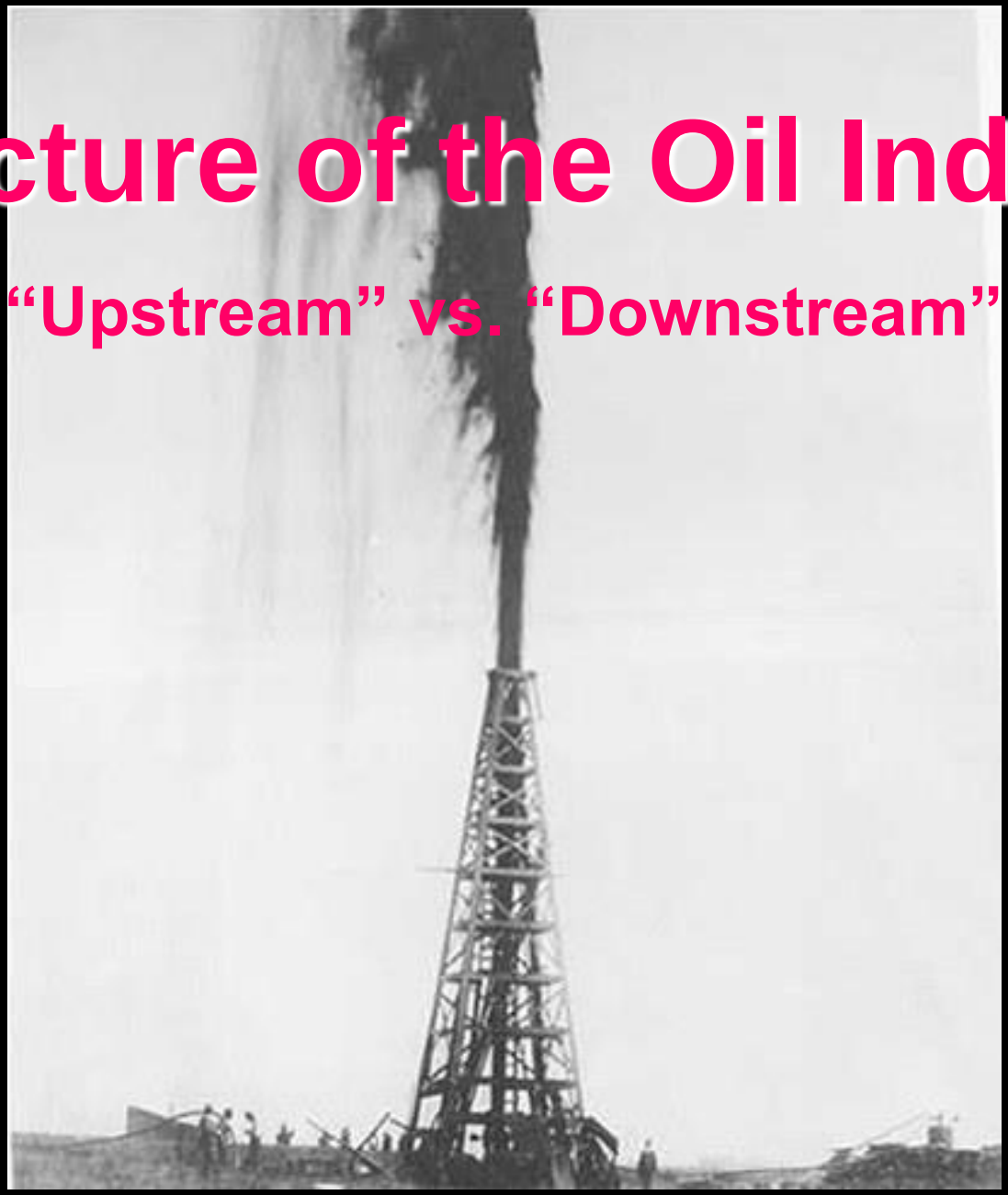

Age of Oil

Structure of the Oil Industry

"Upstream" vs. "Downstream"



“Upstream”

Exploration

Production

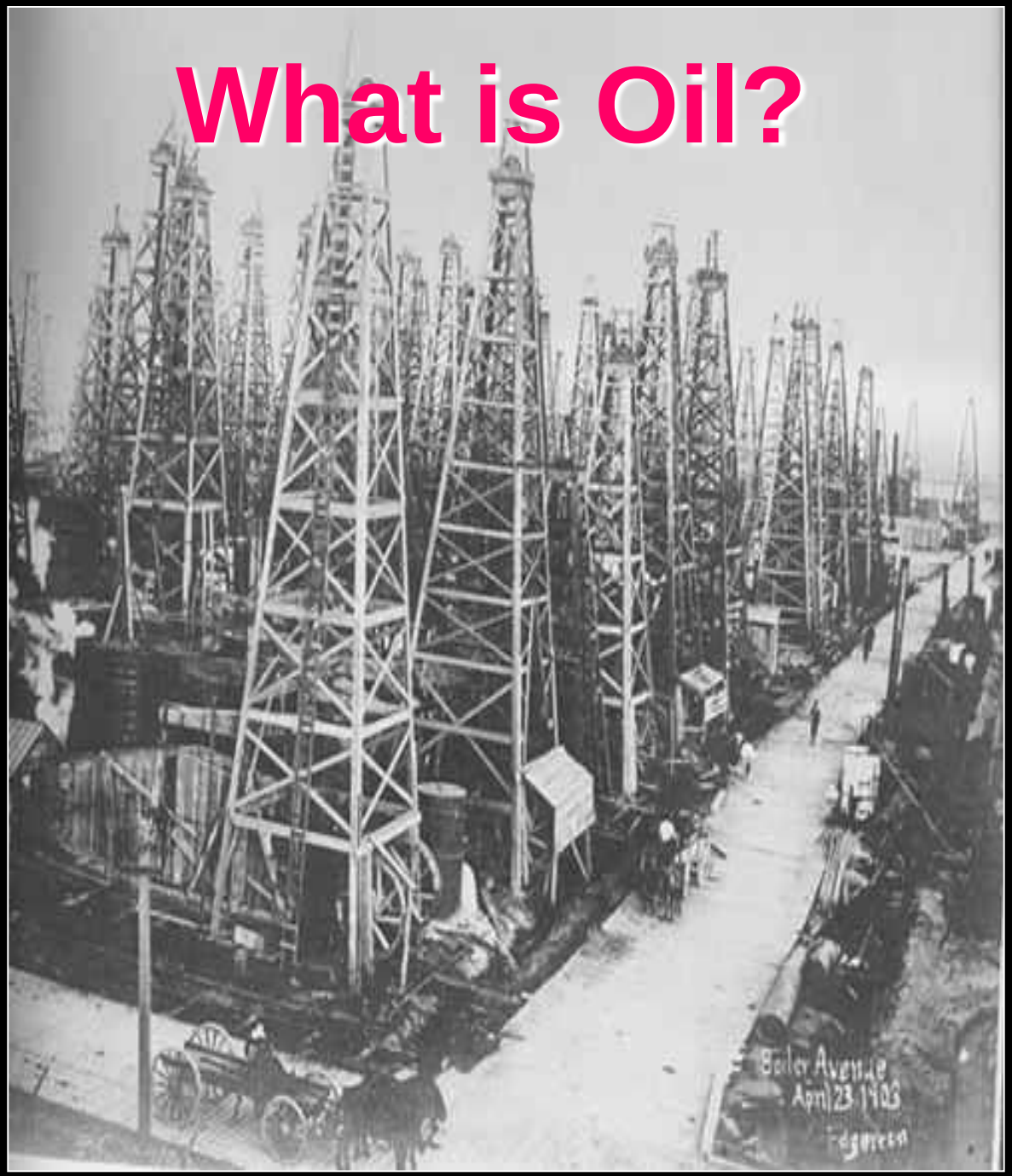
“Downstream”

Oil transport and shipping

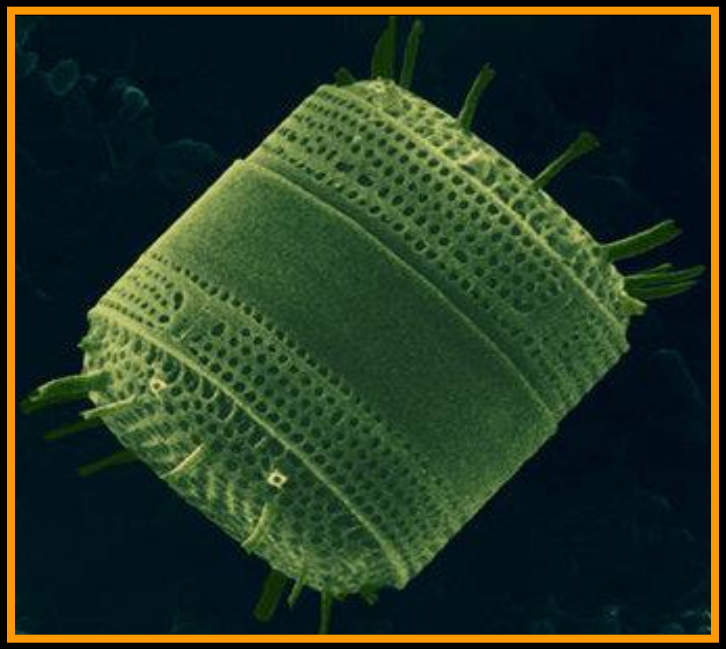
Refining

Distribution and Retailing

What is Oil?



