Quick review of energy/power

Lecture 3

A real life example

	Force	Energy=Work done	Power= Rate of doing work
MKS	Newton e.g. 1 KG weight suspeded in gravity by a string exerts a force 9.8 Newtons	Joule = Newton Meter e.g. 20 KG suitcase pulled up by 10 meters costs ~1960 Joules	Watt= Joule/sec e.g. if the suitcase is hauled up in 3.25 mins (~190 sec) power used in 10 Watts!
FPS	Pound (lb)	Foot pound (ft lb) 1Joule = 1.32 ft lb The FPS system can be very confusing since pound is used in many contexts: Our strategy is to convert ft-lb to Joule as fast as we can!! In above example the work done is ~2500 J = 2.5 KJ	Horse power = 550 ft lb/sec Convert to Watts using 1 HP= 746 Watts In above problem the "puny human" uses a horse power ~.013

Getting used to Watts, Watt hours and Joules

Watt is a power unit and Joule is an energy unit E= P x t (Power in watts t in seconds)

$$1\ kWh = 1000 \times 3600 = 3.6 \times 10^6 J = 3.6 MJ$$

A suitable unit for measuring power from nuclear plants is **Gigawatts:**
We next convert the power into energy per year from the biggest Nuclear plant.

Palo Verde Power Plant, is a nuclear power plant located in Wintersburg, Arizona, about 45 miles west of central Phoenix. It is currently the largest nuclear generation facility in the United States, averaging over 3.2 Gigawatts (GW) of electrical power production in 2003.

Power plants reckon production by GigaWatt

Note the units:
1gigawatt= 10^9 watts

1 year has 3.15 x10^7 secs
or
8760 hours.

Total power calculation:
This figure gives us the power available on average through 2003.
If we want the total power during the year 2003, we multiply by
3.15 x10^7 secs (the number of seconds per year)
to get 1.008 x10^{17} Joule
This is better expressed in terms of Watt hours:
(1kW Hour= 3.6x10^6 J) as
2.8x 10^{13} WattHours= 28 TWH

Tera= 10^{12}

Recall that the total electrical power generation in the US in 2010 is 3992 TWh

Total energy usage 100 Quads per year. Since 1000 TWh= 3.41 Quad, 28 TWh= .09 Quad. Hence we need about a thousand such power stations to fulfil the needs of the US.

$\text{Mega Watt} = 10^6\text{Watts}$ $\text{Giga Watt} = 10^9\text{Watts}$ $\text{K Watt hour} = 3.6 \times 10^6\text{Joules}$

Some occasionally used special energy units

Toe Tonne equivalent of energy obtained by burning 1 metric tonne of a standard crude. 1000 MToe= 40 Quads	1 Toe	6 Giga Joule or 40 x10^6 BTU
Therm Unit used e.g. in power and utilities bills for homes.	1 Therm	10^5 BTU = 29.3 KWh

PG&E Bills

Electricity Usage (July 2010): 405 Kwh   Charges: $54.84   (@).1188 / Kwh (first 215) then @ .2902 /Kwh

Gas charges   :29 Therms   Charges: $4.22   @1.09 /Therm

Compare: After rounding off Gas is ~$4 for 30 KWh, i.e. .133 /KWh

Forms of energy
Summary of types

a) Chemical energy : Combustion (Burning of coal, wood, gas..) Sources: carbon and hydrogen based, batteries
b)Heat energy: Heat = energy (Thermodynamics)
c)Mass energy: $E= M c^2$ Einstein: nuclear energy 1.gm lead is 9×10^{14} J (enormous!!)
d) Kinetic energy (energy of kinetic motion can be converted to heat) $1/2\ mv^{2:}$
e)Potential energy: Dams Hydroelectric, gravity
f) Solar energy= Electromagnetic energy
g) Electrical energy: Invisible yet powerful: motors, DC (direct current) and AC (alternating current):
AC related to time dependent fields,
DC related to PE: Q V = PE in a battery; partly chemical

Heat energy examples:

Food is energy too and we are mostly water!!

What about my 2000 C Diet plan?

