Petroleum Geology lectures

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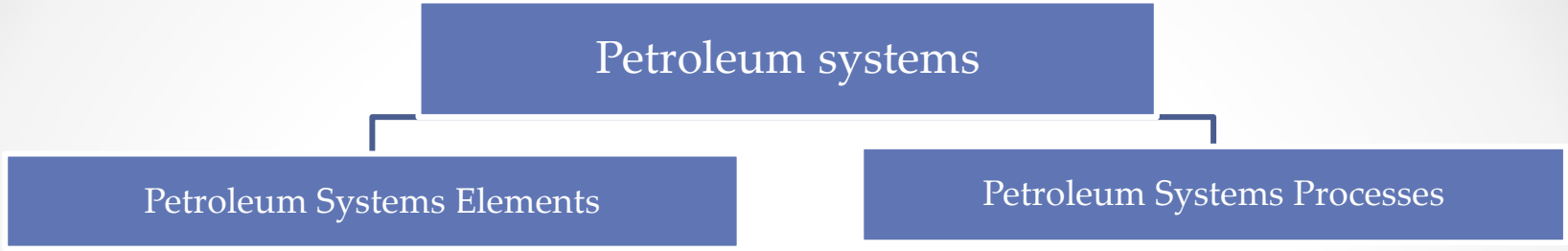
LECTURE 2
PETROLEUM SYSTEM ELEMENTS
(Source rock)

Petroleum Systems Analysis



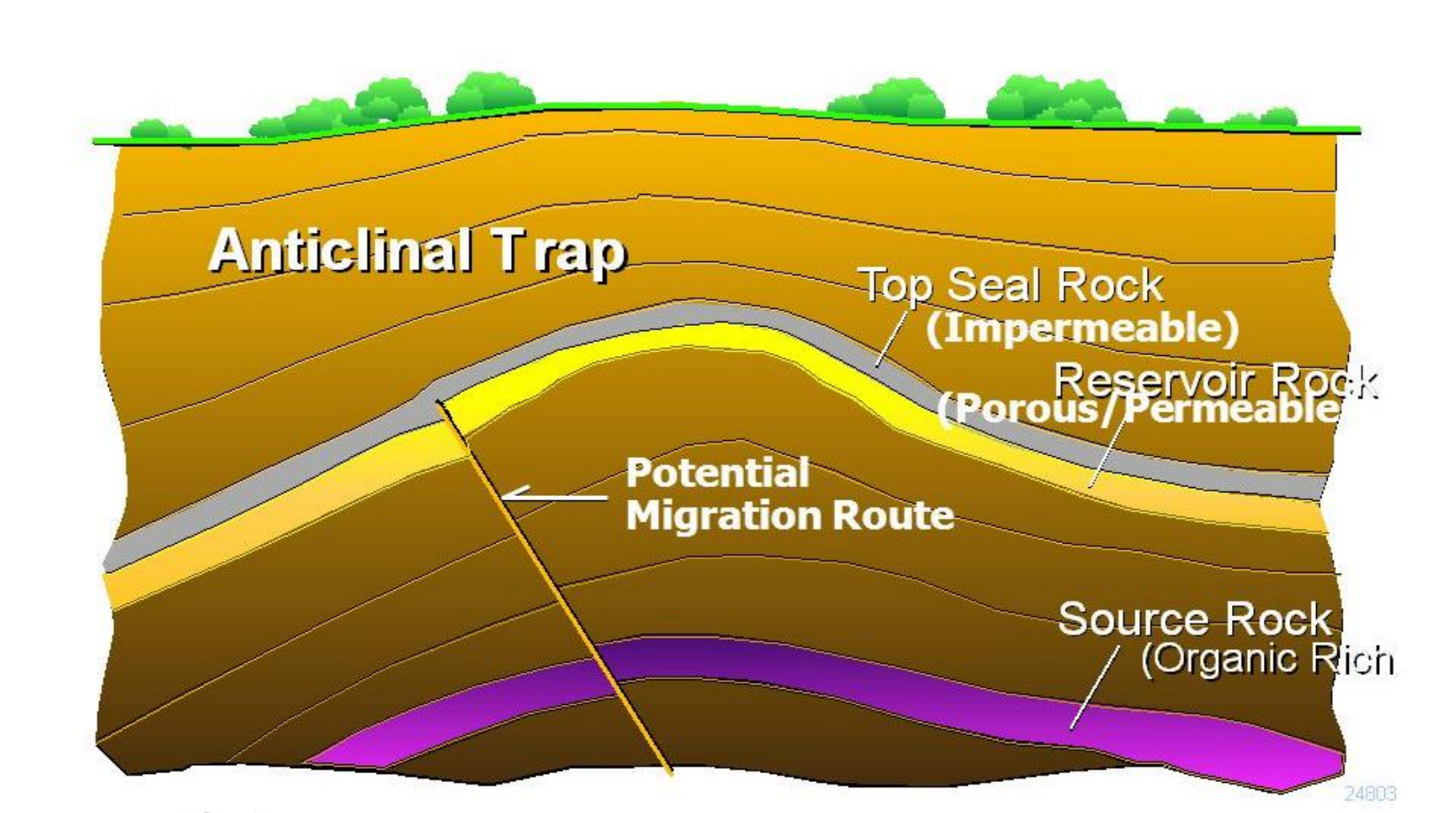
- Source rock
- Reservoir rock
- Seal rock
- Migration route
- trap

