Oil & Gas

From exploration to distribution

Week 1 – V05 – Origin of hydrocarbon resources – part 1

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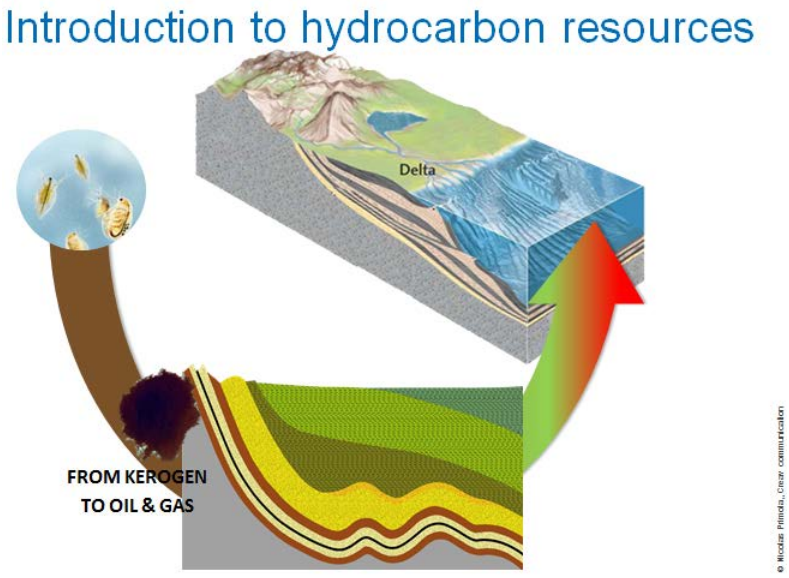
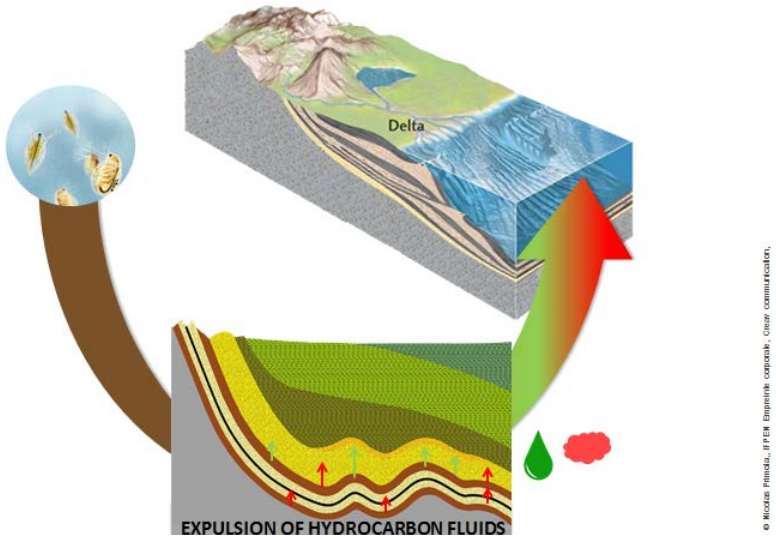
Introduction to hydrocarbon resources

You will discover some basic notions on where hydrocarbon resources (i.e. oil and gas) come from and understand what we mean by a petroleum system.

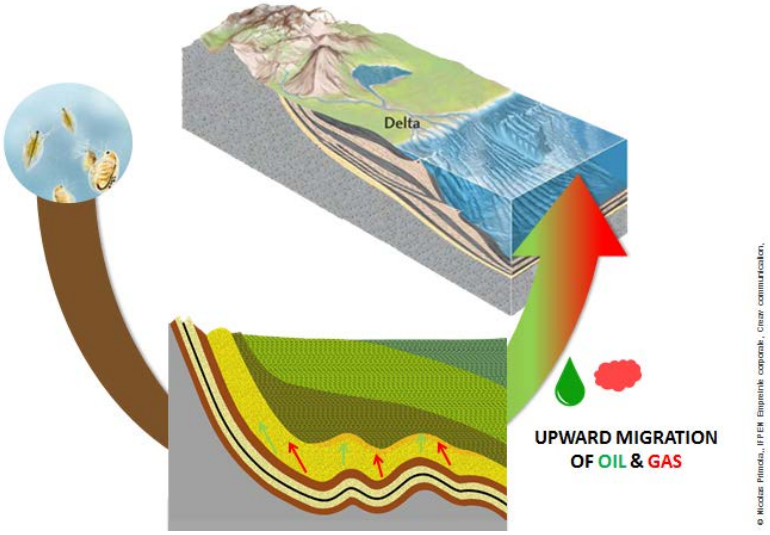
Our objective is to understand why and how sediments can generate hydrocarbon resources: oil & gas. The brown part of the arrow corresponds to the accumulation of sediments, the formation of a source rock, and their burial which allows the organic matter it contains to progressively mature as it is buried deeper and deeper generating first kerogen and then oil and gas after millions of years.



