia"



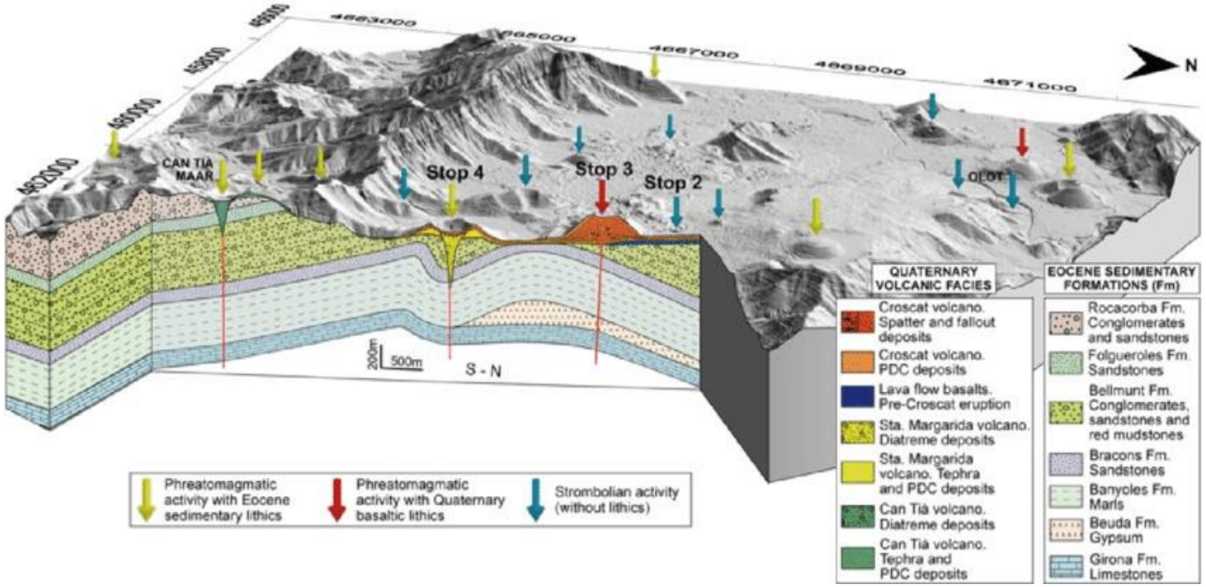
The geological map & the geological section

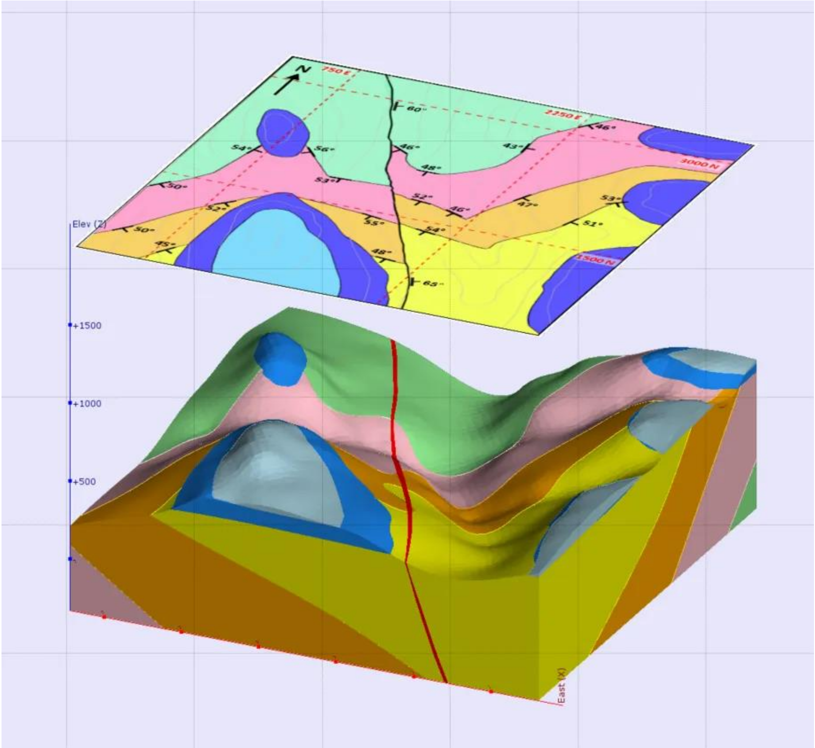


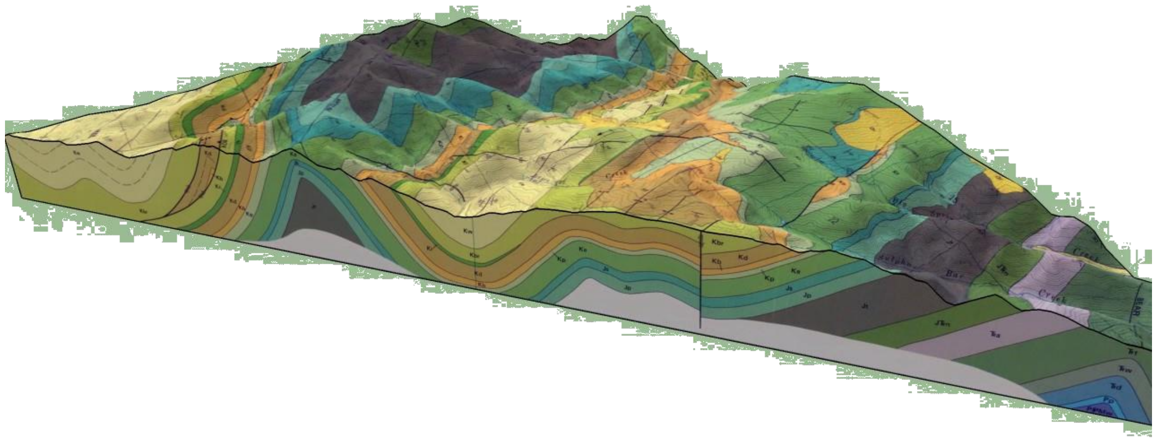


Fundamentals of Geology

The geological map & the geological section

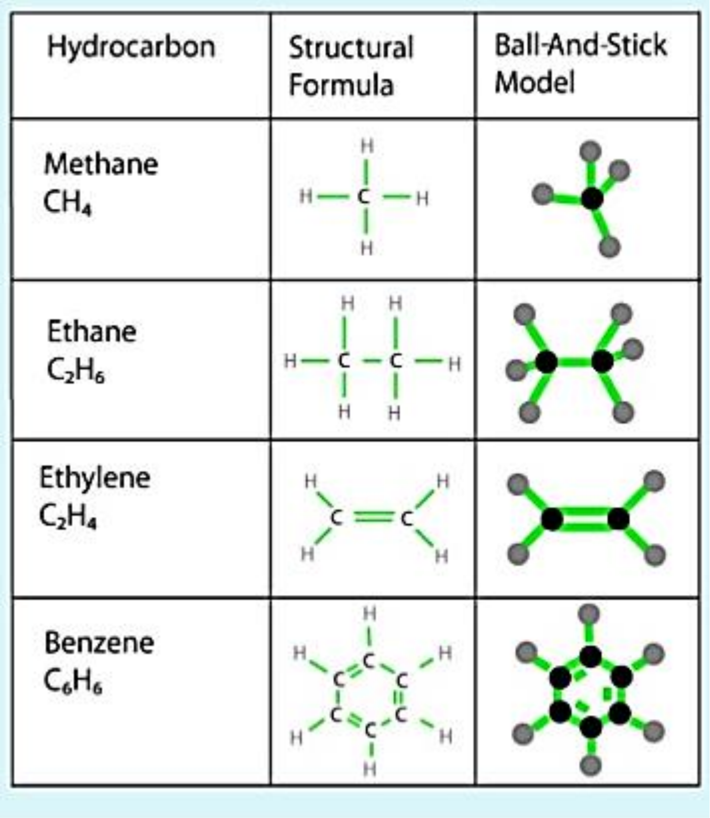


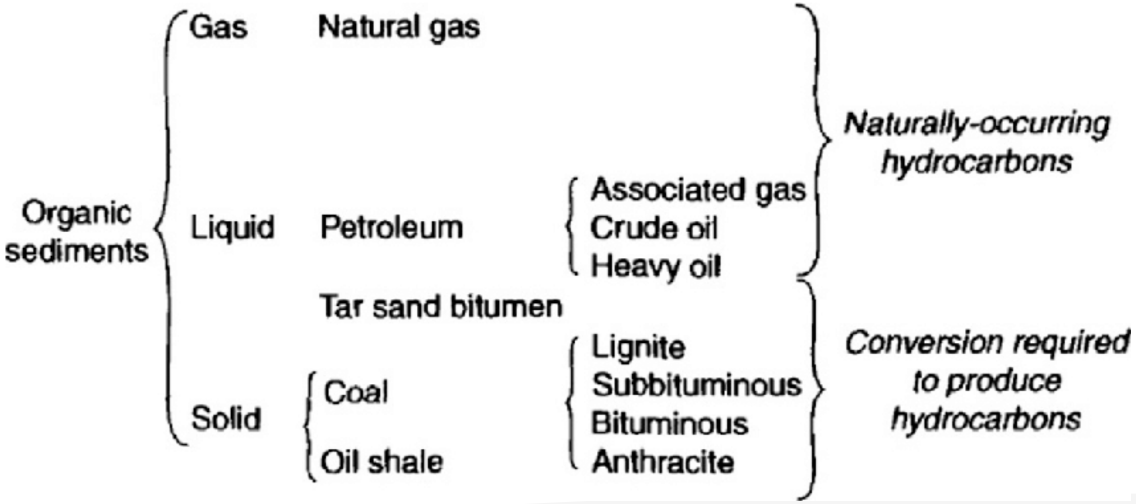




Hydrocarbon, any of a class of organic chemical compounds composed only of the elements carbon (C) and hydrogen (H).
The carbon atoms join together to form the framework of the compound, and the hydrogen atoms attach to them in many different configurations.

The most known hydrocarbons are **oil** and **natural gas**.





Fundamentals of Petroleum Geology

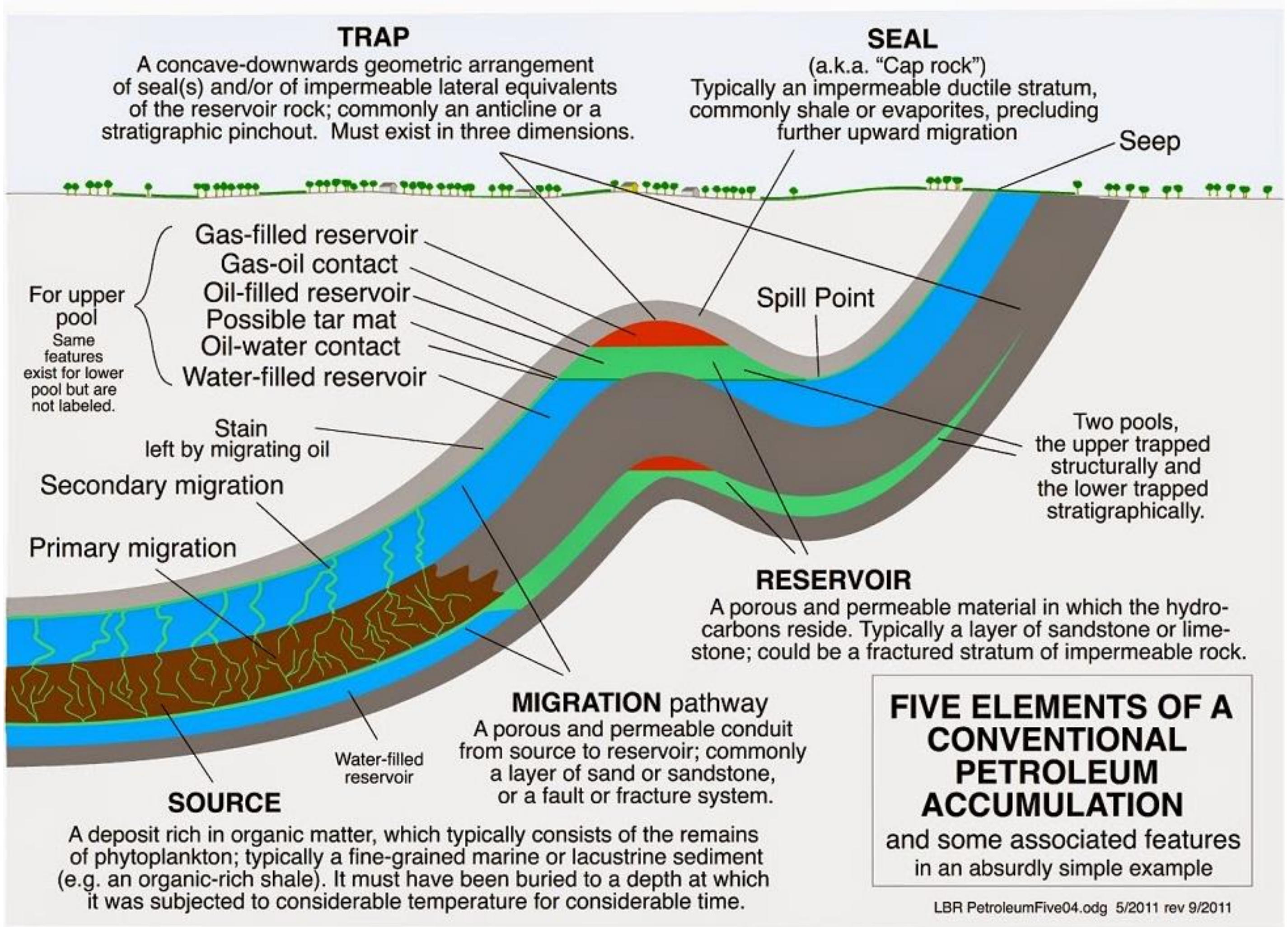
Petroleum system

A **Petroleum System** consists of a series of elements, whom combination may or may not contribute to generate hydrocarbon and accumulate them in an underground reservoir

The elements are:
- **Source rock**
- **Maturation & Migration**
- **Reservoir rock**
- **Trap**
- **Seal**

Appropriate relative timing of formation of these elements and the processes of generation, migration and accumulation are necessary for hydrocarbons to accumulate and be preserved.

The **elements** and critical **timing** relationships of a petroleum system can be displayed in a chart that shows geologic time along the horizontal axis and the petroleum system elements along the vertical axis.



Source rock

Petroleum — oil and natural gas — comes from a process that started in ancient seas.

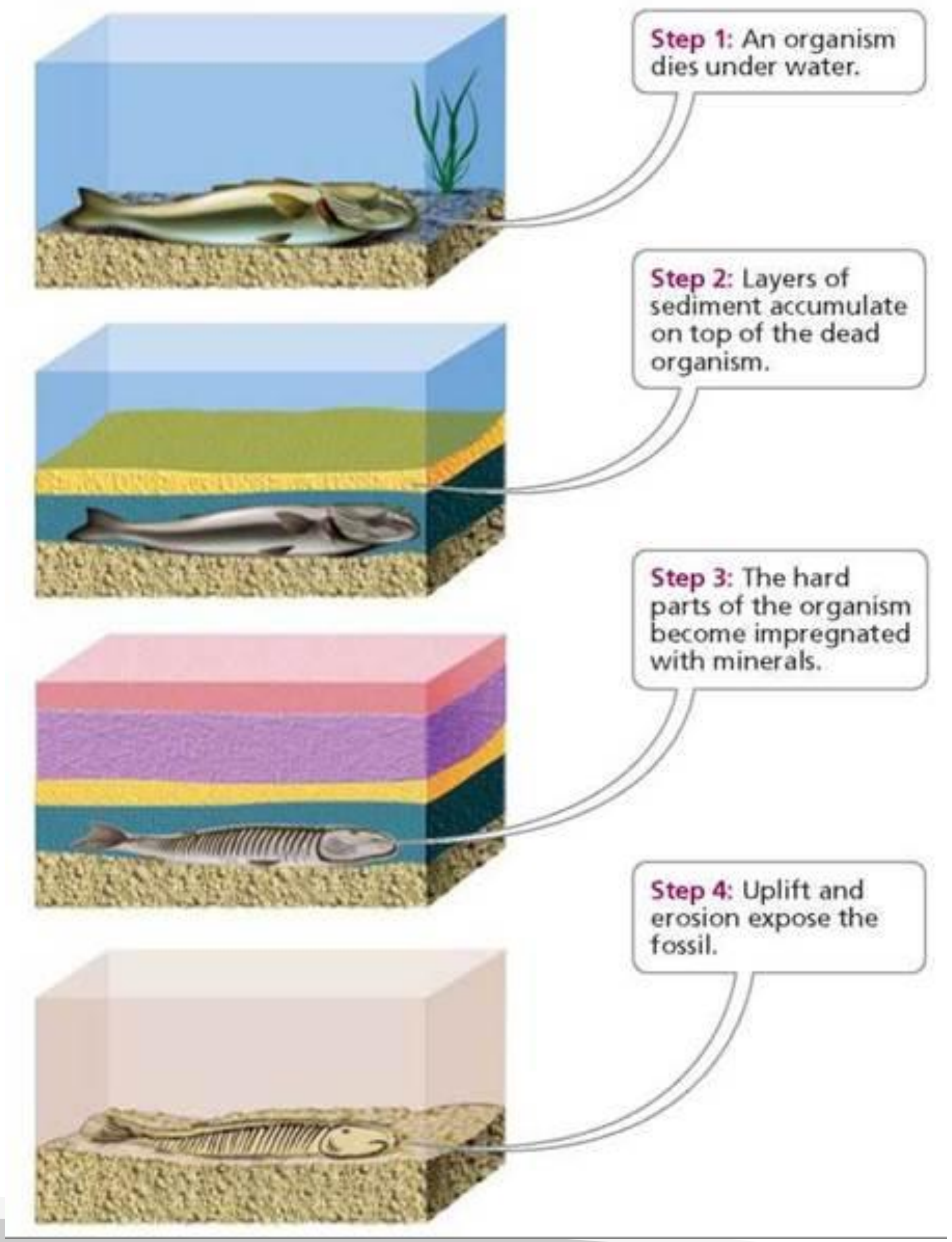
1. Small organisms called plankton lived, died and sank to the bottom of those oceans.

2. As debris settled down through the water, it covered the dead plankton. Microbes dined on some of the dead.

3+4. Chemical reactions further transformed these buried materials.

Eventually, two substances formed: waxy *kerogen* and a black tar called *bitumen* (one of the ingredients of petroleum).

A source rock is a rock with an elevated content of organic matter



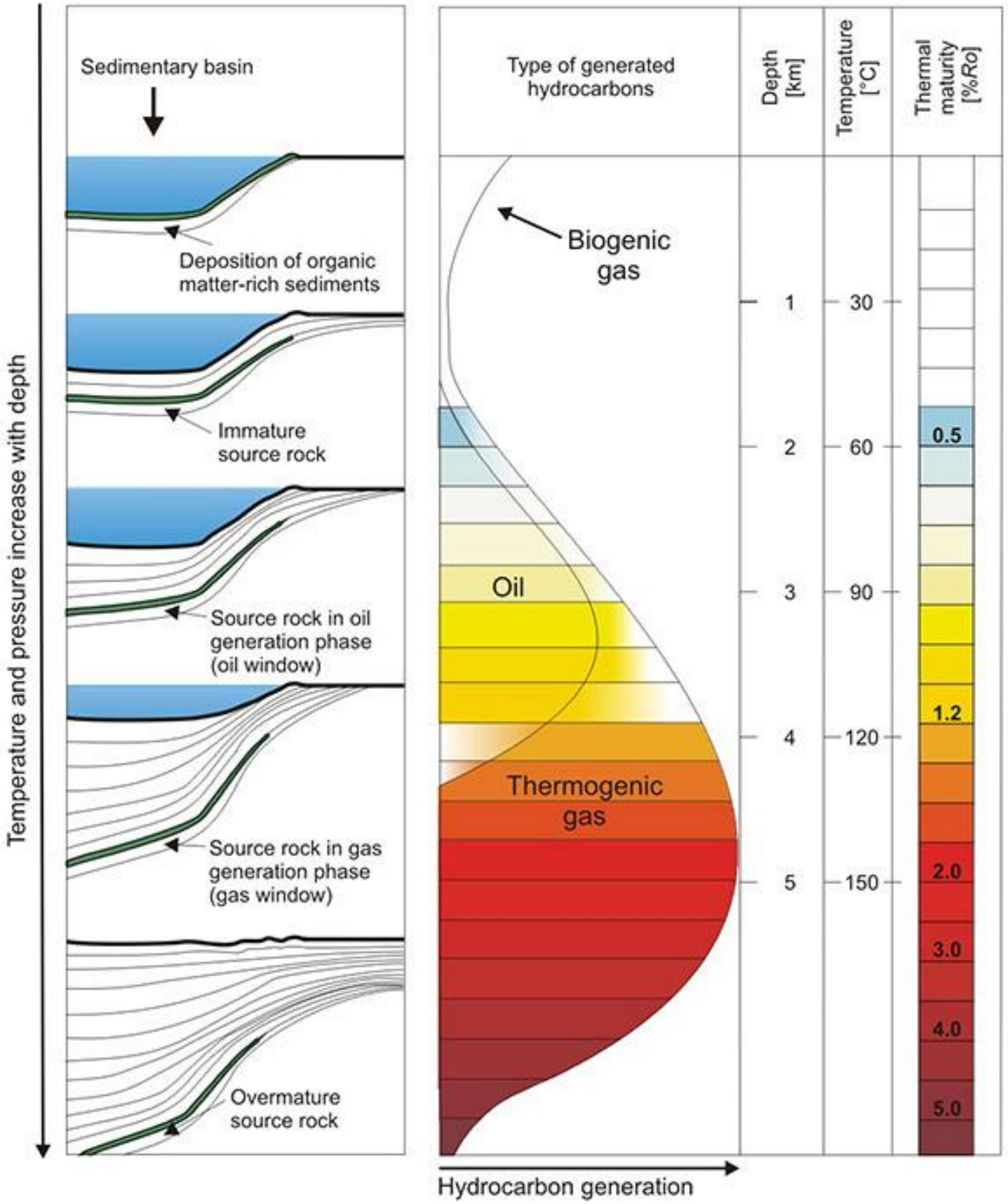
Maturation & Migration

Maturation of hydrocarbon depends on three main factors:

- the presence of **organic matter** rich enough to yield hydrocarbons,
- Adequate combination of **temperature** and **pressure/depth (burial history)**
- sufficient **time** to bring the source rock to maturity.

Pressure and the presence of bacteria and catalysts also affect generation.

Generation is a critical phase in the development of a petroleum system.



Maturation & Migration

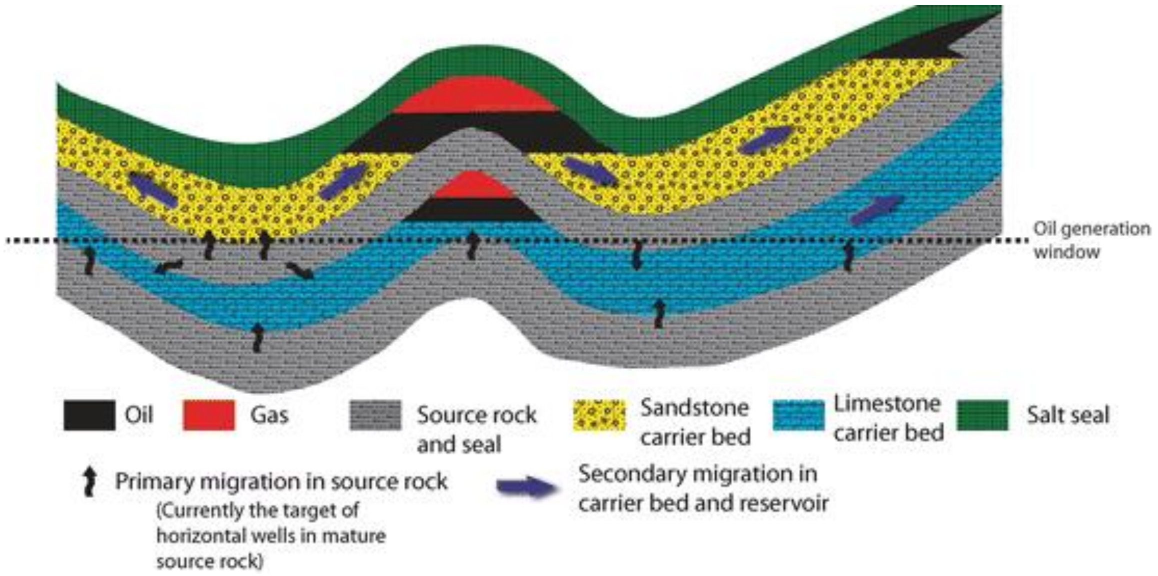
Hydrocarbons are **less dense** than the rock and water. That prompts them to **migrate upward**, at least until they get trapped by some ground layer that they can't move past.

Migration is the movement of hydrocarbons from their source into reservoir rocks.

The movement of newly generated hydrocarbons out of their source rock is primary migration, also called expulsion.
The further movement of the hydrocarbons into areas of accumulation is secondary migration.

Migration typically occurs from a structurally low area to a higher area in the subsurface because of the relative buoyancy of hydrocarbons in comparison to the surrounding rock.

Migration can be local or can occur along distances of hundreds of kilometres in large sedimentary basins, and is
critical to the formation of a viable petroleum system.

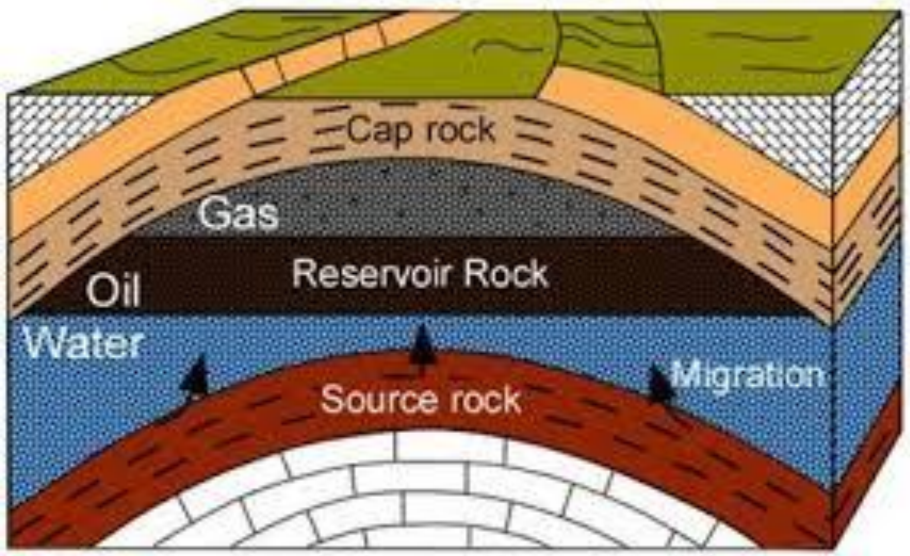


Reservoir

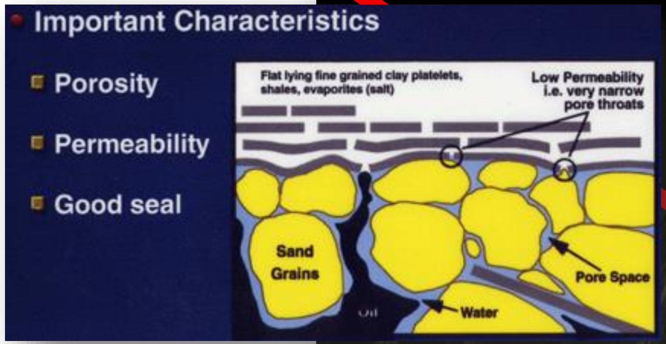
A subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and they form under temperature conditions at which hydrocarbons can be preserved.

A reservoir is a critical component of a complete petroleum system.

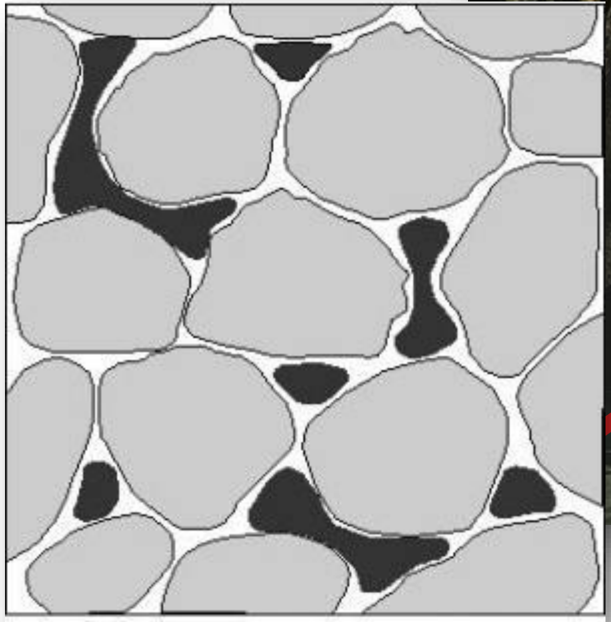
- Sands
- Carbonates
- Dolomites



Reservoir


Important Characteristics
Porosity
Permeability
Good seal
Flat lying fine grained clay platelets, shales, evaporites (salt)
Low Permeability i.e. very narrow pore throats
Sand Grains
Pore Space
Water

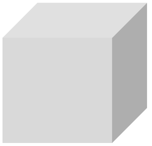

0.1 mm



Reservoir (porosity)

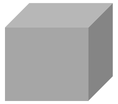
1 cubic meter of rock

1 cubic meter



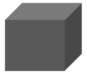
Porosity = 30%

0.30 cubic meter



Gas saturation= 70% of 30% = 21%

0.21 cubic meter



VOLUME OF RECOVERED GAS = 70% of 21%
= 15%

0.147 cubic meter

The voids created by the recovered gas tend to be filled with water, which therefore tends to counterbalance the pressure drop, reducing the compaction of the loose rock

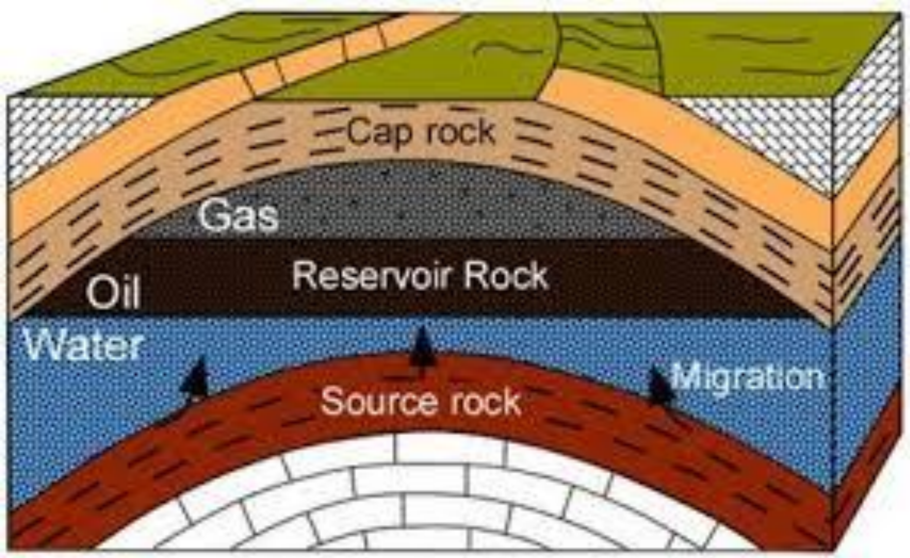
Seal (Cap) Rock

An impermeable rock that acts as a barrier to further migration of hydrocarbons.

Rocks that forms a barrier or cap above and around reservoir rock forming a trap such that fluids cannot migrate beyond the reservoir.

The permeability of a seal capable of retaining fluids through geologic time is very low.