- Generation
- Migration
- Accumulation
- Preservation
- Timing

PETROLEUM SYSTEM

Petroleum System Elements
Source Rock Reservoir Rock Seal Rock Migration Route Trap

PETROLEUM SYSTEM



DEFINITION OF SOURCE ROCK

The term ``source rock`` is meant to be any rock thate has the capability to generate and expel enough of hydrocarbons to form an accumulation of oil and gas.

TYPE OF SOURCE ROCK

- **Effective source rock:** any sedimentary rock that has already generated and expelled hydrocarbons.
- **Possible source rock:** any sedimentary rock whose source potential has not yet been evaluated ,but which may have generated and expelled hydrocarbons.
- **Potential source rock:** any immature sedimentary rock known to be capable of generating and expelling hydrocarbons if its level of thermal maturity were higher.

تصنيف الصخور المصدرية

1. **الصخور الكلسية المتطينة argillaceous limeston rocks** : تتصف بكونها دقيقة التبلور ذو انضغاطية متوسطة الى عالية اي متماسك وتتميز باحتوائها على نسب جيدة من المواد غير قابلة للاذابة Insoluble residual تترسب هذه الصخور في البيئات الحوضية العميقة الى الجرف الخارجي العميق والبيئات اللاكونية او المستنقعية او الخلجانية المغلقة هذه الصخور غالبا ما تترسب في هذين الحوضيين وتمتاز بتطبق الفلسي.
2. **الصخور الكلسية السجيلية والطفلية shaly marly lst. Rx.:** تتصف هذه الصخور بالاضافة الى كونها دقيقة التبلور ذو انضغاطية متباينة لاحتوائها على نسب عالية من الفضالة الغير ذائبة وغالبا ما تزيد على 50% وزنا من الصخرة اذا تميزت بخاصية التطبق معناه صخور كلسية سجيلية واذا تميزت بخاصية المرونة تصبح مارلي لايمستون تترسب هذه الصخور في البيئات الحوضية العميقة الى الجرف الخارجي العميق واحيانا البيئات اللاكونية.
3. **صخور السجيل shale:** تتصف هذه الصخور باحتوائها على نسب عالية من الفضالة الغير ذائبة وغالبا ماتزيد على 90% وزنا من الصخرة بالاخص معادن الصلصال تتميز بخاصية التطبق (الفلسي) حاوية على نسب جيدة من المواد العضوية مما يكسبها الوان المختلفة الداكنة مثل السجيل الاسود تترسب هذه الصخور في البيئات الحوضية العميقة والبيئات اللاكونية المغلقة وبظروف اختزالية.

FACTORS INFLUENCING ORGANIC RICHNESS

- **PRODUCTIVITY**

Nutrient availability.

Light intensity.

Temperature.

Carbonate supply.

General water chemistry.

- **PRESERVATION**

The concentration and nature of oxidizing agents.

The type of organic matter deposited.

The sediment-accumulation rate.

CONDITIONS FAVORABLE FOR PRESERVATION

Two important factors

(1) Sedimentation rate.

(2) Bottom water oxgen content (oxidation of the organic matter).

Sedimentation rate: the amount of organic matter is positively correlated with sedimentary rate.