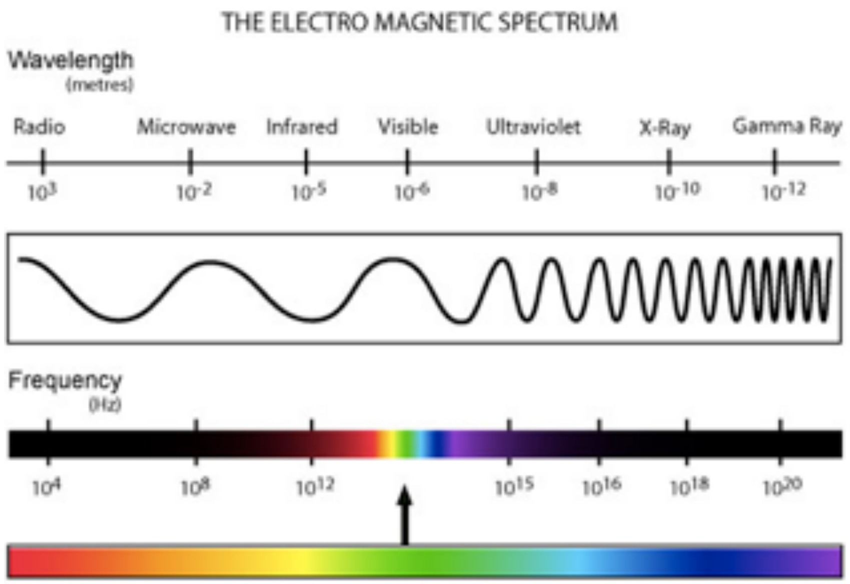
Kilocalories not calories: 1C= 1Kc= 10^3 calories

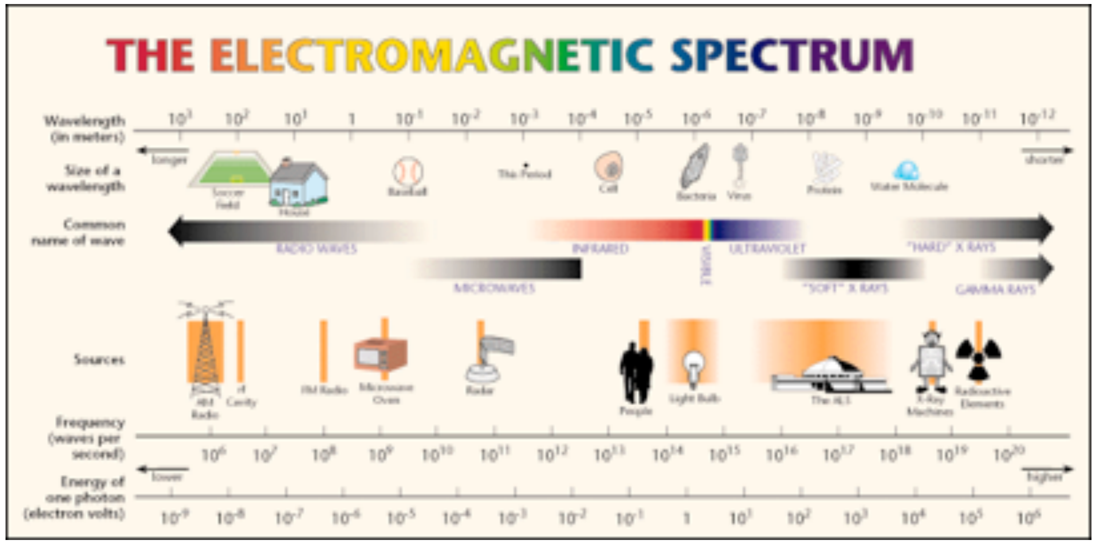
Human with weight 70 kgs eats 2000C/day: How much energy can this supply?

70kgs water = 7x 10^4 gms water

$$\Delta T = \frac{2 \times 10^6 \text{ calories}}{7 \times 10^4 \text{ gm}} \sim 29^0 C$$

The Electromagnetic Spectrum





Basic theory and formulas:

EM spectrum consists of different wavelengths. Colors correspond to different wavelengths. VIBGYOR of high school science.