- *shale*
- *mudstone*
- *anhydrite*
- *salt*



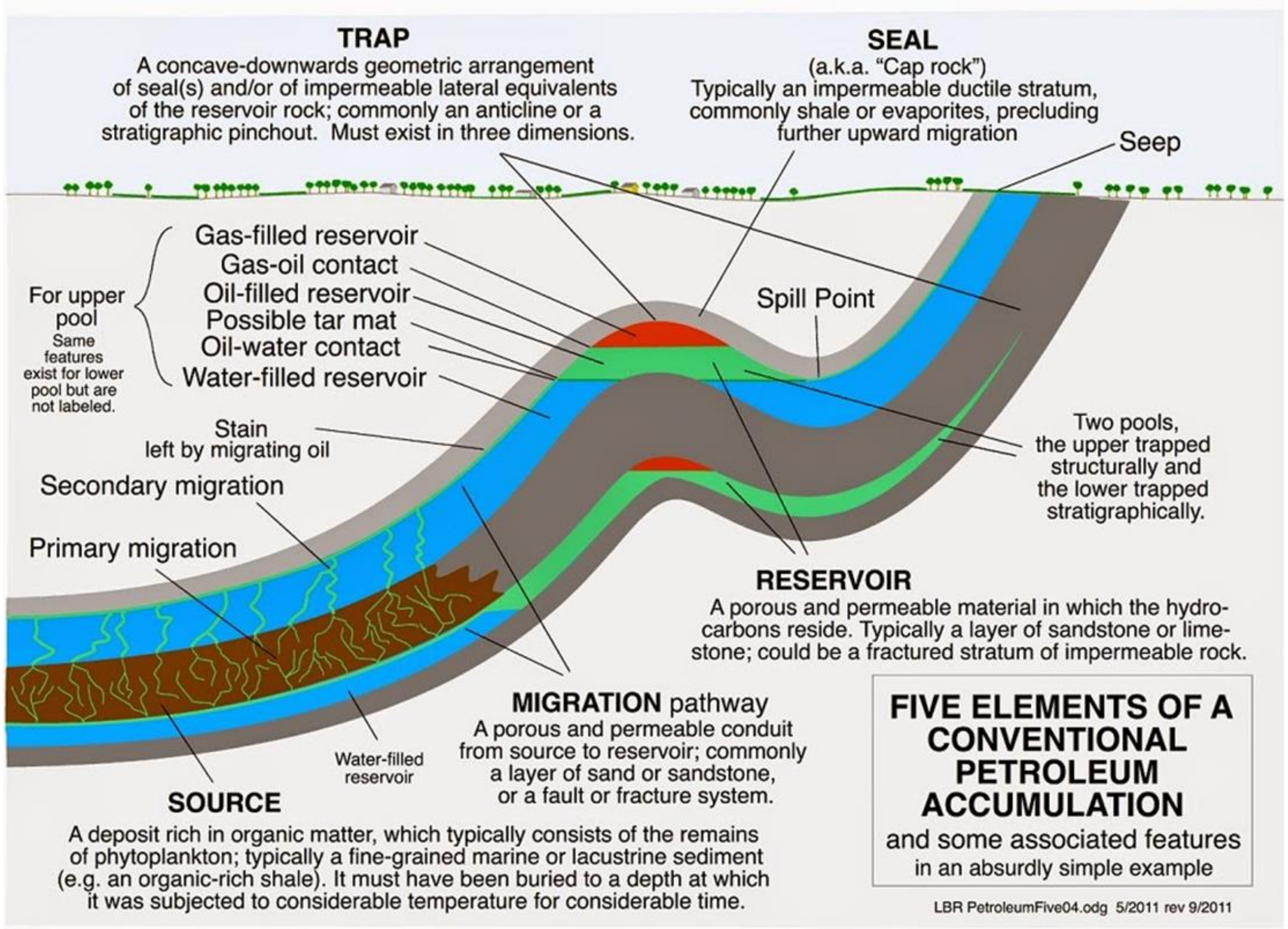
Fundamentals of Petroleum Geology

Trap

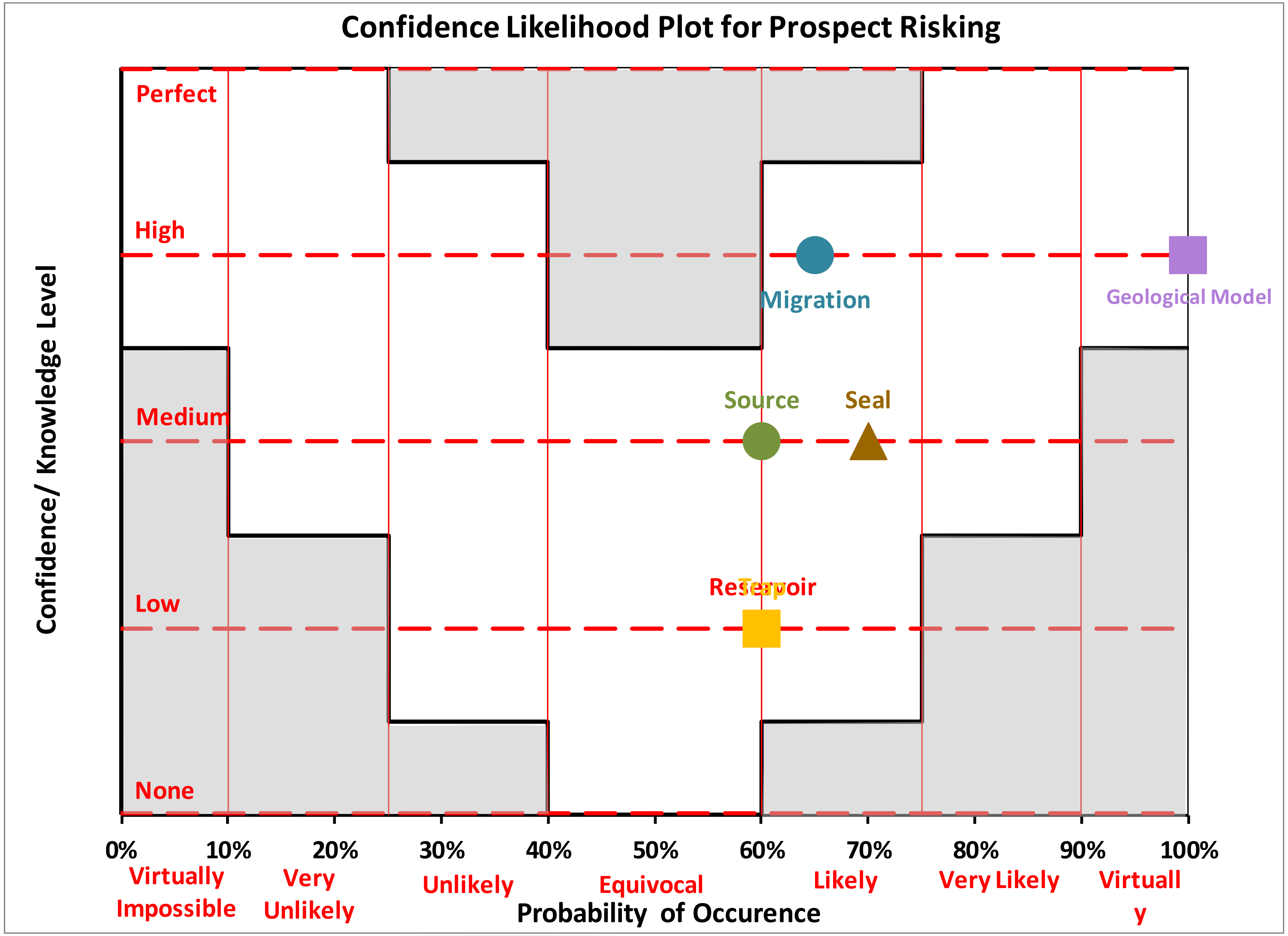
A configuration of rocks suitable for containing hydrocarbons and sealed by a impermeable formation through which hydrocarbons will not migrate.

Traps are described as

- **structural traps**: Hydrocarbon traps that form in geologic structures such as folds and faults
- **stratigraphic traps**: Hydrocarbon traps that result from changes in rock type, unconformities or other sedimentary features (reefs, fluvial channels & deltas, …)



Confidence – likelihood plot



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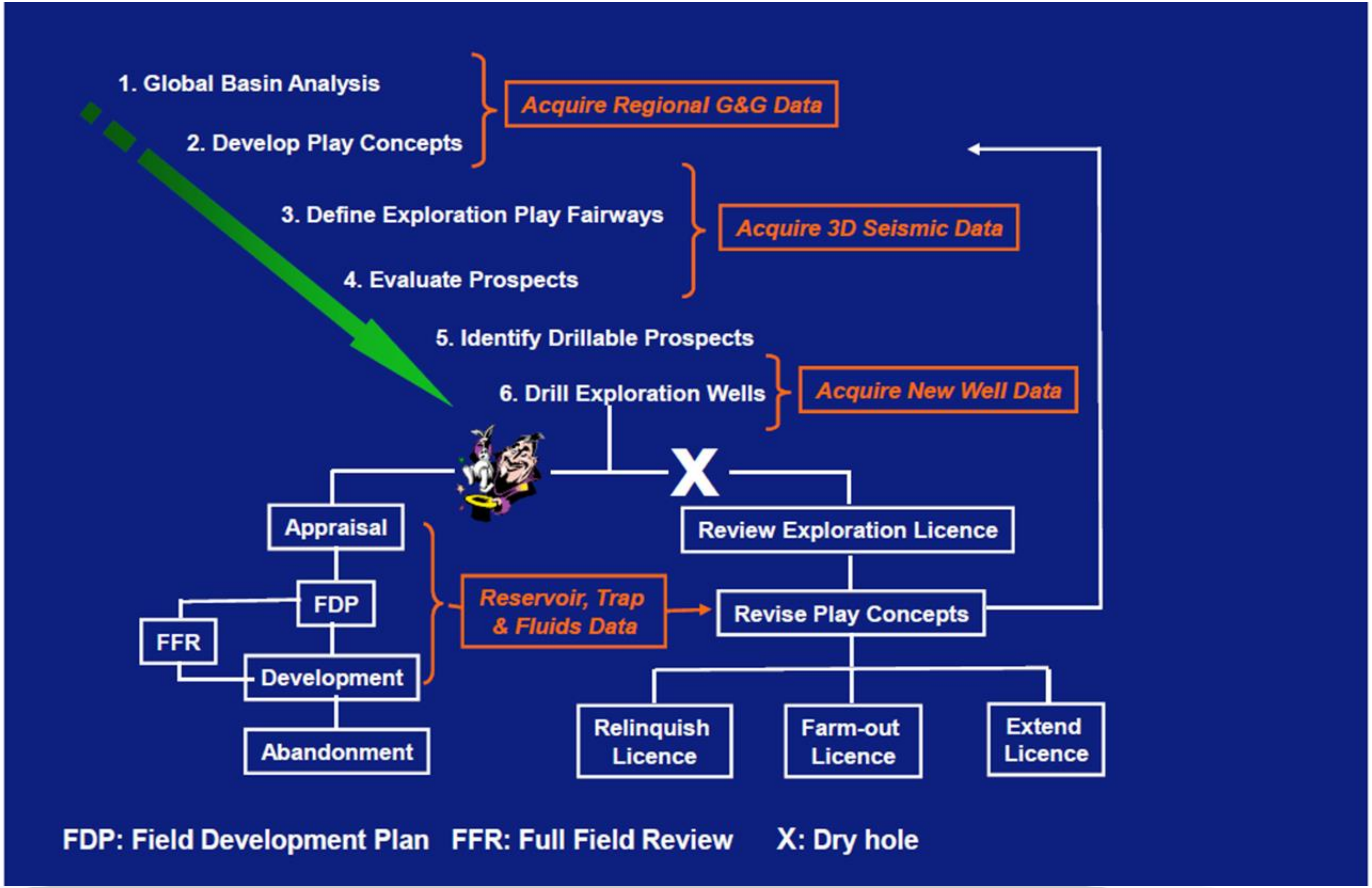
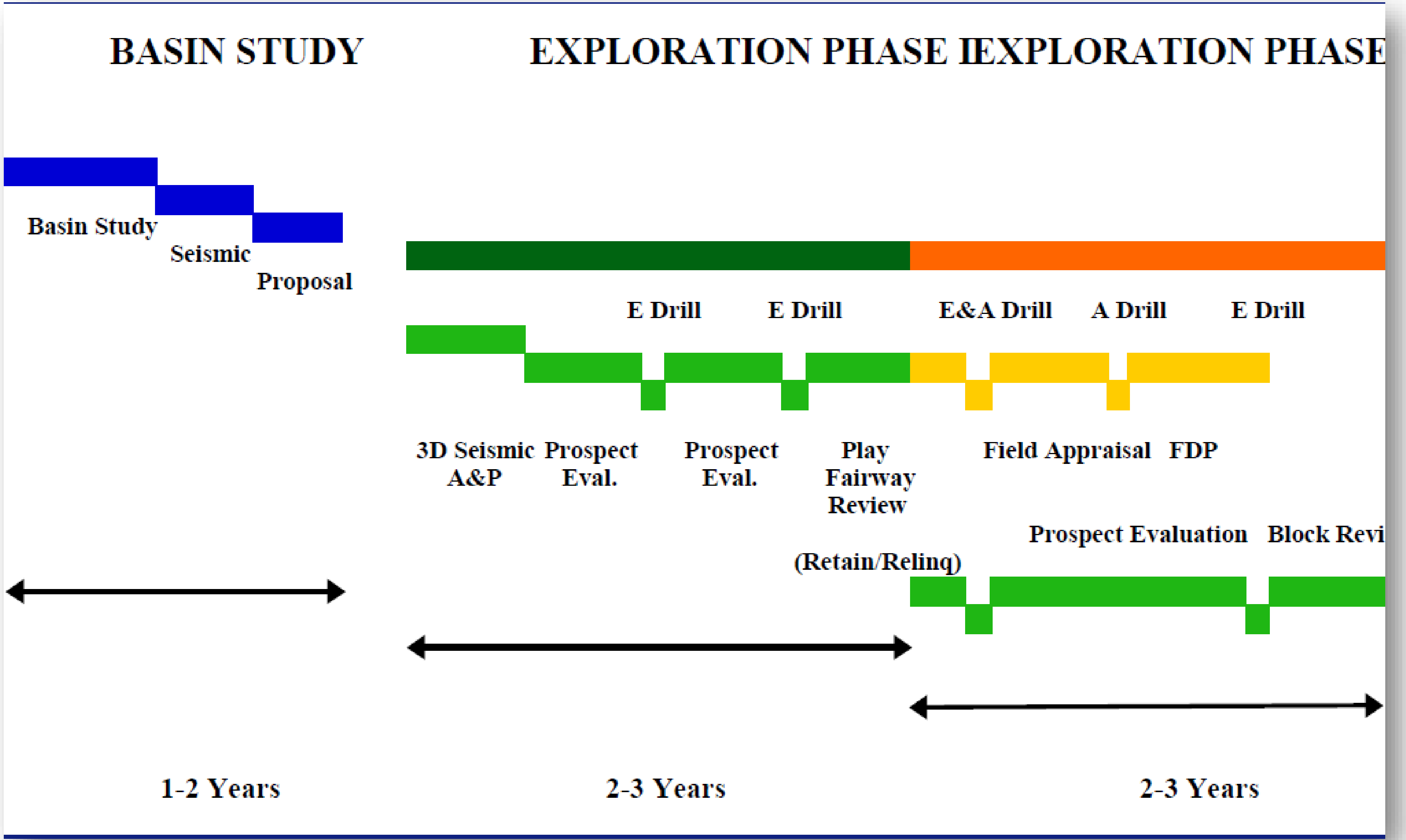
Simplified E&P Workflow and Data Acquisition

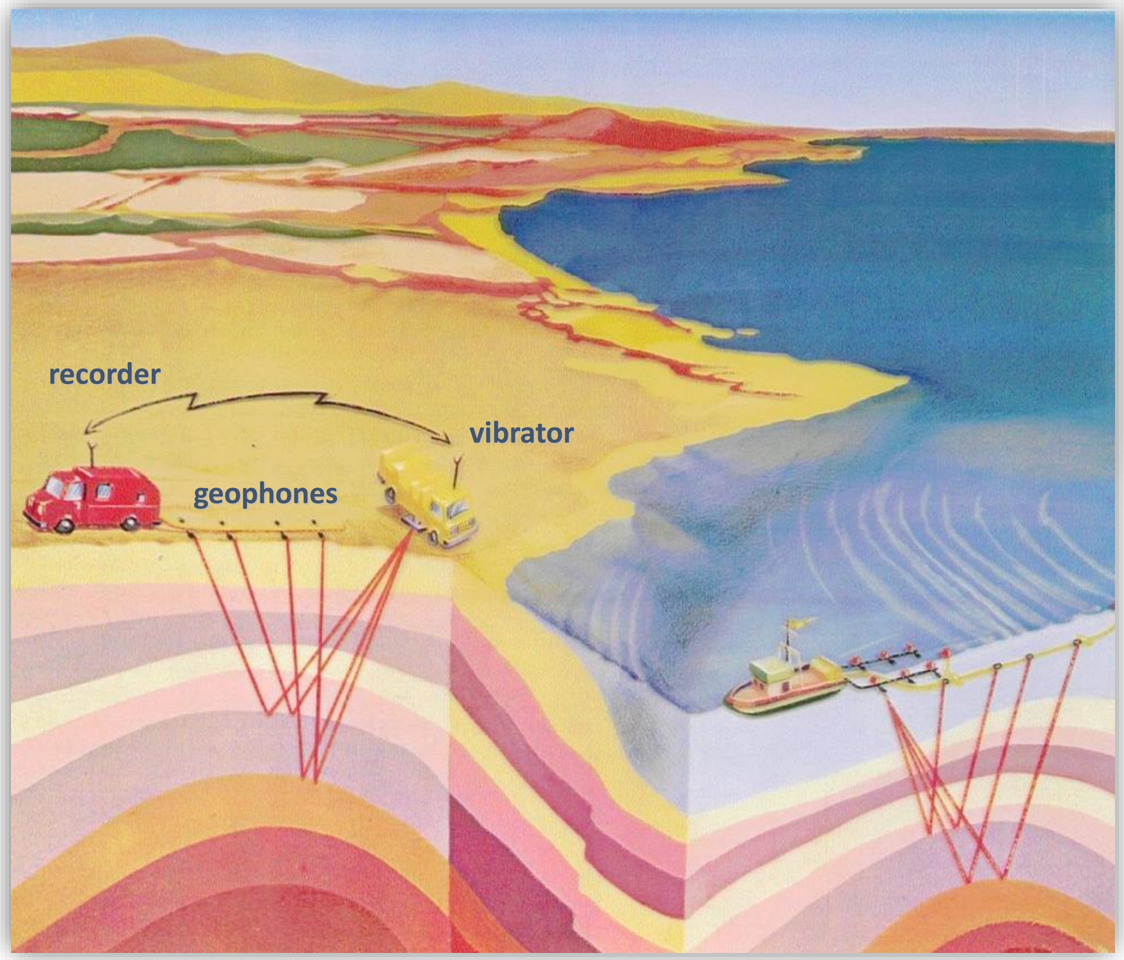


Typical Exploration Work Programme



Fundamentals of Petroleum Geology

Geophysical exploration



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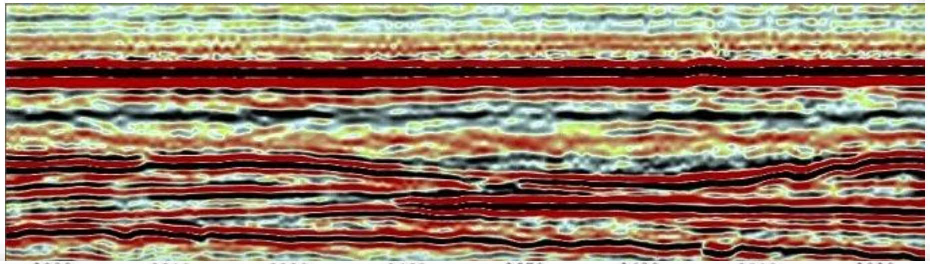

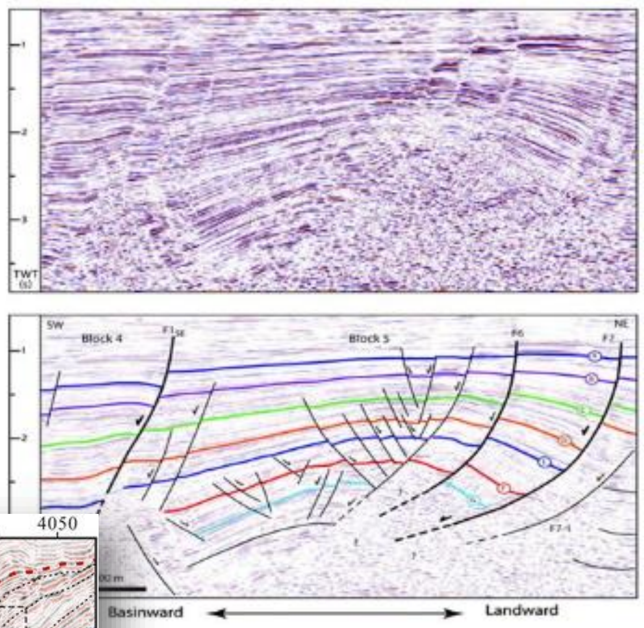

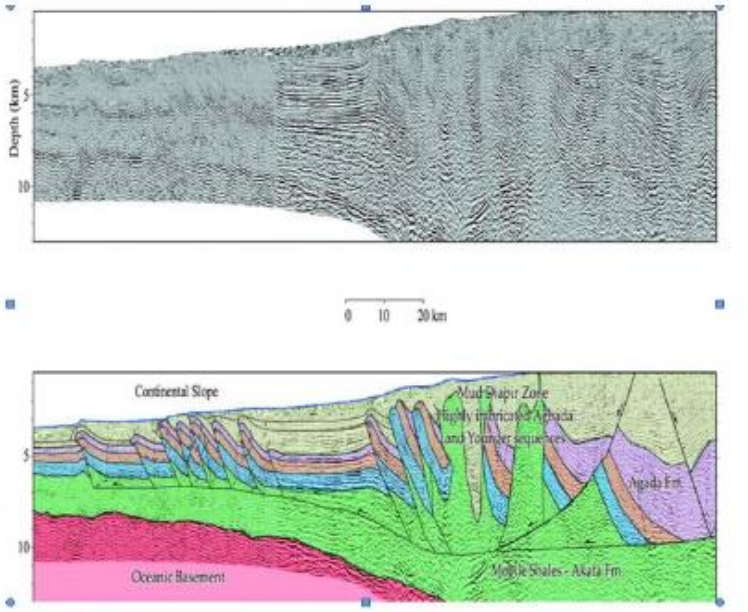

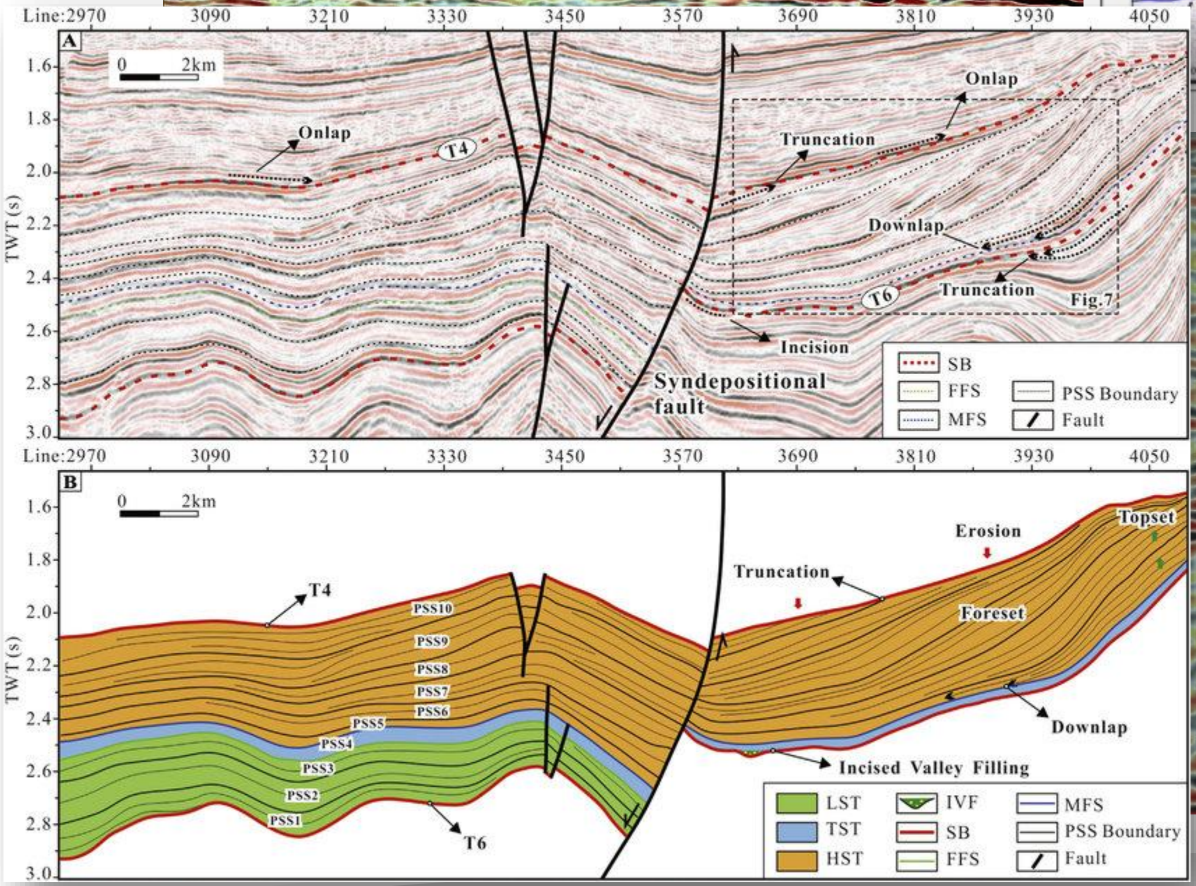

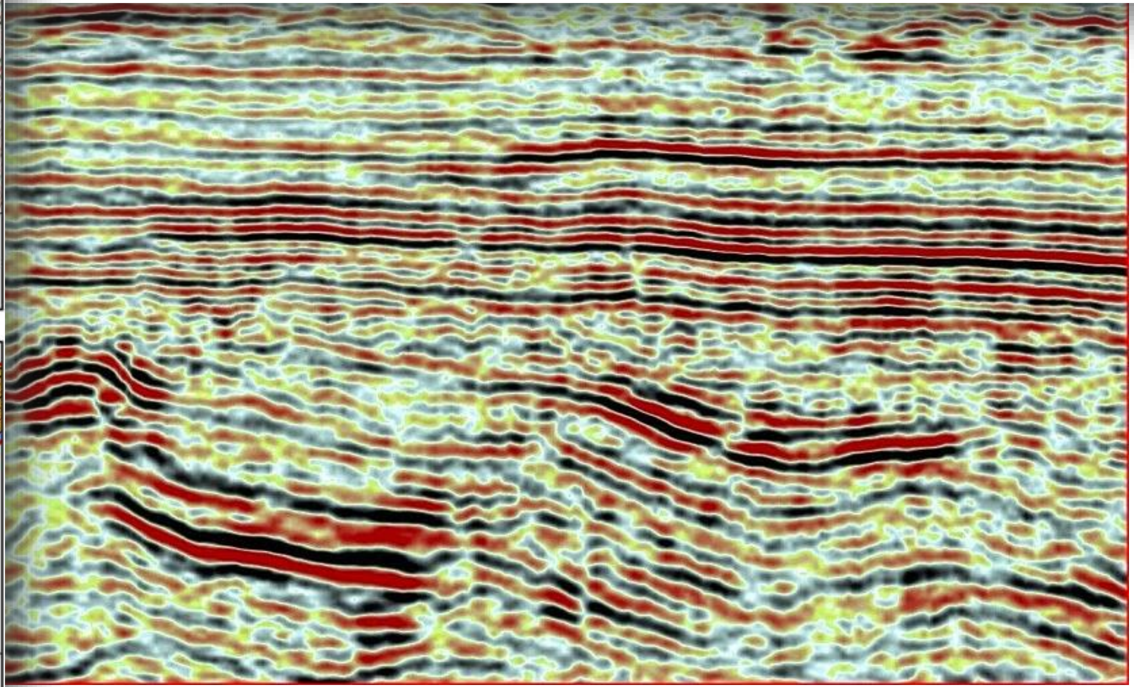

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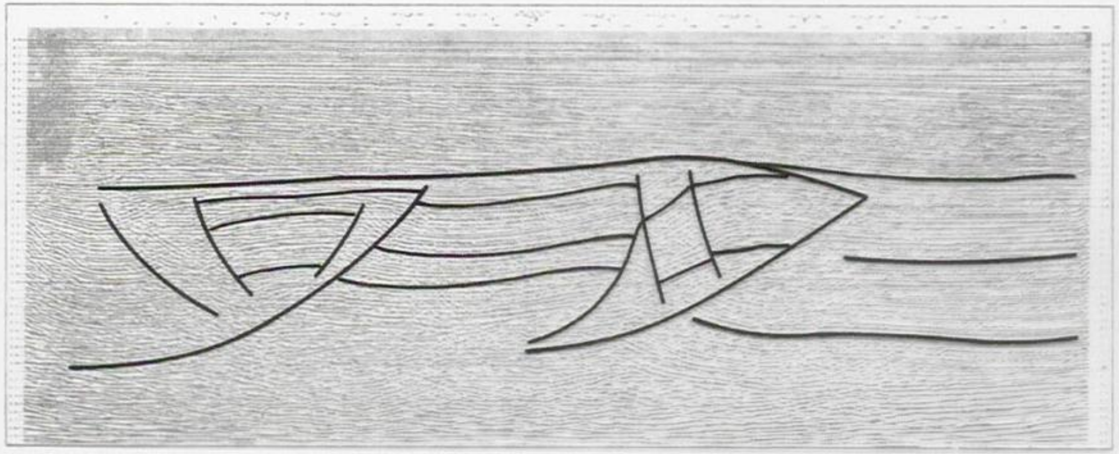


Fig. III.1a - SW-NE seismic section (1976) and its interpretation.