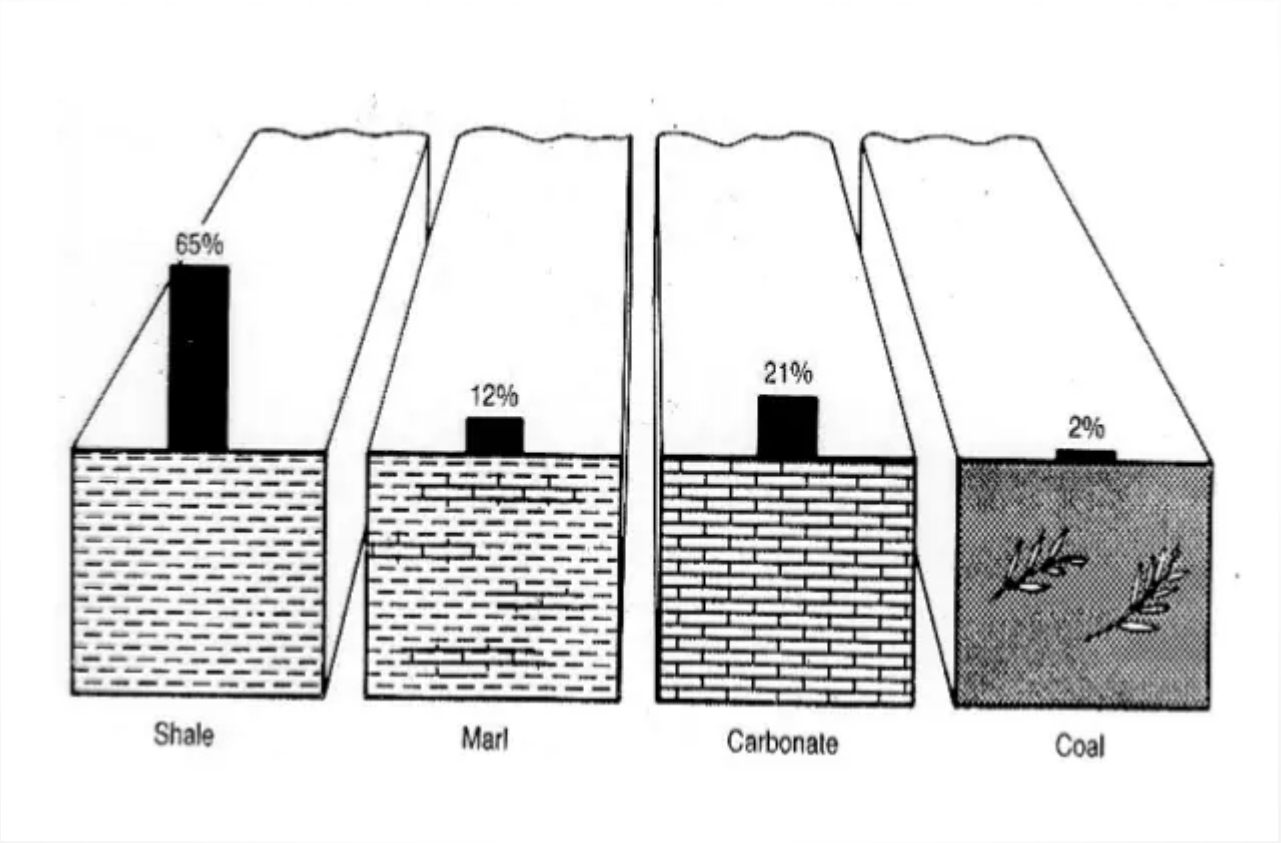
QUANTITY OF ORGANIC MATERIAL

The amount of organic material present in sedimentary rocks is almost always measured as the total-organic carbon (TOC) content.

Some significant TOC **values**

0.3%	limit for carbonate source.
0.5%	“poor” source potential.
0.5 – 1.0%	“fair” source potential.
1.0 – 2.0%	“good” source potential.
>2.0%	“excellent” source potential.

A rock rich in organic matter which, if headed enough, will generate oil or gas. Typical source rocks, usually shales or shaly limestones, contain about 1% organic matter and at least 0.5% total organic carbon (TOC), although a rich source rock might have as much as 10% organic matter.