$$E = \frac{hc}{\lambda}$$

or

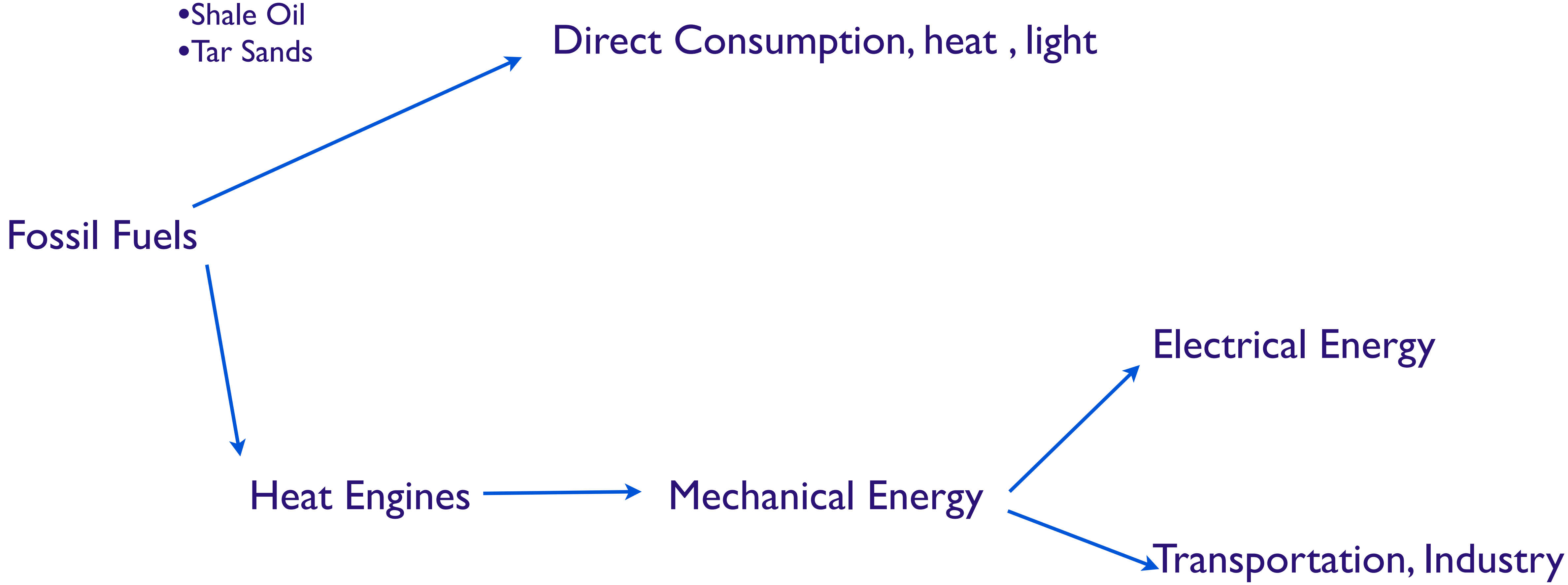
$$E = h\nu$$

E = energy of light (photons)
h = Planck's constant 6.63x 10^{-34} J x sec
c= Velocity of light 3x10^8 m/sec
λ = wavelength in meters
ν = frequency Hertz (=inverse sec)

Example: freq = 10^{13} Hertz energy = 6.63 x10^{-23} J (!!small)

Fossil Fuels

- Petroleum- History and production information
- Petroleum Resources and their depletion: M K Hubbert's thesis
- Petroleum Refining: some facts.
- Natural gas:
- Coal:
- Shale Oil
- Tar Sands



Energy is transported in lossy ways: need to study these mechanisms

Brief introduction to Fossil Fuels FF
Occurrence to extraction

Overview of Geophysical and other processes

- Most of the continental land was actually ocean floor 100 million years ago. Continents rose and oceans receded where we live today.
- Plant life/organic matter deposited on the then ocean floors 100 million yrs ago.
- Organic matter gets "digested" by bacteria
- Sand deposition and mud create high pressure and Temperature conditions that fluidize + some solid hydrocarbons
- Liquids and gas flow through porus sedimentary rocks: yes rock are very permeable: ask any water diviner
- Natural gas and oil collect in geological traps or are accreted in sandstone
- Use sound echoes to locate oil: differences in rock composition give rise to reflection of waves
- Wildcat drilling (i.e. exploratory drilling) success rate 1 out of 9!
- Establish existence of oil hence estimate "proven reserves". (reservoir modeling)

Oil - *the uncertain energy source*

The oil and gas we have today was formed in the distant geological past. Microscopic organisms like photo plankton and algae had excessive growth in warm eras in the past. Such warm eras were there 90 to150 million years ago. The dead organisms which sink cause organic debris to be formed. The debris are buried under the sedimentary load brought in by the rivers flowing into the sea. When the debris are buried deep and are subjected, over extended period, to high pressure and temperature, oil is formed. Oil, being lighter than water, moves up along the porous rock till the impervious rock checks the movement and forms a trap for the oil.