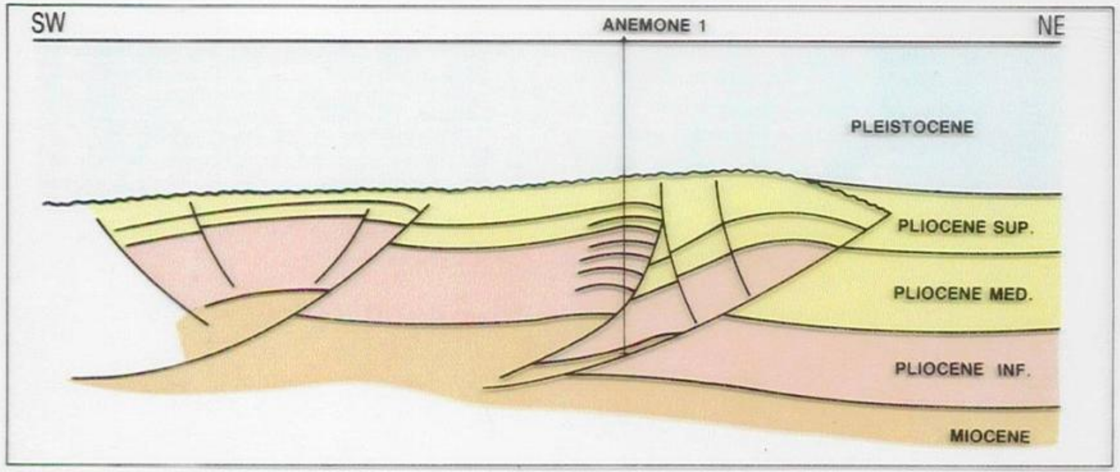
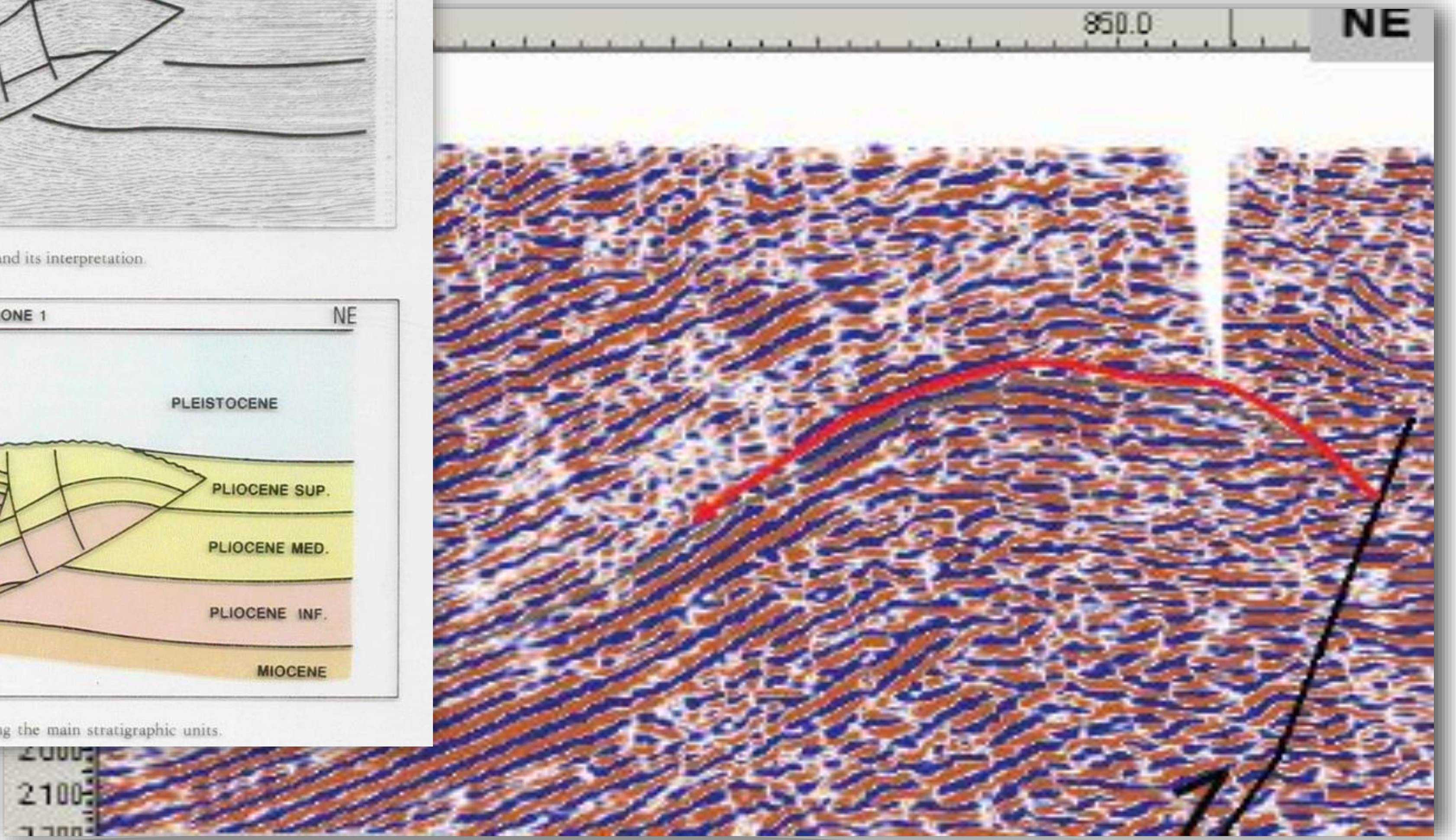
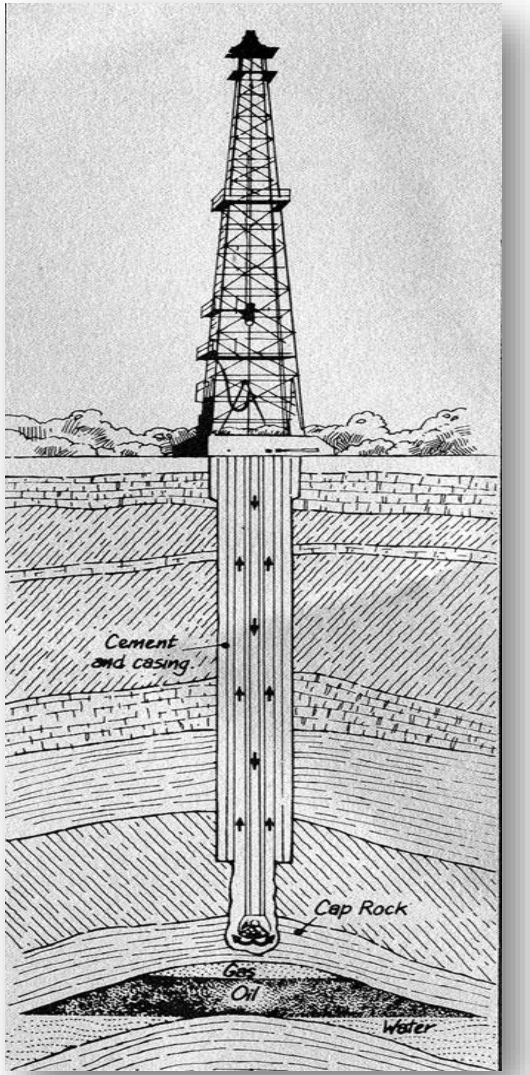


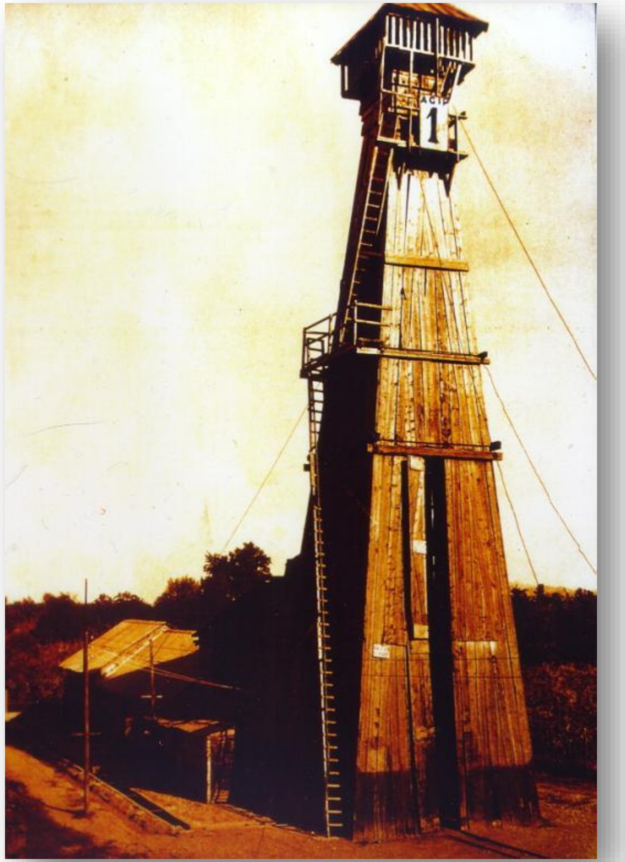
Fig. III.1b - Interpreted cross-section showing the main stratigraphic units.



Fundamentals of Petroleum Geology

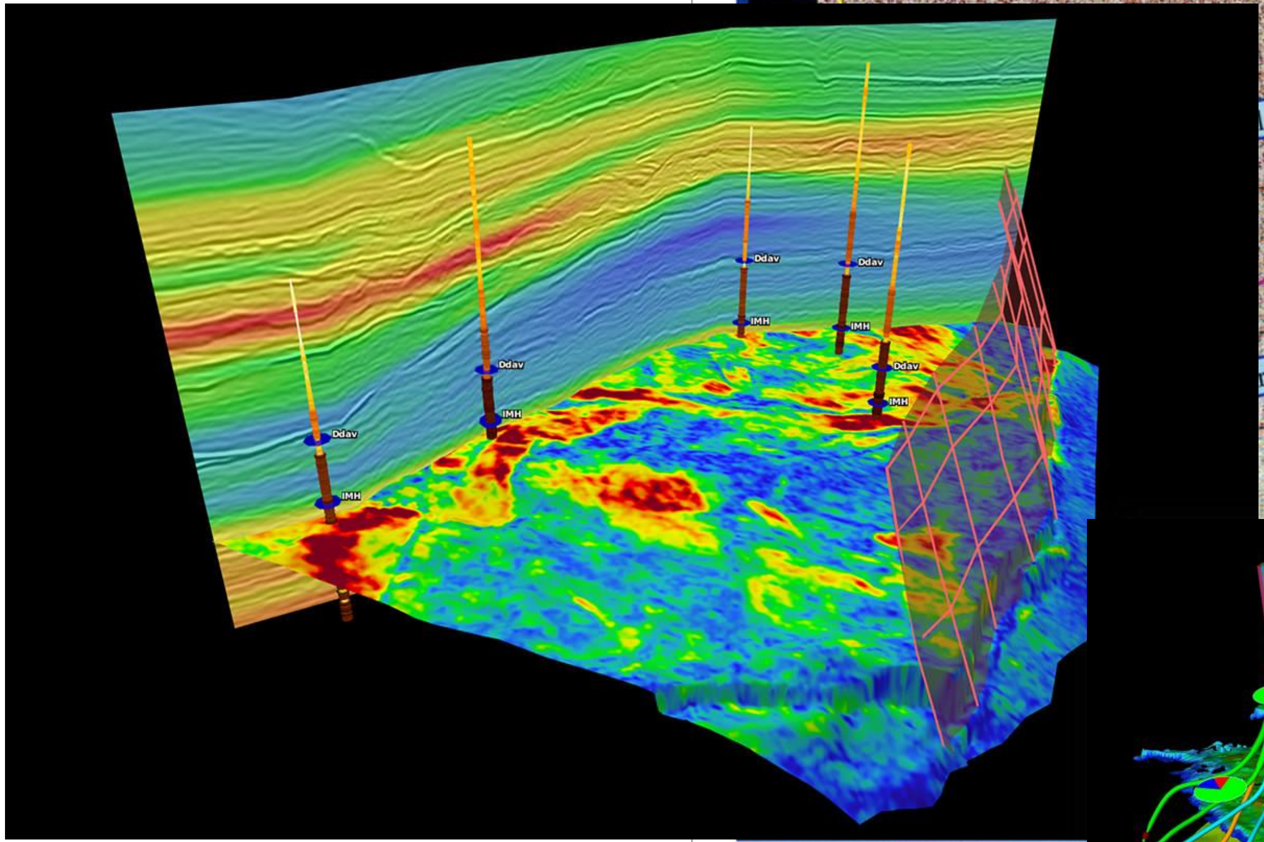
Well drilling

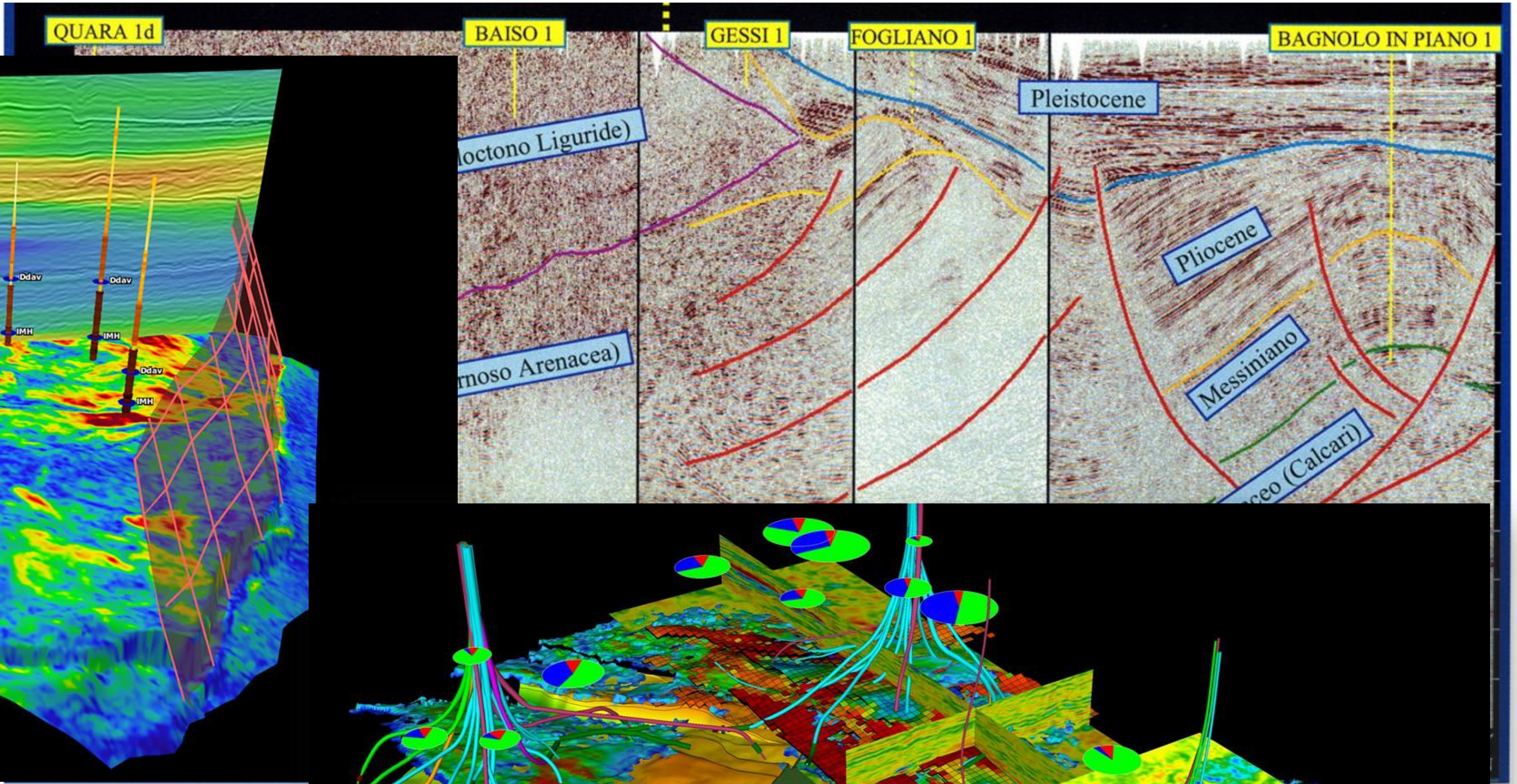


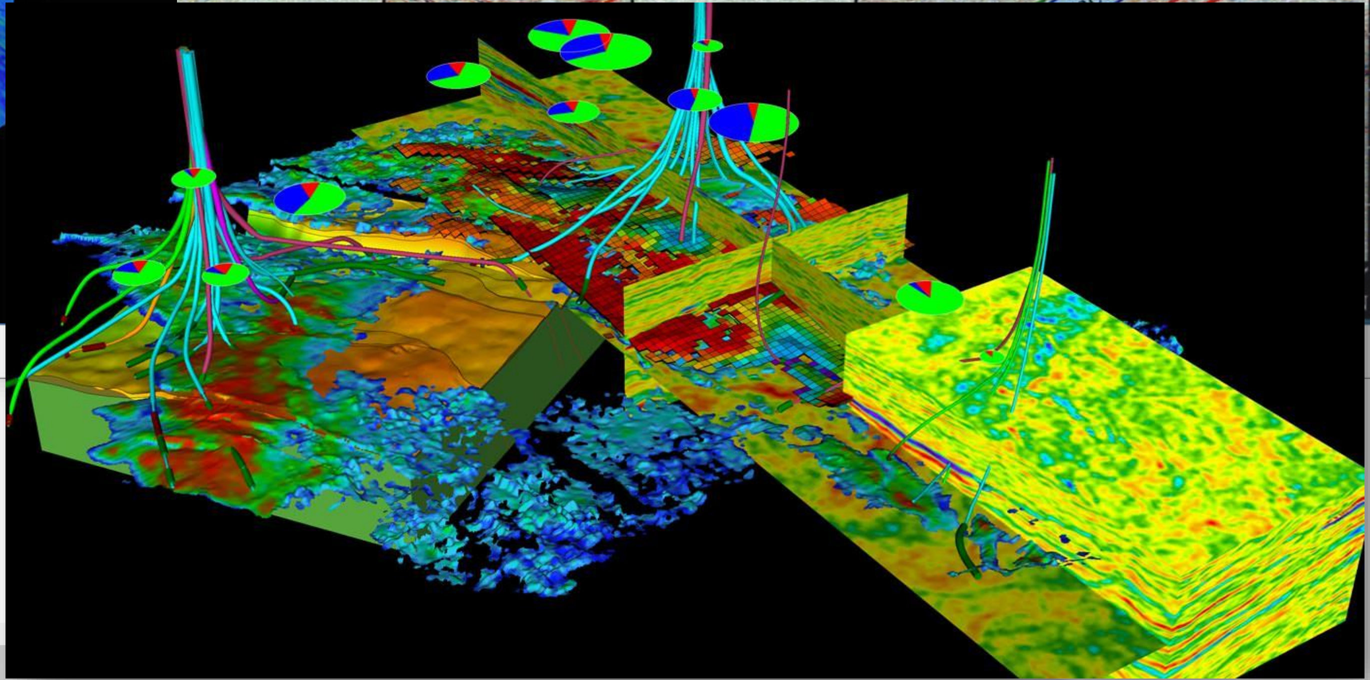


Fundamentals of Petroleum Geology

Well drilling and field knowledge improvement







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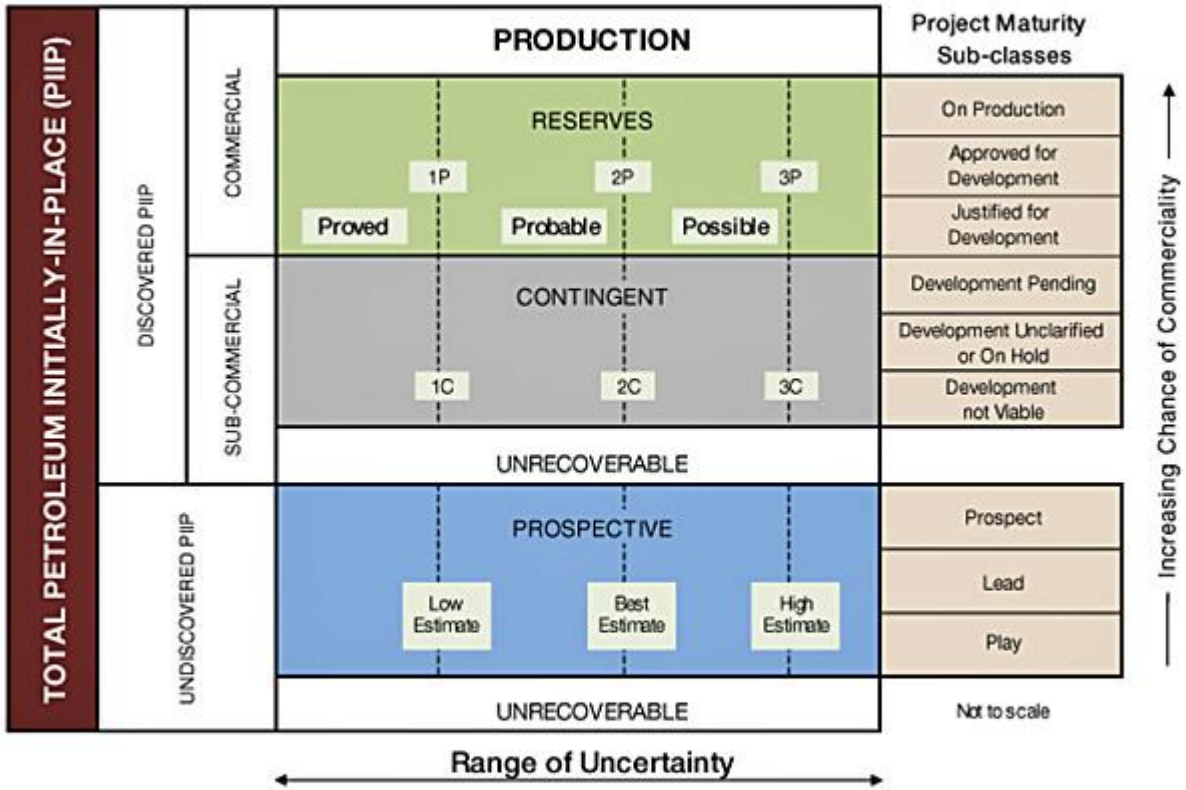
<u>Reserves</u> are those quantities of HC which are anticipated to be commercially recovered from known accumulations from a given date forward.
<u>Resources</u> are those quantities of HC which are estimated, on a given date, to be potentially recoverable from unknown or poorly known accumulations but which are not currently considered to be (commercially) recoverable.

Unrecoverable Reserves/Resources *are that portion of Discovered or Undiscovered Petroleum Initially-in-Place quantities that are estimated, as of a given date, not to be recoverable by future development projects. A portion of these quantities may become recoverable in the future as commercial circumstances change or technological developments occur; the remaining portion may never be recovered due to physical/chemical constraints represented by subsurface interaction of fluids and reservoir rocks.*



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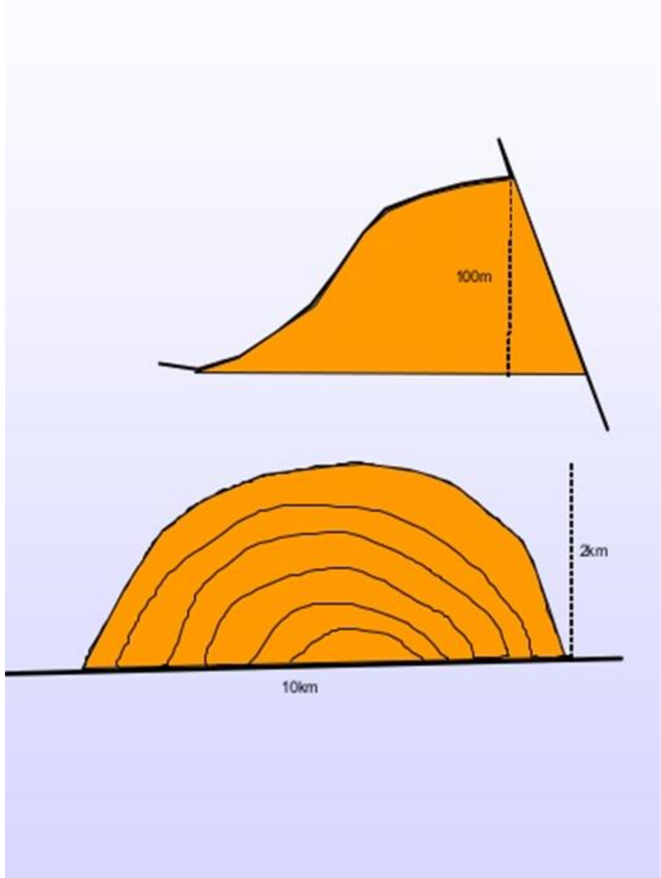
Volumetric calculation

Prospective Resource = GRV * N/G * Ø * S_{hc} * FVF * RF * C

Where:

GRV	=	Gross rock volume = Area * Gross Thickness * Shape factor
N/G	=	Net to Gross
Ø	=	Porosity
S_{hc}	=	Hydrocarbon saturation
FVF	=	Formation volume factor
RF	=	Recovery factor
C	=	A conversion factor for units

These are properties of the trap, the reservoir and of the fluids



Where do these numbers come from?

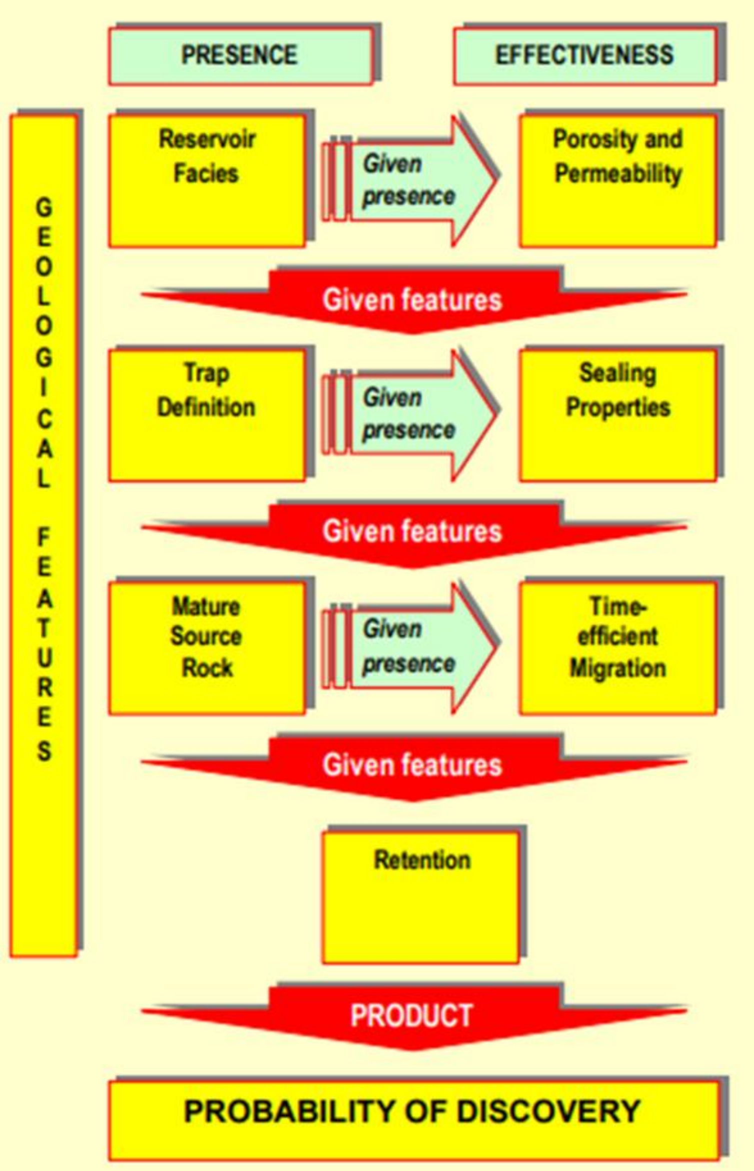
- Analysis of nearby wells and fields.
- Seismic data
- Analysis of analogues elsewhere in the world.
- Intelligent guesses

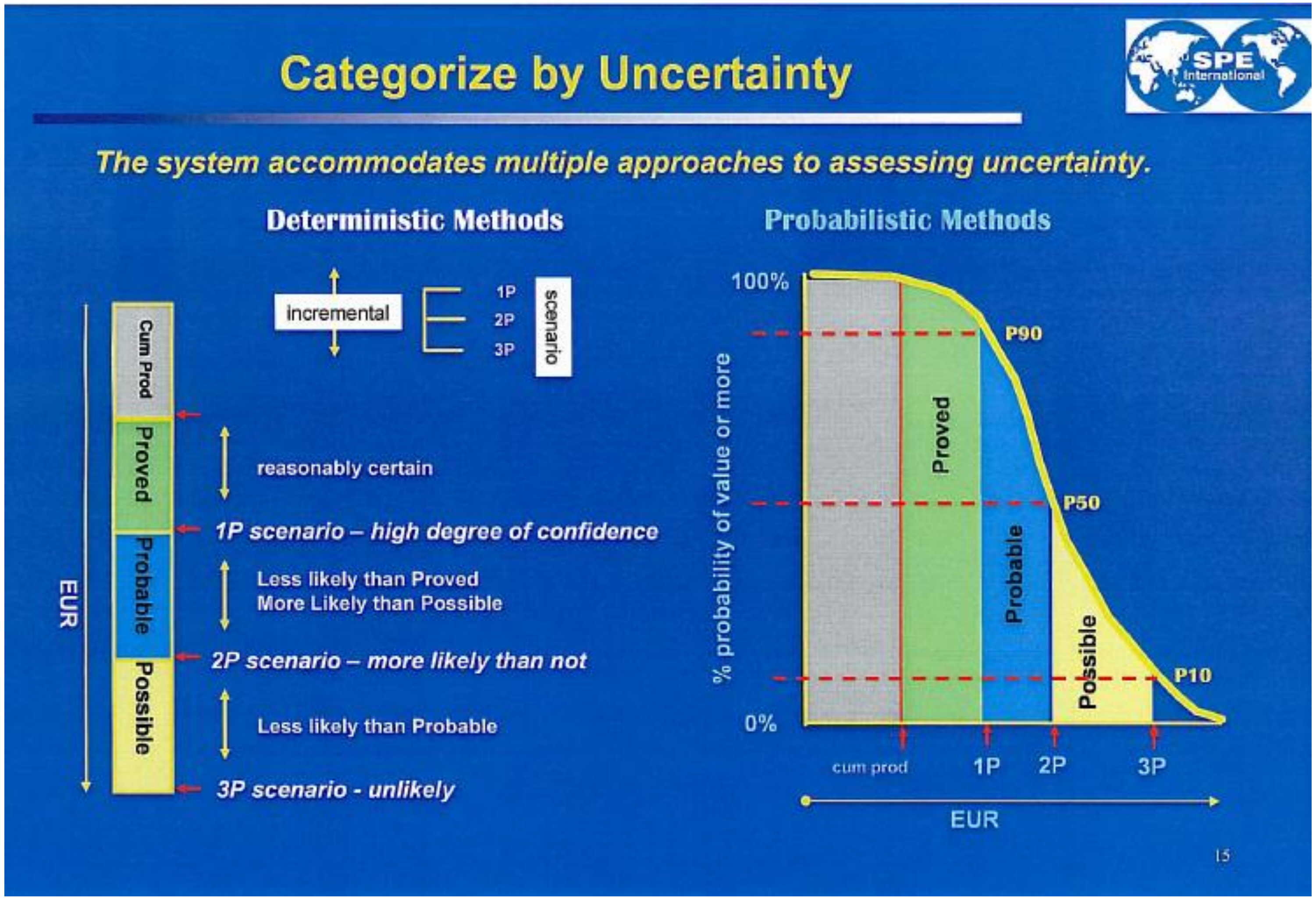
Predictions always need sense checking against what we know is true elsewhere

Uncertainty in the input variables means we almost always define them as ranges

- Uncertainty is at a maximum in exploration phase & decreases -> appraisal -> development -> production
- Distributions in input variables combined using Monte Carlo Analysis to produce an output range
- Defined ranges need to be consistent with range of possible success case outcomes

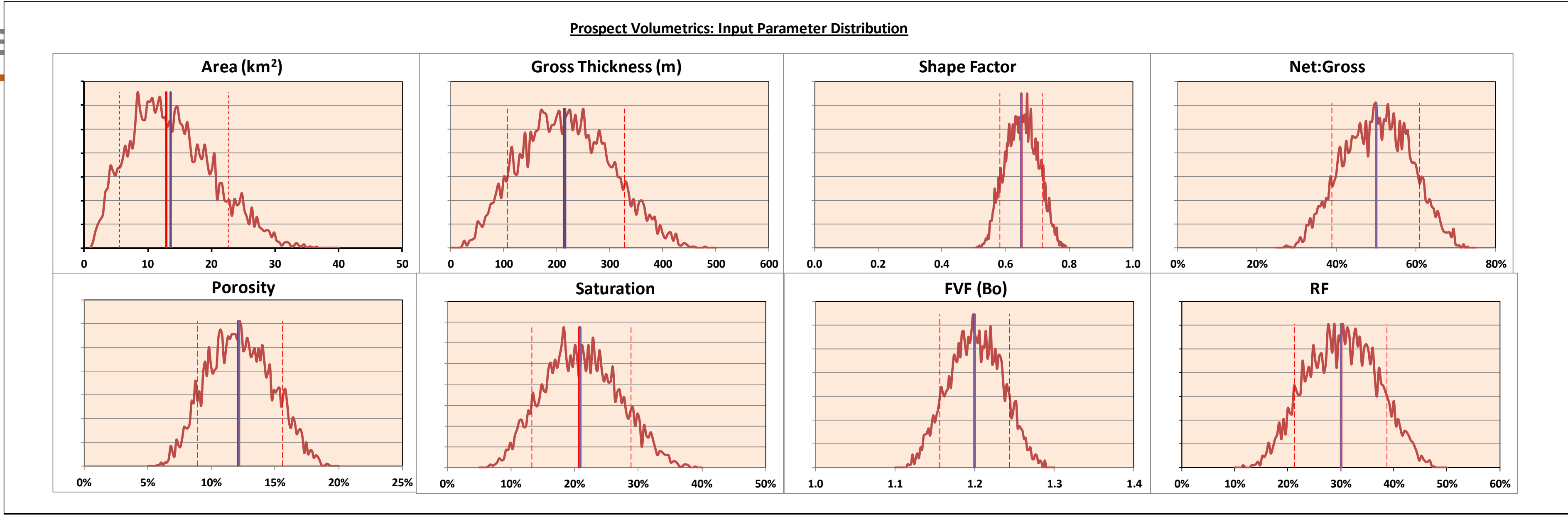
Risk Assessment





Fundamentals of Petrole

Risk Assessment



- Parameterised based on geological model & definition of technical success
  - Absolute minimum: smallest value consistent with a successful well test
  - **P90: “a reasonable minimum”**
  - Most Likely/ mode: single most probable value
  - **P50: equal probability that value will be higher or lower than P50**
  - Mean: arithmetic average displaced from mode in direction of skew
  - **P10: “a reasonable maximum”**
  - Absolute maximum: physically possible but so large as to be scarcely credible
- Input distributions should not be truncated to reflect ‘commercial’ outcomes
- Well data that represents a failure outcome is not relevant to defining distributions

- Distributions need to be consistent with geological model being risked
  - May be several alternatives -> scenario definition
  - Caution needed to avoid over-complicated evaluations
    - if input distributions overlap treat as one case

- Distributions represent average (mean) value over entire prospect
  - depth dependent parameters (f , FVF) should be estimated at average depth NOT crest
  - distribution range is therefore not the same as range of single point estimates (core or well datapoints)
    - The distribution of the mean is related to the mean of distribution by *Central Limit Theorem*

$$s_{mean} = s_{population} / \mathrm{sqrt}(n)$$

So the uncertainty in the mean will be less than that of the population

- However available dataset may not reflect full range of parameter uncertainty….

