Lecture on Tuesday 17-3-2020

About organic matter in Source Rock

Organic matter

- Under normal conditions, organic matter is very minor in sediments.

- **most source rocks** contain about 1.0 wt% of organic carbon.

- **rich source rocks** contain >5.0 wt%

How petroleum is formed?

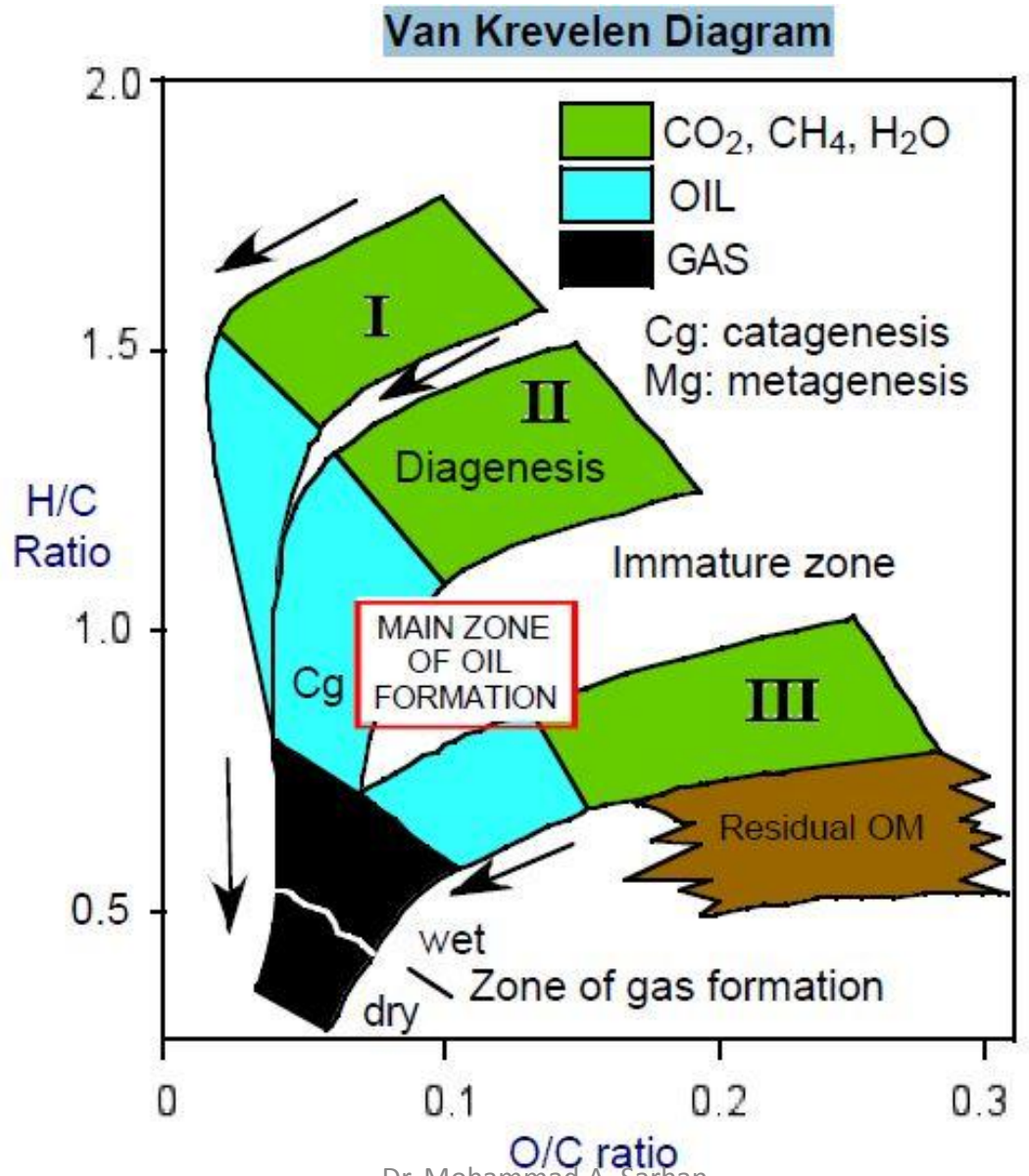
- **Petroleum originates from heating and alteration of organic matter:**

1- Diagenesis

2- **Catagenesis**

3- **Metagenesis**

Van Krevelen Diagram



What is **diagenesis, catagenesis and metagenesis**?