Oil is Stored Sun Light (Energy)



Diatom

Phytoplankton use sun light for photosynthesis and growth

The organic remains of phytoplankton provide most of the organic material for oil

Dead dinosaurs do not form oil!!

What is Oil?

Petroleum: Lt: petra (rock); oleum (oil).

Petroleum is composed of a combination of hydrogen and carbon atoms.

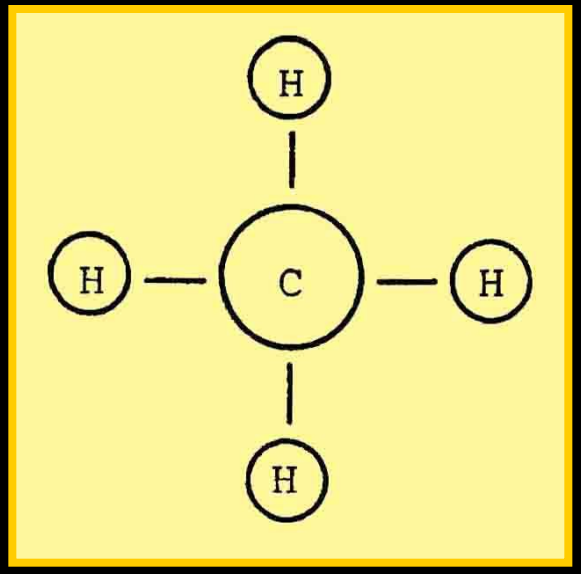
Crude oil is derived from kerogen which is comprised of organic compounds containing the elements of hydrogen and carbon.

The relative proportion of hydrogen to carbon is vital to the nature of oil.

Table 1. Approximate elemental composition (in wt. %) of selected organic matter (after Hunt, 1979, 1996).

Element	Gas	Oil	Asphalt	Kerogen (immature)			Coal	
				Type I	Type II	Type II	Lignite	Bituminous
Carbon	76.0	84.5	84.0	76.0	72.6	72.7	68.0	83.0
Hydrogen	24.0	13.0	10.0	9.4	7.9	6.0	5.0	5.0
Oxygen	0.0	0.5	2.0	8.8	12.4	19.0	22.0	8.0
Sulfur	0.0	1.5	3.0	3.8	4.9	0.0	2.0	2.0
Nitrogen	0.0	0.5	1.0	2.0	2.1	2.3	2.5	1.0
(Trace elements)	0.0	0.0	0.1	0.5	0.0	0.1	0.0	highly variable

Simplest Hydrocarbon Molecule



Methane gas = CH_4

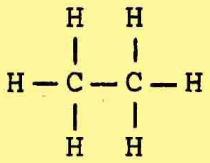
One carbon and four hydrogen atoms = methane

Simple paraffinic molecules are straight chain

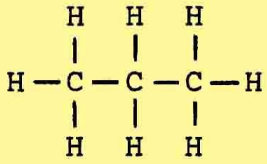
Methane is a gas at normal atmospheric pressure

Types of Hydrocarbon Paraffinic Molecules (Straight Chain Molecules)

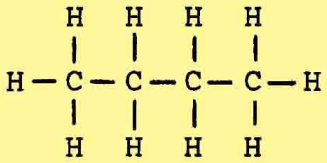
Ethane
(C_2H_6)



Propane
(C_3H_8)



Butane
(C_4H_{10})



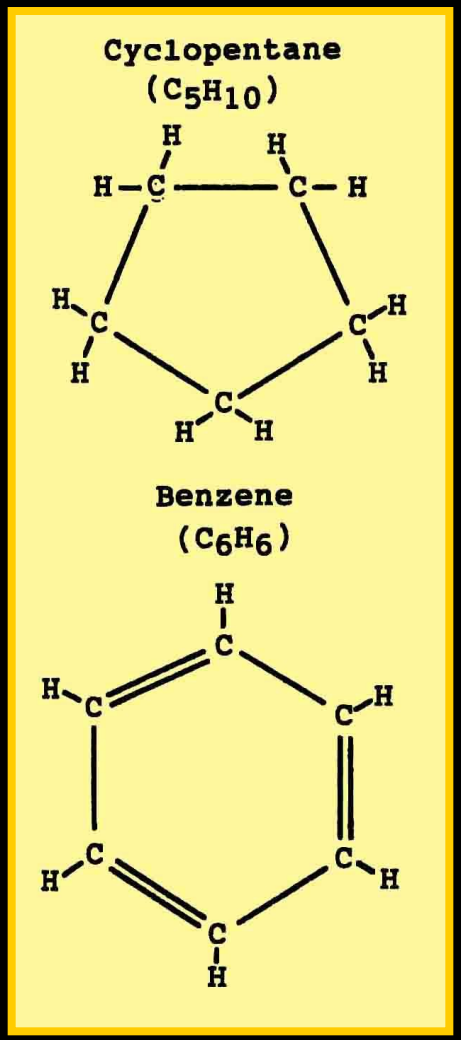
Number of hydrogen atoms in straight-line molecules is derived from H = 2n+2 where n = carbon atoms

Ethane (2 X 2) + 2 = 6 H atoms

Propane (2 X 3) + 2 = 8 H atoms

Butane (2 X 4) + 2 = 10 H atoms

Ring Type Hydrocarbons
(Cyclohydrocarbons)



Cyclopentane - 5 C atoms

Benzene - 6 C atoms

Gases vs. Liquids

The smaller the hydrocarbon molecule, the more volatile it is.

Hydrocarbons of 4 carbon atoms or less is a gas under normal atmospheric conditions:

Methane, ethane, propane and butane

Hydrocarbons with 5 or more carbon atoms are liquids or solids under normal atmospheric conditions.

Familiar Distillate Hydrocarbons

	Carbon Atoms
Gases	> 5
Gasoline	5 - 10
Jet fuel/Kerosene	12 - 15
Distillates:	
diesel & heating oil	15 - 18
Lubricating oils	18 - 20
Heavy semi-solid:	
asphalt	> 20

Crude Oil

Crude oil is a mixture of several types of hydrocarbon molecules.

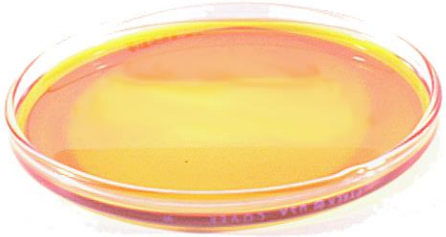
The character of a crude oil is determined by its relative proportions of different hydrocarbon molecules that contain sulfur and other elements.

Crude oil varies in composition.

No two crude oils are identical.

No Two Crude are the Same

Light Texas Crude
Palo Pinto Field
North Texas



Heavy Texas Crude
Humble Oil Field
Southwest Texas

Very heavy crude
Athabasca Sands
Canada

Value of Crude Oil

The economic value of crude oil depends on the amount, type, and range of products that can be derived from distillation and refining.

Since crude oil is traded internationally, a means of comparing and distinguishing between types of crude oils becomes necessary.

Characteristics of Oil

API gravity:

One measures the density of crude oil by its gravity. The higher the gravity the lighter of oil.

The density of oil is less than water (ºAPI 10) and varies with temperature. The higher the temperature, the lower the density.

$$^{o}\text{API} = \left\{ \frac{141.5}{\text{specific gravity}} \right\} - 131.5$$

American Petroleum Institute defines gravity of oil in AIP units according to the above formula.

API of 30º or higher is light oil is preferred.

API of 10º or less is considered heavy oil and is not preferred.