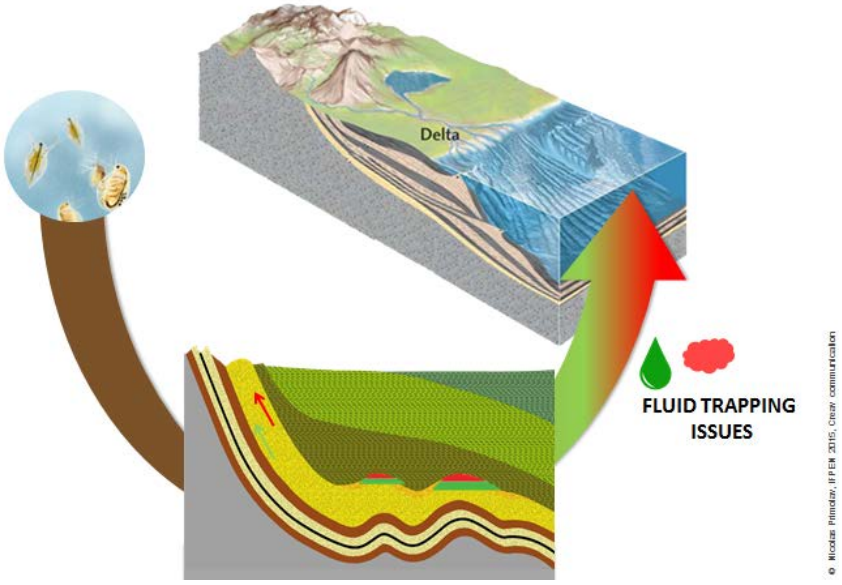
In other words sediments move down from the Earth's surface to the underground before generating hydrocarbon fluids.



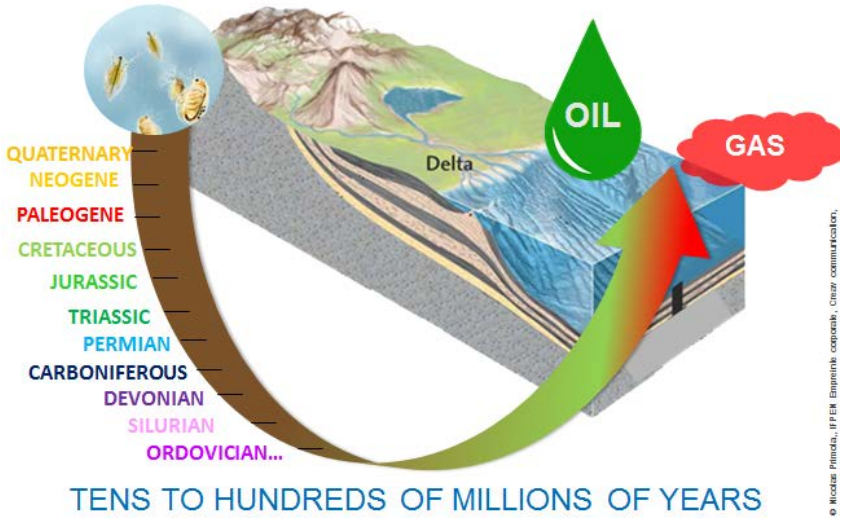
The right part of the arrow refers to the upward migration of oil and gas fluids after expulsion from the source rock. Note that the green and red colors refer to oil and gas respectively.



Depending on fluid migration pathways within the underground and associated trapping scenarios, a portfolio of hydrocarbon resources in different contexts can be observed worldwide. This will be the object of our next lecture.