A

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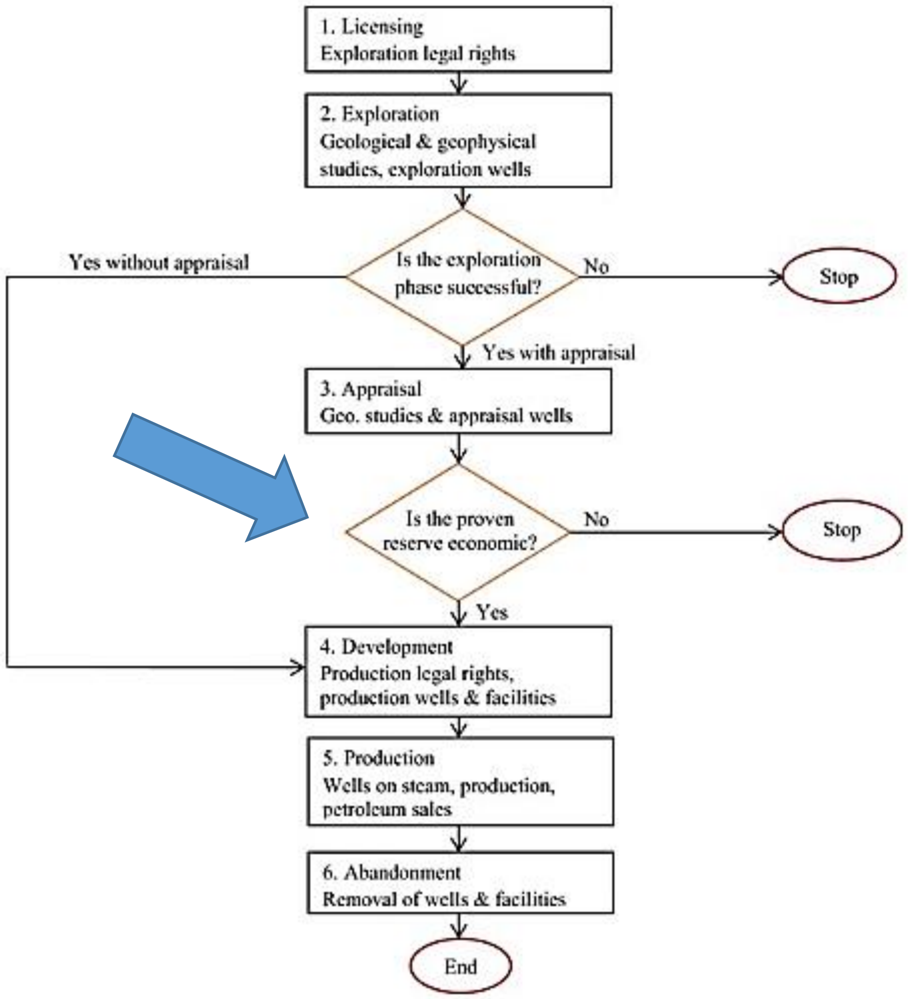
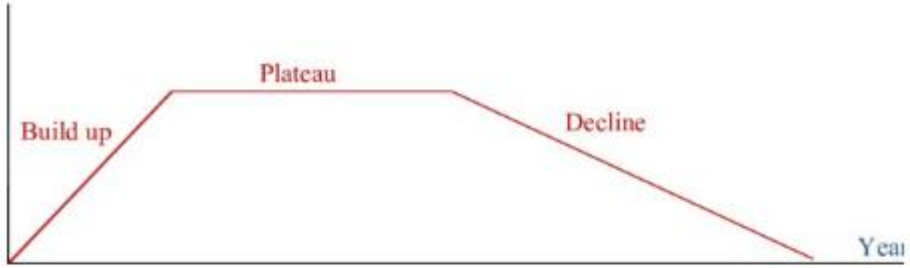
2. **How many wells** have been drilled in Italy?
3. How much Oil&Gas has **still to be discovered**?
4. **Economic** and **Energy scenarios**: World, Europe, Italy

Fundamentals of Petroleum Geology

Development & Economics



Life cycle of petroleum projects (modified after Johnston, 2003)



Typical petroleum production curve (modified after Robelius, 2007)

Fundamentals of P

Development & Economi

- **OPEX**: an ongoing cost for running a product, business, or system.
- **CAPEX**: the cost of developing or providing non-consumable parts for the product or system
- **NPV**: the difference between the present value of cash inflows and the present value of cash outflows over a period of time.
- **IRR**: estimation of the profitability of a potential investments

Operator: … | Values in 2013 k€ | Updated: September 2013 | W.I.= 75,00 %

Description/Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Capital expenditure, k€	**63,1**	**25,0**	**1120,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**1208,1**
Farm in expenditure	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Farm in option share	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
G&G exploration + other costs	25,0	25,0	25,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	75,0
Drilling	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Completion	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Project Management	2,6	0,0	75,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	78,0
Facilities (incl. Enginnering)	0,0	0,0	900,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	900,0
Pipes (incl. Enginnering)	0,0	0,0	100,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	100,0
Operations (Test, WO, ST, …)	35,0	0,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	40,0
Insurance	0,5	0,0	14,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,1
Facilities removal	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
									0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
									0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
									116,3	**126,7**	**127,0**	**132,3**	**192,6**	**143,0**	**148,3**	**155,9**	**152,9**	**204,3**	**159,9**	**154,9**	**2524,1**
									5,0	10,0	5,0	5,0	10,0	5,0	5,0	10,0	5,0	5,0	10,0	5,0	135,0
									0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
									100,0	100,0	100,0	100,0	150,0	100,0	100,0	100,0	100,0	150,0	100,0	100,0	1925,0
									5,3	10,7	16,0	21,3	26,6	32,0	37,3	39,9	41,9	43,3	43,9	43,9	362,1
									6,0	6,0	6,0	6,0									102,0
									0,0	0,0	0,0	0,0									0,0
									0,0	0,0	0,0	0,0									0,0
									0,0	0,0	0,0	0,0									0,0
									45,5	**45,5**	**45,5**	**45,5**									**978,0**
									44,0	44,0	44,0	44,0									948,0
									1,5	1,5	1,5	1,5									30,0
									0,0	**0,0**	**0,0**	**0,0**									**0,0**
									0,0	0,0	0,0	0,0									0,0
									0,0	0,0	0,0	0,0									0,0
									161,8	**172,2**	**172,5**	**177,8**									**4710,2**
									121,4	129,1	129,4	133,4									3551,4
									2,8	2,8	2,8	2,8									45,6
									0,0	0,0	0,0	0,0									0,0
									0,0	0,0	0,0	0,0									0,0
									0,0	0,0	0,0	0,0									0,0
Acqua (10^3 m^3)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,2	0,3									4,8
Revenues	17,6	17,6	44,8	656,6	656,6	656,6	656,6	656,6	656,6	656,6	656,6	656,6									0643,1
Gas sales	0,0	0,0	0,0	639,0	639,0	639,0	639,0	639,0	639,0	639,0	639,0	639,0									0263,9
Sour gas sales	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0									0,0
Condensate sales	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0									0,0
Oil sales	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0									0,0
Operating	17,6	17,6	44,8	17,6	17,6	17,6	17,6	17,6	17,6	17,6	17,6	17,6									379,2
Royalties on gas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0									0,0
Royalties on sour gas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0									0,0
Royalties on oil	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0									0,0
Cash flow per year	**-88,9**	**-75,3**	**-905,3**	**535,5**	**539,2**	**539,2**	**535,5**	**501,7**	**535,2**	**527,5**	**527,2**	**523,3**									**7091,7**
Cumulated cash flow	-88,9	-164,1	-1069,4	-534,0	5,3	544,5	1080,0	1581,7	2116,9	2644,4	3171,6	3694,9	41								
Depreciation on Capex	0,4	0,4	161,7	161,7	161,7	161,7	161,6	161,3	107,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1078,0
Taxes	0,0	0,0	0,0	137,9	139,3	139,3	138,0	125,6	157,8	194,6	194,6	193,1	176,4	190,1	188,7	171,8	157,9	129,0	126,5	113,1	2673,7
Net cash flow post taxes	**-88,9**	**-75,3**	**-905,3**	**397,6**	**399,9**	**399,9**	**397,5**	**376,1**	**377,4**	**332,8**	**332,7**	**330,2**	**301,6**	**325,1**	**322,6**	**293,8**	**270,0**	**220,5**	**216,3**	**193,5**	**4418,1**
NPV (Discount rate = 10%)	-88,9	-68,4	-748,2	298,7	273,1	248,3	224,4	193,0	176,1	141,2	128,3	115,7	96,1	94,2	85,0	70,3	58,8	43,6	38,9	31,6	1411,8

Sensitivities

Gas price		NPV	IRR	NPV/CAPEX
Variation, %	Value, €/stm^3	10^3 €	%	ad
-20	0,224	5375	59	2,74
-10	0,252	6353	67	3,23
0	0,280	7331	74	3,73
+10	0,308	8309	81	4,23
+20	0,336	9286	88	4,73
-74,965	0,250	0	-	Breakeven

CAPEX		NPV	IRR	NPV/CAPEX
Variation, %	Value, k€	10^3 €	%	ad
-20	2376,5	7637	88	4,84
-10	2570,4	7484	81	4,23
0	2764,3	7331	74	3,73
+10	2958,3	7178	68	3,33
+20	3152,2	7024	63	2,99
+578,5	12044,0	0	1	Breakeven

Economical data:	Discount rate:	10,0	%	FX Rate (€/$)	1,35		Corporate + regional taxes:	0,369		Depreciation on capex: 15%, 15%, 15%, 15%, 15%, 15%, 10%	
Prices:	Oil price	100,00	$/bbl	Gas Price (flat over period)	0,3000	€/stm^3	Sour gas price	0,080	€/stm^3	Condensate price	550,00 €/tonn
Sensitivity:	on CAPEX	1,00		on OPEX	1,00		on prices	1,00		on production	1,00
NPV in Euro	**2.219**	Data Input:	Water disposal	75,0	€/stm^3	Farm-in expenditure	0,0	k€	Ass. investimenti	1,35	%
NPV in $	2.996		Minimum O.H.	44,0	k€	Gas treatment	0,000	€/stm^3	Drilling Project Mngt	2,50	%
IRR at 10%	**33%**		Oil/Cond. trasp.	40,00	€/tonn	Gas Compression	0,000	€/stm^3	Dev. Project Mngt	7,50	%
NPV/CAPEX	**2,45**		Oil/Cond. density	0,850	kg/l	Oil treatment	2,00	€/bbl	Aband. Project Mngt	1,75	%

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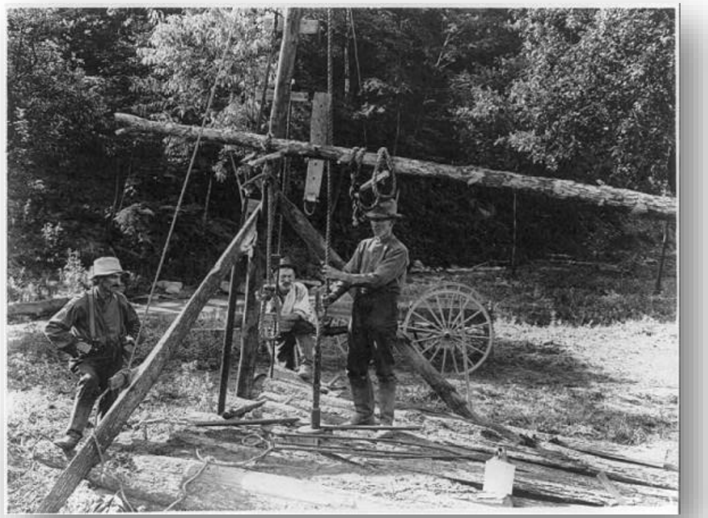
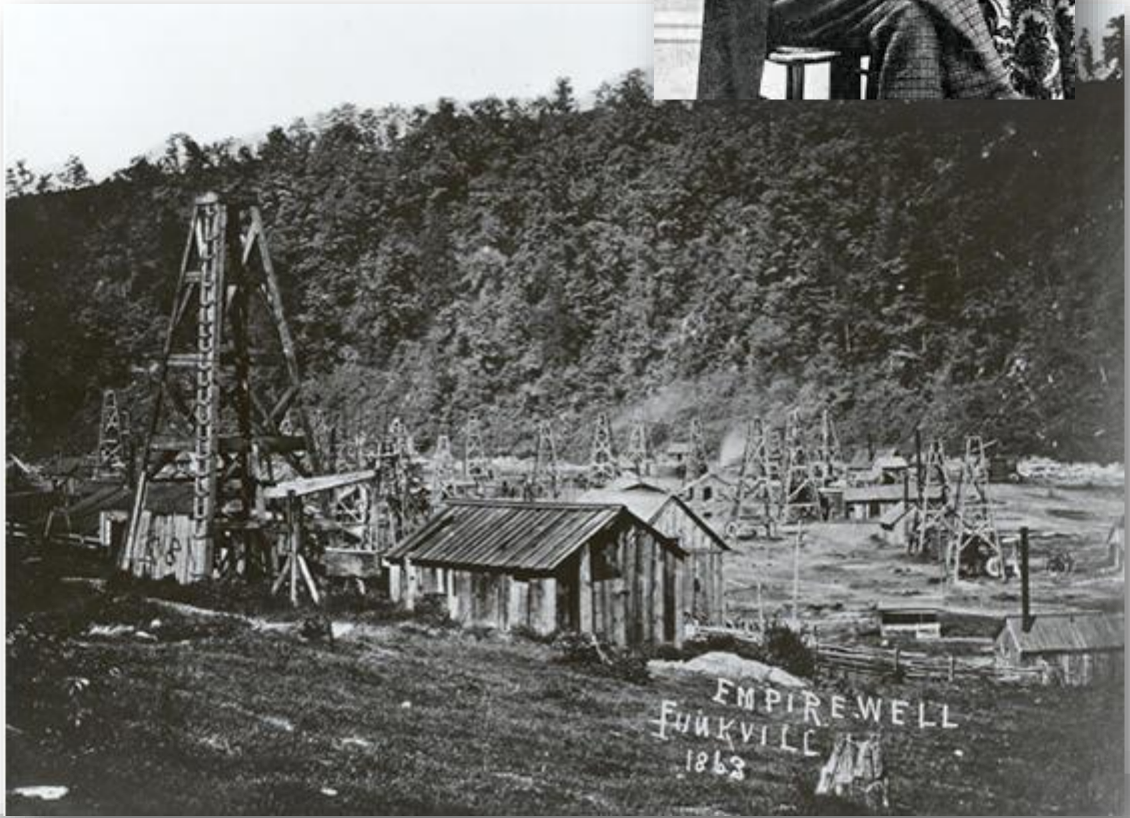
1859: Titusville, in northern Pennsylvania, a village of 125 inhabitants.
The “fake colonel” designs a drilling tower based on the simple assembly of a wooden stick with a rocker drill, moved by an alternating vertical movement.

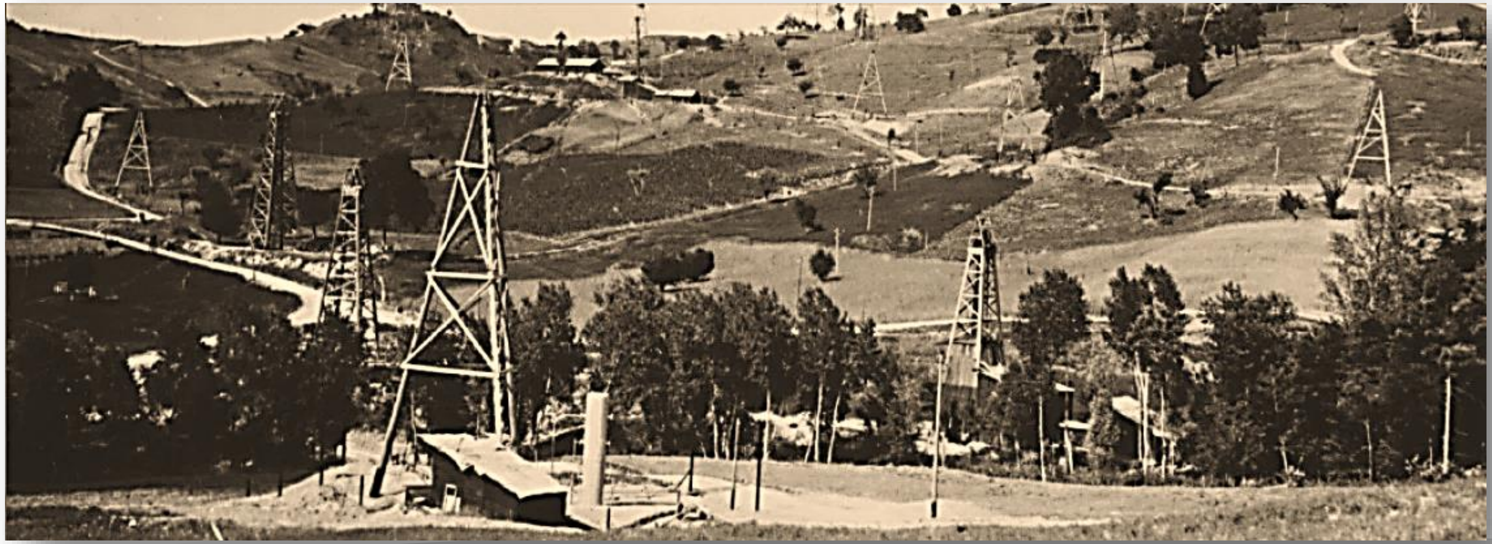




After months of unsuccessful work and continued loss of money, the financiers of the Seneca Oil Company send a letter with the order to stop drilling.
On August 29, before the letter was delivered, the "colonel" sees the oil gushing from a well 20 meters deep.

Italy: > 7000 WELLS DRILLED FROM 1860

1860	First modern well drilled (Parma)
1860	First «petroleum mines» in Tocco Casauria (Abruzzo, central Italy)
1868	Oil mine of Petroglie (Latium, central Italy)
1869	First gas-lit cities
1926	AGIP
1944	Caviaga (Po Valley): first gas field in Europe
1959	Sicily: first offshore well drilled in Europe
1973	Malossa (Po Valley): deepest oil field in Europe (>5000 m)
1980	Adriatic Sea: first well drilled in deep water (>300 m water table)
1984	Trecate (Po Valley): deepest oil field in Europe (>6000 m)
1988	Basilicata Region: biggest oil felds onshore Europe



Parma and Piacenza Apennines: a very long story

Since ancient times, seeps of gas and oil (Petrolio: Latin medieval. Petroleum, petraeum "stone oil") are known in Emilia, and their presence was also feared as a demonic presence.

- I century aC: **Plinio il Vecchio** (*Naturalis Historia*) during a Modena earthquake, speaks about "...*scontro di due monti che poi tornavano ad allontanarsi con grande frastuono, fiamme e fumo*..."
- 1200: **Giovanni De Mussis** (*Chronicon Placentinum*) tells of oil outcrops: *"Sunt etiam in dicto episcopatu Placentino aliquae fonte set putei qui producunt oleum petronicum quod vales ad multa infirmitates"* ("There are indeed in this episcopate of Piacenza also some sources and wells that produce stone oil, which serves against many diseases")
- 1781: the priest **Serafino Volta** told of the fires of Velleja (Piacenza)
- 1876: the abbot **Antonio Stoppani** (Il Belpaese) tells of Fornovo (Parma) and thirty masonry wells such as water wells, 10-20 meters deep, which each produced about 25 kg of oil per day

Since the **'600**, in many small towns there were pools of water covered with an oily layer, then "drained" from water and marketed for countless uses, especially medicines.

Until the **nineteenth century** oil was used for different purposes; fuel for lamps or medical remedy for skin problems (fungi, psoriasis), and was present in several medicinal preparations.

Fires produced by the land in the Emilian countryside. Print in A. Volta, Lettere, 1777)

Boatmen collect bitumen with sponges off the coast of Agrigento. Engraving by P. Galle (1537-1612) based on a drawing by J. van der Street (1523-1605)

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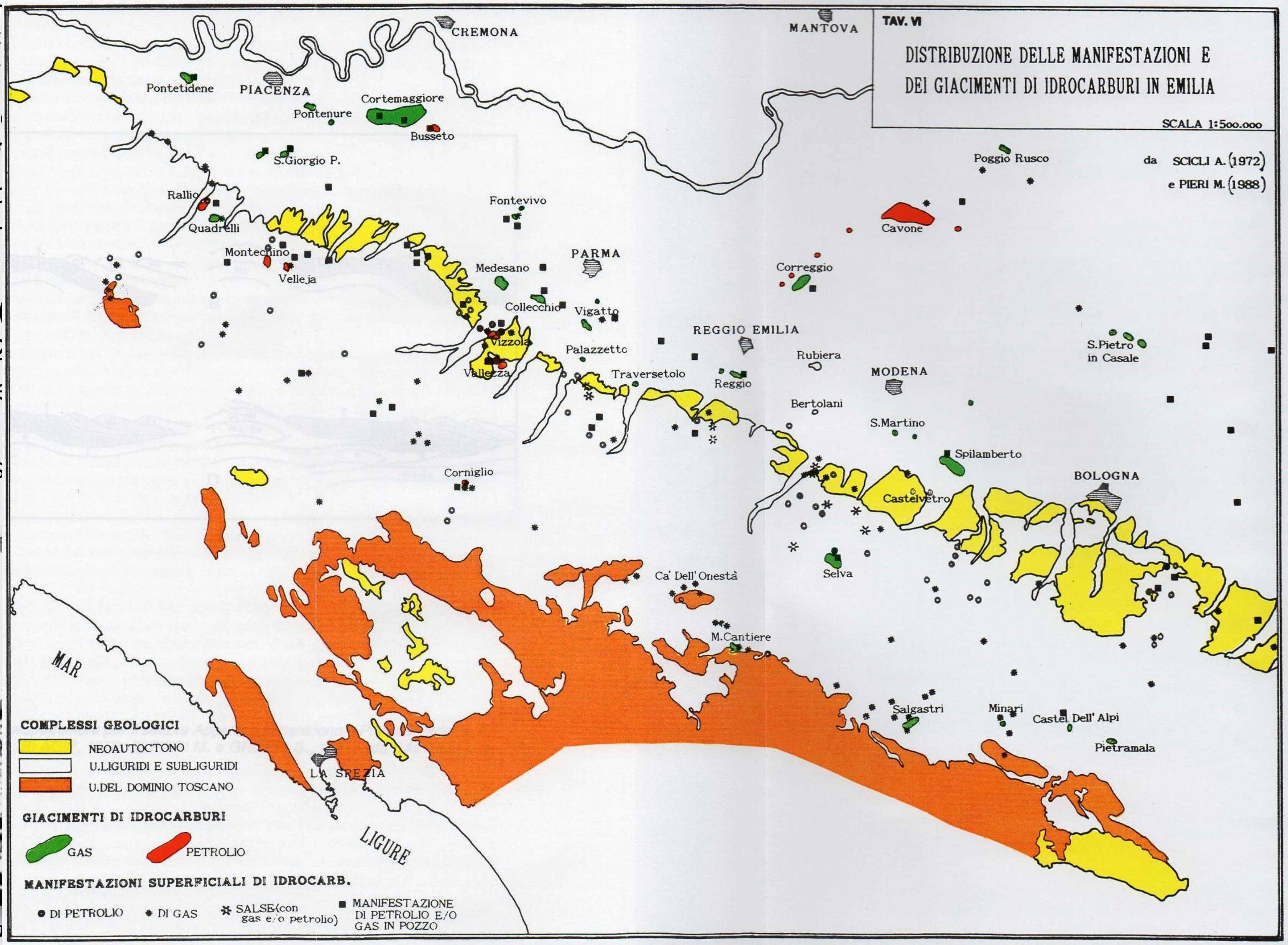
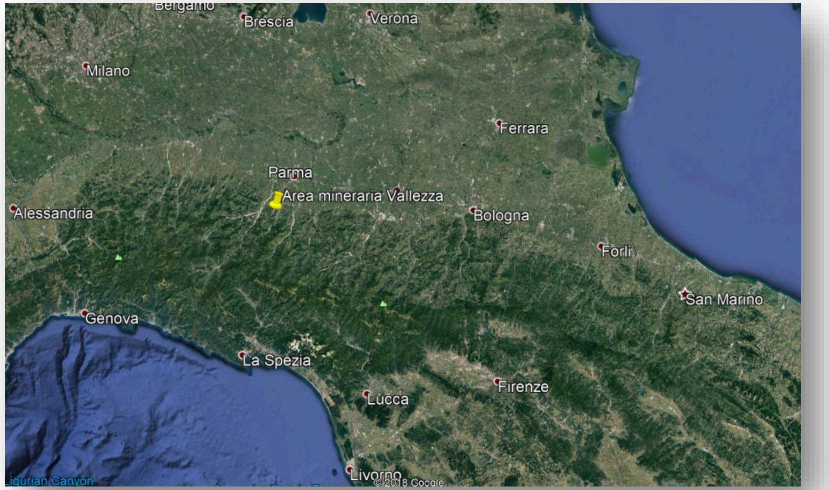
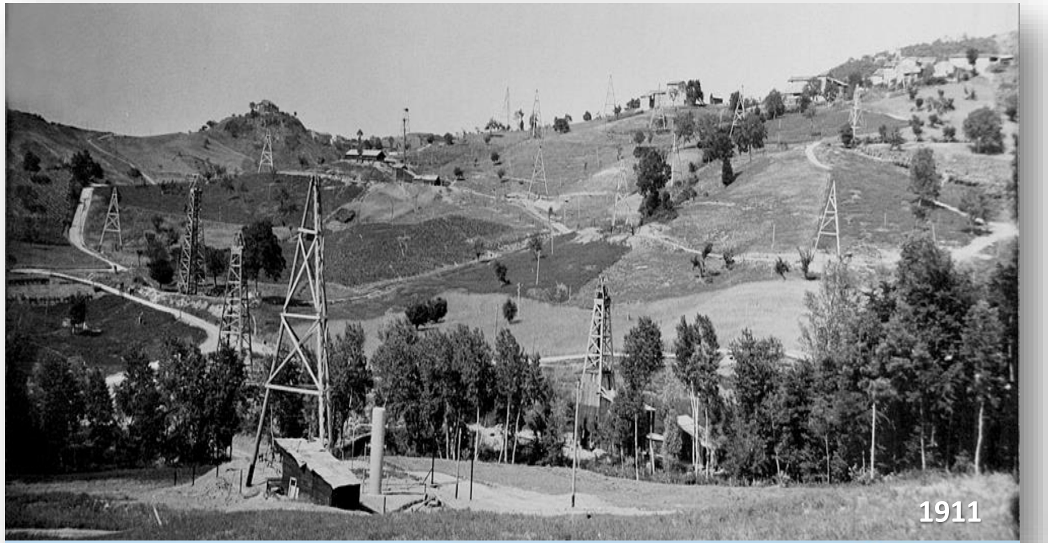
Fires produced by the land in the En … *Lettere, 1777)*



Engraving by … *based on a drawing by J. Van der Street (1523-1605)*

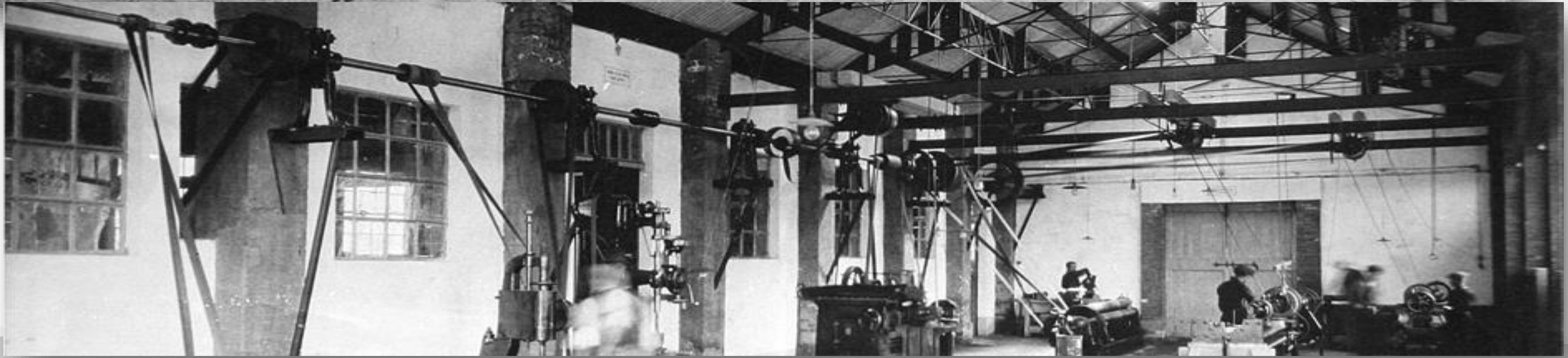
Vallezza (Parma)





1860: first "modern" well in Europe
1905: the Società Petrolifera Italiana spa is founded, the oldest in Italy, for drilling and extracting oil in the Parma Apennines.
1912: 10 wells producing 15 quintals / day. About 250-300 workers with their families
1916: the first "modern" refinery in Italy
1933: 16 wells producing 20,649 tons (80% of national production). SPI funds the Department of Geological Studies
1946: the SPI passes to the Standard Oil & Company (ESSO) which starts the reconstruction after the Second World War bombings
1980: well 201 drilled
1994: the Vallezza field is declared depleted and begins the closure of the wells (P&A) and the reclamation of the sites