Oil is found in such traps. The geological and geophysical data collection and analysis helps explorers in locating such traps in the sub surface. This is a natural process and we can not, in any manner, make it happen. So, whatever was formed in the past and were preserved during the intervening geological upheavals, are the only oil deposits we can discover and produce.

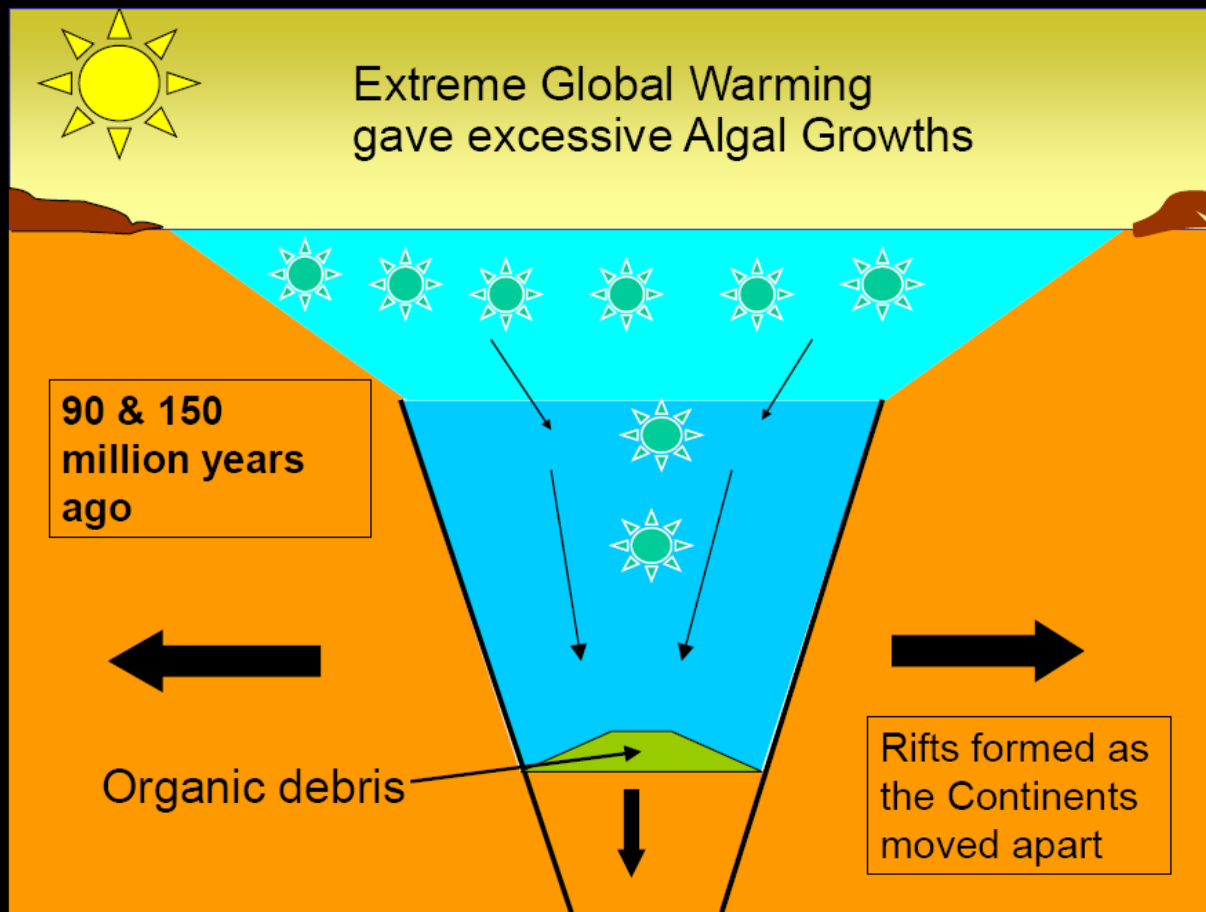
The process takes place in relatively deeper basin areas. There are 500 odd sedimentary basins in the world. About half of them are known to be productive. It is not necessary that every sedimentary basin will be prone to form and preserve oil deposits. The life cycle of oil reservoir formation is of millions of years.