- The three stages represent combinations of **temperature**, **pressure**, and **time** that yield different types of hydrocarbons.

Diagenesis

- Diagenesis --> Shallow burial with near-surface temperatures up to about 60 degrees C.

- Organic matter is degraded and methane, carbon dioxide, and water are produced.

- Kerogen (petroleum), and bitumen, are also formed.

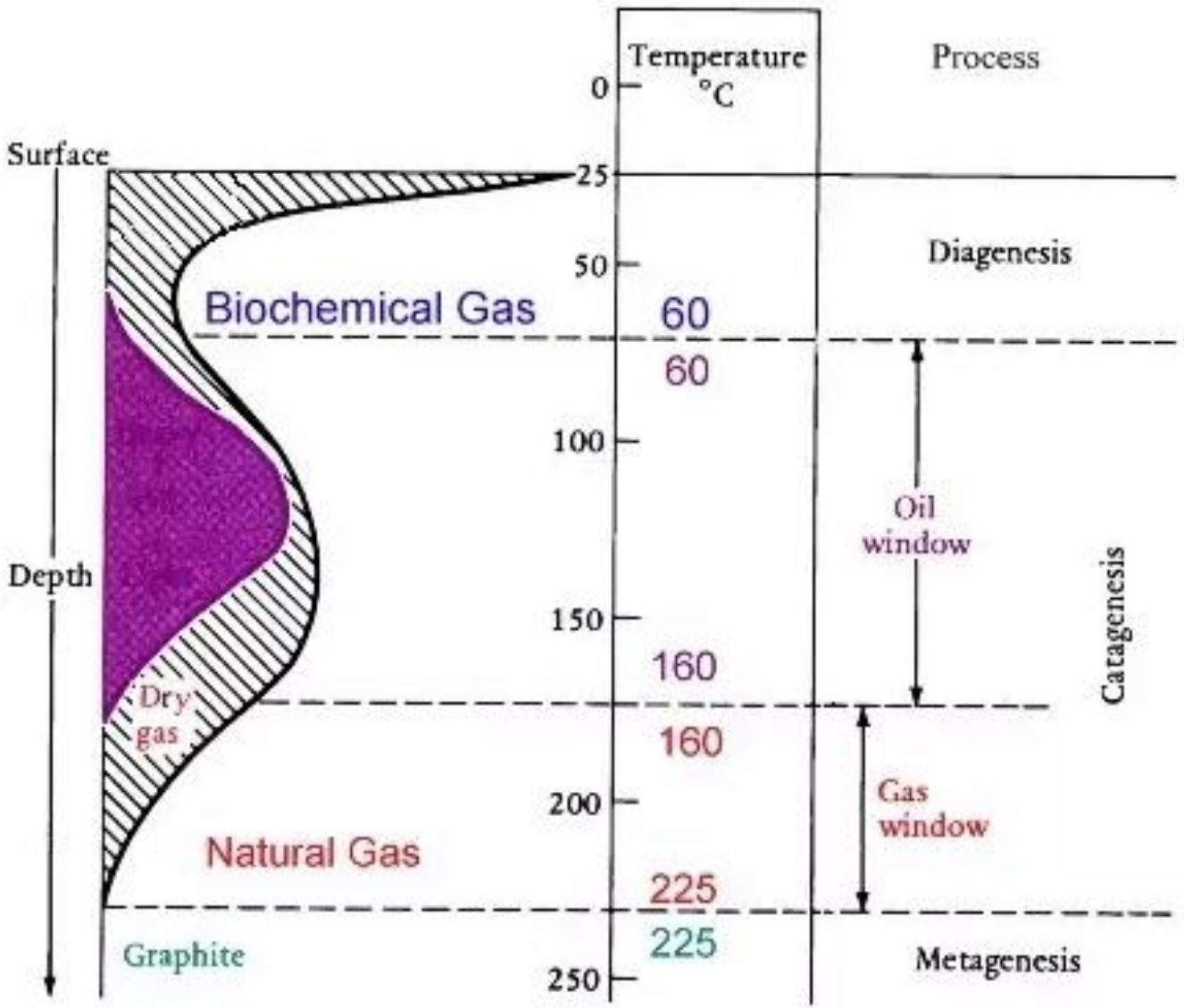
Catagenesis

- Catagenesis --> 60 - 225degrees C.
- 1- 60 - 160 degrees C. (Liquid hydrocarbons are generated from the **kerogen**).
- 2- 160 to 225 degrees C, Methane is generated from the remaining kerogen and bitumen.