VALLEZZA: AN ANCIENT TECHNOLOGY



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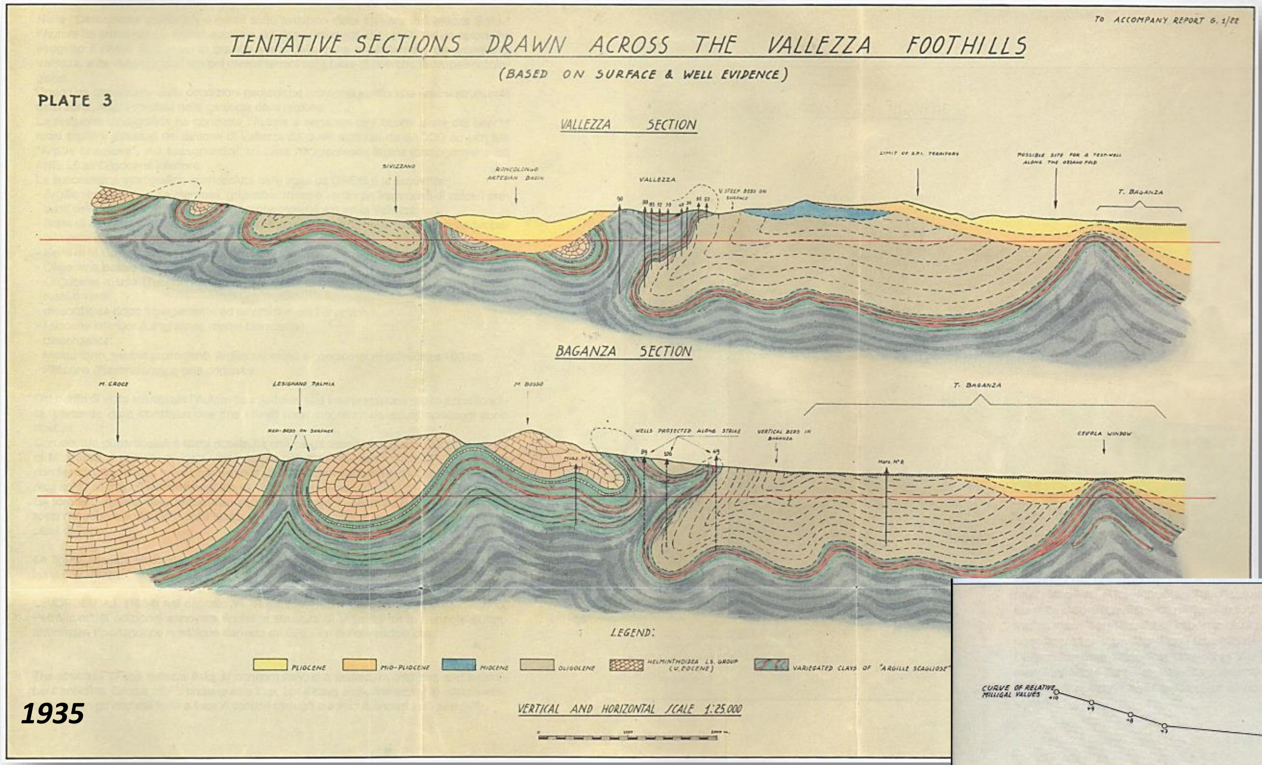
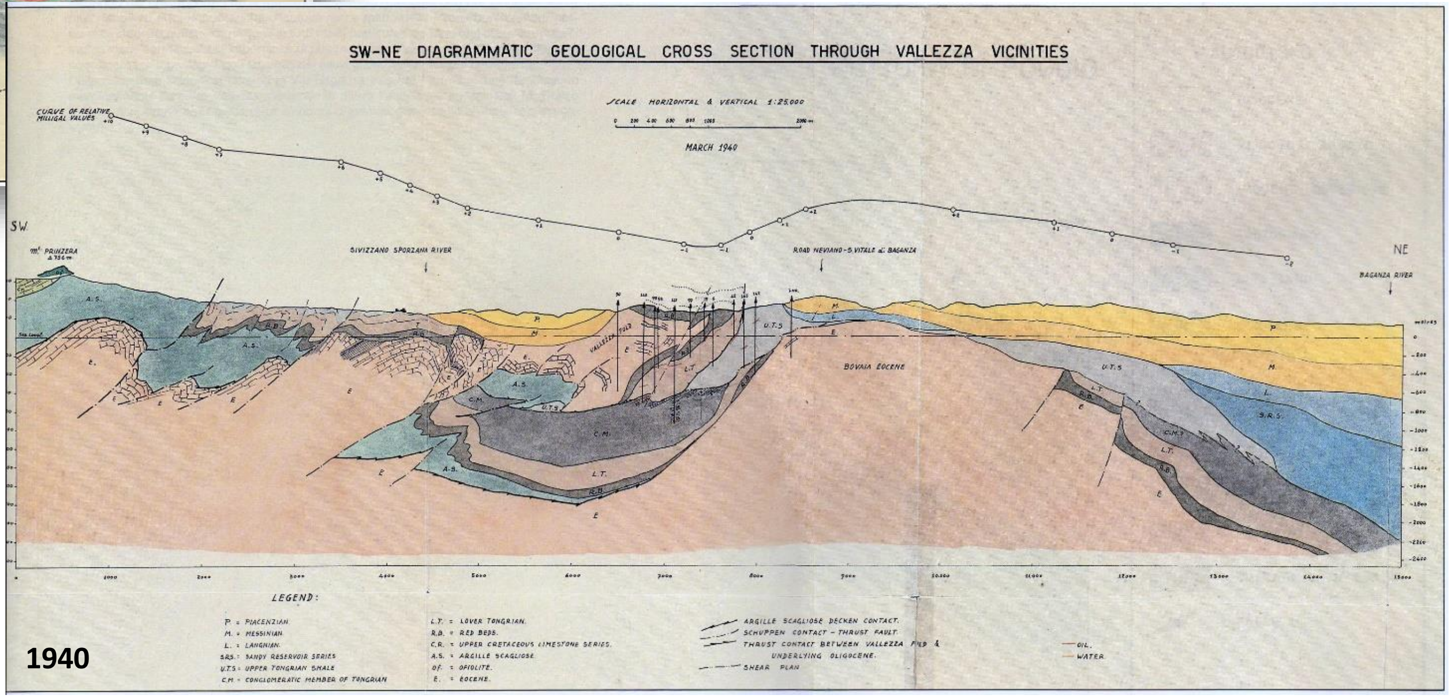
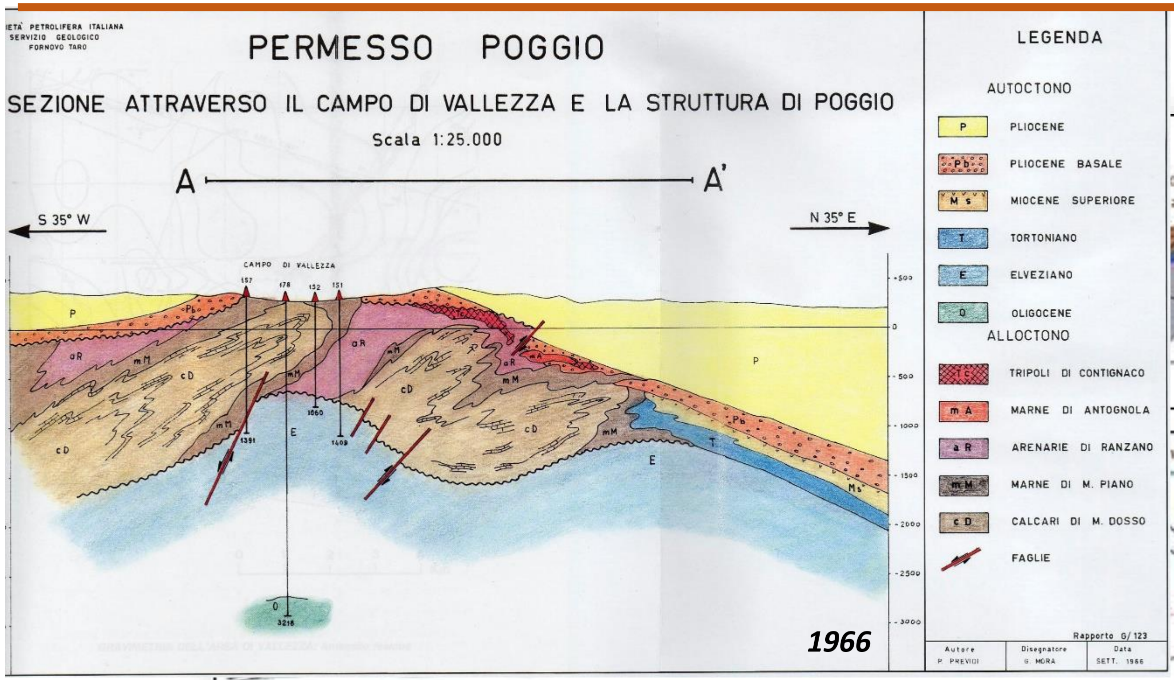
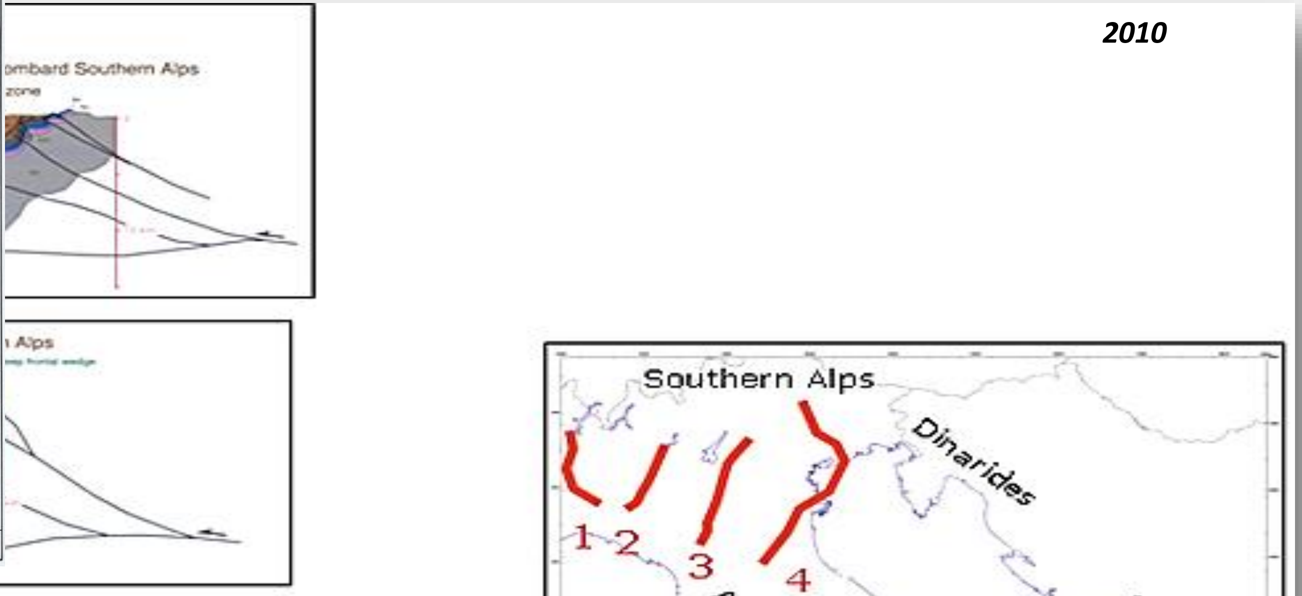
VALLEZZA: GEOLOGICAL STUDIES

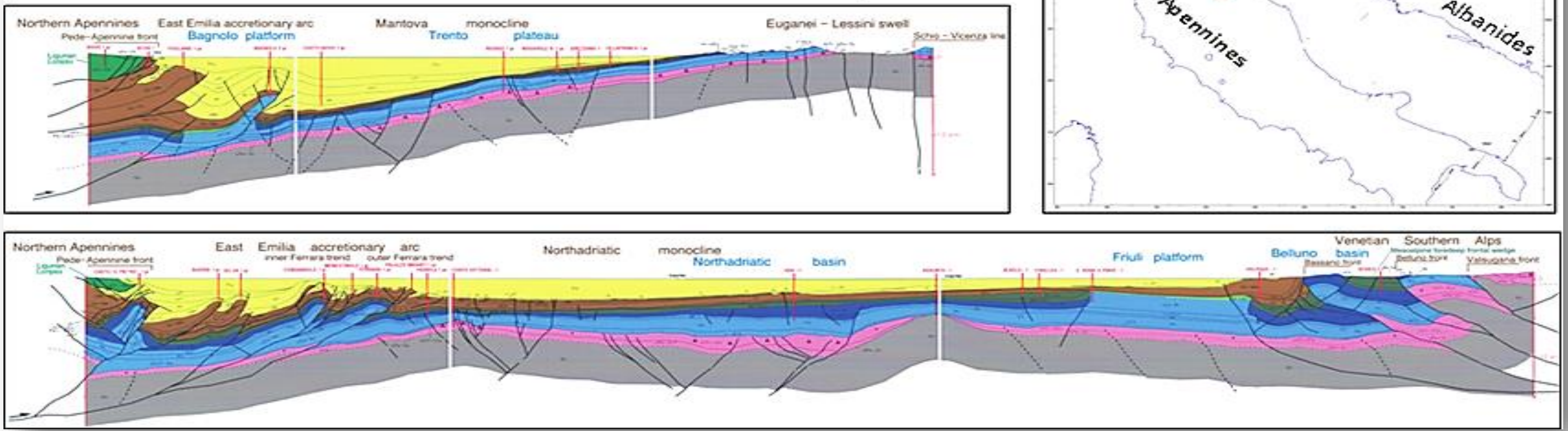


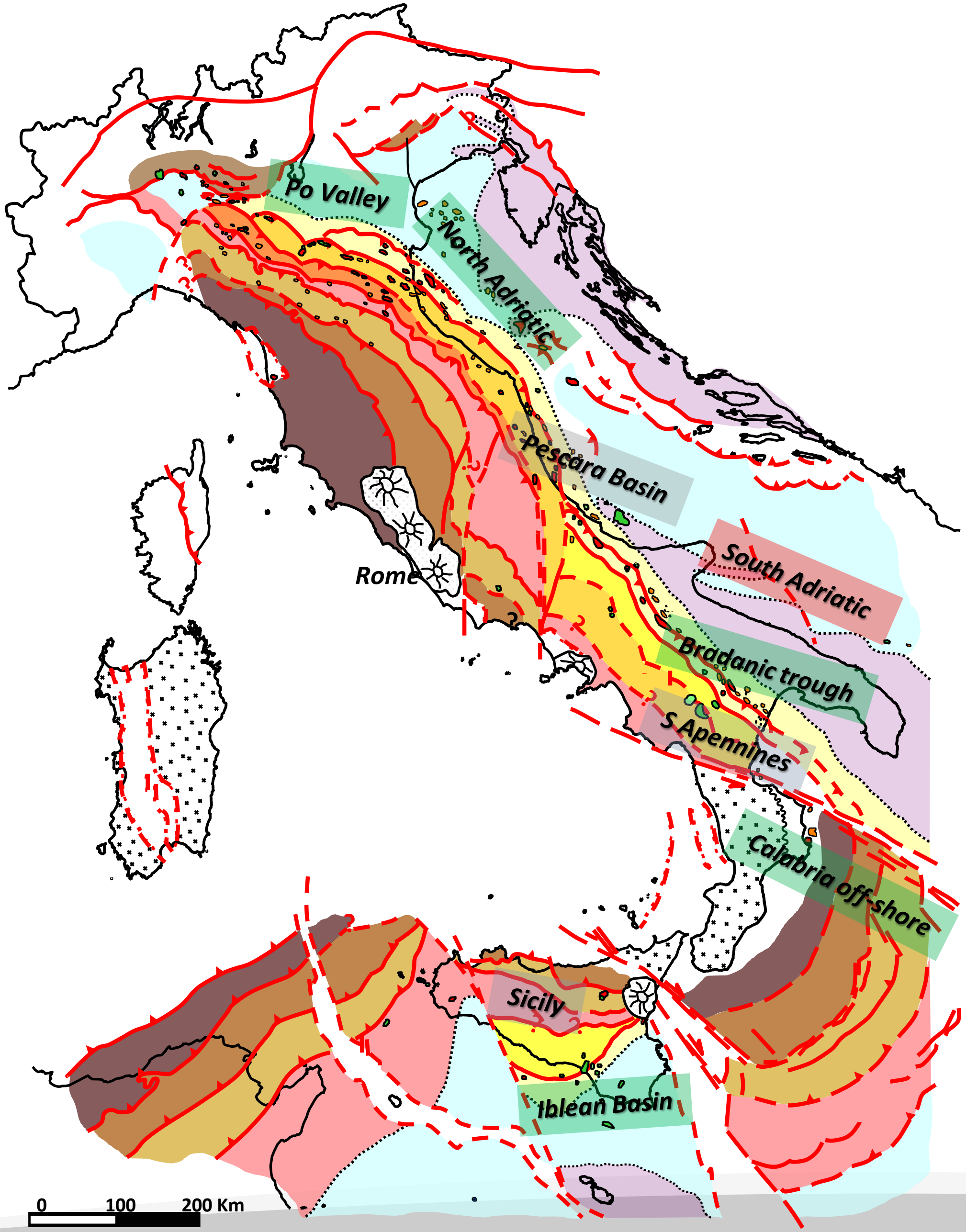


VALLEZZA: GEOLOGICAL STUDIES









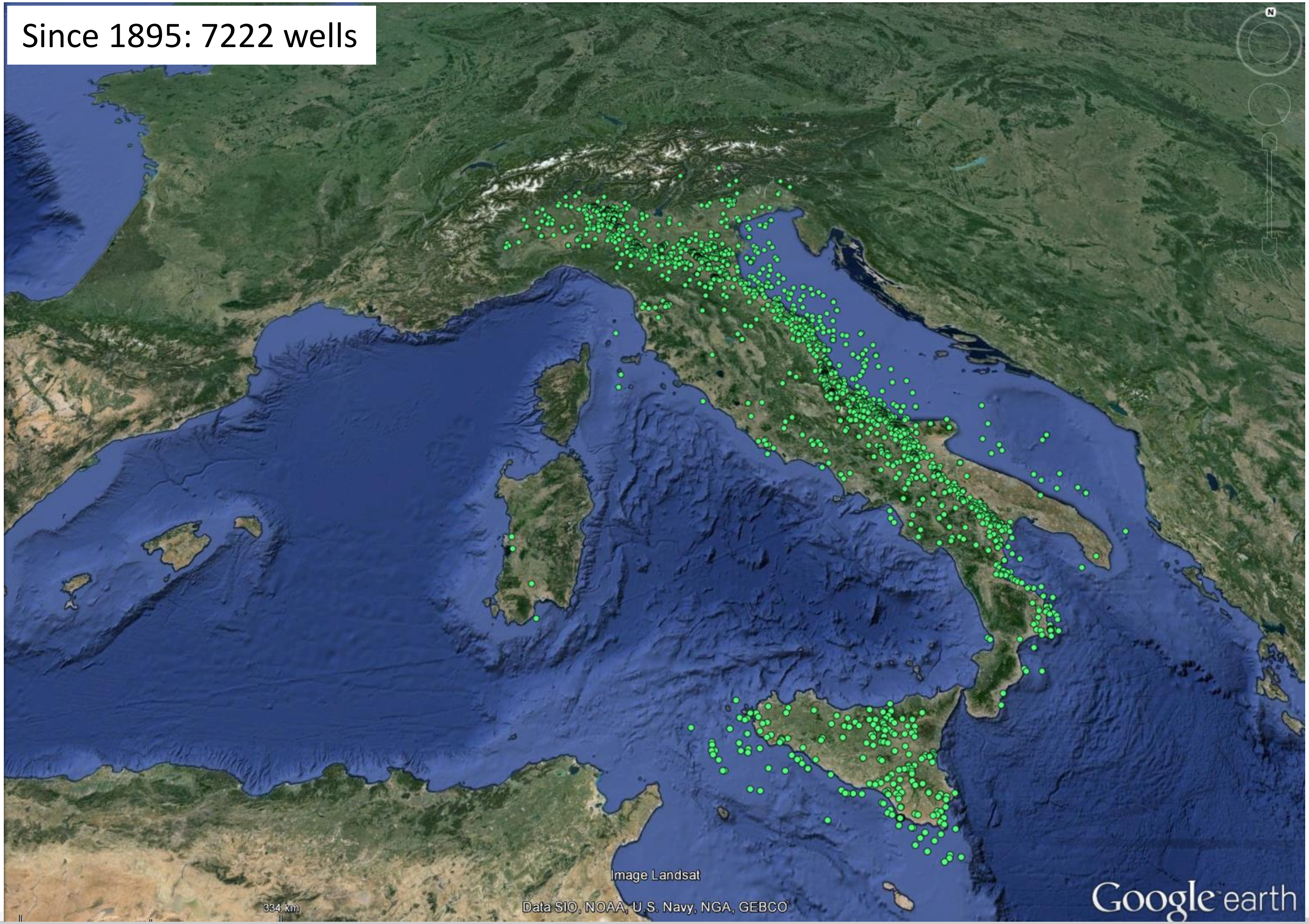
An indissoluble union

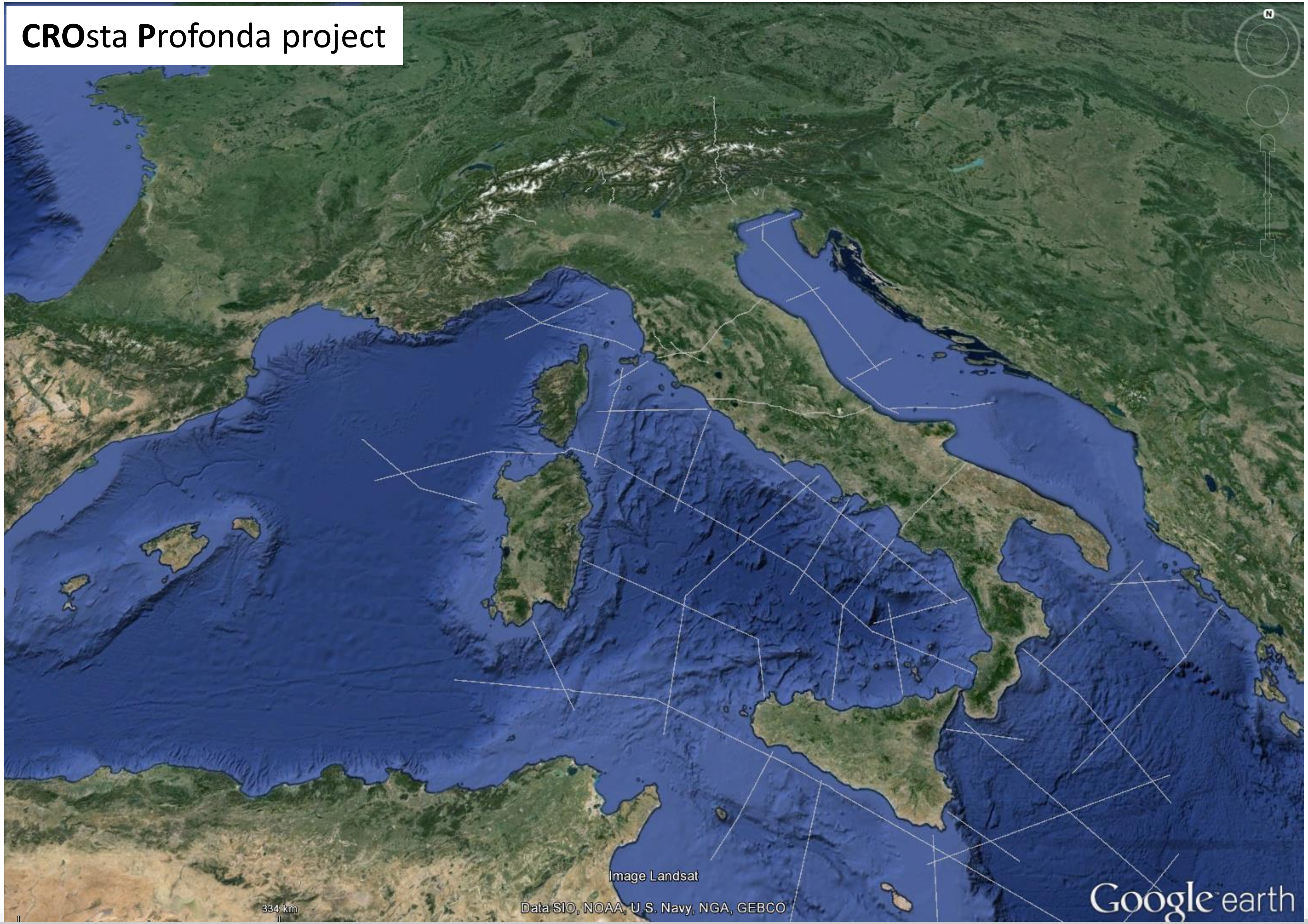
Geosciences: knowledge and awareness of the territory, dissemination of knowledge

Underground Georesources: energy hunger, dependence on foreign countries, considerable potential resources, school of science

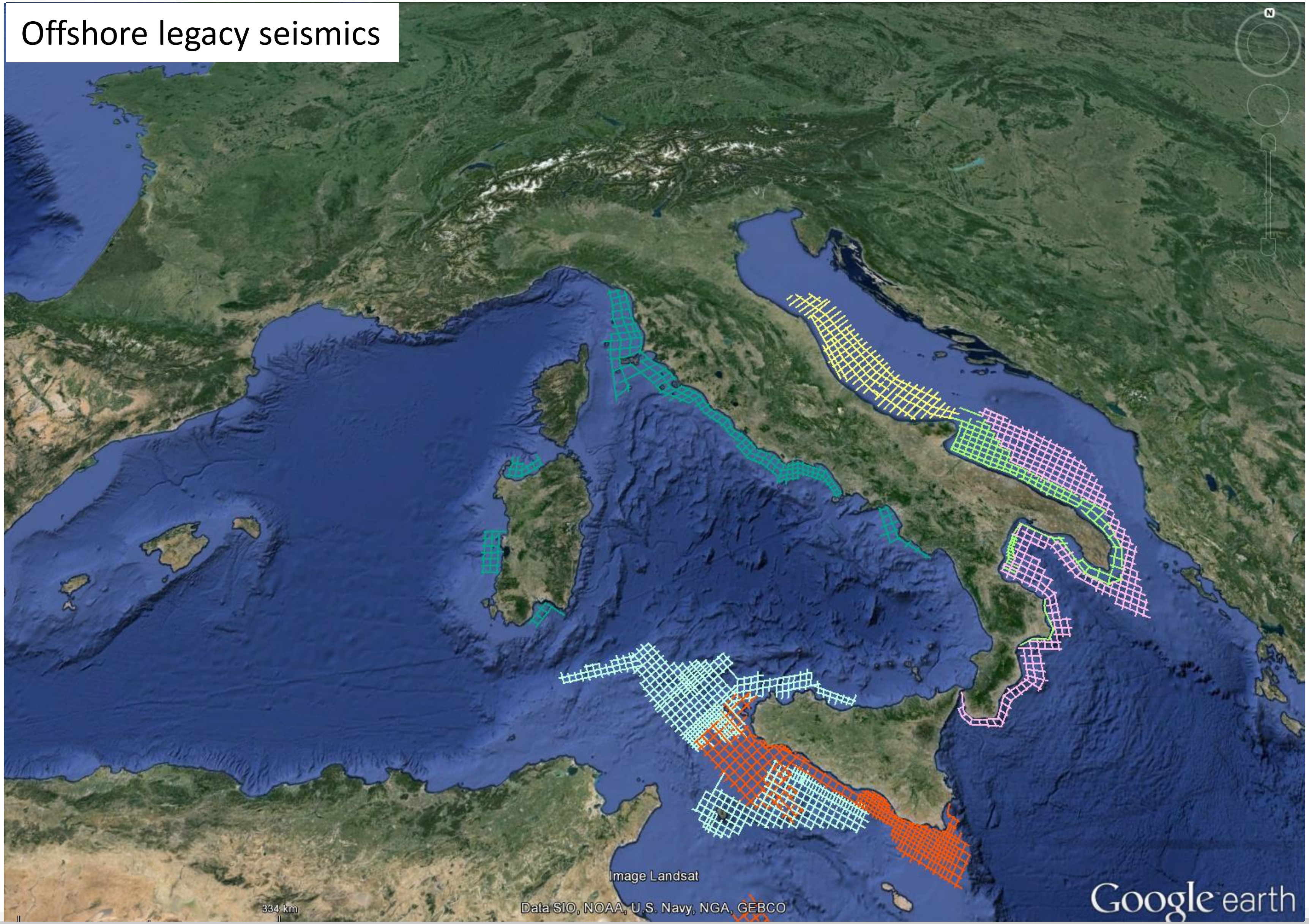
Since the 1950s, the Peninsula has been the subject of **geophysical surveys** and **drilling** of wells (scientific, hydrocarbon research, geothermal), which in addition to giving access to **natural resources**, have increased the knowledge of the **underground geology**

DATA

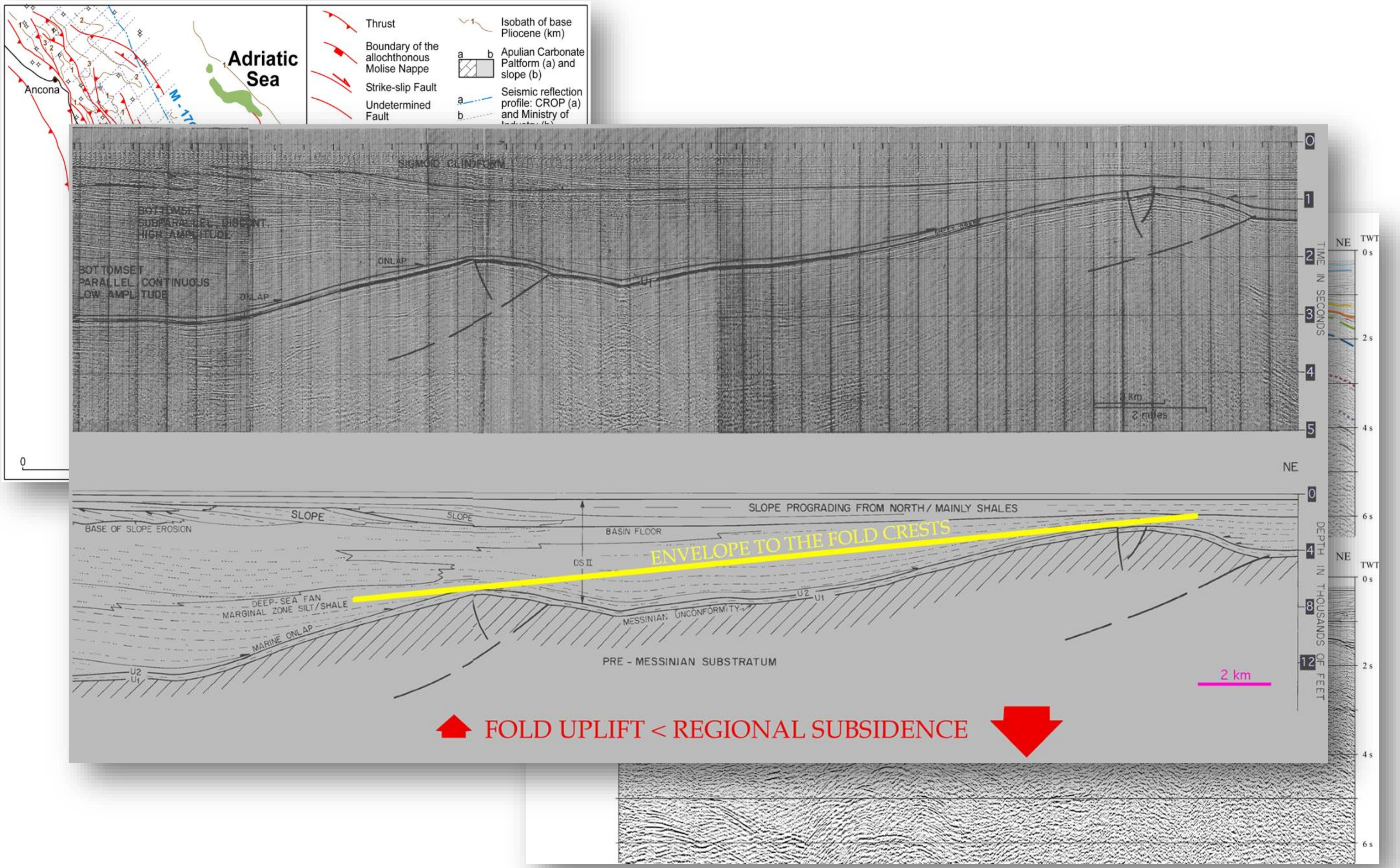

Since 1895: 7222 wells
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
334 km
Google earth


CROsta **P**rofonda project
Image Landsat
334 km
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

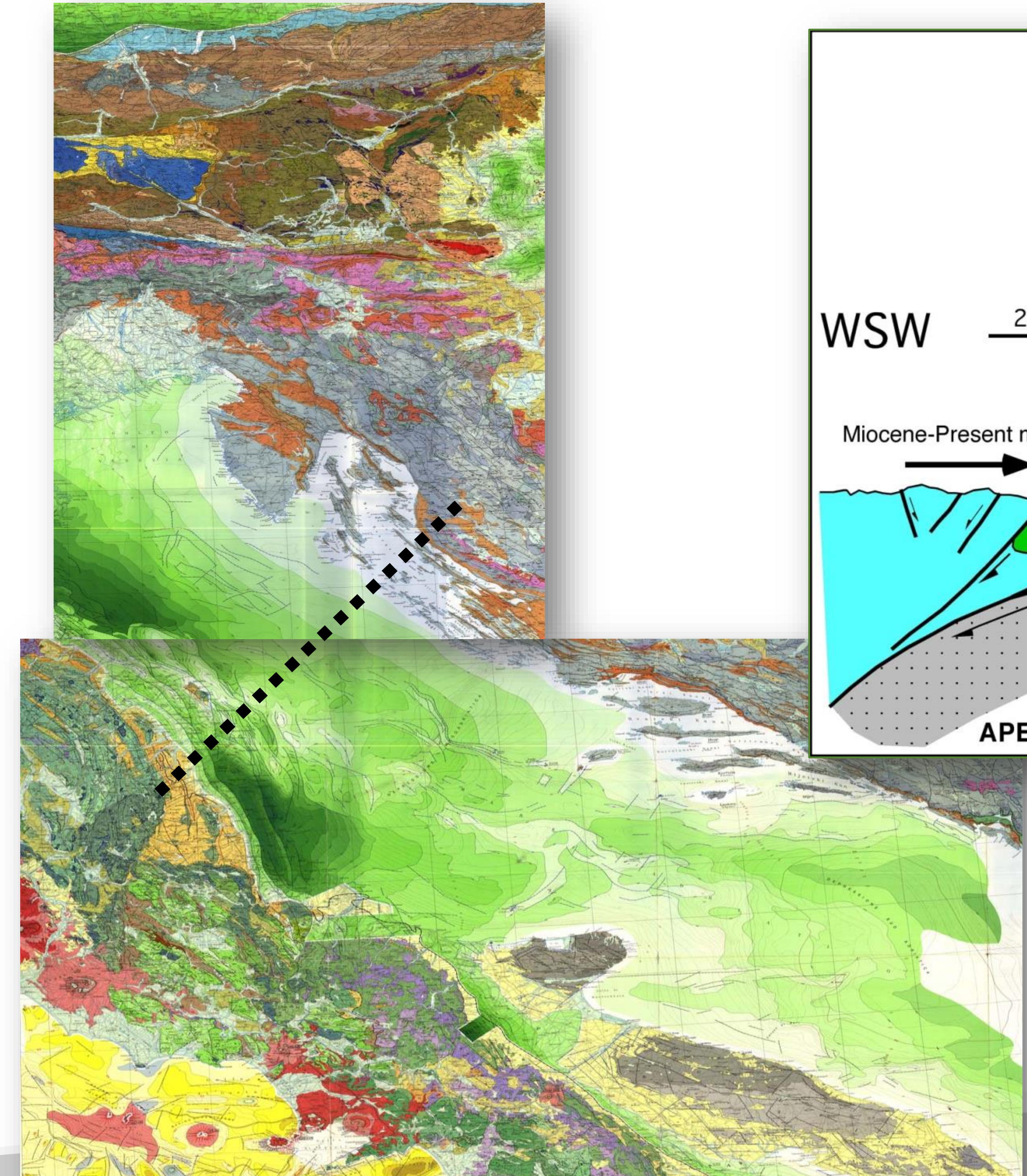
DATA

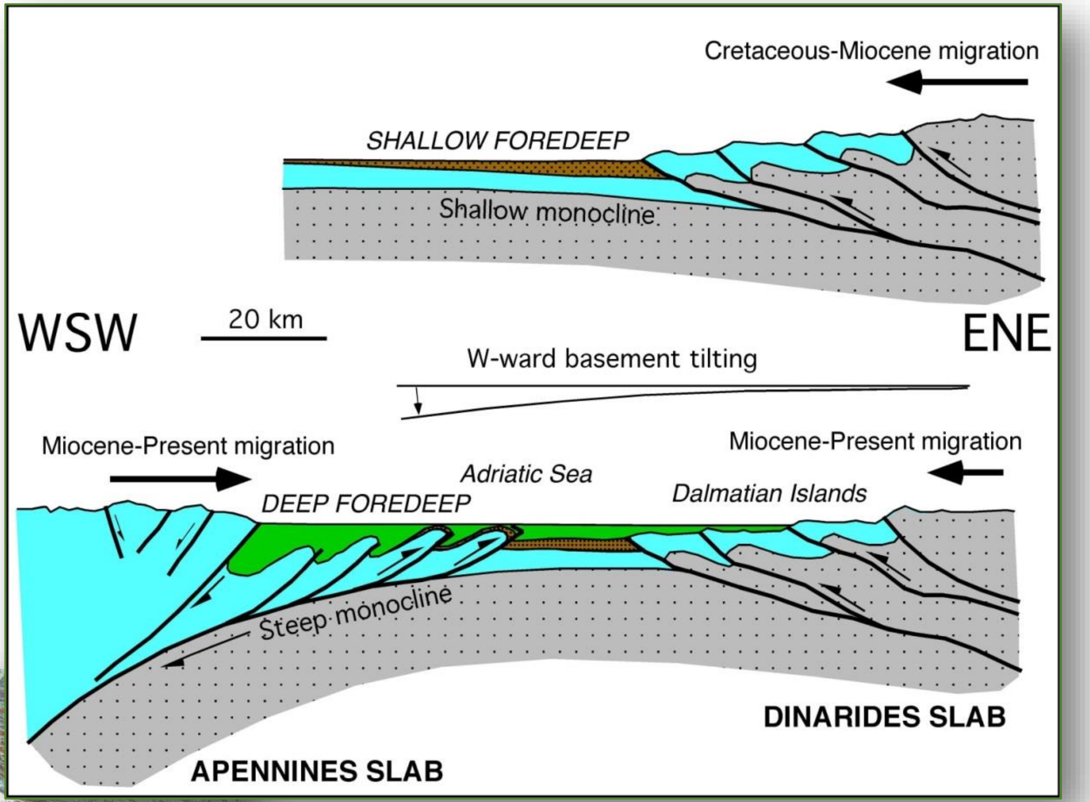

Offshore legacy seismics
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
334 km
Google earth