Important Attributes of Crude oil

Amount of sulfur:

Sweet <1%

Sour >1%

Viscosity: resistance to flow (thicker and stickier, the higher the viscosity)

Pour Point: lowest temperature at which oil will pour (+125° -75°F)

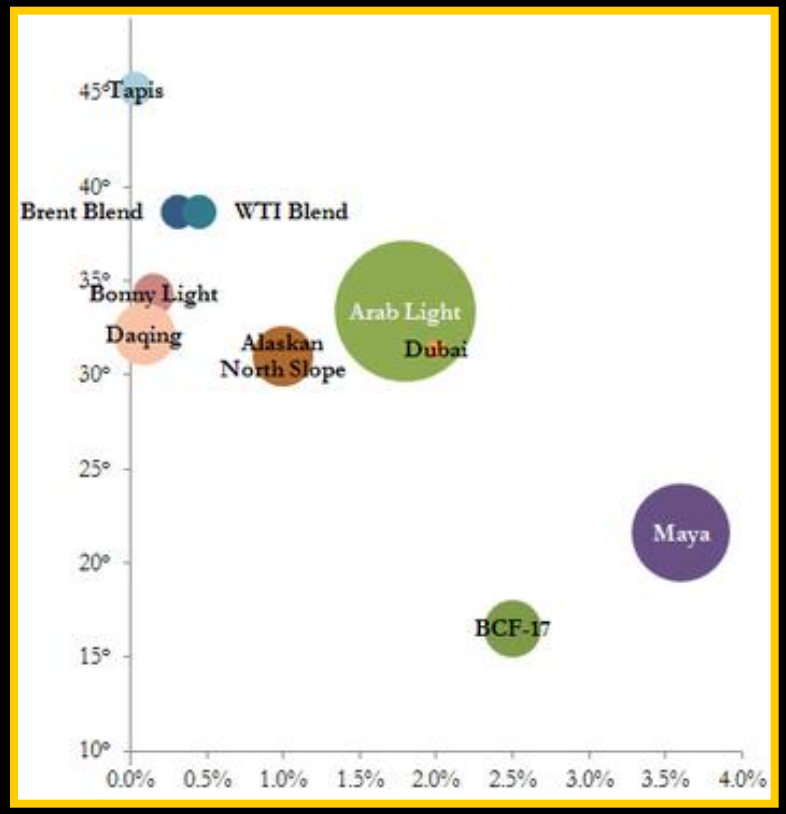
Pour point reflects the percentage of paraffin molecules (18 carbon atoms or longer). The higher percentage of paraffin the higher the viscosity.

Caloric heat value: 18,300 to 19,500 Btu/lb.

Conventional Oil

Characteristics:

- Easily produced
- Readily flows (API > 10°)
- Easy to refine
- Costs less to refine = greater profit



Sweet Crude

West Texas Intermediate (WTI)

- Light crude (>30°)
- Low sulfur (<1%)
- Easier to refine
- More gasoline generated per barrel of crude
- More profit per barrel!!

Sour Crude

Arabian sour

Venezuela heavy

Heavy crude (<30°)

High sulfur (>1%)

Harder to refine

Less gasoline generated per barrel of crude

Less profit per barrel!!

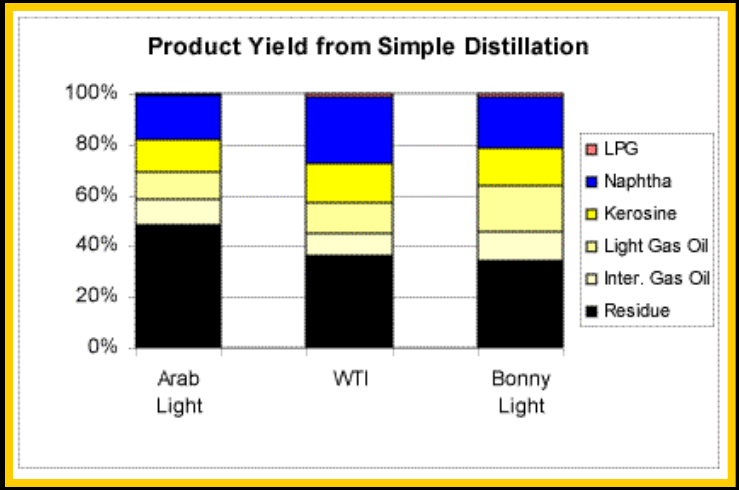
Bench Mark Crude Oils

The value of a crude oil depends on its physical and chemical characteristics.

There are 161 types of crude oil traded internationally.

The prices vary with its desirability (API & sulfur content).

Crude oil is priced against a certain number of **bench marked crudes.**



Bench Mark Crude Oil Prices

Cash Petroleum .... Spot Prices					
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		8/22/06	8/21/06	Change	
West Texas Intermediate fob	$/BBL	72.64	72.46	+ 0.18	+ 0.25%
Alaska North Slope delivered to West Coast	$/BBL	71.33	71.15	+ 0.18	+ 0.25%
Dubai fob	$/BBL	68.26	68.84	- 0.58	- 0.84%
North Sea Brent fob	$/BBL	72.18	72.18	NC	NC

"Spot price" is the price that oil can be bought or sold, on the day, or time it is posted.

Spot prices continually change depending on market conditions.

Types of crude oil determine the price.

Bench Mark Crude Oils

U.S.A.:

West Texas Intermediate (WTI) = 38º - 40º API , 0.3% sulfur

West Texas Intermediate Sour = 33º API, 1.6% sulfur

North Sea:

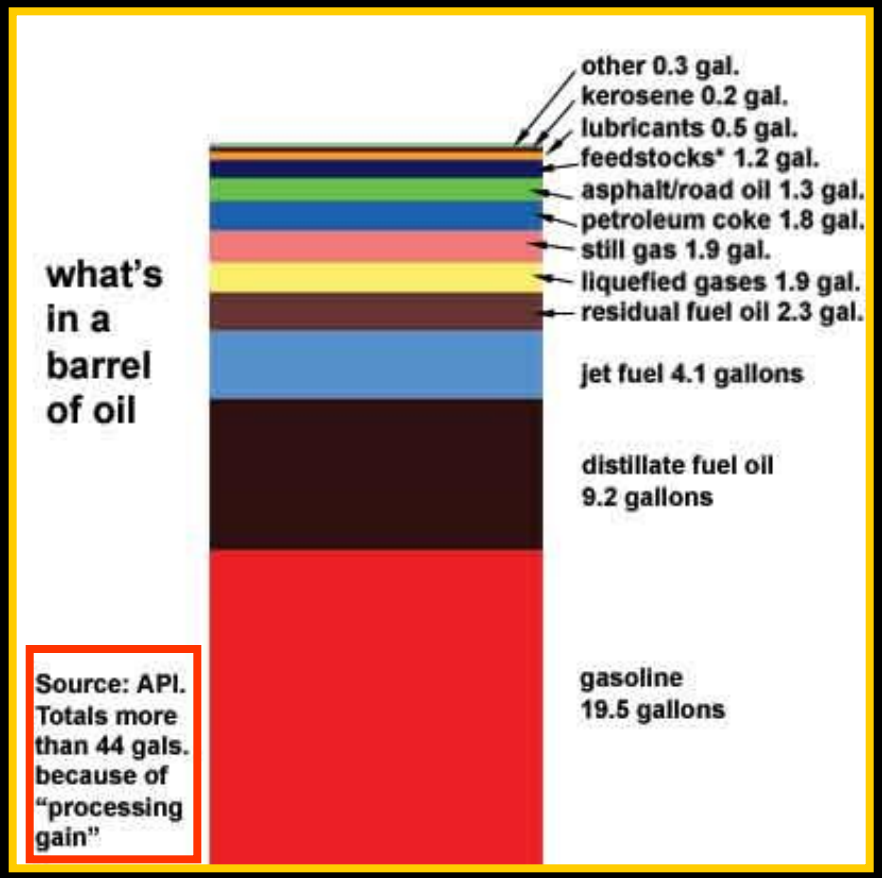
Brent = 38º API, 0.3% sulfur

Middle East :

Dubai = 31º API, 2.0% sulfur

OPEC basket = lump 7 different crude oils on average as the bench mark measure

Refined Products from a 42 gal Barrel of Crude Oil



1 barrel (42 gal) of crude will produce 44 gal of refined products

Unconventional Oil = Heavy Oil

1. Heavy oil and greater viscosity (<10°)
2. Lower volatility
3. Darker color

Canadian Heavy Crude Oil

^ The Athabasca oil sands of Alberta, Canada.