Metagenesis

- T > 225°C.

- Metamorphism take places. Graphite/Coal (end product) forms.


Temperature
°C
Process
0
Surface
25
Diagenesis
50
Biochemical Gas
60
60
100
Oil
window
Depth
150
Catagenesis
160
Dry
gas
160
Gas
window
200
Natural Gas
225
225
Graphite
Metagenesis
250

- **Organic matter can be usefully divided into two components:**

- 1- **Bitumen:-**

- **is composed of compounds that are soluble in organic solvents.**

- **includes the aliphatic, aromatic, and N—S—O compounds.**

1- Bitumen

- **Naturally-occurring, organic matter formed from kerogen in the process of petroleum generation.**
- **Bitumen includes hydrocarbons such as asphalt and mineral wax.**
- **Typically solid or nearly so, brown or black, bitumen has a distinctive petroliferous odor.**

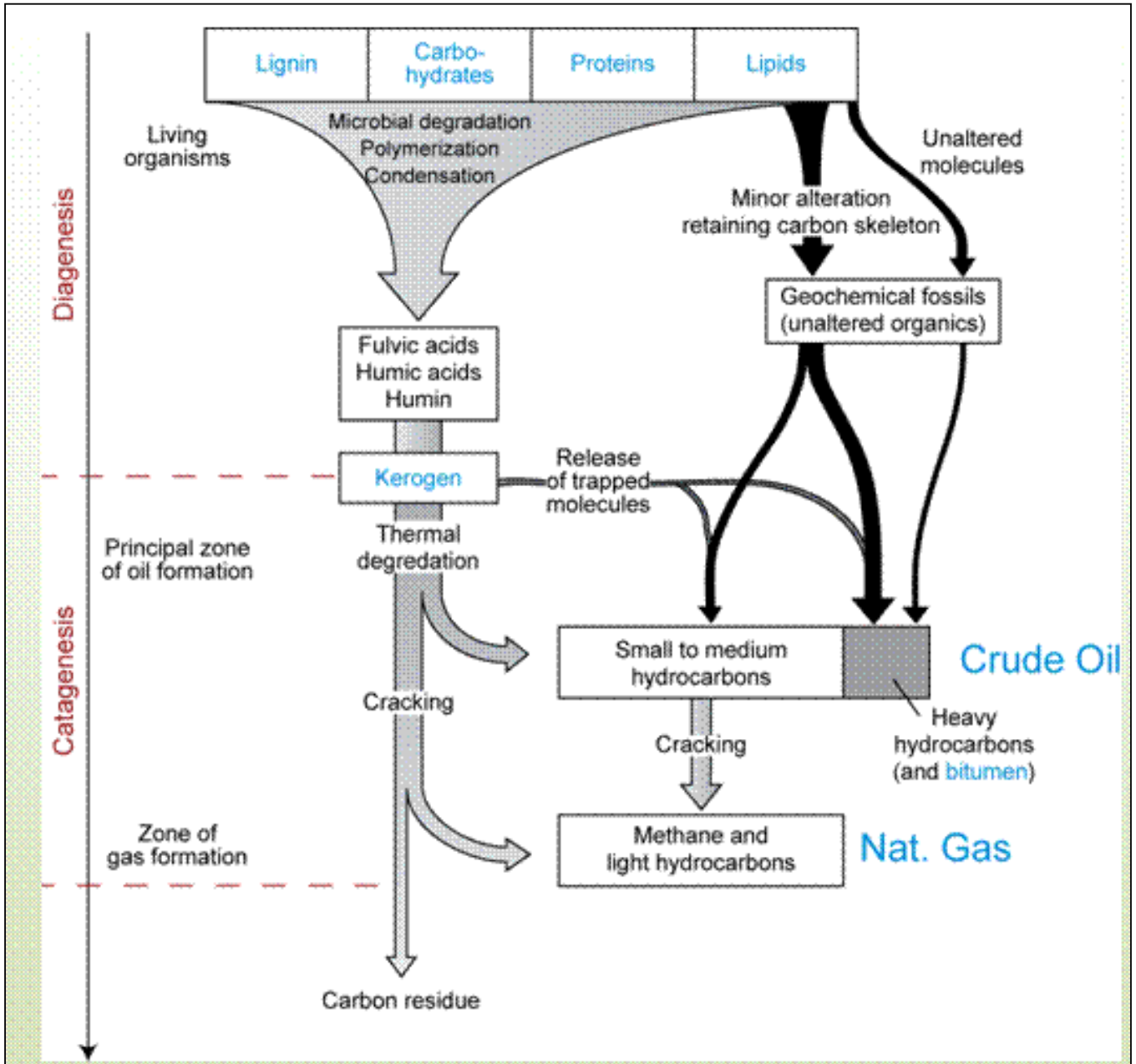
2- Kerogen

- **2- kerogen**
- **the insoluble components.**
- **composed of C, H, and O compounds.**

2- Kerogen