KNOWLEDGE – Deep geological setting

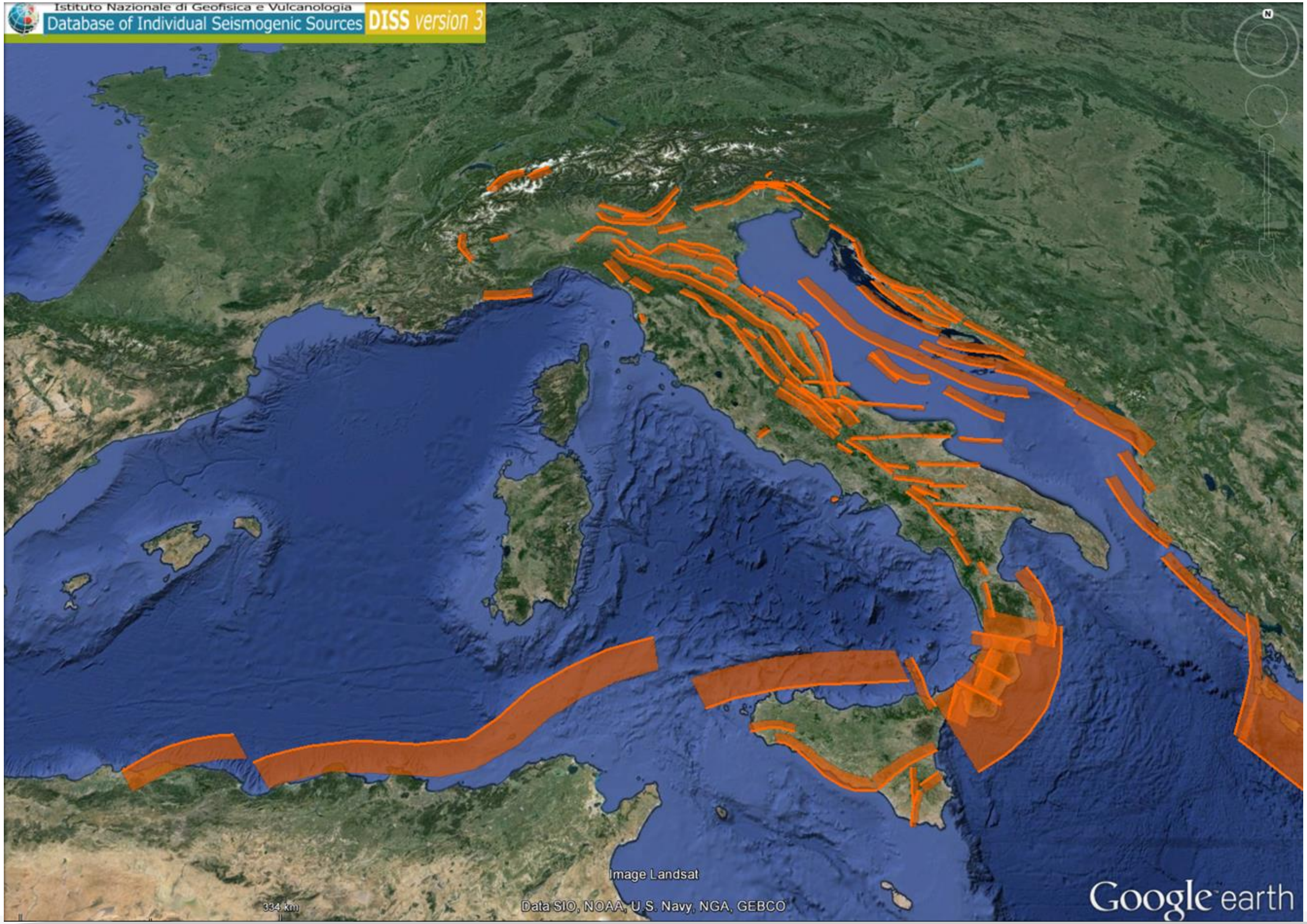


KNOWLEDGE – Deep geological setting

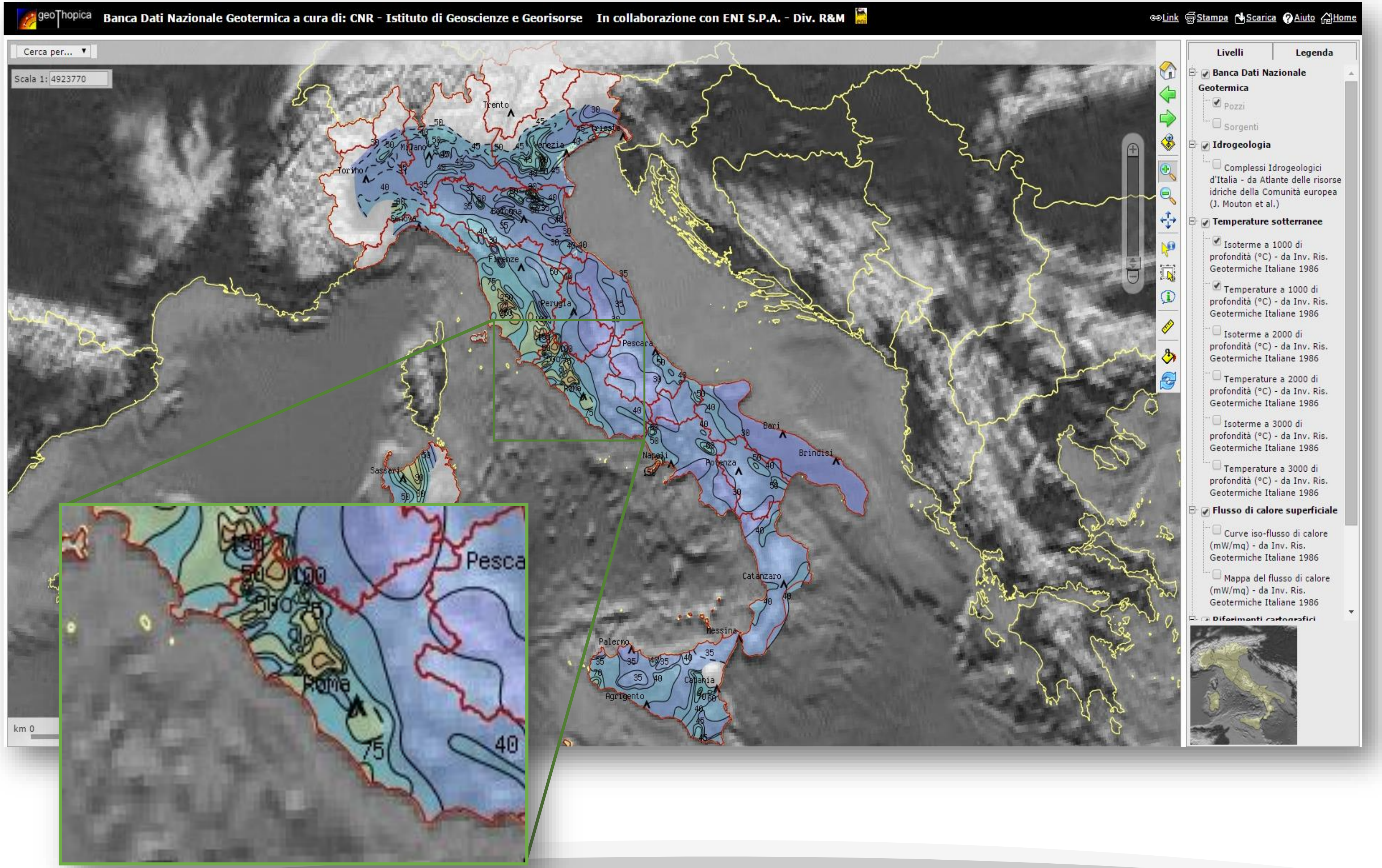




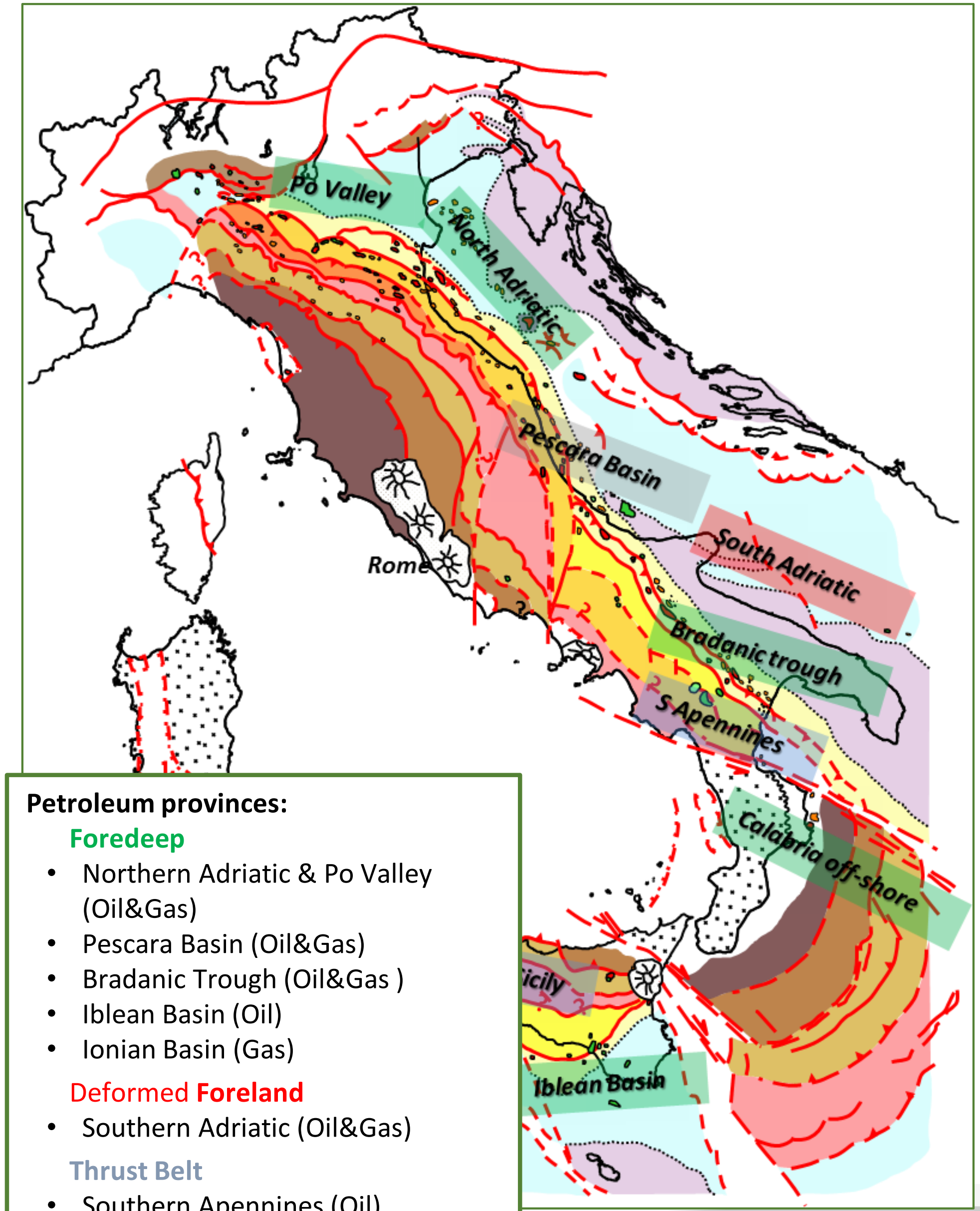
KNOWLEDGE – Seismogenic Structures



KNOWLEDGE - Geothermal resources



KNOWLEDGE – Oil&Gas resources



Petroleum provinces:

Foredeep

- Northern Adriatic & Po Valley (Oil&Gas)
- Pescara Basin (Oil&Gas)
- Bradanic Trough (Oil&Gas)
- Iblean Basin (Oil)
- Ionian Basin (Gas)

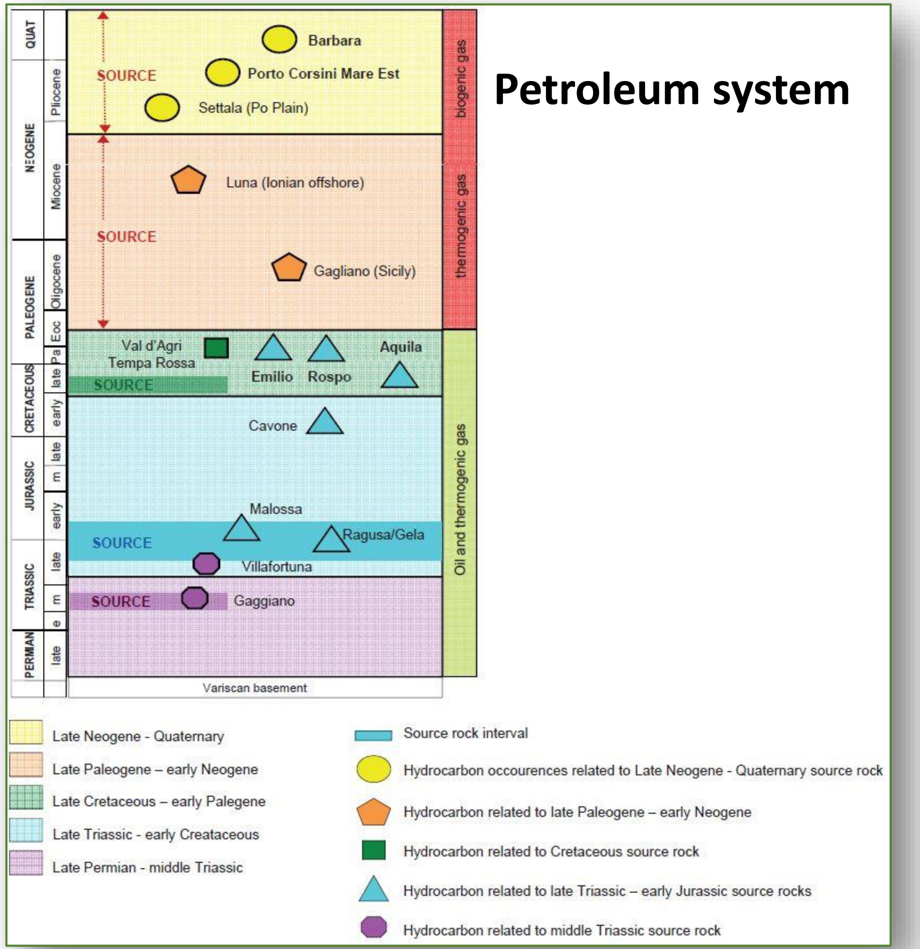
Deformed Foreland

- Southern Adriatic (Oil&Gas)

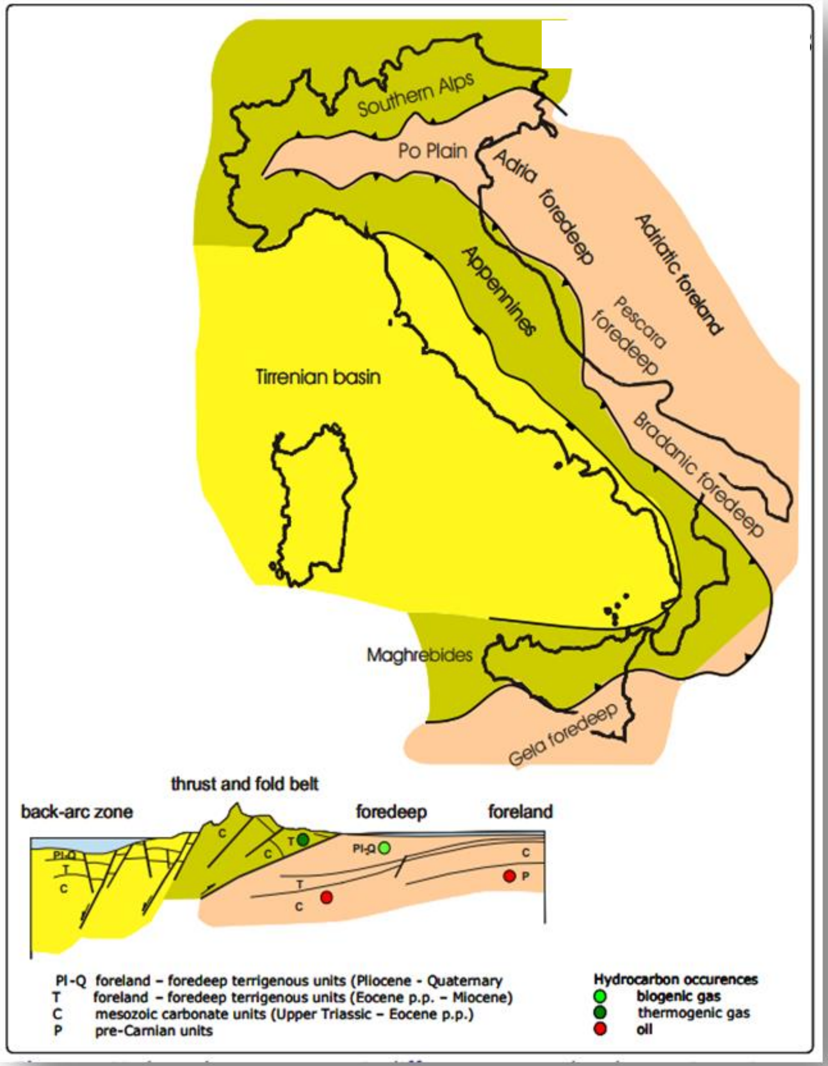
Thrust Belt

- Southern Apennines (Oil)
- Sicily (Gas)

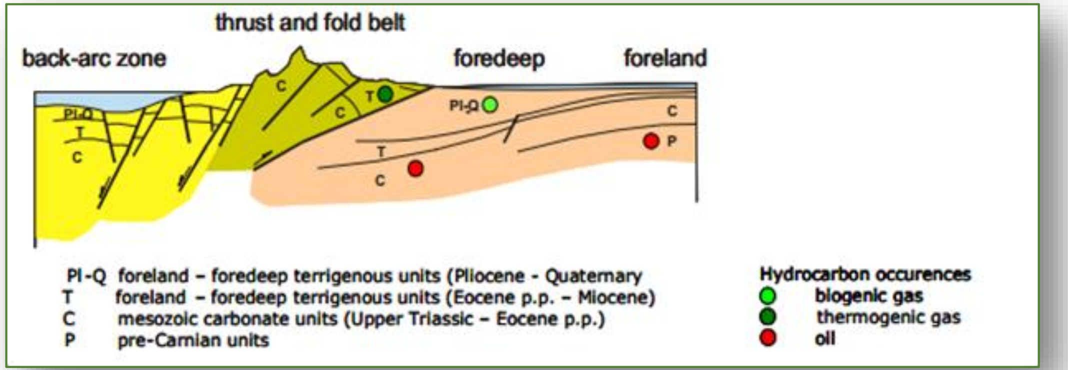
Petroleum system



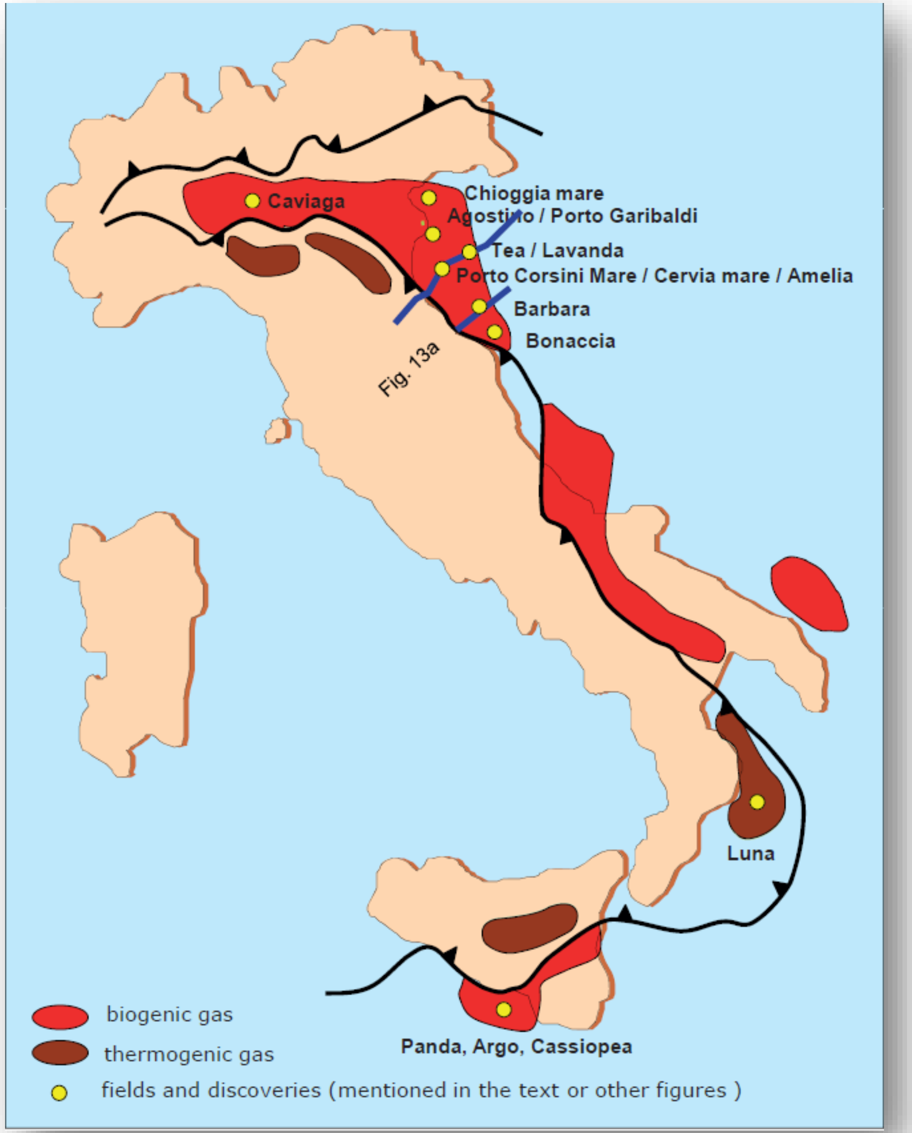
KNOWLEDGE – Oil&Gas resources



Bertello et al., 2008



KNOWLEDGE – Oil&Gas resources



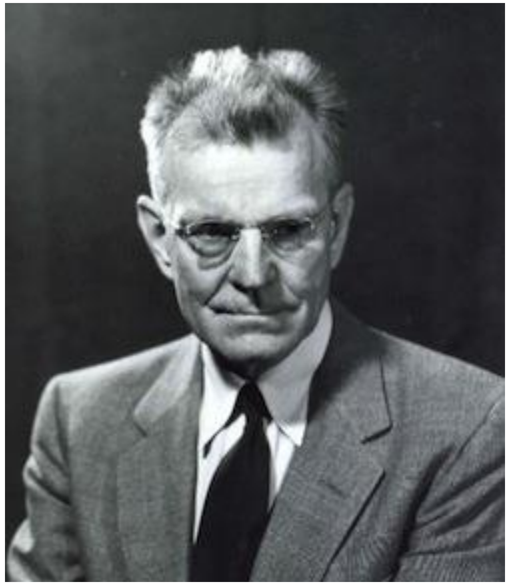
Cazzini et al., 2015

A

1. **Primary source** and **secondary source** of energy
2. **Renewable** and **non-renewable** energy sources
3. The **use of oil and gas** in the modern society
4. Fundamentals of **Petroleum Geology**:
    1. Petroleum system
    2. Exploration
    3. Resources/Reserves classification
    4. Volumetric calculation
    5. Development & Economics

B

1. When the **first well** has been drilled in USA? And in Italy?
2. The evolution of the **knowledge**
3. How much Oil&Gas has **still to be discovered**?
4. **Economic** and **Energy scenarios**: World, Europe, Italy



Marion King Hubbert

- Geologist and geophysicist for Shell from 1943 to 1964.
- Researcher in geophysics for the US Geological Survey until 1976
- Professor of Geology and Geophysics at Stanford University from 1963 to 1968 and at the University of Berkeley from 1973 to 1976.
- Member of the National Academy of Sciences and the American Academy of Arts and Sciences, president of the Geological Society of America.

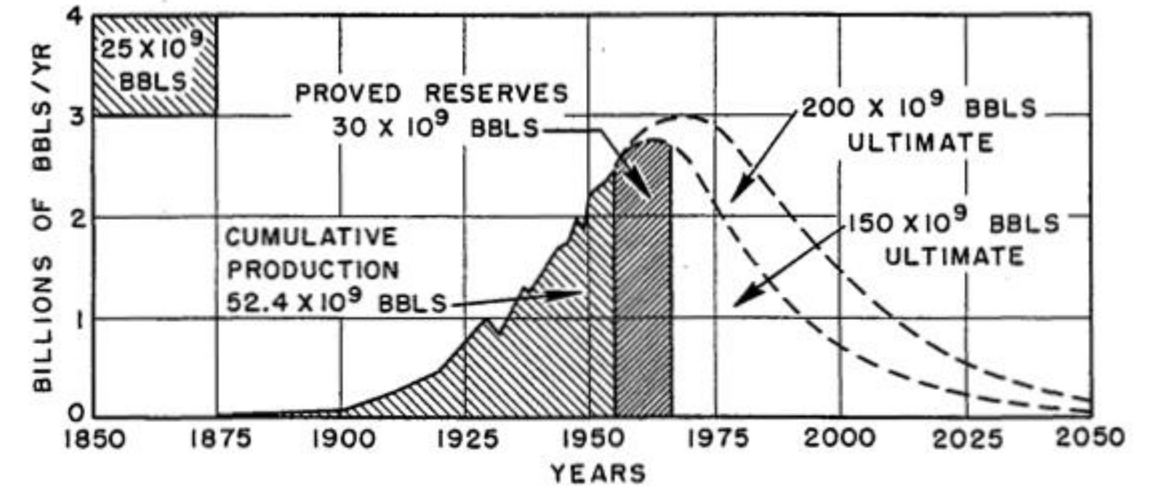


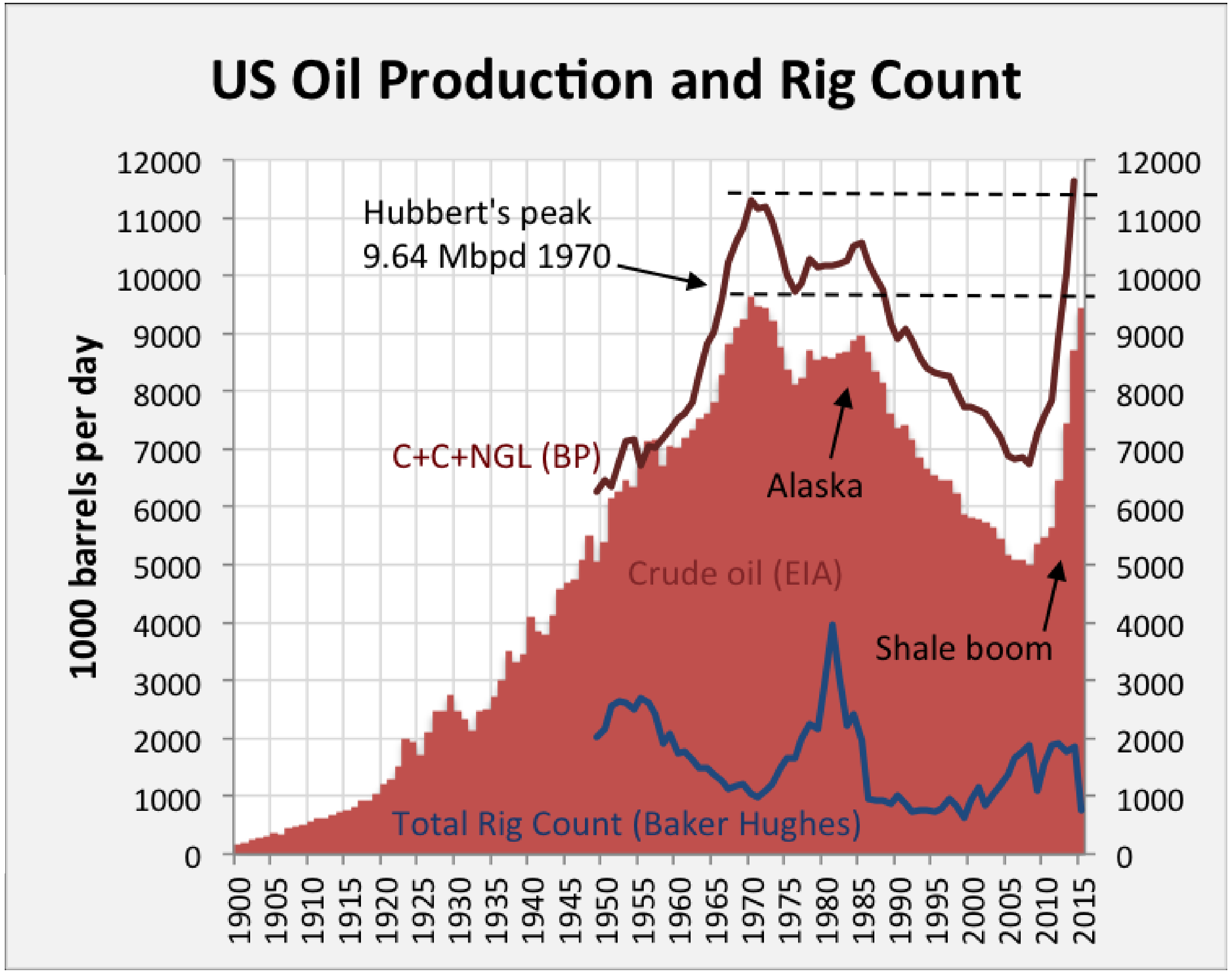
Figure 21 – Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

Peak and fall in US production for a final recovery of 150 and 200 billion barrels (Hubbert, 1956).