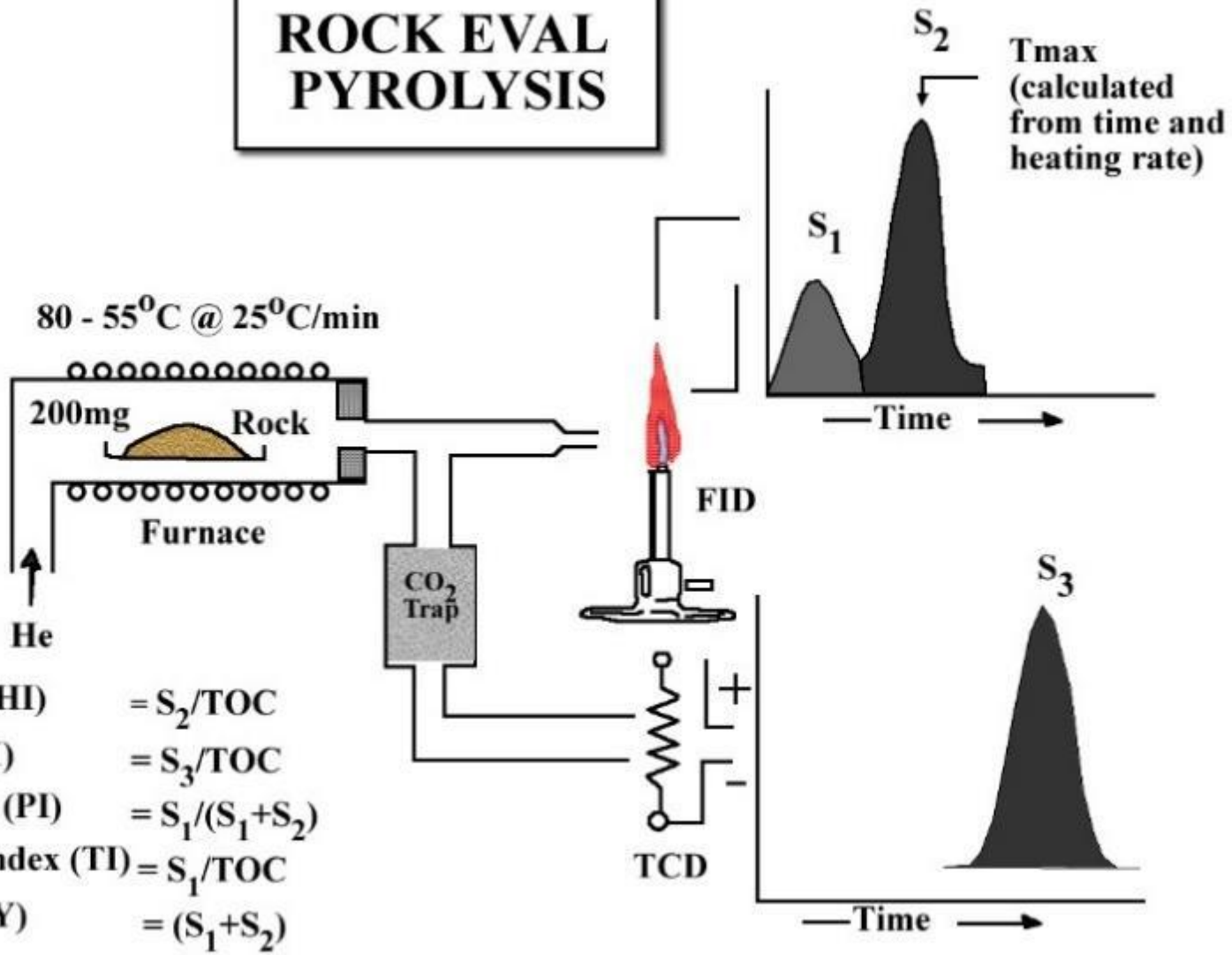
ROCK_EVAL PYROLYSIS

Rock – eval " is a brand name for an instrument made by the french company Vinci Technologies.

Small powdered rock samples are progressively heated up to about 550°C over a period of 20 minutes (crudely simulating the effects of the much slower geological rates of heating).

As oxygen is excluded, the organic matter in the rock is pyrolysed , not combusted . The products are carried to a detector in an inert gas stream and their mass (mg) determined. As the temperature is increased , 2 peaks in hydrocarbons (mgHC/g rock = kg/t) are registered.

ROCK EVAL PYROLYSIS



Hydrogen Index (HI) $= S_2/TOC$

Oxygen Index (OI) $= S_3/TOC$

Production Index (PI) $= S_1/(S_1+S_2)$

Transformation Index (TI) $= S_1/TOC$

Potential Yield (PY) $= (S_1+S_2)$

FID = Flame Ionization Detector TCD = Thermal Conductivity Detector

Normalisation of the Rock-Eval pyrolysis yields to the sample TOC allows the calculation of two key quality parameters:

Hydrogen index (HI):

Total range: 20-1200 mgHC/g TOC

>200 = oil-prone , well preserved immature Type II = 600.