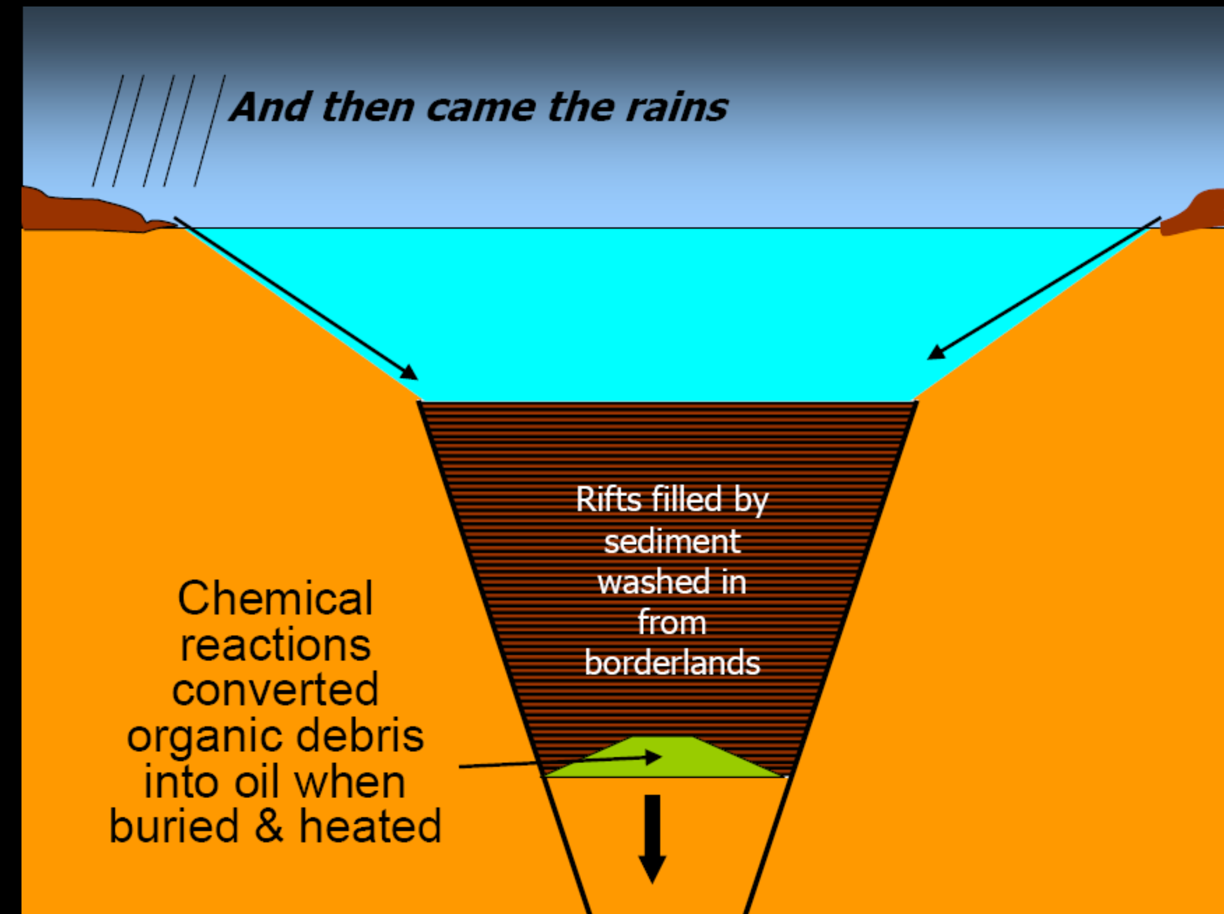
The very fine-grained shale is one of the most common sedimentary rocks on earth. In many places, thousands upon thousands of feet of shale are stacked up like the pages in a book, deep underground. It is not unusual to have layers in the earth's crust made up mostly of shale that are 4 miles thick. These shales were deposited in deep, quiet ocean waters over millions of years time.