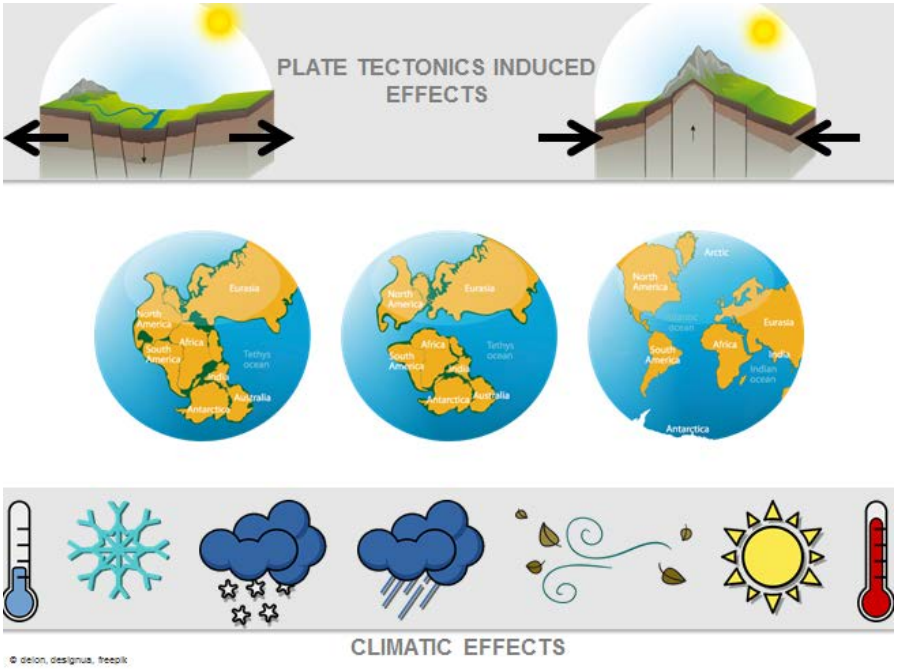
From sediment deposit up to having available oil and gas resources, the full process takes tens to hundreds of millions of years. It means the gasoline you are using today in your car may correspond to organisms that were living before dinosaurs existed…



The accumulation and burial of huge amounts of rich organic sediments takes place over hundreds of millions of years. The transformation of the organic matter into oil and gas is made possible because of the high levels of pressure and temperature within the subsurface.

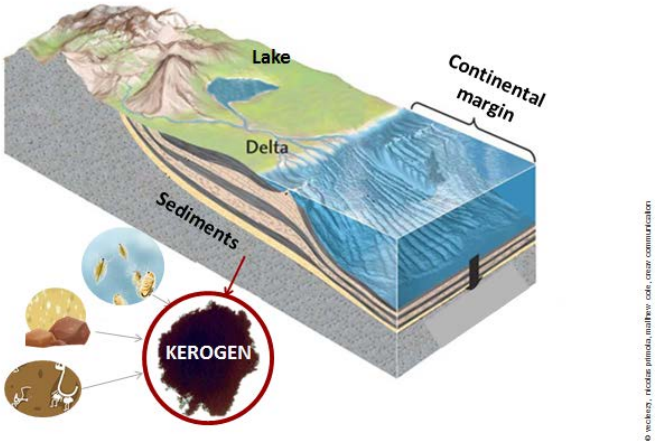
Such a transformation of the organic matter contributes to over-pressurizing the source rock itself until micro-fracturing of the matrix occurs, allowing the oil and the gas to be expelled, with more and more gas as depth increases.

Since the Earth has existed, internal and external elements have continuously modified and modeled the planet's appearance. The Earth we know today is not the one that existed a hundred million years ago but similar phenomena, such as plate tectonics, and climatic effects, continue to occur helping us to understand the past.
Any period of time is preserved or erased in a permanent reshaping of our world. Huge amounts of sediments are generated and transported. They are at the origin of the process that has generated fossil fuels.