How much Oil&Gas has still to be discovered?

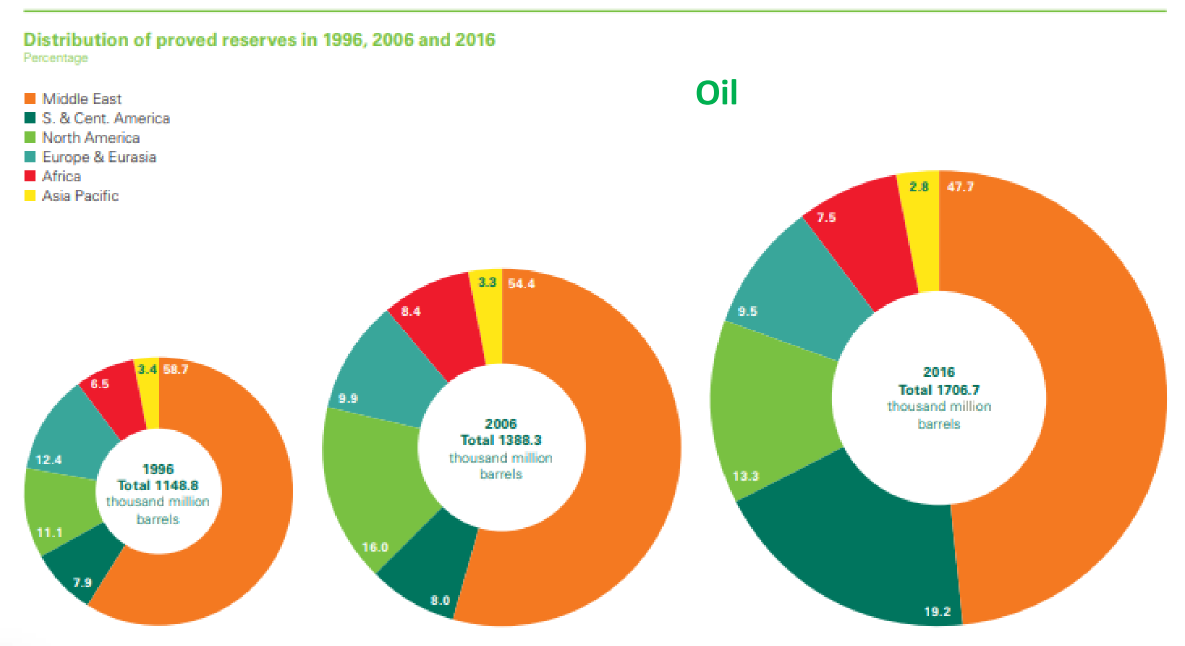
US crude oil production (IEA). The US oil industry believed that this growth would continue forever; ***in 1956 M. King Hubbert warned that the growth of US production would end in 1970.***

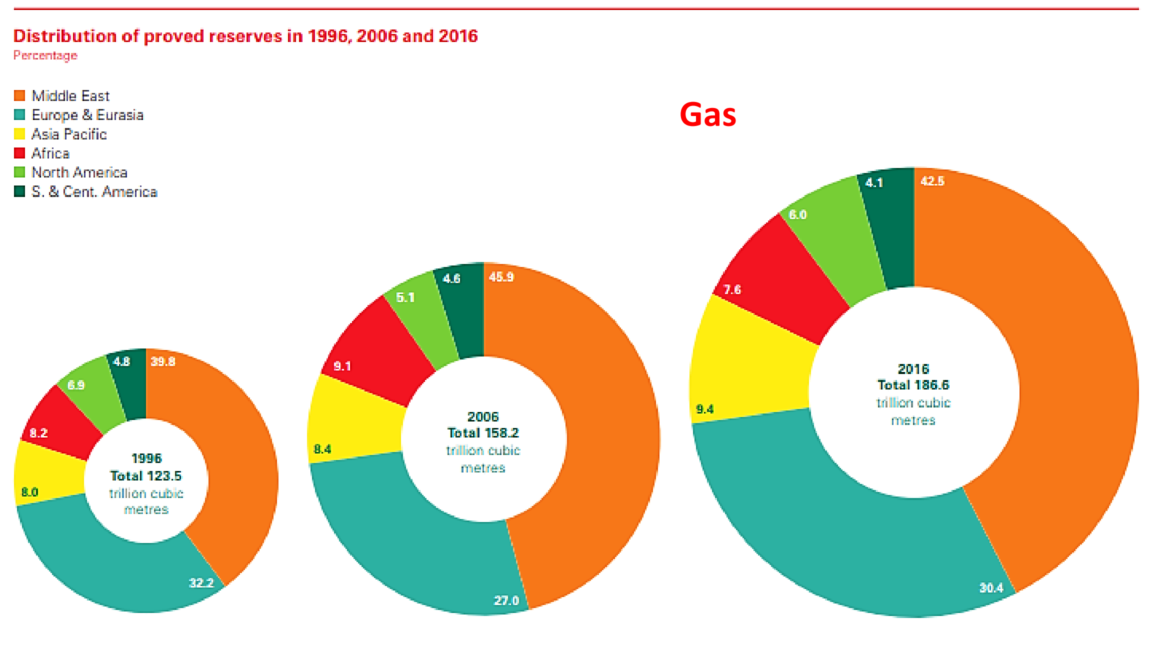
The discovery of oil in Alaska has created a shoulder on the curve of decline, but the forecasts remained valid until 2008, with the advent of shale-oil and shale-gas. The "Hubbert peak" of 1970 was equaled and surpassed in 2015.



How much Oil&Gas has still to be discovered?

BP Statistical Review
of World Energy
June 2017

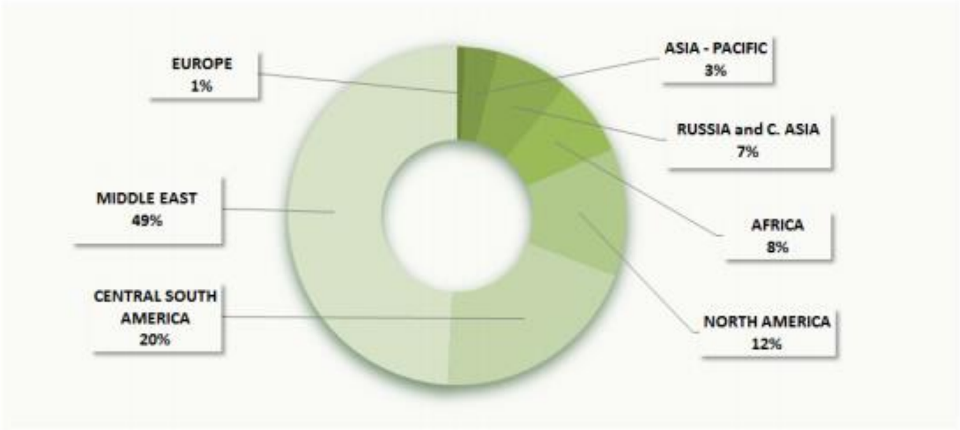




How much Oil&Gas has still to be discovered?

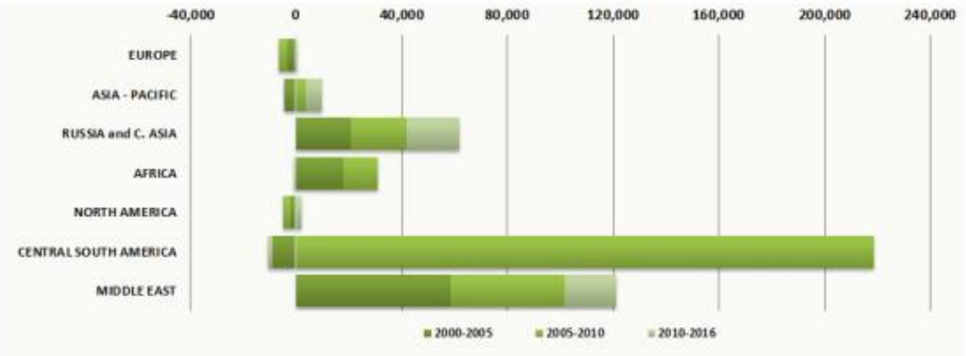
World Oil Reserves (2016)

1,657,658 million barrels as at 31st December



World Oil Reserves Growth (2000-2016)

417,889 million barrels as at 31st December



- 2016: crude oil reserves increased (+ 0.2%) mainly due to the contribution of additional reserves in Iraq.
- World oil demand grows by 1.7%
- Global refining capacity has increased by 1.5 Mb/d driven by the Middle East and Asia.
- **World demand for crude oil in 2017 and 2018 has further increased**

Oil

Reserves

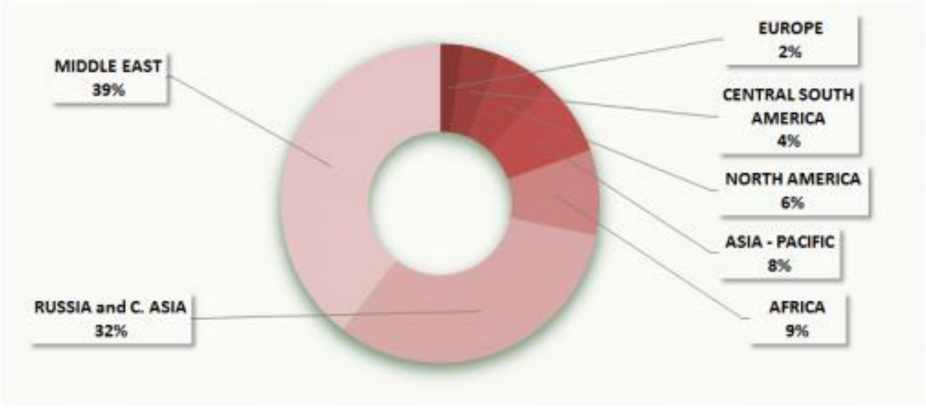
Countries (*)

(million barrels as at 31st December)

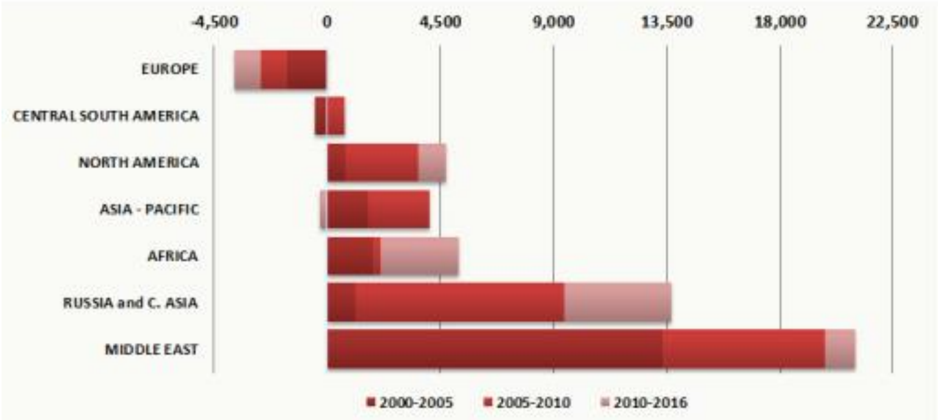
	2000	2005	2010	2012	2013	2014	2015	2016	Δ y/y (2016-2015)	CAGR (2016-2000)
Europe	19,429	16,121	12,865	12,555	12,902	12,312	11,682	12,942	10.8%	-2.5%
Albania	176	200	204	173	179	178	178	178	0.0%	0.1%
Austria	92	63	51	47	49	49	49	46	-5.3%	-4.2%
Belarus	211	200	203	199	206	205	205	205	0.0%	-0.2%
Bulgaria	16	15	15	15	16	16	16	16	0.0%	-0.2%
Croatia	98	70	73	71	74	74	74	74	0.0%	-1.8%
Czech Republic	16	15	15	15	16	16	16	16	0.0%	-0.2%
Denmark	1,113	1,277	899	730	673	610	554	493	-11.0%	-5.0%
France	155	159	93	86	88	88	88	81	-7.8%	-3.9%
Germany	405	370	283	256	264	263	263	289	9.8%	-2.1%
Greece	11	7	10	10	10	10	10	10	0.0%	-0.2%
Hungary	117	104	28	27	28	28	28	25	-12.2%	-9.3%
Italy (**)	577	443	559	599	582	619	595	572	-3.9%	-0.1%
Lithuania	13	12	12	12	12	12	12	12	0.0%	-0.2%
Netherlands	114	107	318	246	150	145	141	113	-19.6%	0.0%
Norway	9,447	7,705	5,670	5,366	5,825	5,497	5,139	6,611	28.6%	-2.2%
Poland	123	97	99	158	163	163	163	163	0.0%	1.8%
Romania	1,170	458	600	600	600	600	600	600	0.0%	-4.1%
Serbia	83	79	80	78	81	81	81	81	0.0%	-0.2%
Slovakia	10	9	9	9	9	9	9	9	0.0%	-0.2%
Spain	22	159	154	151	156	155	155	155	0.0%	12.9%
Turkey	315	303	277	272	281	280	280	348	24.5%	0.6%
Ukraine	421	399	405	397	411	409	409	409	0.0%	-0.2%
United Kingdom	4,725	3,870	2,805	3,038	3,030	2,805	2,618	2,436	-6.9%	-4.1%

How much Oil&Gas has still to be discovered?

World Natural Gas Reserves (2016)
202,566 billion cubic metres as at 31st December



World Natural Gas Reserves Growth (2000-2016)
44,972 billion cubic metres as at 31st December



- 2016: world gas reserves increased by 0.9% (USA, Nigeria and Iraq). Russia is the first country (25% of world reserves)
- World gas production has increased by 0.7%.
- Global consumption of solar and wind energy is still marginal compared to total energy consumption (around 1%), while in terms of electricity generation it represents 4.5% (3.5% wind power and 1% % solar).
- Global gas demand has increased (+ 2.0%) in 2018 thanks to the economic recovery in Europe and the Asia-Pacific area.

Natural Gas

Reserves

Countries (*)
(billion cubic metres as at 31st December)

	2000	2005	2010	2012	2013	2014	2015	2016	Δ y/y (2016-2015)	CAGR (2016-2000)
Europe	8,432	6,875	5,790	5,504	5,347	5,048	4,887	4,728	-3.3%	-3.6%
Albania	1	0	0	0	0	0	0	0	0.0%	-10.6%
Austria	26	21	15	12	11	10	9	8	-11.5%	-7.3%
Belarus	2	1	1	1	1	1	1	1	0.0%	-8.3%
Bulgaria	6	3	5	5	5	5	5	4	-11.1%	-2.5%
Croatia	29	30	25	16	14	13	11	10	-12.3%	-6.4%
Czech Republic	4	3	3	3	3	3	3	3	0.0%	-1.1%
Denmark	144	122	101	91	90	88	80	77	-3.8%	-3.8%
France	8	7	5	10	9	9	9	9	-1.6%	0.5%
Germany	264	178	87	71	63	51	46	42	-9.5%	-10.9%
Greece	1	1	1	1	1	1	1	1	0.0%	0.0%
Hungary	32	21	12	11	9	9	9	7	-17.6%	-9.1%
Ireland	34	25	25	25	25	30	30	30	0.0%	-0.8%
Italy(**)	199	117	66	59	56	54	49	38	-22.4%	-9.8%
Moldova	20	20	20	20	20	20	20	20	0.0%	0.0%
Netherlands	1,684	1,431	1,236	1,072	989	864	825	789	-4.4%	-4.6%
Norway	3,841	3,108	2,762	2,687	2,654	2,547	2,461	2,388	-3.0%	-2.9%
Poland	119	106	71	73	69	63	61	58	-4.4%	-4.4%
Romania	202	143	110	119	113	109	103	99	-3.9%	-4.4%
Serbia and Montenegro	25	10	8	7	7	6	6	6	0.0%	-8.3%
Slovakia	7	6	5	5	5	5	5	5	0.0%	-2.3%
Slovenia	0	0	1	1	1	1	1	1	0.0%	
Spain	5	3	3	4	4	4	3	3	0.0%	-2.4%
Turkey	4	8	6	7	6	6	6	6	0.0%	2.9%
Ukraine	1,040	1,030	969	960	952	944	936	936	0.0%	-0.7%
United Kingdom	735	481	253	244	241	205	207	187	-9.9%	-8.2%

How much Oil&Gas has still to be discovered?

OIL

	Field Name	Location	Discovery	Start prod.	Peaked	ORR, RRR (Bbbl)	Prod. (MMbbl/d)
1	Ghawar	Saudi Arabia	1948	1951	2005, disputed	88-104	5
2	Burgan	Kuwait	1937	1948	2005	66-72	1.7
3	Upper Zaku	Abu Dhabi, UAE	1963	1982	Prod. increasing	50 (21)	0.750
4	Ahvaz	Iran	1958		1970s	37	0.750
5	Gachsaran	Iran	1927	1930	1974	66	0.480
6	Cantarell	Mexico	1976	1981	2004	35 (18)	0.340
7	Ku-Maloob-Zaap	Mexico	1979	1981	Prod. increasing		0.867
8	Bolivar Coastal	Venezuela	1917	1922		30-32	2.6-3
9	Aghajari	Iran	1938	1940		28	0.300
10	Lula	Brazil	2007			5-8	0.1
11	Safaniy	Kuwait, S.Arabia	1951			30	1.2
12	Esfandiar	Iran				30	
13	Rumaila	Iraq	1953			17	1.3
14	Tengiz	Kazakhstan	1979	1993	2010	26-40	0.53
15	Kirkuk	Iraq	1927	1934		8.5	0.480
16	Shaybah	Saudi Arabia				15	
17	Agha Jari	Iran	1937			8.7	0.200
18	Majnoon	Iraq	1975			11-20	0.5
19	Samotlor	Russia, W Siberia	1965	1969	1980	14-16	0.844
20	Shaikan Sheikh Adi	Iraq Kurdistan	2009	2013	Prod. increasing	4-6	0.04
21	Romashkino	Russia Volga-Ural	1948	1949	in decline	16-17	0.301
22	Prudhoe Bay	USA, Alaska	1967-68	1977	1988	25 (~13)	0.66
23	Sarir	Libya	1961	1961		12 (6.5)	

How much Oil&Gas has still to be discovered?

GAS

№	Field name	Country	Year	Original Recoverable Reserves
1	South Pars	Iran and Qatar	1971	35,000 Bm^3
2	Urengov	Russia	1966	6,300 Bm^3
3	Yamburg	Russia	1969	3,900 Bm^3
4	Hassi R'Mel	Algeria	1956	3,500 Bm^3
5	Shtokman	Russia	1988	3,100 Bm^3
6	Galkynysh	Turkmenistan	2006	2,800 Bm^3
7	Zapolyarnoye	Russia	1994	2,700 Bm^3
8	Hugoton	USA	1930's	2,300 Bm^3
9	Groningen	Netherlands	1959	2,100 Bm^3
10	Bovanenkovo	Russia	1972	2,000 Bm^3
11	Medvezhye	Russia	1967	1,900 Bm^3
12	Dauletabad	Turkmenistan	1974	1,400 Bm^3
13	Karachaganak	Kazakhstan	1979	1,370 Bm^3
14	North Pars	Iran	1967	1,340 Bm^3
15	Kish	Iran	2006	1,300 Bm^3
16	Orenburg	Russia	1966	1,300 Bm^3
17	Kharasavey	Russia	1966	1,200 Bm^3
18	Shah Deniz	Azerbaijan	1999	1,200 Bm^3
19	Golshan	Iran	2007	850 Bm^3
20	**Zohr**	**Egypt**	**2015**	**850 Bm^3**
21	Tabnak	Iran	1967	620 Bm^3
22	Kangan	Iran	1967	570 Bm^3

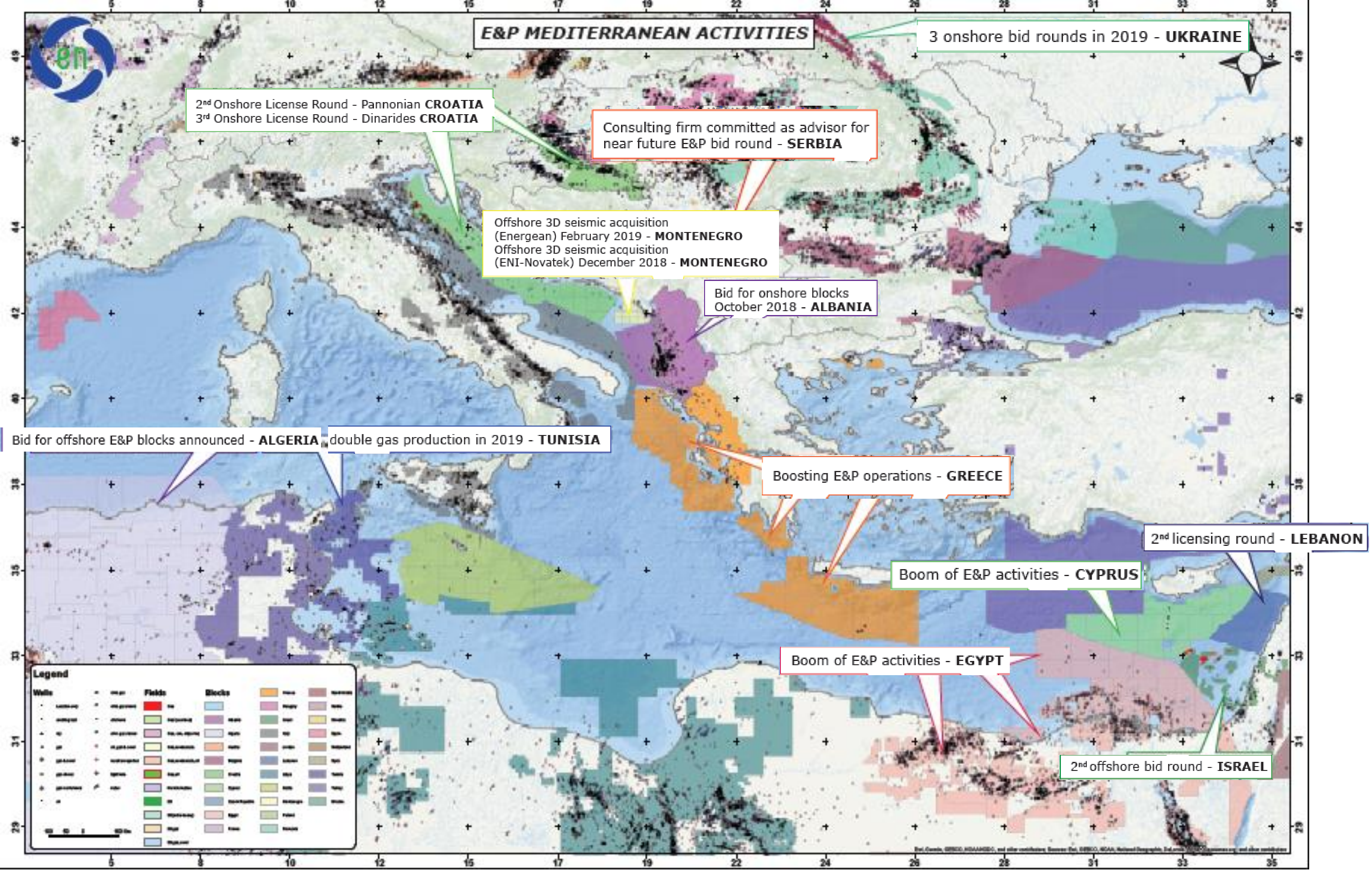
How much Oil&Gas has still to be discovered?

- **The discovery of a major gas field at Zohr (20th in the worldwide ranking)** made by Eni in Egyptian waters in 2015 opened a new play-concept in the Eastern Mediterranean and a possible re-vamping of similar play-concepts in the Central and Western Mediterranean, as well as in the Far Pacific. The widespread distribution of this promising play has been confirmed by:
  - **Feb 2018:** discovery of Calypso gas field (offshore Cyprus, ENI)
  - **Feb 2019**: discovery of Glaucus gas field (offshore Cyprus, ExxonMobil): 142-227 Bcm of gas
- **ICPs are a relevant feature of Mediterranean geology & host important hydrocarbon reservoirs**
  - Developed in the context of the opening & closure of Tethys
  - 2 different types of ICP can be identified based on scale, duration, nature of carbonate factory & tectono-stratigraphic context
  - Carbonate factories evolve with time
- **All petroleum system elements can be found within Mediterranean ICPs**
  - Temporal and spatial distribution is controlled by tectono-stratigraphic development of ICP
  - Integration of subsurface data with surface analogues is a powerful tool for understanding the distribution of petroleum system elements

Geology has been <u>the</u> key factor in facilitating high-level decision to invest in the area

"never stop to explore"

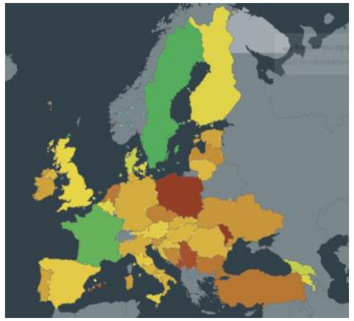
(C.Descalzi - CEO, ENI)



E&P MEDITERRANEAN ACTIVITIES
3 onshore bid rounds in 2019 - UKRAINE
2nd Onshore License Round - Pannonian CROATIA
3rd Onshore License Round - Dinarides CROATIA
Consulting firm committed as advisor for near future E&P bid round - SERBIA
Offshore 3D seismic acquisition (Energean) February 2019 - MONTENEGRO
Offshore 3D seismic acquisition (ENI-Novatek) December 2018 - MONTENEGRO
Bid for onshore blocks October 2018 - ALBANIA
Bid for offshore E&P blocks announced - ALGERIA
double gas production in 2019 - TUNISIA
Boosting E&P operations - GREECE
2nd licensing round - LEBANON
Boom of E&P activities - CYPRUS
Boom of E&P activities - EGYPT
2nd offshore bid round - ISRAEL
Legend
Wells
Fields
Blocks

How much energy do we use?

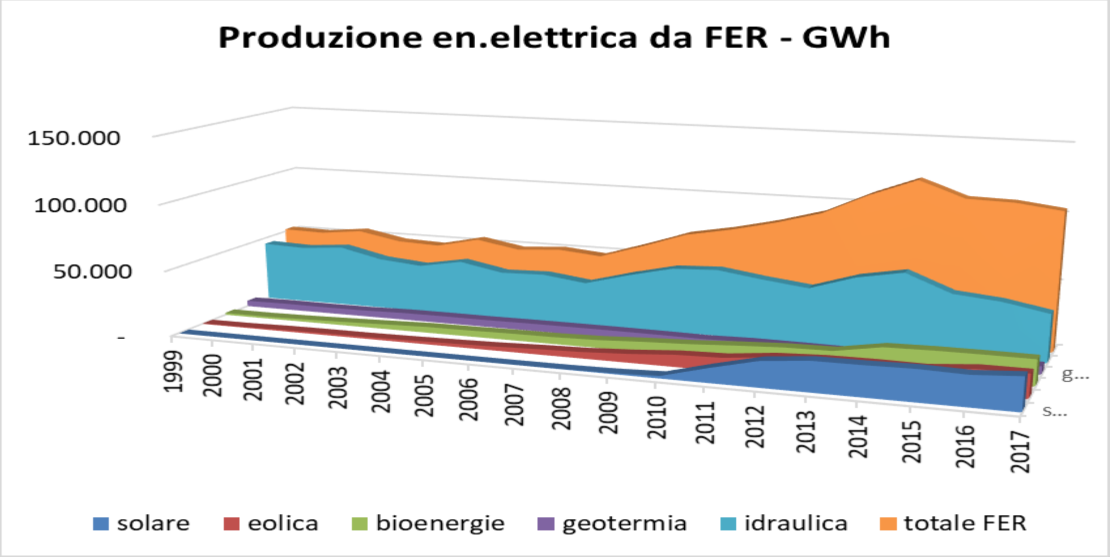
https://www.iea.org/statistics/?country=EU28&year=2016&category=Energy%20supply&indicator=TPESbySource&mode=chart&dataTable=BALANCES

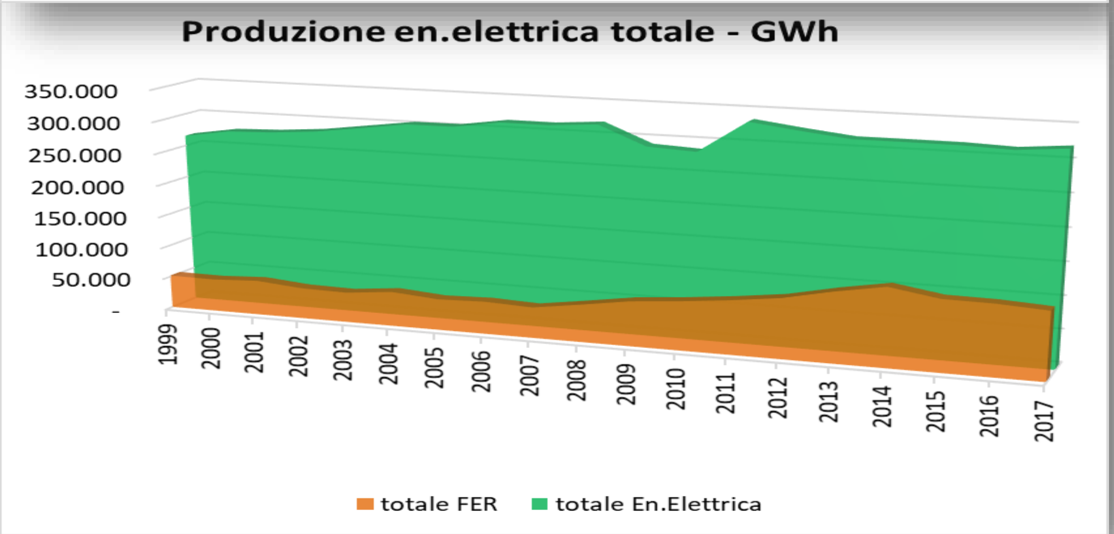


https://www.electricitymap.org/?page=map&solar=false&remote=true&wind=false

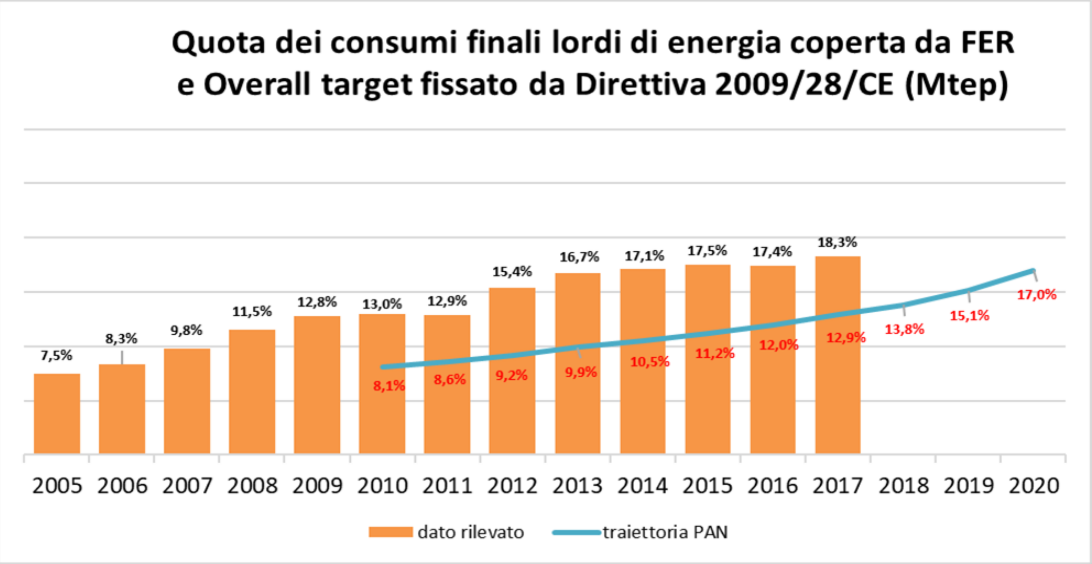
Which energy do we use? Italy

GSE: Rapporto Statistico sulle Fonti Rinnovabili (2019)





35% of electricity is generated by REN, but:
53% is generated from non-renewable sources
12% is imported