- The proportion of the kerogen in original organic matter is commonly high, about **85-90% in shales**.

- the composition of Kerogen depends on the **original organic source**.



Modified from Tissot and Welte, 1984. *Petroleum formation and occurrence*, Springer –Verlag, 699 pp.
Summary of the oil formation process

Kerogen types

- kerogen is subdivided into four main types depending on the original organic source material; **liptinite, exinite, vitrinite, inertinite**.

- each kerogen produces different petroleum products.

- kerogen type depends on the **depositional environment** of the source rock .

Kerogen types

- The **kerogen type** or types present in a source rock can be recognized on the basis of

- **1- optical properties :-**

Fluorescence , reflectance and Colour .

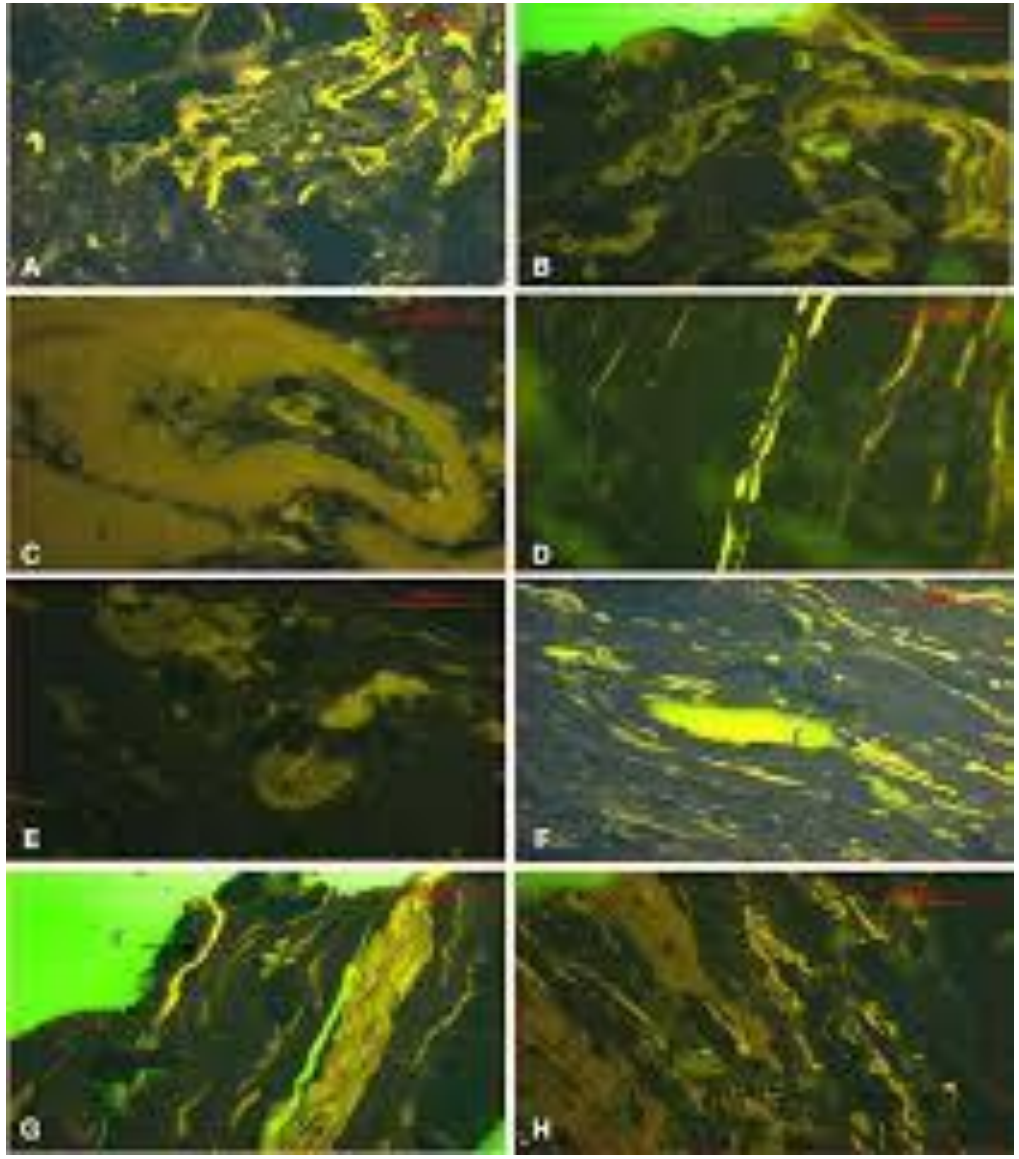
the molecules fluoresce (shine or glow brightly)when excited by ultraviolet radiation.