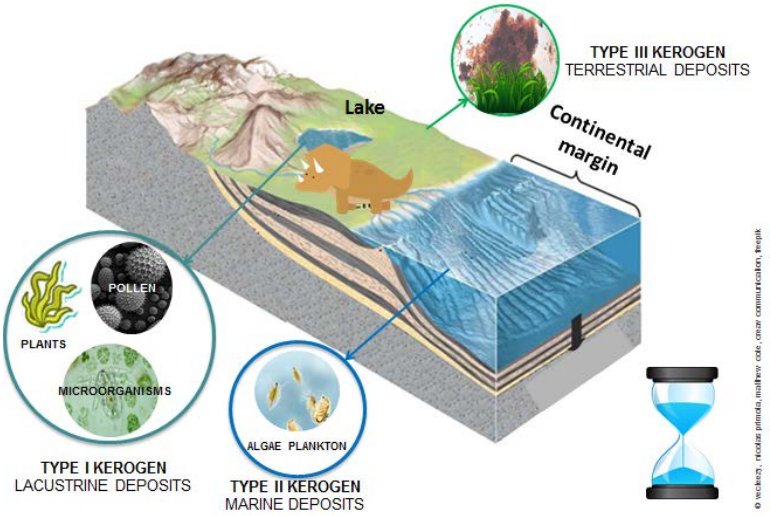
Sediment accumulation and burial

Sediments mainly consist of rock fragments and minerals (clay particles, fine sand grains etc…) resulting from erosion phenomena and, organic matter from dead organisms that has been preserved from destruction: plants and animals but mainly a huge proportion of plankton and phytoplankton.
There are different deposit environments that lead to different types of organic matter. It first evolves into kerogen which is a mixture of organic compounds with various proportions of hydrogen and carbon atoms: the basic components of all hydrocarbon resources.



1. **Type I** kerogen refers to lacustrine deposits such as plants, microorganisms etc...
2. **Type II** corresponds to marine deposits such as deltaic, shelf, slope or pelagic deposits with huge amount of phytoplankton. This is by far the most common type of kerogen.
3. **And finally, type III** corresponds to terrestrial deposits or, more generally, kerogen derived from land plants.

At this stage, it is very important to note that no two source rock plays are alike. Each one depends on the material deposits and the long term geological history of the region.
The slower the deposit process, the better the preservation of the organic matter.
The higher the amount of organic matter in the sediments, the better the hydrocarbon potential.



As an example, shallow sea deposit environments are at the origin of vast oil and gas fields worldwide.
This is typically the case in North America, which has not always been as it looks today! Most of the oil and gas fields of North America correspond to shallow sea deposits.

Maturation of the organic matter

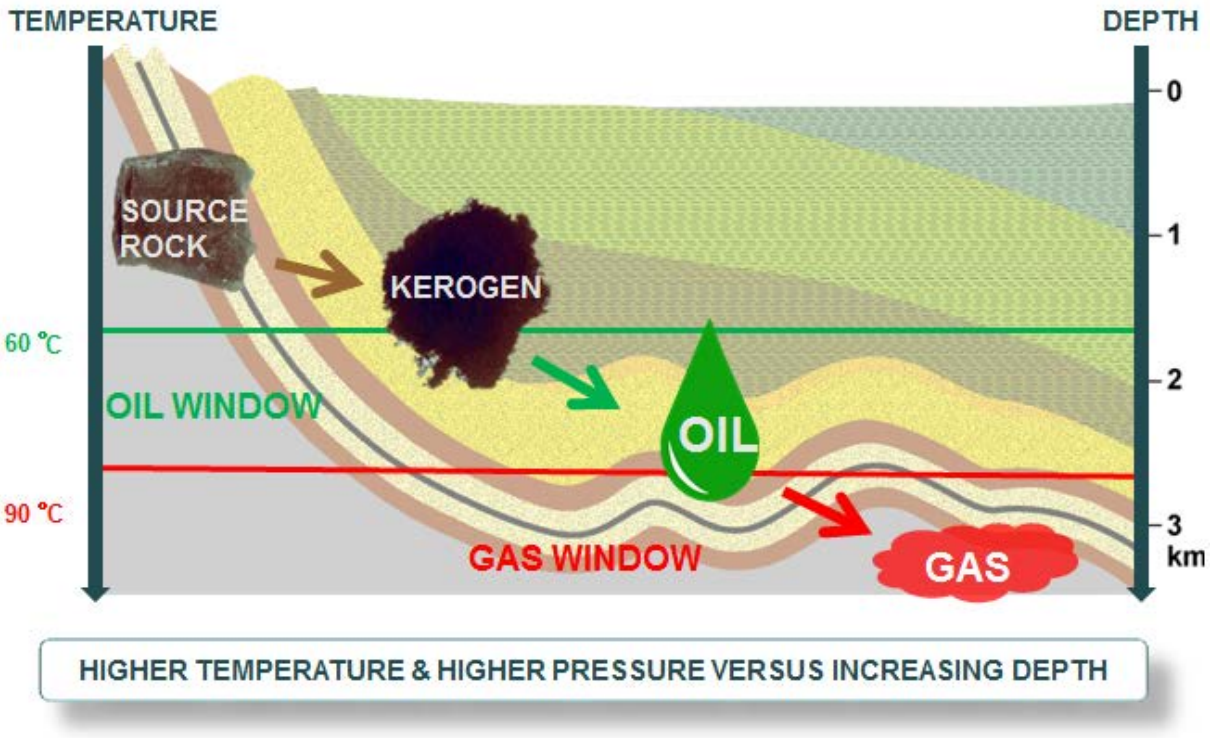
We will now consider a rich-organic sedimentary mud, buried slowly over millions of years because of fresh sediments being continuously deposited over several kilometers of thickness. This mud compacts over time under the increasing pressure while the sedimentary pile subsides. If burial conditions have been optimal for organic matter preservation then such a sedimentary rock may have transformed into a source rock.