Oxygen index (OI):

Ranges from <10 to several hunderd (latter generally only in organic-poor, oxidised sediments , such as many deep-sea samples).

Well preserved immature Type II kerogen = 20-60.

A cross-plot of HI and OI is called a “modified van Krevelen diagram”.A HI vs. Tmax diagram can also be used.

MATURITY OF ORGANIC MATERIAL

Organic matter: is organic compound that has come from the remains of organism such as plants and animals and their waste products in the environment.

-- **the chemical composition** of organic matter is diverse because the organism from which it is derived are complex.

The major chemicals groups that occur in organic matter are proteins , carbohydrates, lipids and lignin.

Stages of Organic Matter Maturation (formation of kerogen)

Tissot (1977) defined three major phase in the evoluation of organic matter in response to burial:-

I. Shallow Diagenesis(phase of kerogen formation)

-This phase occurs inthe shallow subsurface at near normal temperature(50–60)and pressure.

-It iccludes both biogenic decay aided by bacteria and abiogenic reaction

-Formation of kerogen phase

-The net result of the diagenesis of organic matter is the reduction of its oxygen content, leaving the hydrogen carbon ratio fixed.

II. Catagenesis (phase of oil and gas formation)

-This phase occurs in the deeper subsurface (intermediate depths) as burial continues and temperature and oressure increase

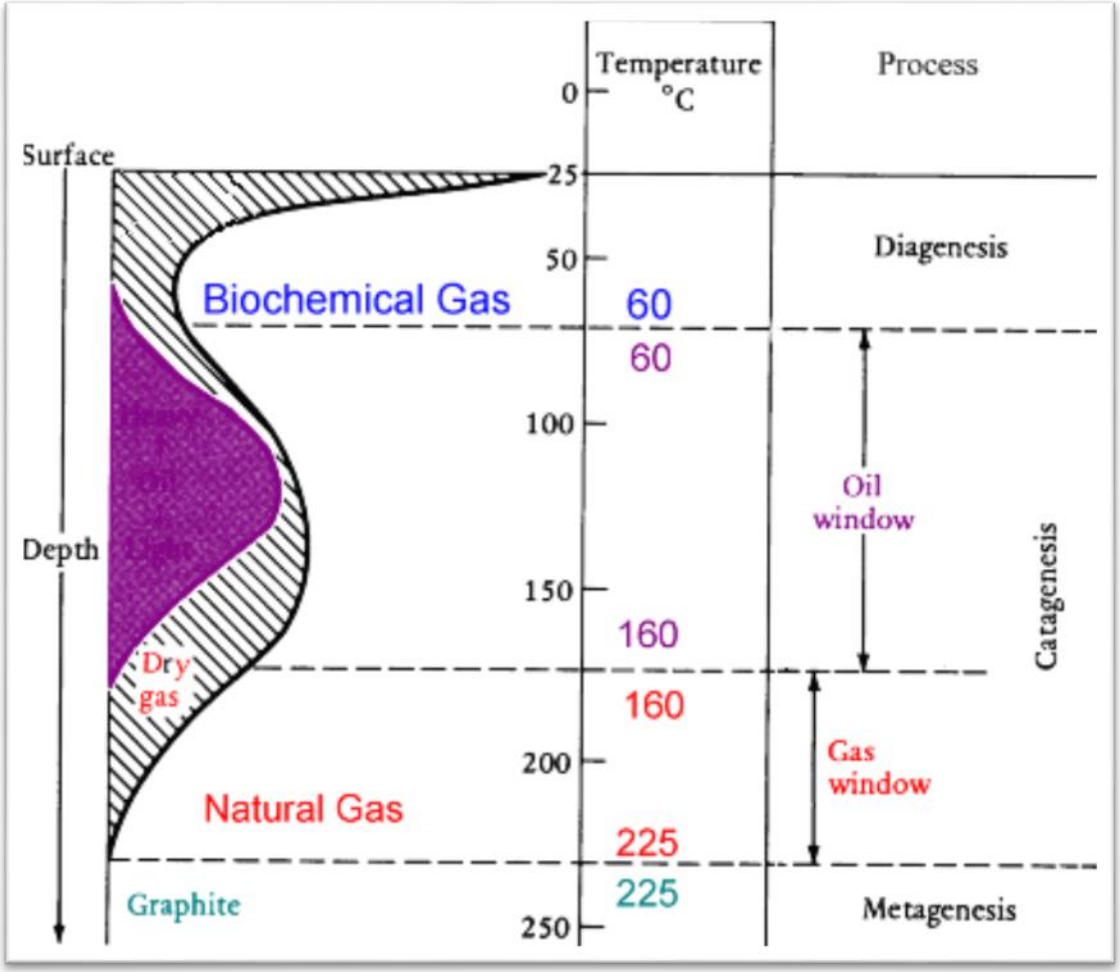
-Thermal cracking of bonds in kerogen .