- **2- H/C and O / C ratios.**

Liptinite (Type I)

- **Liptinite (Type I) :**

- high hydrogen to carbon ratio.
- low oxygen to carbon ratio.
- It is oil-prone.
- a high yield (up to 80%).
- It is derived mainly from an algal source,
- rich in lipids.
- Formed mainly in lacustrine and/or lagoonal environments.
- Liptinite fluoresces under UV light.



Photomicrograph of liptinite under fluorescent light

Vitrinite (Type III)

- has a low ratio of hydrogen relative to carbon.
- high ratio of oxygen relative to carbon.
- forms a low yield kerogen,
- principally generating gas.
- The primary source is higher plant debris found in coals and/or coaly sediments.
- Vitrinite does not fluoresce under UV light.

- **however**, it is increasingly reflective at higher levels of maturity therefore can be used as an indicator of source-rock maturity.

Exinite (Type II)

- intermediate hydrogen to carbon.
- intermediate oxygen to carbon ratios.
- It is oil- and gas-prone.
- with yields of 40—60%.
- The source is mainly plant debris, phytoplankton and bacterial microorganisms.
- Formed mainly in marine sediments.
- Exinite fluoresces under UV light.

Vitrinite (Type III)

- A type of woody kerogen that is relatively uniform in composition.
- Since vitrinite changes upon heating, its reflectance is a useful measurement of source rock maturity.
- The plant material that forms vitrinite did not occur prior to Ordovician time.
- Because vitrinite originated in wood, its occurrence in marine rocks might be limited by the depositional processes that act in a given depositional environment.

Inertinite (Type IV)

- It is high in carbon.
- and very low in hydrogen.
- is often termed "dead-carbon“.
- having no effective potential to yield oil and gas.

- is nonfluorescing product.

Thank you

Quality	Total Organic Carbon (TOC) Content (wt %)	
	From	To
Poor	0	0.5
Fair	0.5	1
Good	1	2
Very Good	> 2	

Organic matter

- The chemical composition of organic **matter** are **proteins**, **carbohydrates**, **lipids**, and **lignin**.

- Animal tissue and enzymes are partially composed of proteins, built from amino acids.

- Carbohydrates are found in animal tissue, being a principal source of energy for living organisms.