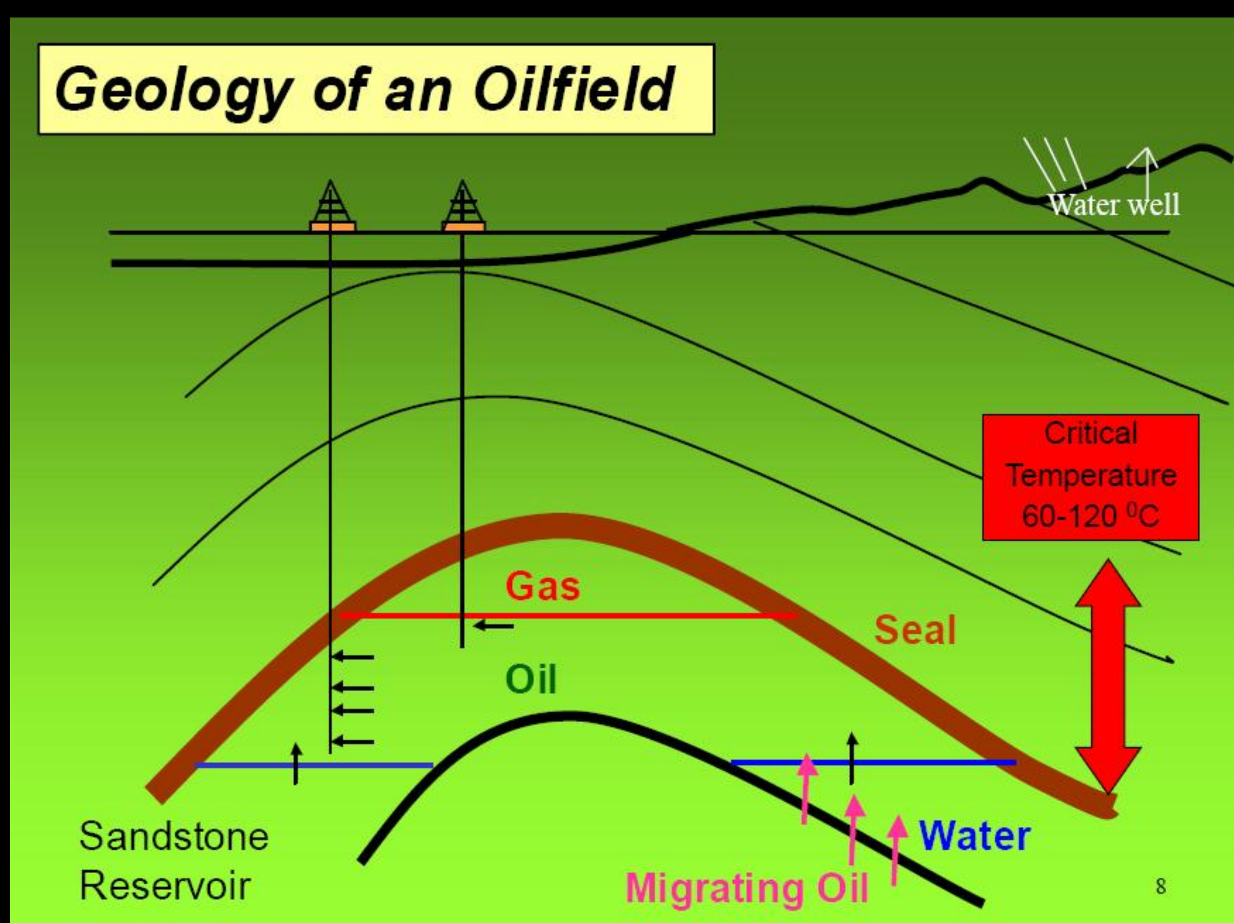
During much of the earth's history, the land areas we now know as continents were covered with water. This situation allowed tremendous piles of sediment to cover huge areas. The oceans may have gone away from the land we now live on, but the great deposits of shale and sandstone remain deep underground....right under our feet!

We often think of sharks and whales as being the kings of the deep oceans. Actually, there are other animals that have established giant kingdoms in the sea...the largest and most impressive kingdoms of all! These animals are various kinds of microscopic creatures....both plant and animal. Most of them would fit on the head of a pin. They are tiny, but there are trillions upon trillions of them. When these creatures die, they sink to the bottom and become part of the shale sediments there. The animals die and rain down on the ocean floor all the time. And since the beginning of life on earth, they have been living their exciting lives in the ocean, dying, sinking to the bottom, and becoming part of the once-living matter that is part of all shale rocks.

Later, when thousands of feet of shale have piled up over millions of years, and the animal bodies are buried very deep (more than two miles down), an amazing thing happens. The heat from deep inside the earth "cooks" the animals, turning their bodies into what we call hydrocarbons......oil and natural gas.