-Formation of oil and gas in Catagenesis phase (first oil and later gas).

-The hydrgen: carbon ratio declines with no change in the oxygen: carbon ratio.

III. Metagenesis

- This third phase occurs at high temperature and pressure leads to metamorphism
- This last hydrocarbons only methane are expelled
- The hydrogen : carbon ratio declines until only carbon is left in the from of graphite
- Porosity and permeability are negligible in this phase because of compactions.



MATURITY OF ORGANIC MATERIAL

Kerogen/Bitumens

-shale rock volume is composed of 99% clay minerals and 1% organic material.

-petroleum is derived mainly from lipid-rich organic material buried in sediments. Most of this organic matter is in a form known as kerogen

-**Kerogen:- is that part** of the organic matter in a rock that is insoluble in common organic solvents Example (Cs_2) .

-As kerogen thermally matures and increases in carbon content , it changes form an immature light greeish-yellow color to an over mature black, which is repersentative of a progressively higher coal rank.

-Maturation of kerogen is a function of increased burial and temperature and is accompanied by chemical changes.

-**Bitumen** normally forms a small proportion of the total organic carbon in a rock

-**Bitumen** forms largely as a result of the breakingof chemical bonds in kerogen as temperature.

Types of Kerogen

Type I:- is essentially algal in origin

- It has higher H:O ratio (about 1.2 – 1.7) than other types.
- The H:C ratio is about 1.65
- Lipids are the dominant compound in this kerogen type.
- Typical depositional environments in this types is lacustrine environment.
- Petroleum types is oil.

Type II:- liptinitic type, kerogen of intermediate composition

-The H:C ratio geater than one

-The original organic matternof this type is algal detritus, but also contained material derived from zooplankton.

-depositional environment in this types is marine environment

-petroleum types is oil and gas.

Type III:- Humic type, kerogen has a lower H:C ratio (about<0.84)

- Humic kerogen is produced from the lignin of the higher woody plants , which grow on land
- This type of kerogen tend to generate largely gas and very little oil or not oil
- Depositional environments in this types is terrestrail.

Type IV:- the origin of this is type is Carbonized wood tissues

- Non hydrogen only (C) found , therefore no oil and /or gas generate in this type
- This review of these types of kerogene have two importants:-