Organic matter

- Lipids are fatty organic compounds, insoluble in water, and found in algae and pollen.

- Lipids are rich in hydrogen so yield high volumes of hydrocarbon molecules on maturation

COMPOSITION OF CRUDE OILS BASED ON MAIN HYDROCARBON GROUPS

(In Weight Percent; from Hunt 1979)

TYPE	Paraffinic	Naphthenic	Aromatic	Asphaltic
Paraffinic	40	48	10	2
Paraffinic-Naphthenic	36	45	14	5
"Average crude oil"	30	49	15	6
Naphthenic	12	75	10	3
Mixed Asphaltic	8	42	27	23
Asphalt	5	15	20	60

Molecular groups of hydrocarbons:

- The size range of molecules in petroleum is huge:

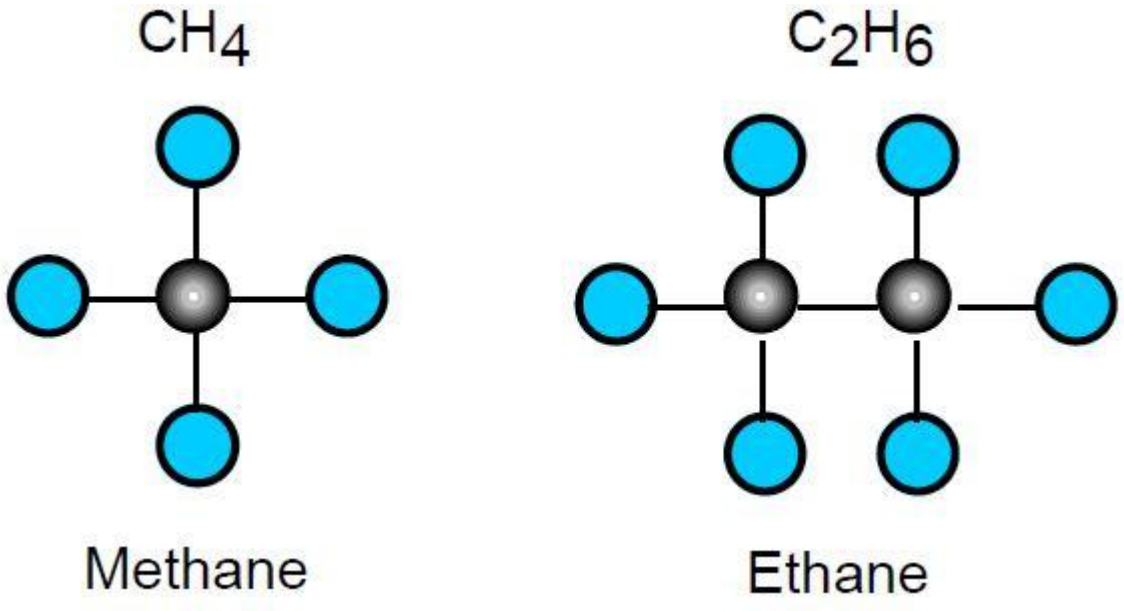
The **smallest** molecule is **methane** (CH_4) with a molecular **weight of 16** [C (12) + 4 x H (1)].

The **largest molecules** are **molecular weights of 10000**.

- **1- Paraffins = alkanes (aliphatics)**
- **2- Napthenes (cycloparaffins) = cycloalkanes**
- **3- Aromatics = arenes**
- **4- Asphaltenes**

1- Paraffins (alkanes)

- They are saturated hydrocarbons: all C bonds are saturated with hydrogen. General formula: CnH2n+ 2.
- (**Natural gas** – mostly methane (CH4) and ethane (C2H6)



1- Paraffins (alkanes)

- From CH4 (methane)up to the formula C4H10 (butane) are **gases** at standard conditions (i.e., at the Earth's surface) of temperature and pressure.

- However, **Liquid** compounds at room temperature range from C5H12 (pentane) to C16H34 (hexadecane).