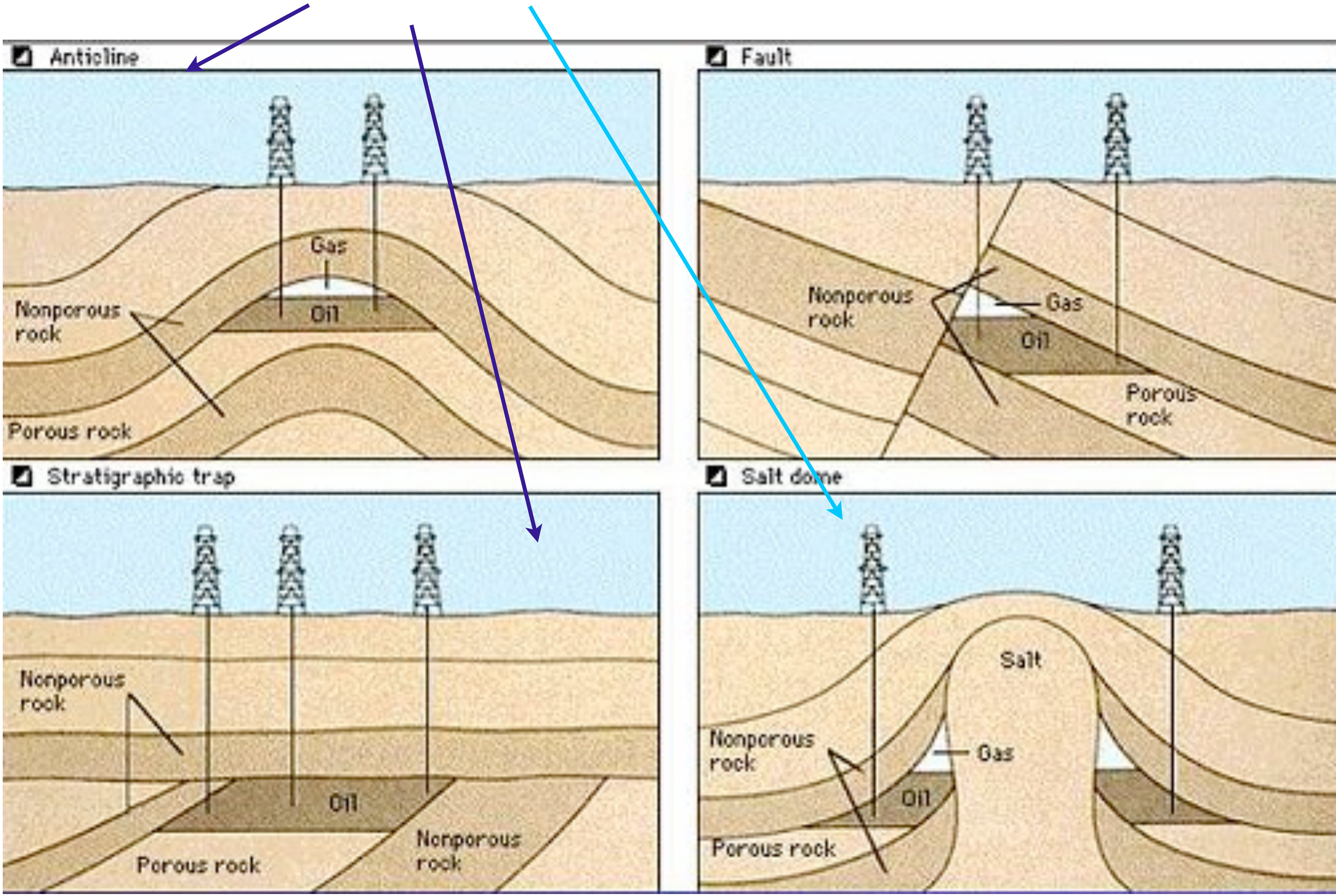




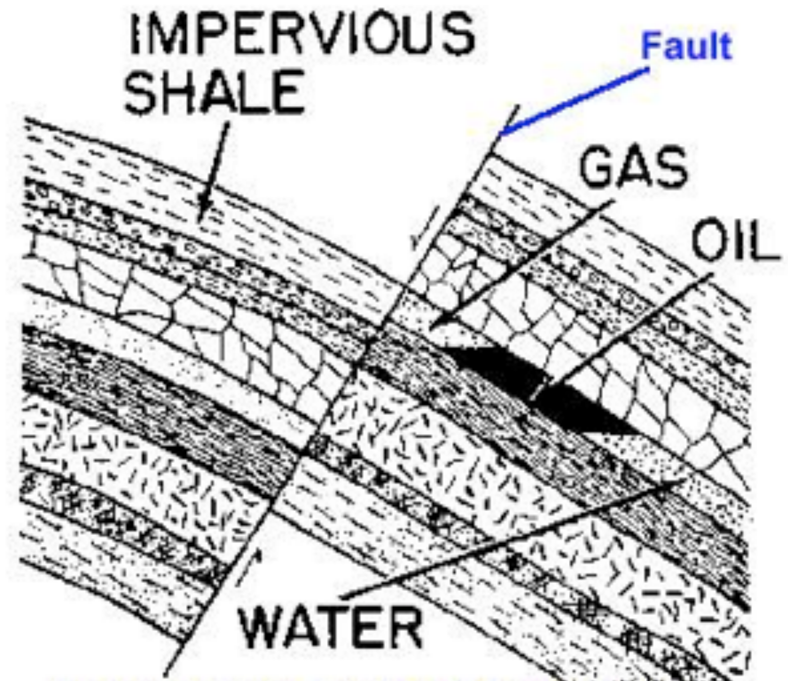
The Formation of Oil and Gas over millions of years under the surface of the earth.

Offshore oil

Structural traps

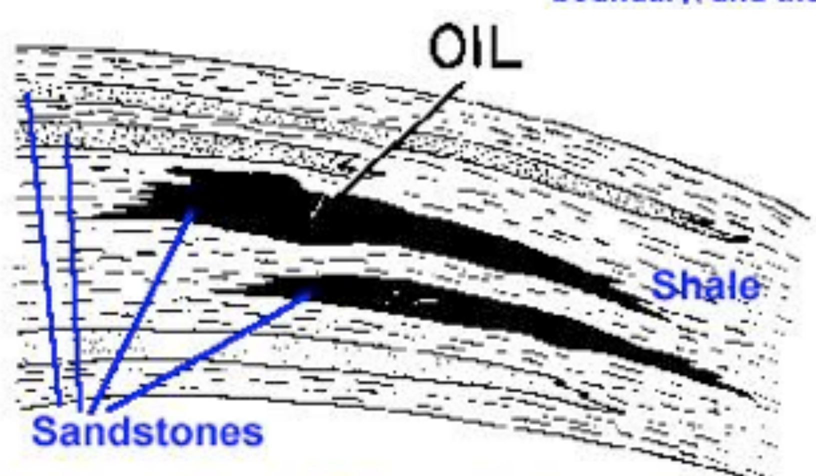


Structural traps hold oil and gas because the earth has been bent and deformed in some way. The trap may be a simple dome (or big bump), just a "crease" in the rocks, or it may be a more complex fault trap like the one shown at the right.



A structural trap. Faulting in the earth has caused vertical movement of the rock layers. Gas and oil cannot pass through the fault boundary, and they are trapped.

Stratigraphic traps are depositional in nature. This means they are formed in place, usually by a sandstone ending up enclosed in shale. The shale keeps the oil and gas from escaping the trap.



A stratigraphic trap. Oil is trapped in two sandstones which are surrounded by shale. The shale prevents the oil from escaping.

At present we are extracting a small part of available gas from a given reservoir: lot of physics goes in here

- Normal extraction: 30% max comes out as gas 70% remains
- Secondary recovery: Pump water or gas into surrounding area to get another 15%
- Ternary recovery: Problems are viscosity of oil and surface tension with rocks:

Viscosity is the rate at which things flow. We can manipulate this with high pressure CO_2 or O_2 pumped into reservoir. Occasionally the oil is burnt in part, so as to heat up the remaining oil which will then flow more easily out of the rocks and into our cars. Physics of viscosity is very important here

Surface tension. The oil is trapped in the pores which are clogged up! To get it out, add detergent and then flood with water + polymers (surfactants). Sounds familiar???? Washing machine ideas

Environmental damage due to ternary recovery is often a serious issue!

Cost Issues

Q: At $4. per gallon, is gasoline cheap or is it not?

A: Compared to all other industrialized nations US and Canada have the cheapest gas by factors of 2 or 3!
In 2002 US taxed $0.40 per gallon compared to $2.80 in Europe and much of Asia.

Saudi and other OPEC countries and Russia have enormous reserves and are producing fast hence the cost is low!!

- USA imports more than 50% (cheaper since OPEC is producing more copiously).
- Low taxation hurts since # cars increases. Deeply political issue in USA more emotion than logic.
- Efficiency has gone up: 2000 /28 mpg 1973/13 mpg (1947-1966 my family Oldsmobile gave 3 mpg boosted to 7 mpg by making many changes!! some quite unbelievable feats of "home engineering"