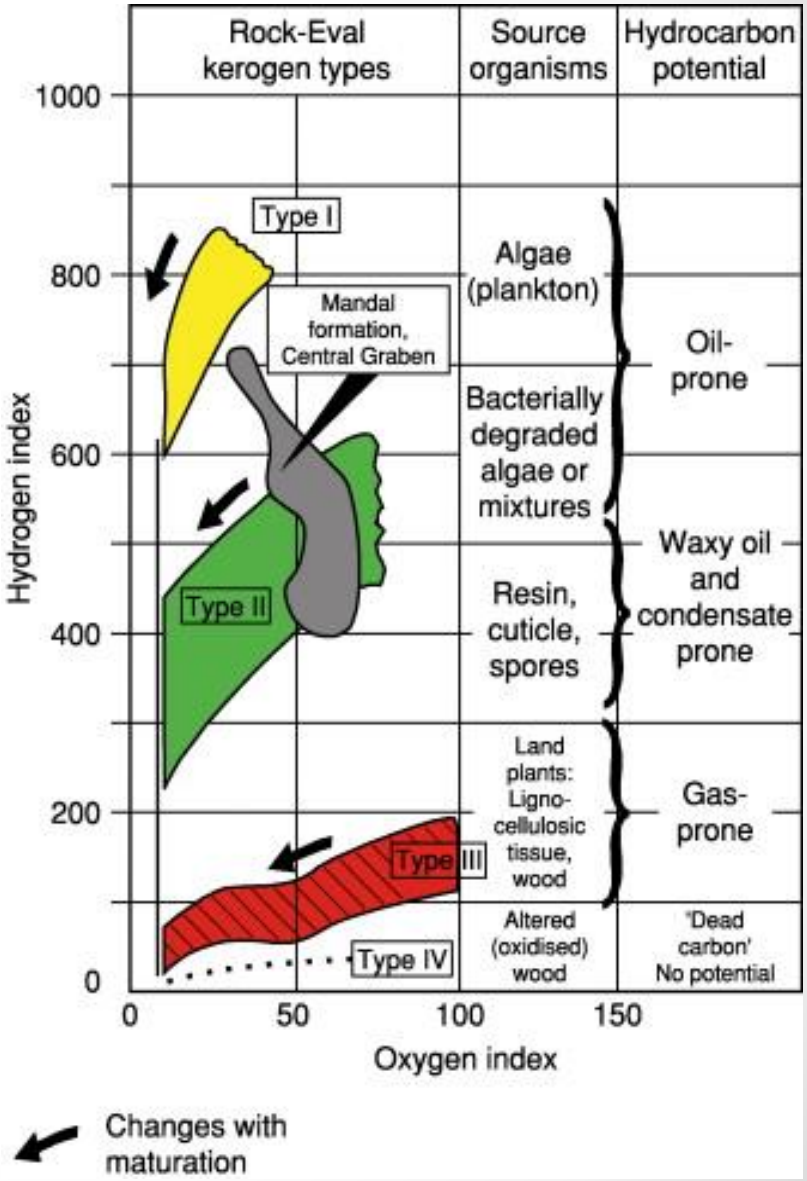
1. Shows the imprtance of identifying the nature of organic matters in source rocks to assess its potential for generating hydrocarbons.
2. The second imprtance factor to consider is not just the quality of kerogen but also the quantity necessary to generate significant amount of oil and gas suitable for commercial production.

The table below lists and defines the basic four kerogen types

KEROGEN TYPE	**Predominant hydrocarbon potential**	**Amount of hydrogen**	**Typical depositional environment**
I	Oil pore	Abundant	Lacustrine
II	Oil and gas pore	Moderate	Marine
III	Gas pore	Small	Terrestrial
IV	Neither(primary composed of vitrinite)or inert material	None	Terrestrial(?)

KEROGEN TYPES

- ✓ Coaly (inert)
- ✓ Woody (gas)
- ✓ Herbaceous (oil,if well perserved)
- ✓ Amorphous (oil,if well perserved)
- ✓ Algal (oil,if well perserved)



- **KEROGEN MATURATION** (thermal maturation)

- Very important changes, called maturation , occur when a kerogen is subjected to high temperatures over long periods of time.
- At temperatures of approximately 60°C and higher (catagenesis phase), the thermal degradation of kerogen yields hydrocarbons under reducing conditions.
- Depending to the rate of maturation there stage of maturity these are, immature, mature, and over mature.

- When kerogen is immature no petroleum has been generated
- With increasing maturity, first oil and then gas are expelled.
- When the kerogen is over mature neither oil nor gas remains.
- The rate of maturation may be depend on temperature, time and pressure.

Stage of Thermal Maturity	Temperature	Process	Product
Immature	<60 C	Bacterial and plant organic matter converted to kerogens and bitumen	Methane generated by microbial activity
Mature (early , peak, late)	60 C -160 C	Rock generates and expels most of it's oil	Oil
	160 C-225C	Post mature for oil/mature for gas	Gas
Post mature	> 225	metamorphism	Graphite

Vitrinite reflectance (Ro):

The method is based on the fact that with increasing thermal stress, the reflectance value of Vitrinite increases.

a. Crude oil generation occurs for (Ro) values between (0.6-1.5).
b. Gas generation take place for (Ro) values between (1.5-3).
c. At (Ro) values above 3 the rocks are essentially graphitic and devoid of hydrocarbons.

NOTE:- all these alteration pccur in the source rocks.