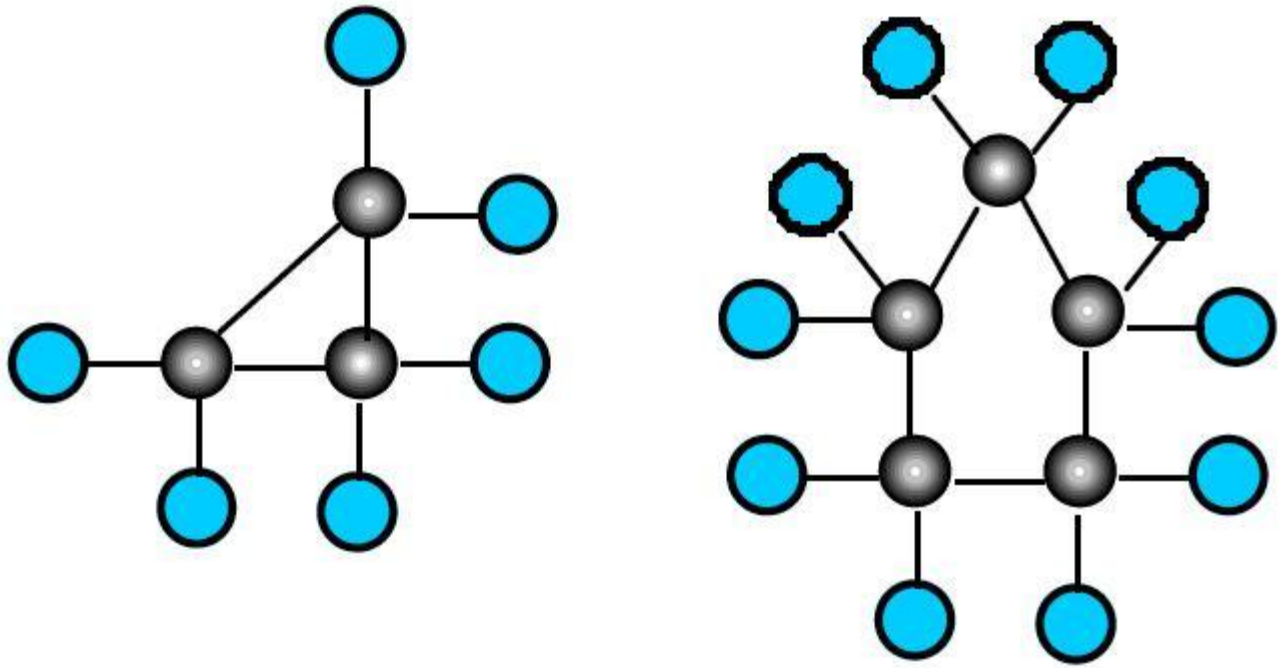
2- Naphthenes (cycloparaffins)

- General formula: CnH2n
- Formed by joining C atoms in a **ring**.

- no rings larger than C7 are found in crude oil.

- The most simple is cyclopropane (C3H6) which is a gas. Cyclopentane (C5H10) and cyclohexane (C6H12) are liquids and are abundant in most crude oils.

2- Naphthenes (cycloparaffins)



C_3H_6

Cyclopropane
(unstable)

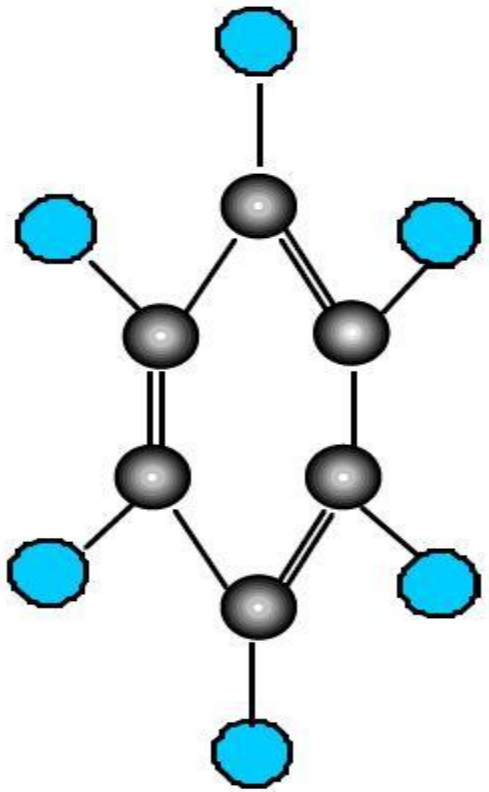
C_5H_{10}

Cyclopentane
(stable)

3- Aromatics (arenes)

- General formula: CnH2n-6
- Take benzene rings in shape.
- Unsaturated hydrocarbon ring compounds.
- Benzene (C6H6) is the most simple.