Very high viscosity requires special processes to:

1. Produce
2. Refine
3. Greater costs

Conventional vs. Unconventional Oil

Conventional oil - easily produced and refined (WTI, Brent, Saudi Light)

Unconventional oil - difficult and expensive to produce and refine (very heavy, high sulfur crudes; crude oil trapped in reservoirs; tar sands; oil shale, oil from arctic regions, ultra-deep offshore,)

Basic difference between conventional and unconventional oil is "cost"

The easier the crude oil is to produce and refine, the higher the price of the crude.

Formation of Oil

Source rocks = where oil is formed

Migration = movement of oil through porous rocks

Reservoir rocks = where oil is trapped

Source Rocks

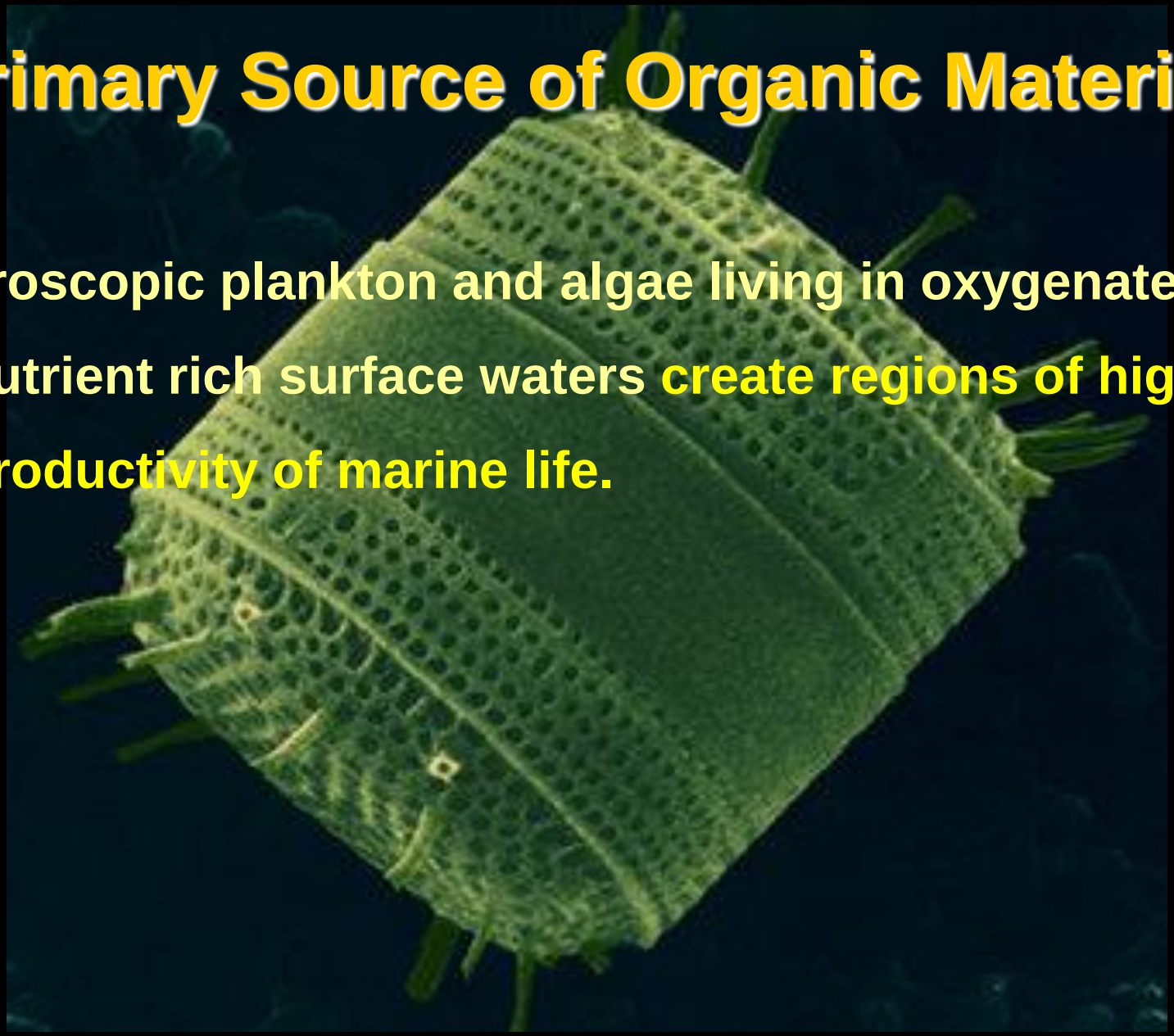
Rocks that contain the organic matter that can be transformed into oil.

Requires massive amounts of organic material.

Preservation of organic material.

Coastal outcrop north of Santa Barbara, California

Primary Source of Organic Material



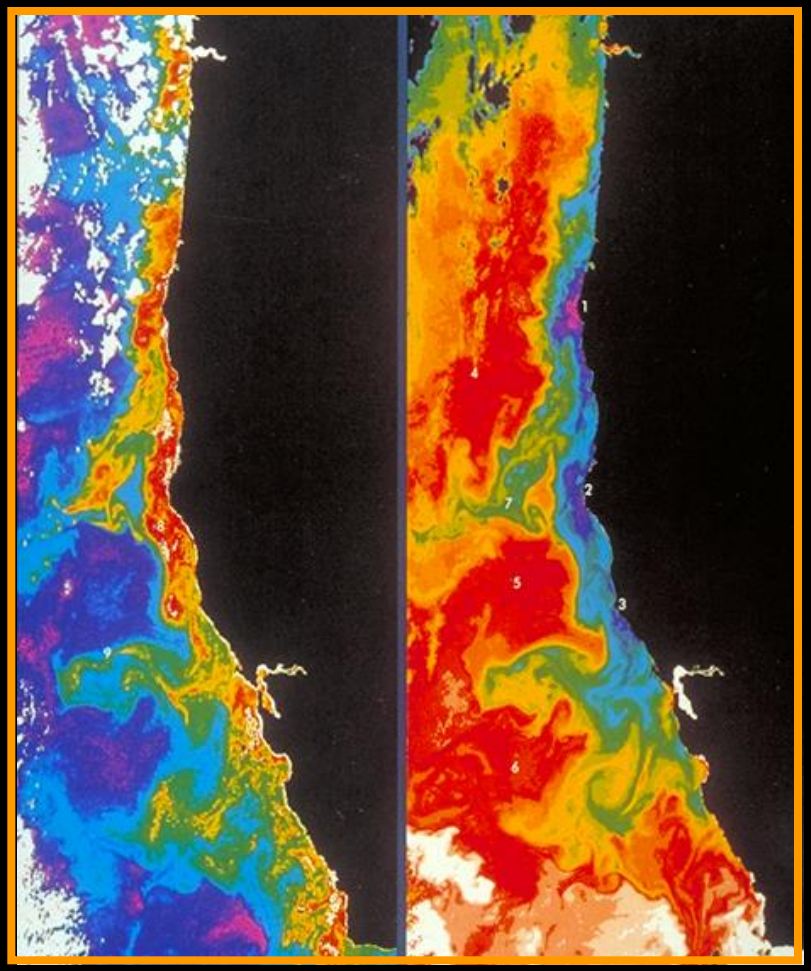
Microscopic plankton and algae living in oxygenated, nutrient rich surface waters create regions of high productivity of marine life.