Tmax:

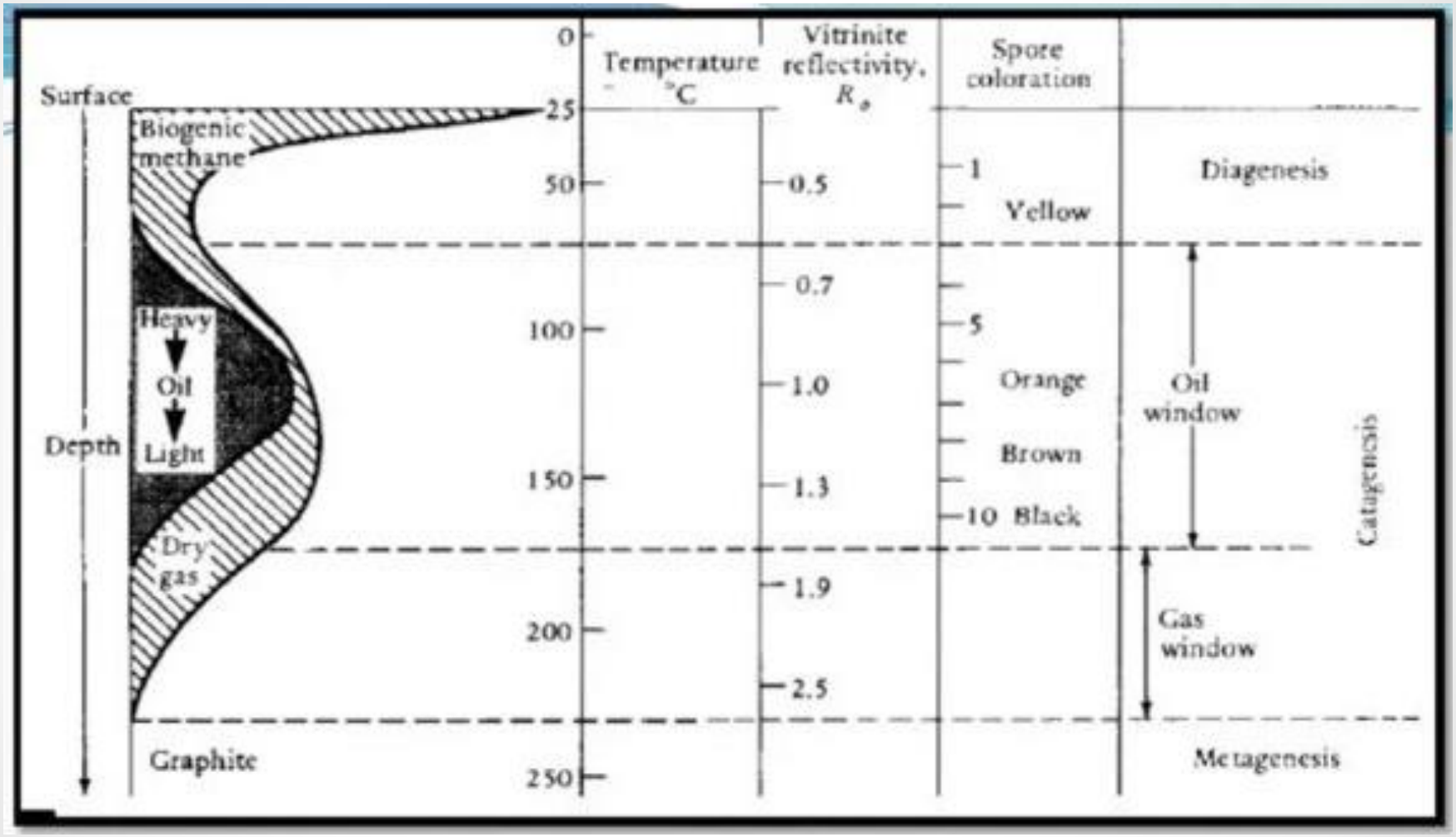
Temperature (°C) at which maximum production of S2 hydrocarbon occurs. Used as an imprecise maturity parameter.

The oil window equates to ~435 to 470°C, peak generation <460°), but also depends upon kerogen type.

Production Index (transformation ratio): S1/(S1+S2).

Oil window values Ranging = (0.1 to 0.4)

Peak rate of HC generation Ranging = (0.15 to 0.25).


Surface
Depth
Biogenic methane
Heavy
Oil
Light
Dry gas
Graphite
0
25
50
100
150
200
250
Temperature °C
Vitrinite reflectivity, R_o
0.5
0.7
1.0
1.3
1.9
2.5
Spore coloration
1
Yellow
5
Orange
Brown
10 Black
Diagenesis
Oil window
Catagenesis
Gas window
Metagenesis