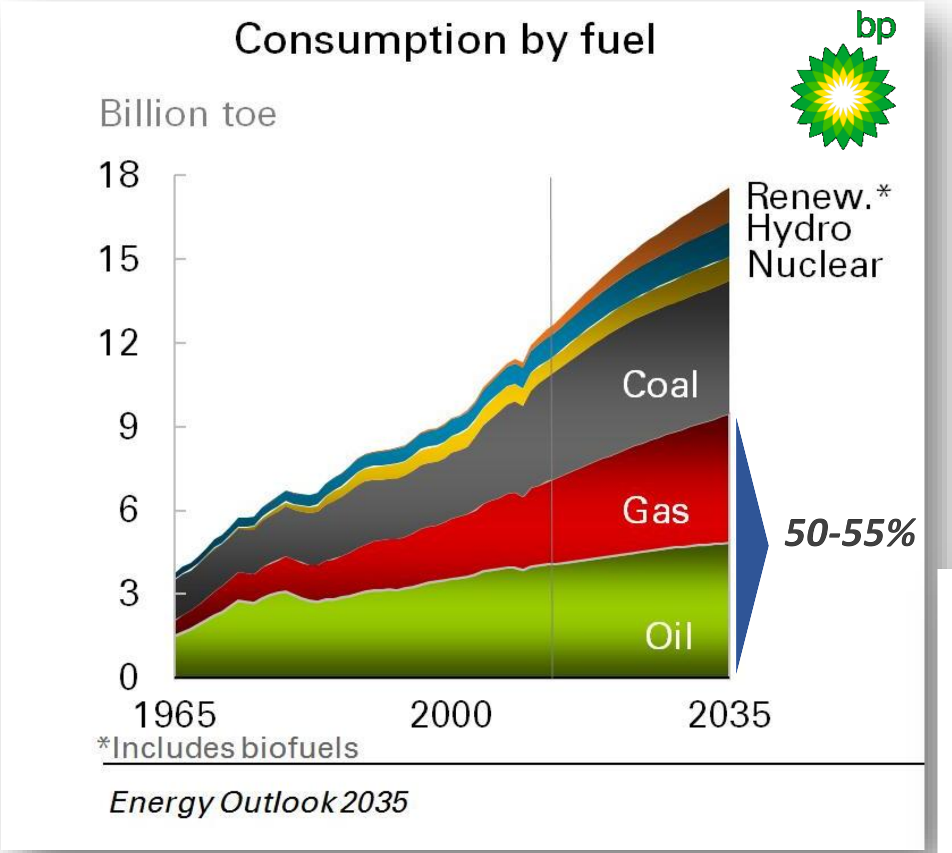


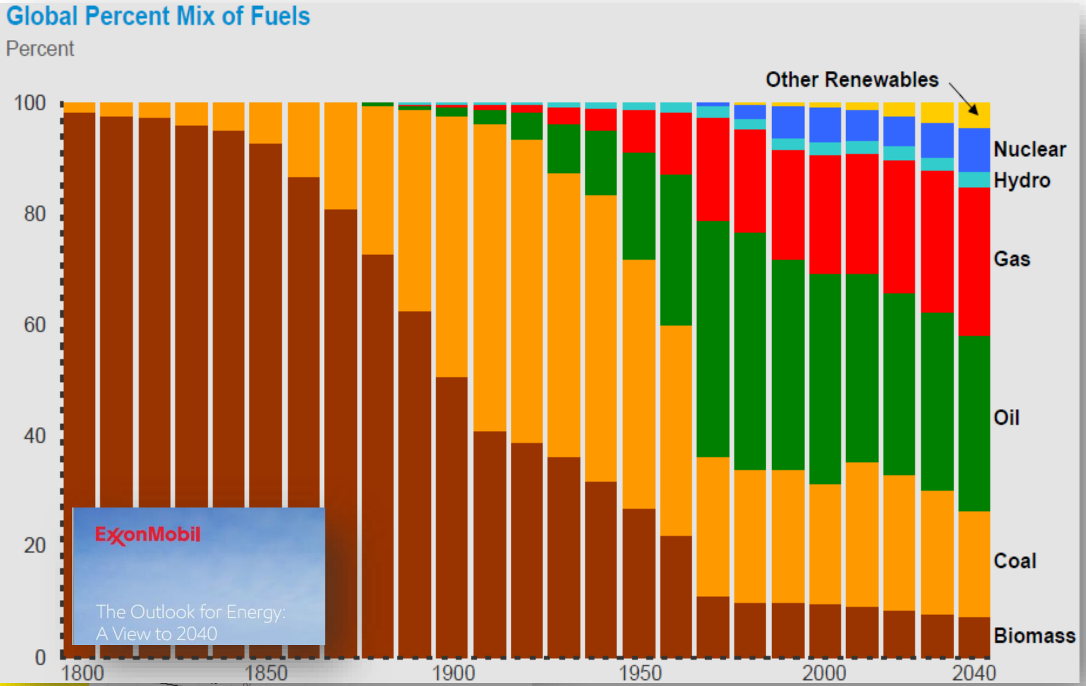
2017:

- share of **total gross energy** covered by REN: 18.3% (2016: 17.4%)
- About 35% of **total gross electricity production** in Italy is generated by plants powered by REN, higher than the data foreseen by the PAN* for 2017, but also to the forecast for 2020
- Just over 20% of energy consumption in the **thermal sector** comes from REN, a value much higher than the PAN* forecasts
- The use of biofuels and electricity from REN in the transport sector covers 6.5% of the total, lower than the targets set by the PAN*

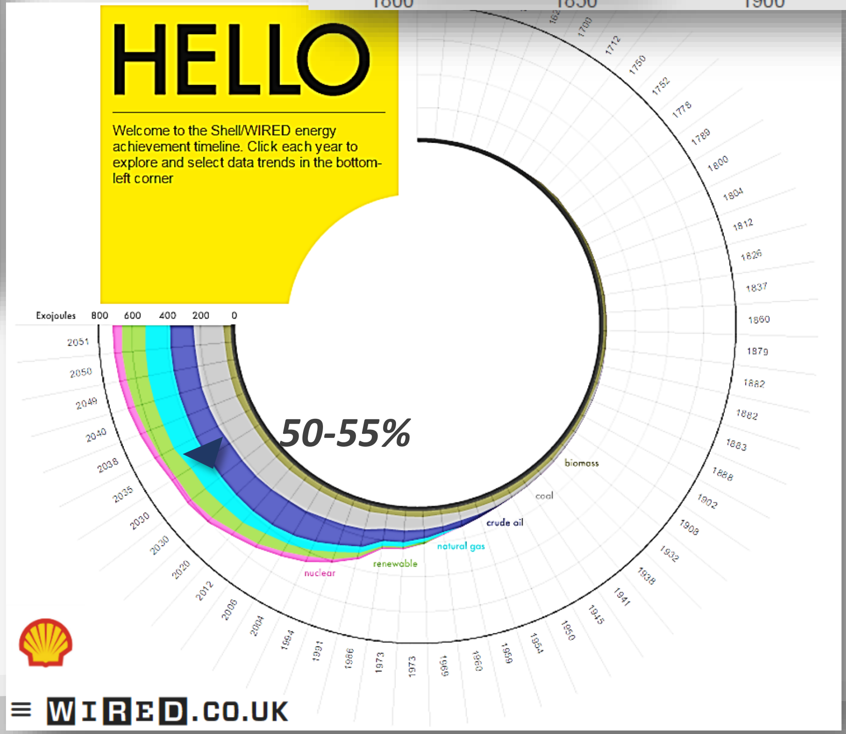
** **Piano d'Azione Nazionale per le energie rinnovabili (PAN)**: recepisce gli obiettivi definiti dalla direttiva 2009/28/CE per ogni Stato membro UE; sono indicate le traiettorie previste per il raggiungimento degli obiettivi e le principali politiche da attuare.*

Outlook - world



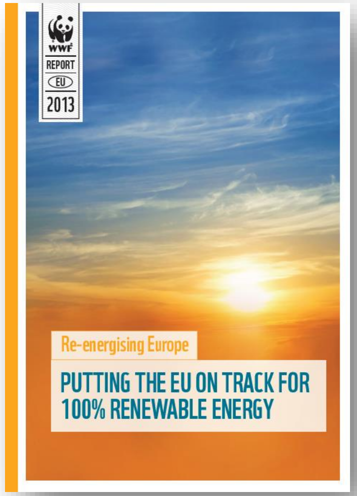


55-60%



RE-ENERGIZE according to WWF

Putting the EU on track for 100% Renewable Energy, 2013



Development scenarios for the European electricity system (EU27)

- Transition to renewable sources
- Policies for energy education and saving
- To reach a 2050 with 100% electricity from renewable sources, at 2030 the EU must be aligned with the following objectives:
- = 40% of electricity from renewables
- - 38% of consumption (compared to the Do Nothing option)
- - 50% of energy for domestic consumption

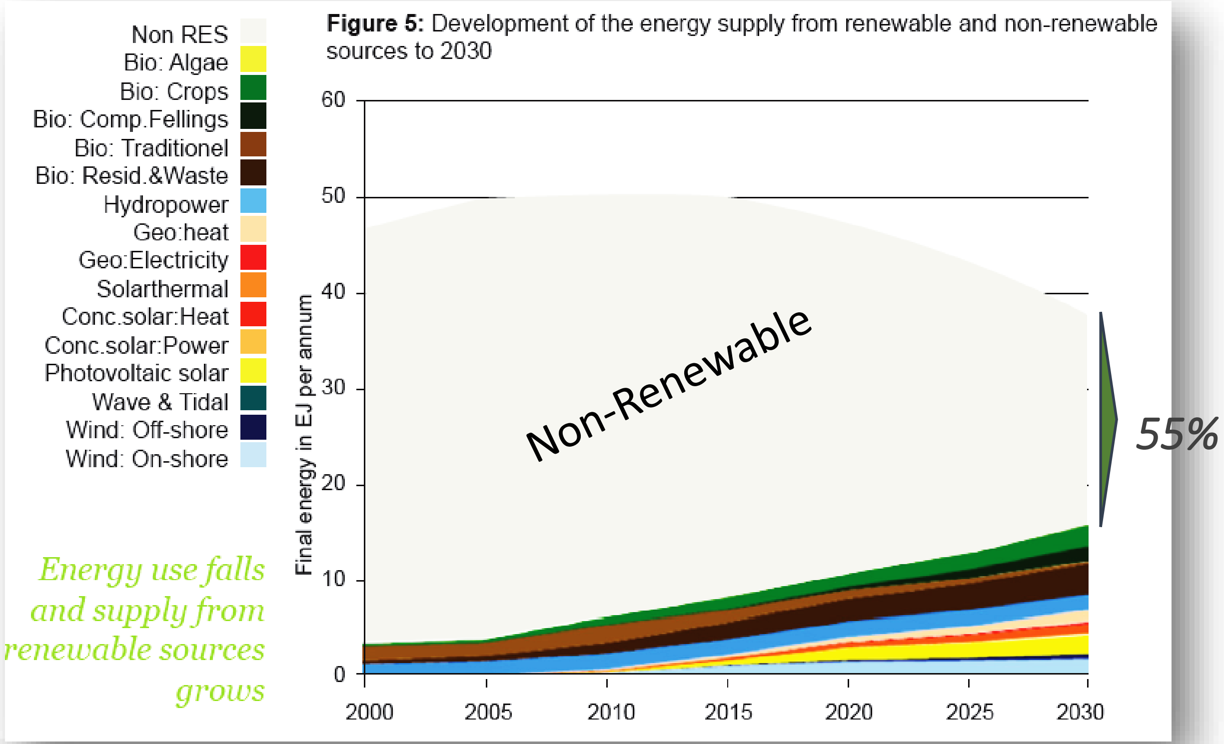
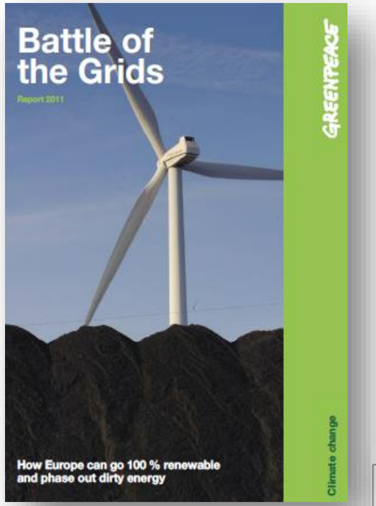


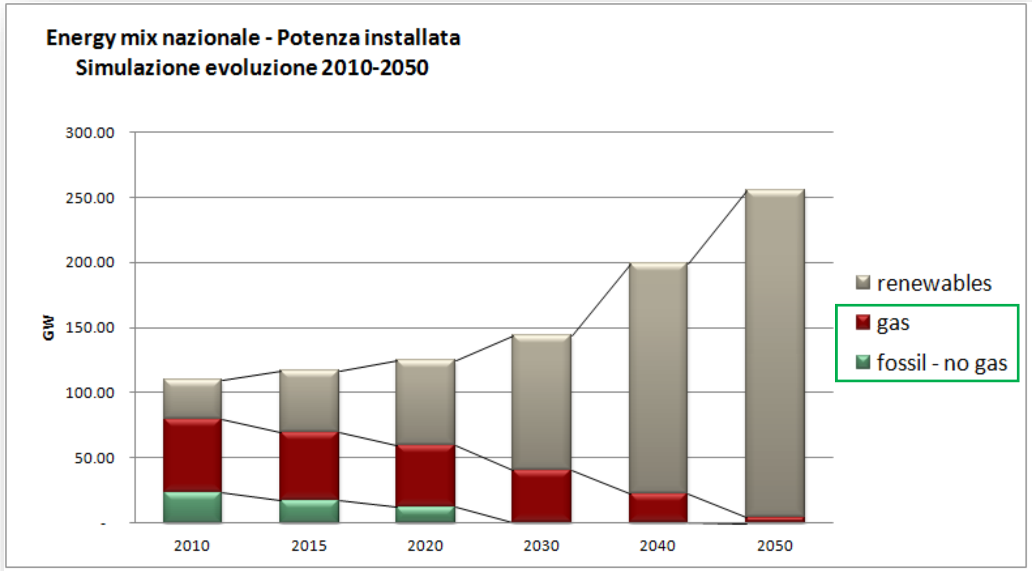
Figure 5: Development of the energy supply from renewable and non-renewable sources to 2030

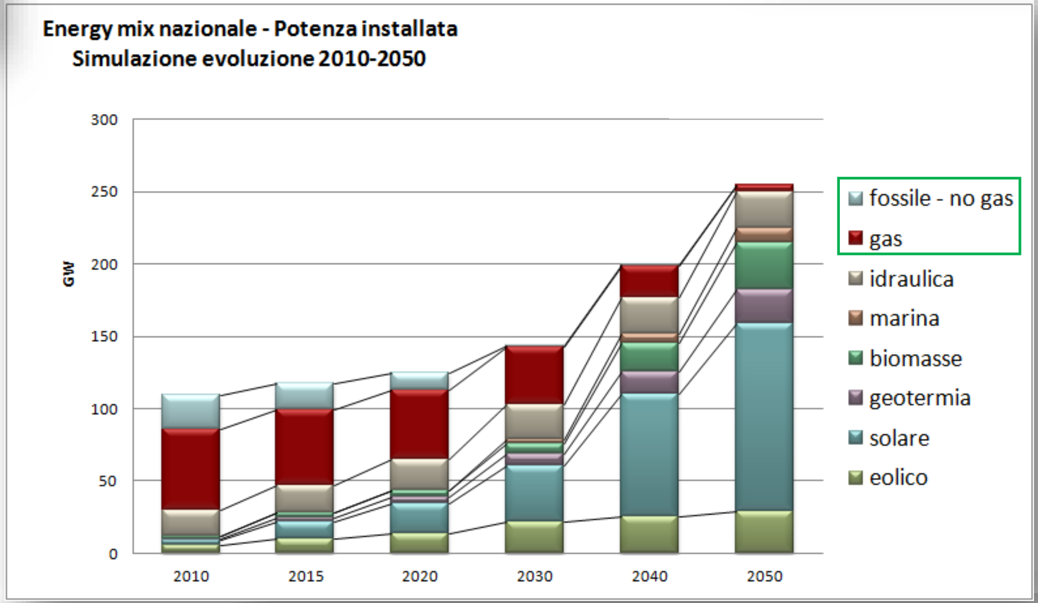
Outlook - EU

[R]EVOLUTION* according to GREENPEACE

- *Battle of the grids, How Europe can go 100% renewable and phase out dirty energy*. Greenpeace report 2011
- *European grid study 2030/2050,* EnergyNautics report 2011



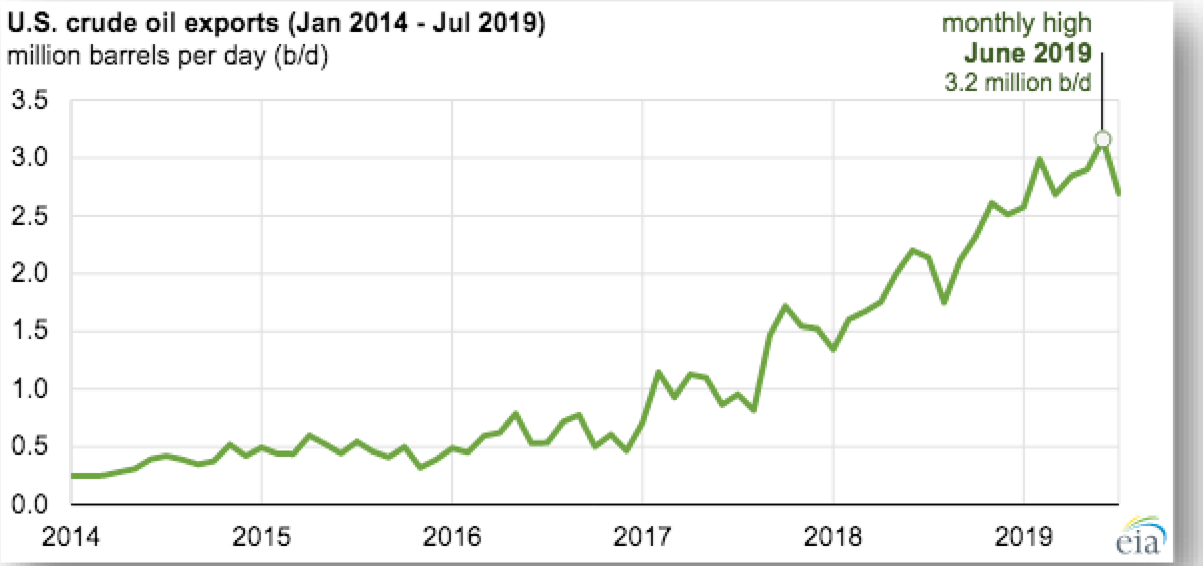




Development scenarios of the European electricity system by single country

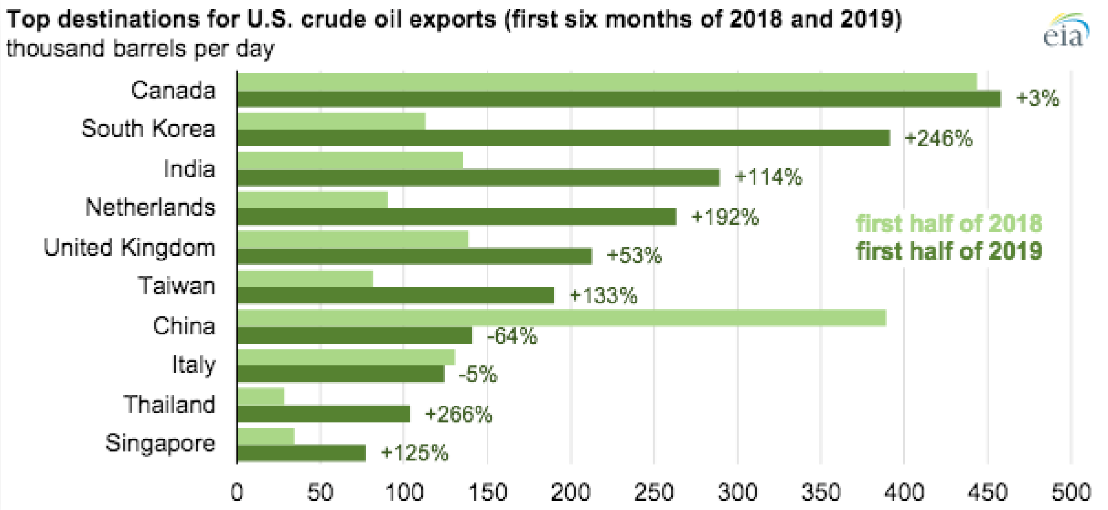
- Switching to **renewables**
- Infrastructure network based on **self-production** and efficient **energy distribution**
- **Optimized production system**, based on storage and transmission of electricity, demand management, peak management

Now – USA



US is still one of the world's largest importers of crude oil: in the first half of 2019, U.S. imports of crude oil less exports (net imports) averaged 4.2 million b/d compared with 6.1 million b/d in the first half of 2018.

Increases in US domestic crude oil production have resulted in reduced imports and increased exports.



CO2 emissions

Global Carbon Budget

2018

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Research. Innovation. Sustainability.

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Atmospheric CO_2 datasets
NOAA/ESRL (Dlugokencky and Tans 2018)
Scripps (Keeling et al. 1976)

Fossil Fuels and Industry
CDIAC (Boden et al. 2017)
Andrew, 2018
UNFCCC, 2018
BP, 2018

Consumption Emissions
Peters et al. 2011
GTAP (Narayanan et al. 2015)

Land-Use Change
Houghton and Nassikas 2017
Hansis et al. 2015
GFED4 (van der Werf et al. 2017)
FAO-FRA and FAOSTAT
HYDE (Klein Goldewijk et al. 2017)
LUH2 (Hurtt et al. in prep)

Atmospheric inversions
CarbonTracker Europe (van der Laan-Luijkx et al. 2017)
Jena CarboScope (Rödenbeck et al. 2003)
CAMS (Chevallier et al. 2005)
MIROC (Saeki and Patra, 2017)

Land models
CABLE-POP | CLASS-CTEM | CLM5.0(BGC) | DLEM | ISAM | JSBACH | JULES | LPJ-GUESS | LPJ | LPX-Bern | OCN | ORCHIDEE-Trunk | ORCHIDEE-CNP | SDGVM | SURFEXv8 | VISIT
CRU (Harris et al. 2014) JRA-55

Ocean models
CCSM-BEC | MICOM-HAMOCC (NorESM-OC) | MITgem-REcoM2 | MPIOM-HAMOCC | NEMO-PISCES (CNRM) | NEMO-PISCES (IPSL) | NEMO-PlankTOM5

pCO_2-based ocean flux products
Jena CarboScope (Rödenbeck et al. 2014)
Landschützer et al. 2016
SOCATv6 (Bakker et al. 2016)

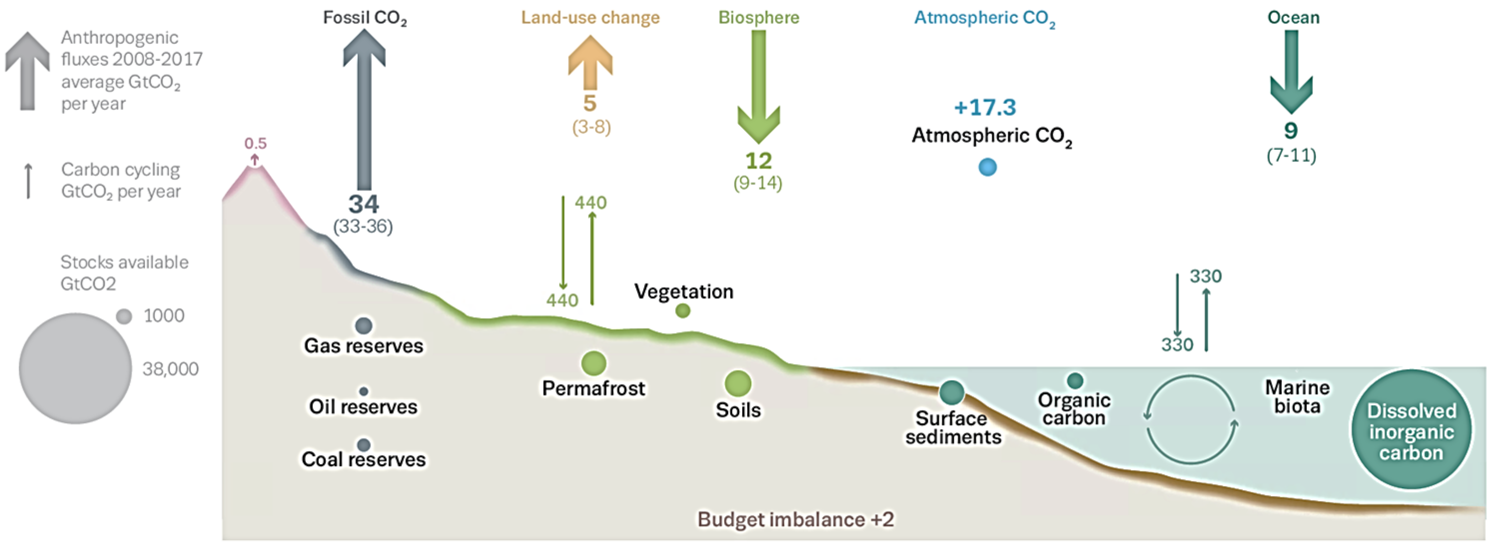
Full references provided in [Le Quéré et al 2018]

http://www.globalcarbonatlas.org/en/CO2-emissions

CO2 emissions

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2008–2017 ($GtCO_2$/yr)

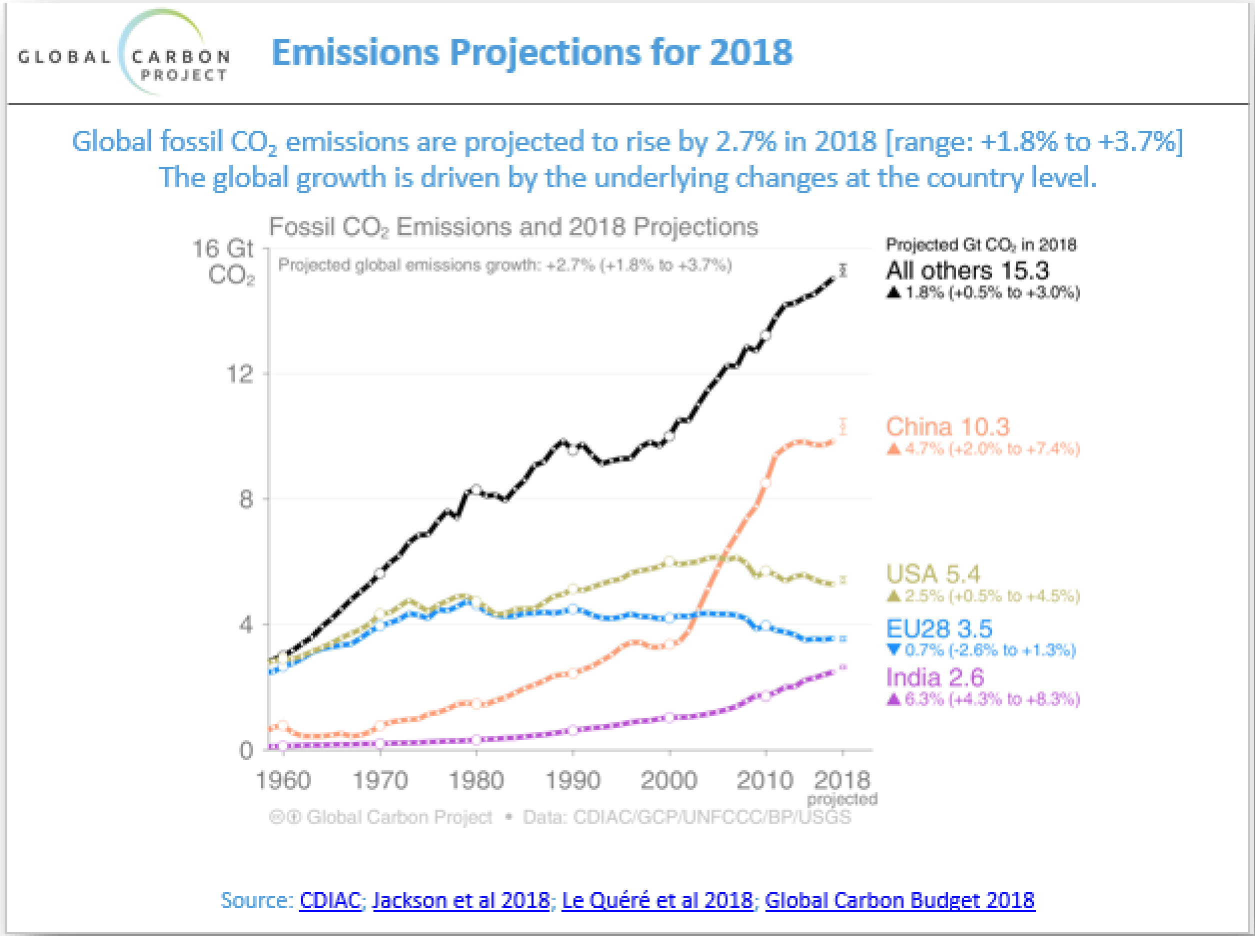


The budget imbalance is the difference between the estimated emissions and sinks.
Source: CDIAC; NOAA-ESRL; Le Quéré et al 2018; Ciais et al. 2013; Global Carbon Budget 2018

The CO2 (im)balance

↑	-34
↑	-5
↓	12
↓	9
↑	21

CO2 emissions

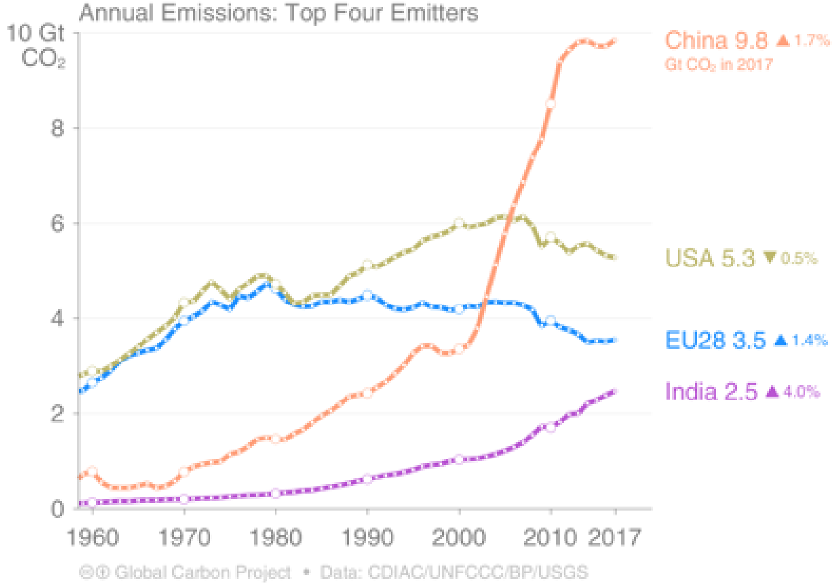


CO2 emissions

GLOBAL CARBON PROJECT

Top emitters: Fossil CO_2 emissions

The top four emitters in 2017 covered 58% of global emissions
China (27%), United States (15%), EU28 (10%), India (7%)

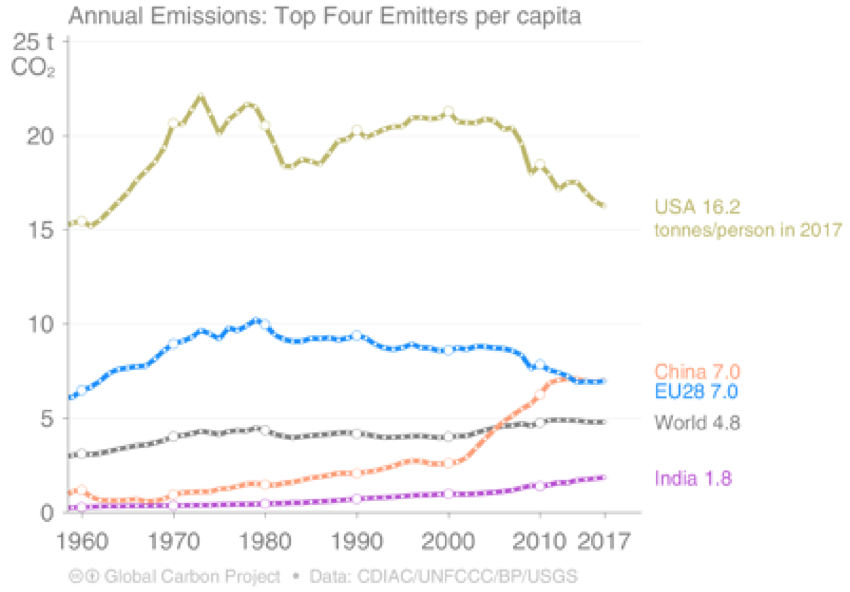


Bunker fuels, used for international transport, are 3.2% of global emissions.
Statistical differences between the global estimates and sum of national totals are 0.7% of global emissions.
Source: CDIAC; Le Quéré et al 2018; Global Carbon Budget 2018

GLOBAL CARBON PROJECT

Top emitters: Fossil CO_2 Emissions per capita

Countries have a broad range of per capita emissions reflecting their national circumstances



Source: CDIAC; Le Quéré et al 2018; Global Carbon Budget 2018