During burial the organic matter it contains will transform into kerogen, at around 55 to 60°C. The source rock is still not fully mature, the temperature being still to low to crack the kerogen chemical bonds.

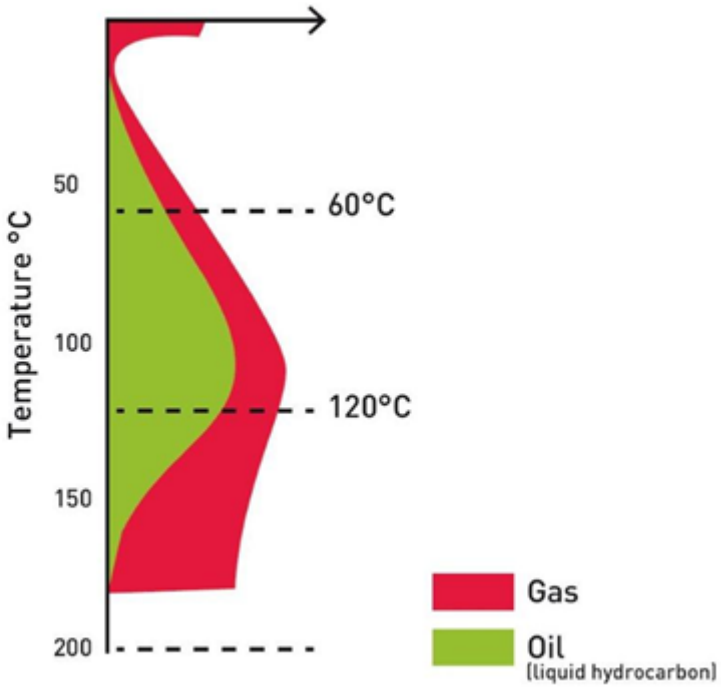
Deeper, the temperature increase makes it possible for those bonds to be cracked, allowing oil to be generated from the kerogen located in the rock matrix porosity.

This occurs at temperatures between 60 to 120°C depending on kerogen types and in situ thermodynamic conditions.
We call the oil window the temperature interval where oil is generated. It corresponds to a depth interval where thermal conditions are suitable for kerogen to be transformed into oil.

The ratio of gas to oil progressively increases in favour of gas over time and depth. At higher temperatures, only dry gas is generated. In addition to hydrocarbons some water and carbon dioxide are also generated during this continuous process.
As for oil, a gas window is defined, it corresponds to the temperature interval where mainly gas is generated.