High Productivity Region

High productivity requires:

- **Sunlight for photosynthesis (shallow water).**
- **A continuous source of nutrients.**

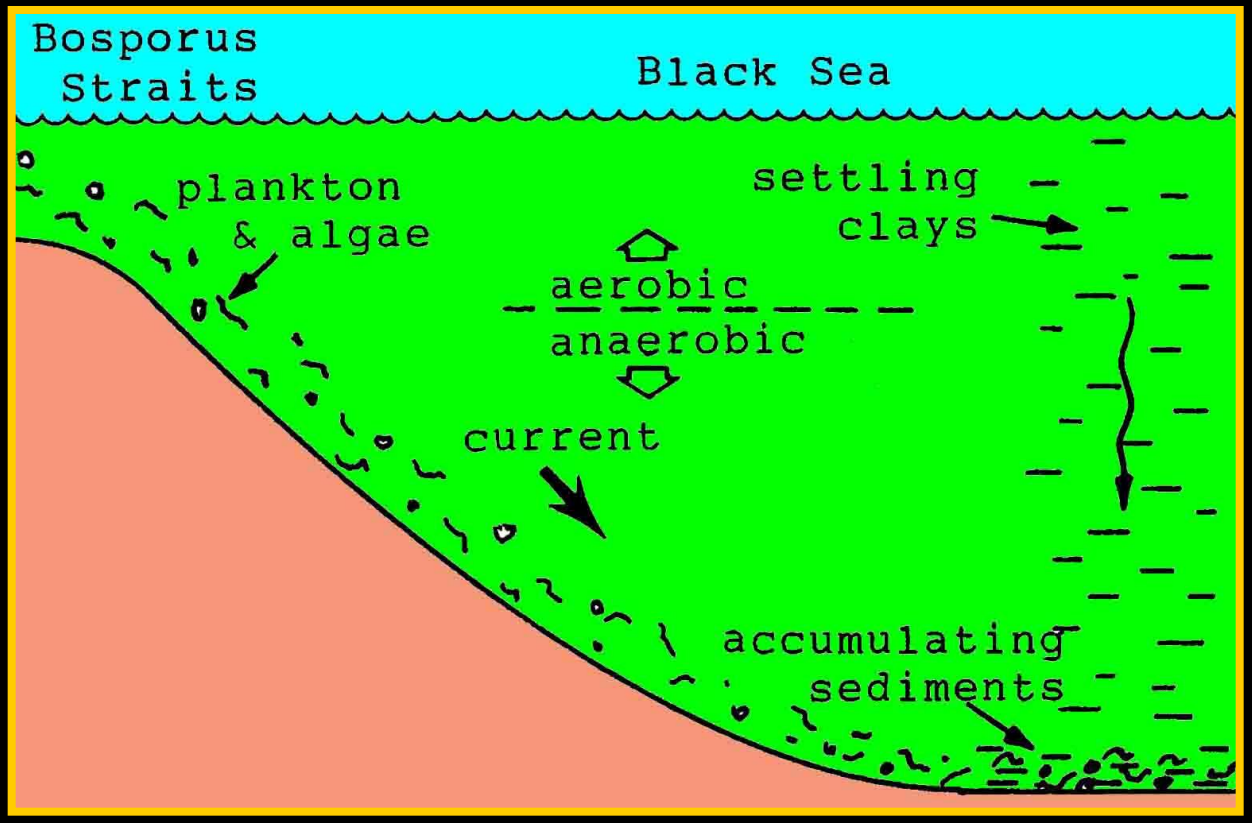
Middle Tertiary, West Coast



Modern coastal upwelling

Monterey Shale (white), Shell Beach, CA

Black Sea



Formation of source rock

Conditions that Convert Plankton and Algae to Oil

Source:

Wholesale death over a long interval of time is necessary to provide sufficient mass of organic material (kerogen) for significant oil formation.

Kerogen

Kerogen is fossilized insoluble organic material found in sedimentary rocks that can be converted to petroleum.

Kerogen gives source rocks a dark to black color.

Kerogen is not oil, but can be converted to oil via temperature and pressure.

Oil shale contains only kerogen that can be converted to oil.

Source Rock

Source rock must contain a sufficient quantity of organic matter.

Organic matter must be of a quality needed to generate oil or gas.

Source rock must attain thermal maturity = sufficiently high enough temperatures and pressure to generate oil.

Black finely laminate organic shale

Maturation
(Generation of Oil and Natural Gas)

Transformation of kerogen to oil is referred to as **maturation.**

Maturation is caused by higher temperatures and pressures.

Temperature is the Key to the Formation of Oil & Gas

The deeper the sediment is buried, the higher the temperature.

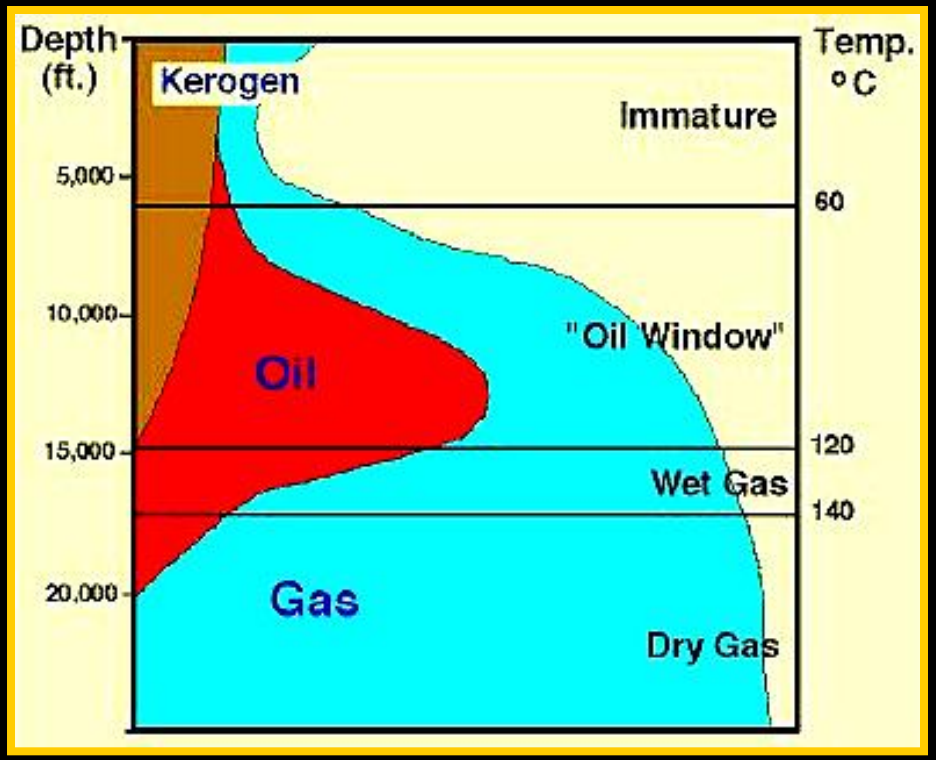
Oil forms at 150ºF (65ºC) - 250ºF (125ºC) - "Oil window" or "Oil kitchen."

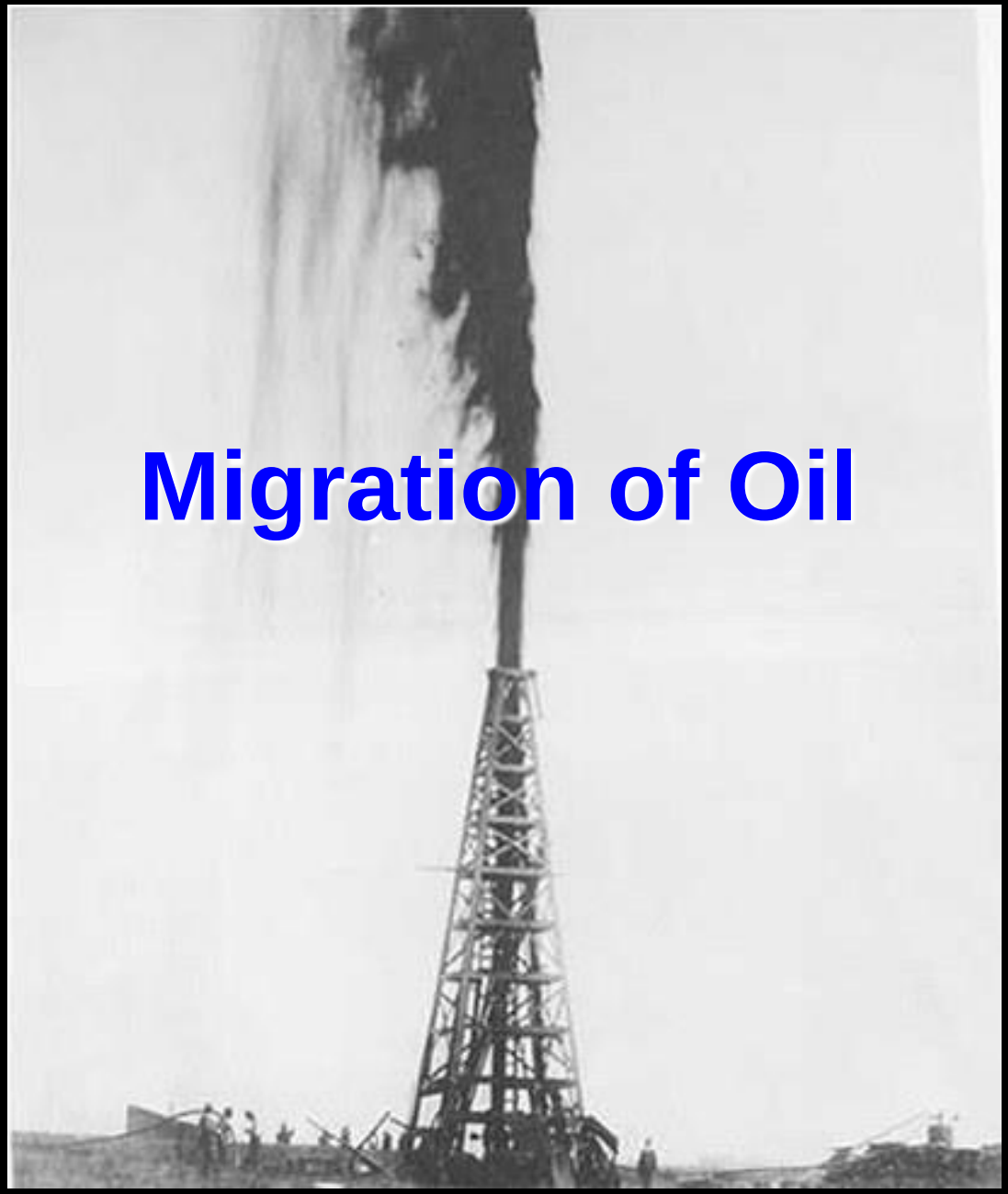
Above 250ºF, oil begins to breakdown to gas.