3- Aromatics (arenes)



Benzene C_6H_6

4- Asphaltenes

- Complex hydrocarbon compounds that are relatively **enriched in N, S, and O are** known as asphaltenes or resins.
- They are characterized by **high molecular weight** and **large size**, and form some of the **heaviest molecules** in crude oils.
- These compounds are frequently **found in:**
- 1- immature oils and
- 2- where the original oil has been altered due to biological activity, generally at low temperatures (below about 90C).

4-Asphaltenes

- The production of oil from a reservoir requires a drop in pressure and temperature around the producing wellbore.

- **Reductions in pressure and/or temperature can lead to asphaltene precipitation.**

- This may occur in the reservoir near to the well, blocking the pores in the rock and "**killing**" the well.

- Cleaning, either **mechanically** or by **solvent washing**, is **difficult** and **expensive** in pipework and is **not** possible in the reservoir.

Generation & Preservation of organic matter

- The two basic requirements for the generation and preservation of organic matter in sediments are:-
- (1) high productivity
- (2) oxygen deficiency of the water column and the sea bed.
- (3) rapid burial

1- productivity

- The supply of organic matter to any depositional site is controlled by productivity (commonly within the top 50 m of the water column). Why?

2- Preservation

- Preservation beneath the sediment/water interface is a function of the rate of burial and oxygenation of the bottom waters.

- Both productivity and oxygen deficiency at the site of deposition can combine to produce excellent source rock, although some source rocks may result from a dominance of only one control.

- **Environments** of high organic productivity include:-
- (1) continental margins (shelf and slope),
- (2) lagoons and restricted seas,
- (3) deltas
- (4) lakes.

Thank You

Lecture on Tuesday 24-3-2020

About suitable depositional environments for Source Rock

Depositional Environments

- **1- Restricted Environments**

- Ex. Gulf of California and Lake Maracaibo, where the amount of organic matter in the seabed sediments is as high as 10.0 wt% (Peridon 1983).


Caribbean Sea
Gulf of Venezuela
Maracaibo
VENEZUELA
COLOMBIA
Lake Maracaibo
La Ceiba
NORTH
0
50
100
200
Kilometres
Atlantic Ocean
Pacific Ocean


United States of America
Gulf of California
Mexico
Pacific Ocean

Depositional Environments

•2- Deltas

- have the highest sedimentation rates of any depositional environment.
- Rapid deposition leads to quick burial near the sea bed.
- Thick sediment piles contain a great deal of terrestrially derived, organic matter.
- Today and in the Neogene, the Mississippi, Nile Delta and Niger Deltas are, and were, sites of source-rock accumulation.


NIGERIA - NIGER DELTA
Abuja
Yenagoa
BAYELSA
RIVERS
CAMEROON
Port Harcourt
Gulf of Guinea
EQUATORIAL GUINEA

Depositional Environments

- **3- Freshwater lakes:**

- are sites for high productivity and preservation in the anoxic bottom waters at the lake bed.

- lakes have a low clastic sediment input but have very organic rich mud.

The quantity (quality) of kerogen

- The quantity of kerogen in a rock defines its richness as a source rock, which in turn relates to its petroleum potential in two ways.:-

- First, the richer the source rock, the larger is the volume of hydrocarbons that can be generated.

- Secondly, the higher the proportion of the rock that is organic material, the greater is the efficiency of migration of hydrocarbons out of the source rock.

- The quantity of kerogen in a source rock is determined from the total organic carbon (TOC) and reported as a weight percentage of the rock.

The quantity (quality) of kerogen

- Geochemical techniques used to evaluate potential source rock samples including:

- 1- pyrolysis (decomposition by high temperatures).

- 2- vitrinite reflectance (%Ro) analysis.

- These analyses define the **kerogene type,** the **level of maturation**, **TOC**.

Thank you