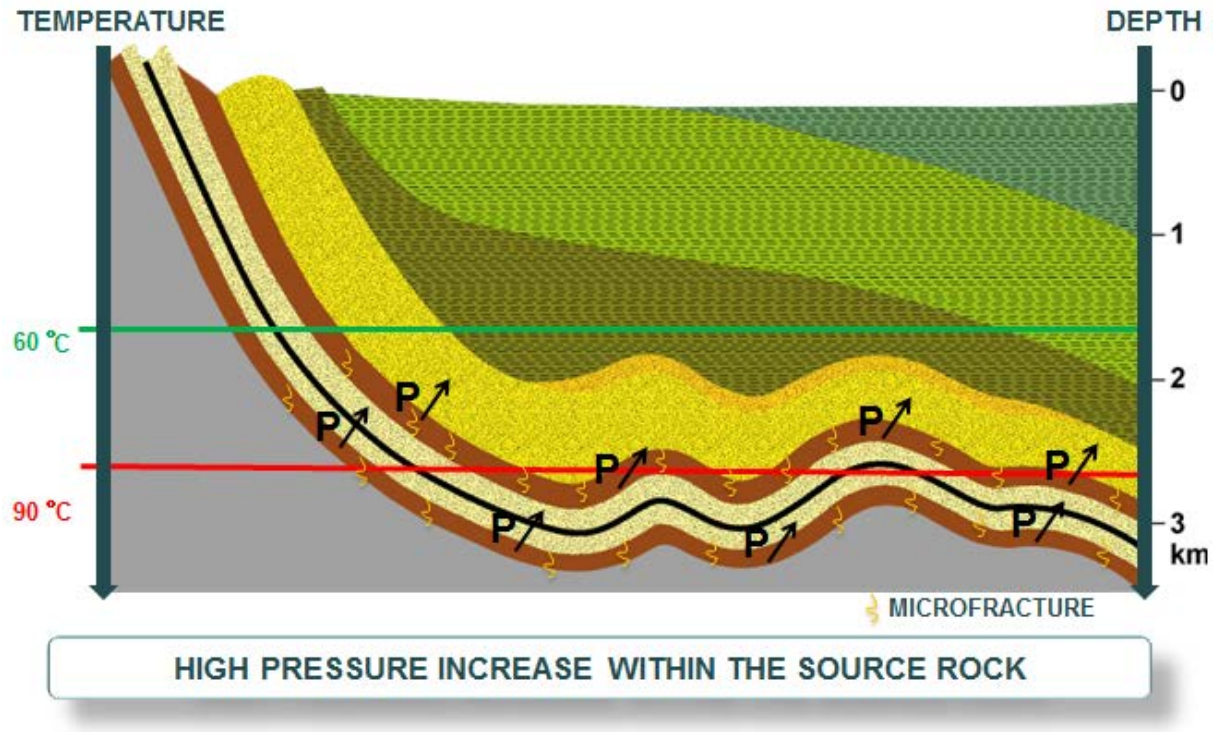
Indeed the amount of oil and gas generated directly depends on the kerogen type and the initial organic matter within the sediments but it also varies depending on in situ temperature and depth.
The deeper the organic matter the more gas there is.



Biogenic gas not discussed

Expulsion of hydrocarbon fluids

The transformation of organic matter into hydrocarbons (remember they are molecules made of only hydrogen and carbon atoms) induces a high pressure increase within the pore space of the source rock.
This pressure increase leads to microfracturing of the impermeable matrix allowing fluids to be expelled into adjacent layers. It is a sort of self-hydraulic fracturing phenomenon.



You can also think of it as a pressure cooker equipped with a valve.

Conclusion

First point: The progressive accumulation and burial of sediments containing preserved organic matter forms a rich-organic source rock. This source rock is impermeable but it contains some organic matter in its matrix porosity. No two source rocks are alike.

Second point: The transformation of the organic matter into hydrocarbons occurs while the long-term burial of the source rock is on-going (over hundreds of millions of years and under kilometers of accumulated sediments). Without burial, the source rock remains immature.

Third point: The generation of hydrocarbons within the maturing kerogen located in the source rock porosity, is associated with a strong pressure increase that leads to micro-fracturing of the matrix and expulsion of the hydrocarbon fluids within the adjacent layers.

Next time we will focus on the hydrocarbon upward migration process within the underground and we will see an inventory of the wide spectrum of hydrocarbon natural resources.