Between 250ºC - 350ºC oil converts to gas.

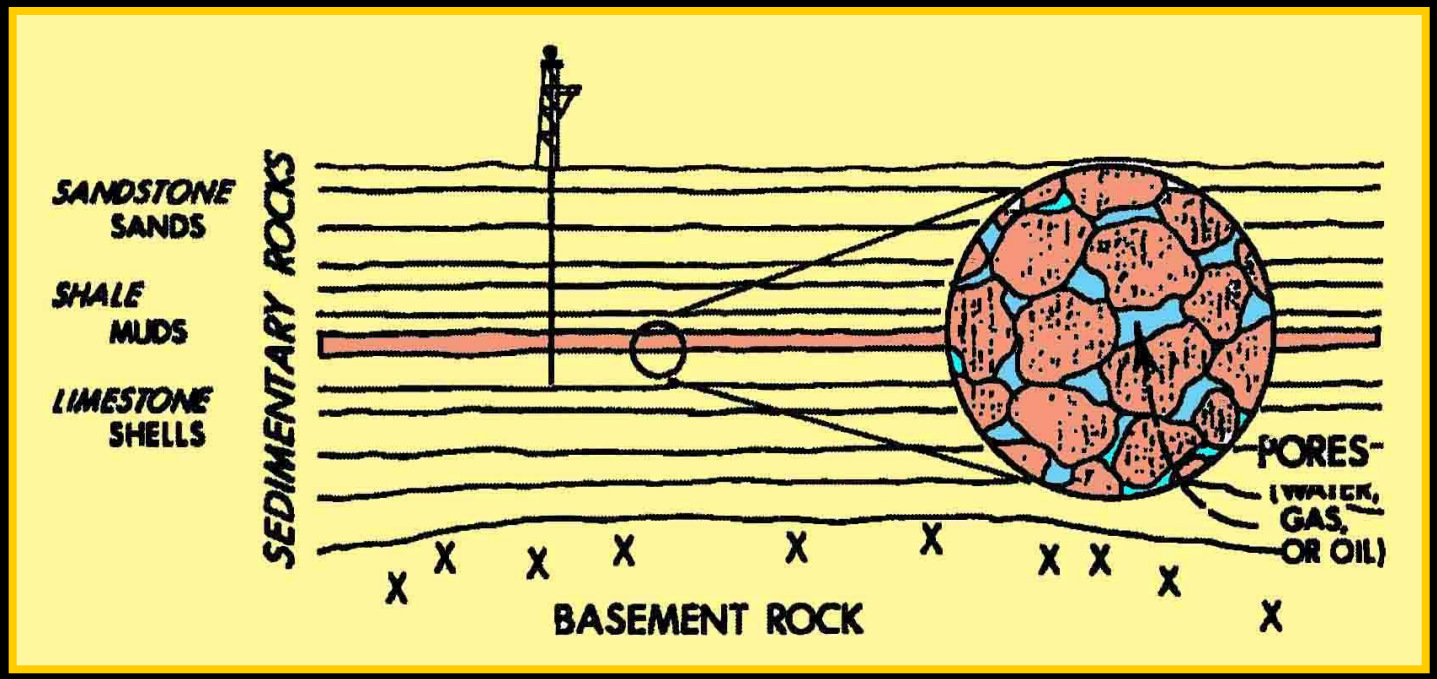
Above 500ºF organic material is carbonized or destroyed.

Typically, gas forms at greater depths below oil.




Migration of Oil

Properties of Reservoir Rocks



Oil doesn't occur in underground lakes.

Oil and gas reservoirs occur in "solid rocks".

Hydrocarbons occupy the tiny pore spaces and fractures within the rocks.

Migration

Migration is the movement of oil from source rocks to reservoir rocks.

Oil moves from the source rocks through reservoir rocks to various types of geologic traps.

Trap = geologic feature where oil accumulates.

Reservoir Rock

Reservoir rock possess a certain degree of porosity and permeability that allows them to function as petroleum reservoirs.

Porosity & Permeability

Porosity = percentage of open space within rock.

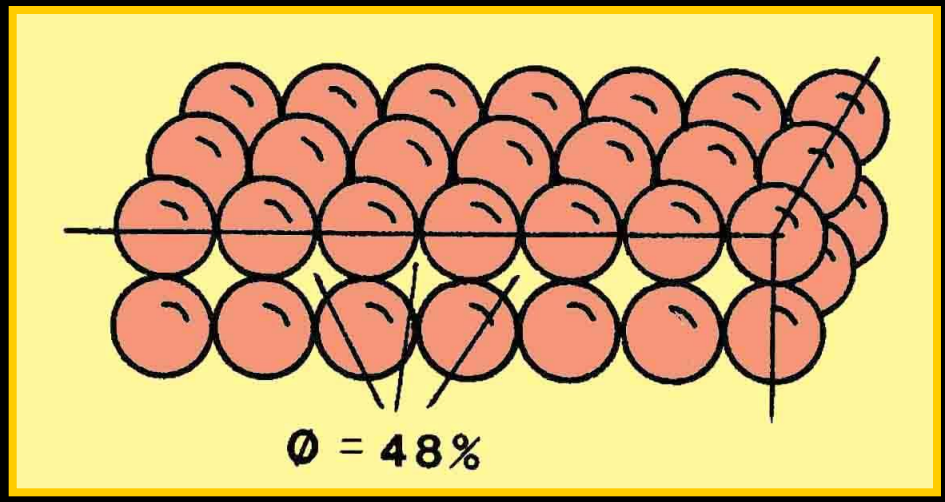
Permeability = connections between open spaces that permit fluids to freely flow.

Porosity

Rock with 25% porosity is composed on of 75% rock and 25% open space.

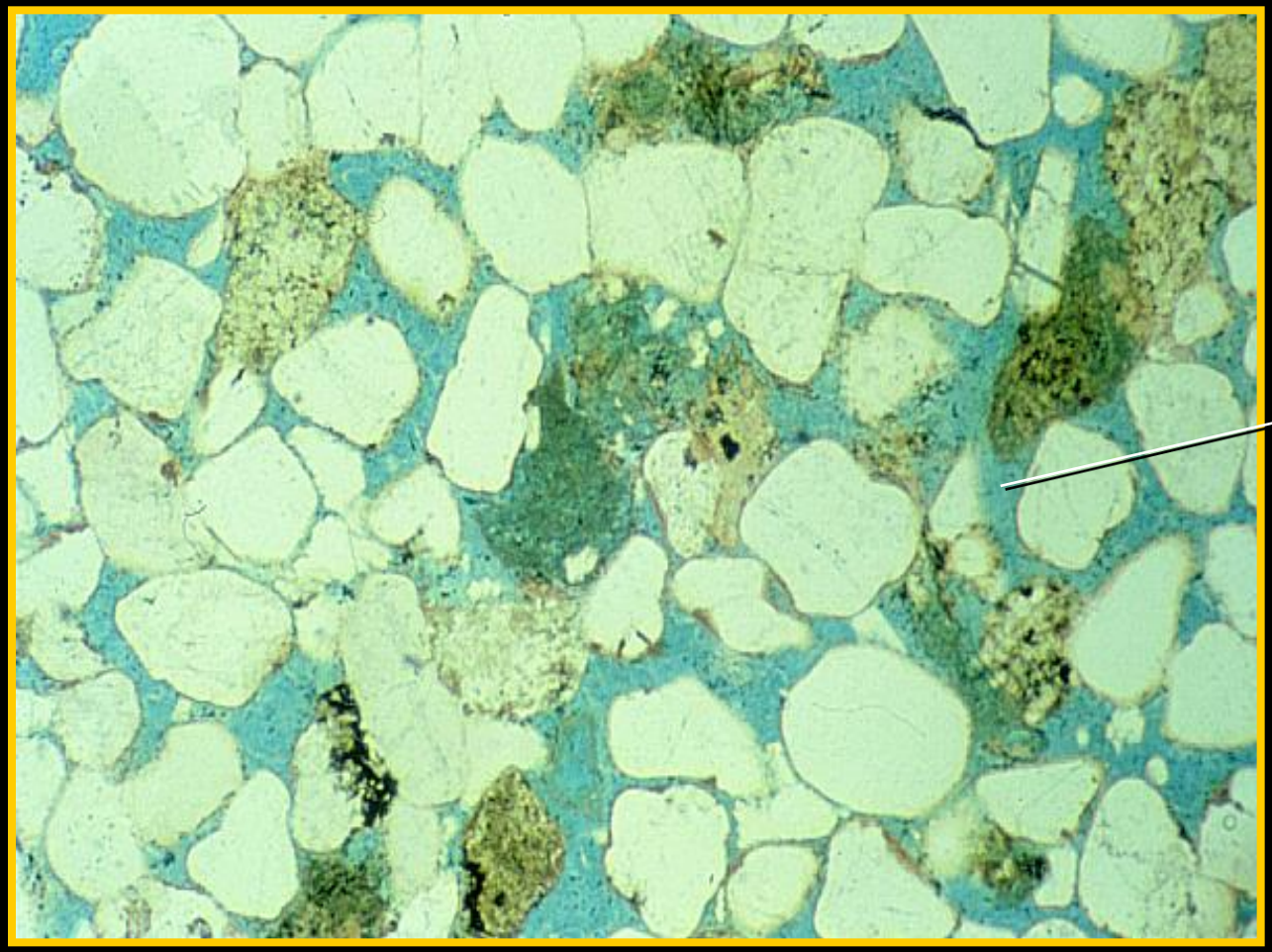
Porosity is denoted by the Greek letter *Phi (Φ)*.

Porosity depends on the nature of its sand grains **(clasts).**



Stacked, same–size spheres

Reservoir Sandstone



Good porosity = lots of space for oil

Permeability

Inter-connections of pore spaces.

Vugular and fracture porosity may have very high permeability.

Inter-granular permeability is highly variable.

Permeability is the first test run on a new field.

Fluid Saturation

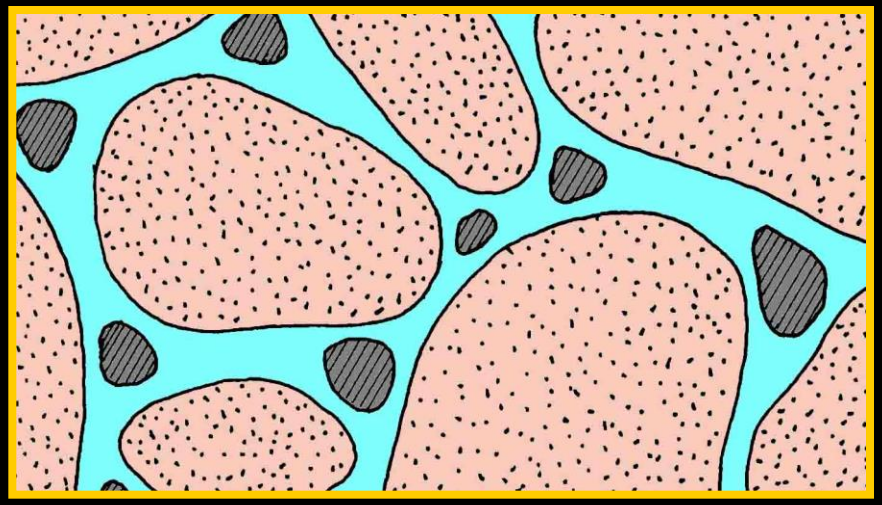
Sediments laid down in the ocean and salt water occupy pore spaces.

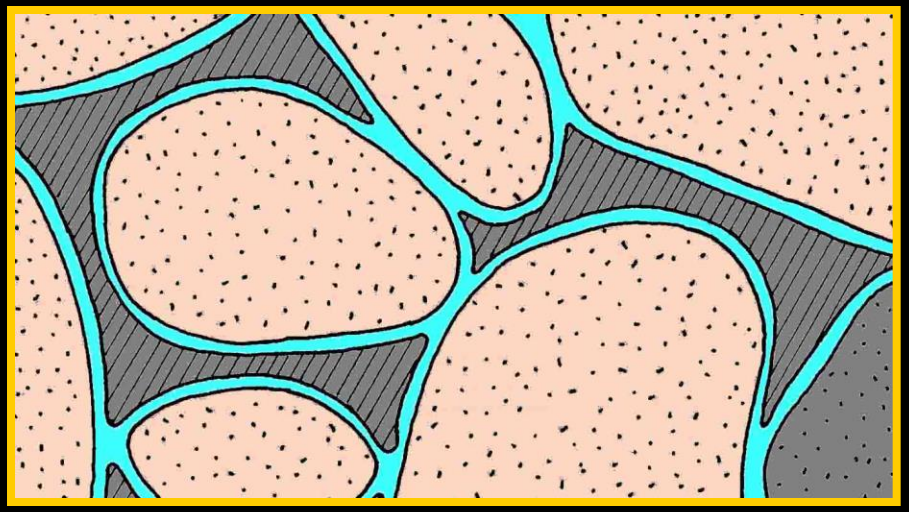
Salt water remains unless it has been displaced by gas, oil, or water.

Displacement is slow, and in most reservoirs the process is not complete.

Fluid saturation affects the amount of pore space available to be filled with oil or gas.

Fluid Saturation
Relative Permeability





Water and oil co-exist = 25% oil, remainder is water.

Discrete oil globules will not flow.

Water is continuous between pores and will flow.

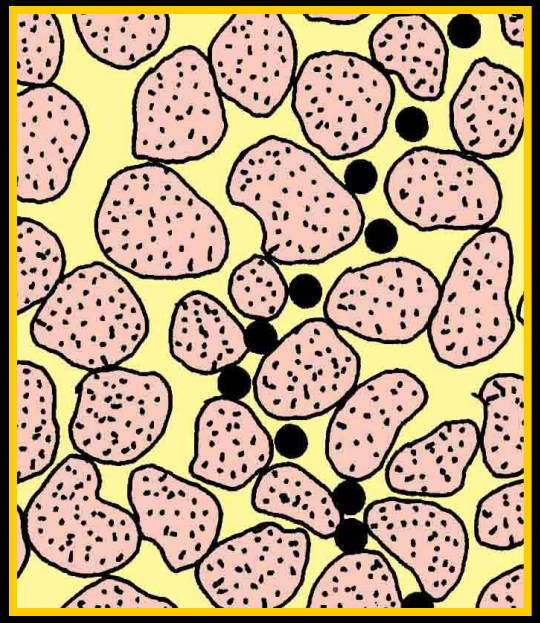
Therefore only water in well will flow.

Oil saturation in pore spaces is 80%, and will flow.

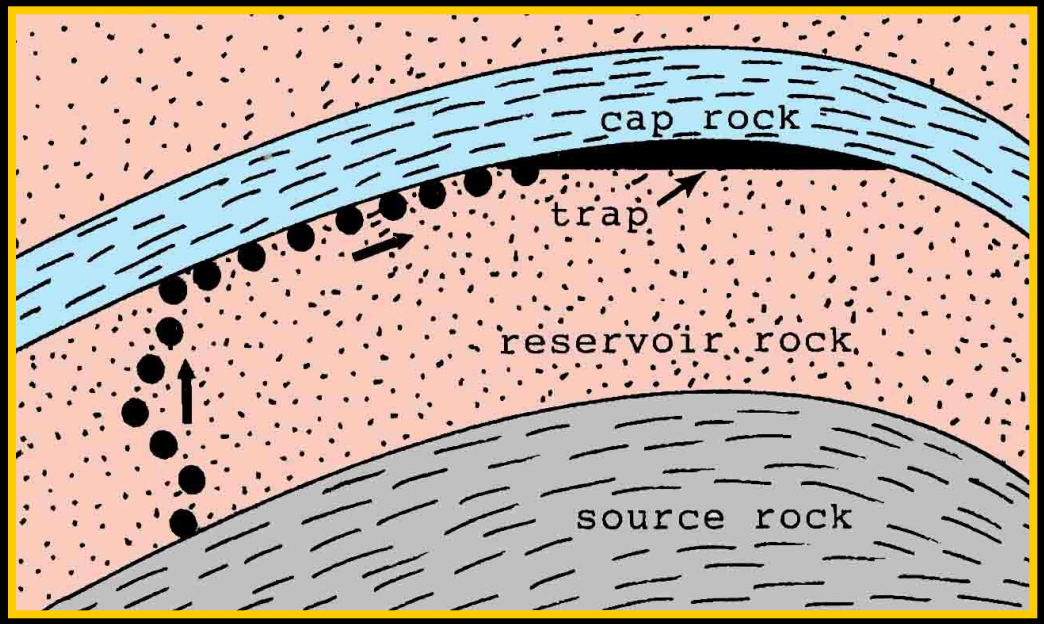
Water is bound to grains by capillary forces, and therefore only oil will flow.

Well will produce 100% oil.

Vertical and Horizontal Migration of Oil to Trap (Reservoir)

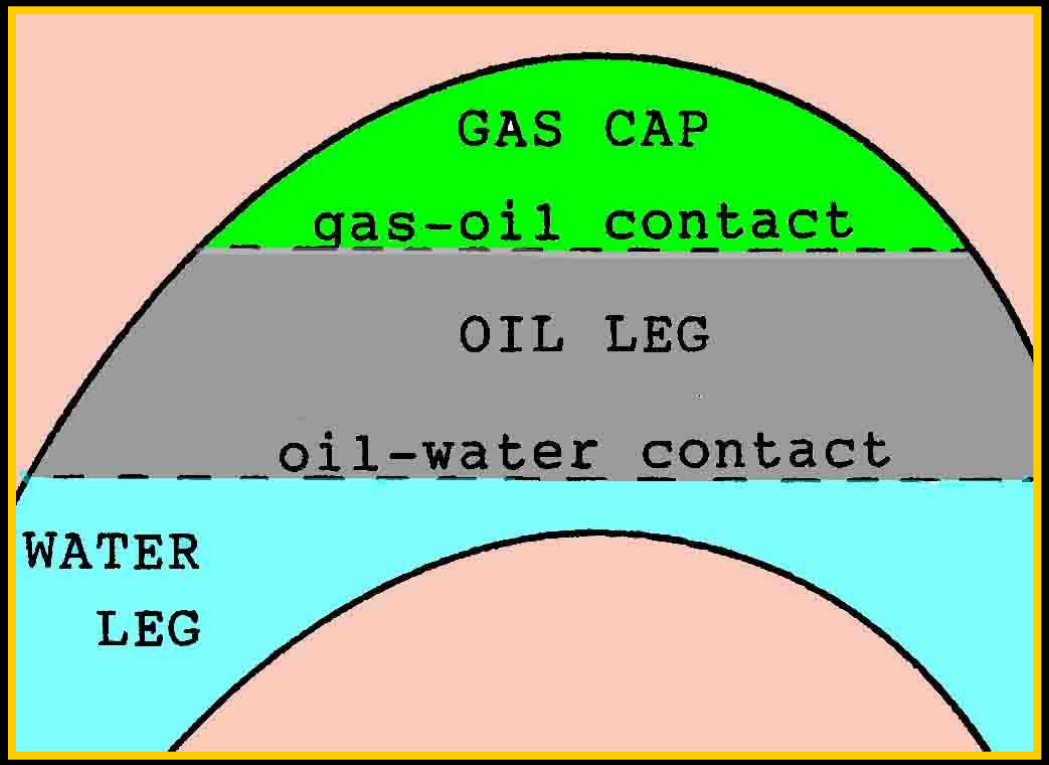


Expulsion and Vertical Migration



Cap rock = impermeable layer halts upward migration

Hydrocarbon Distribution within a Trap

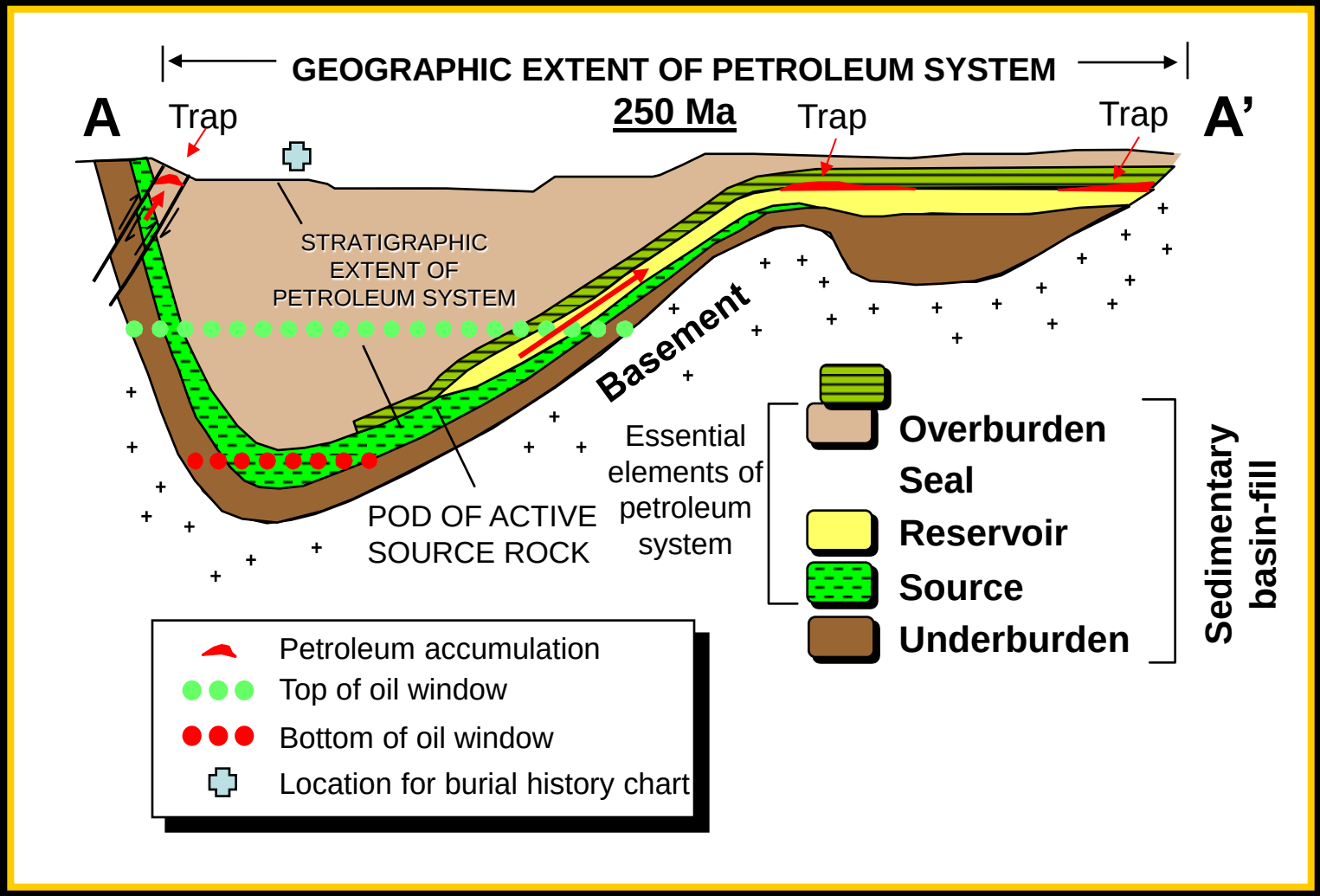


Fluid density results in separation into distinct horizons referred to as legs.

Some traps will have all three legs, whereas some traps will not have initial gas caps

Petroleum System at Critical Moment

(Critical Moment = Time of Expulsion/Migration)



Magoon and Dow, 1994

Anadarko Basin, Oklahoma