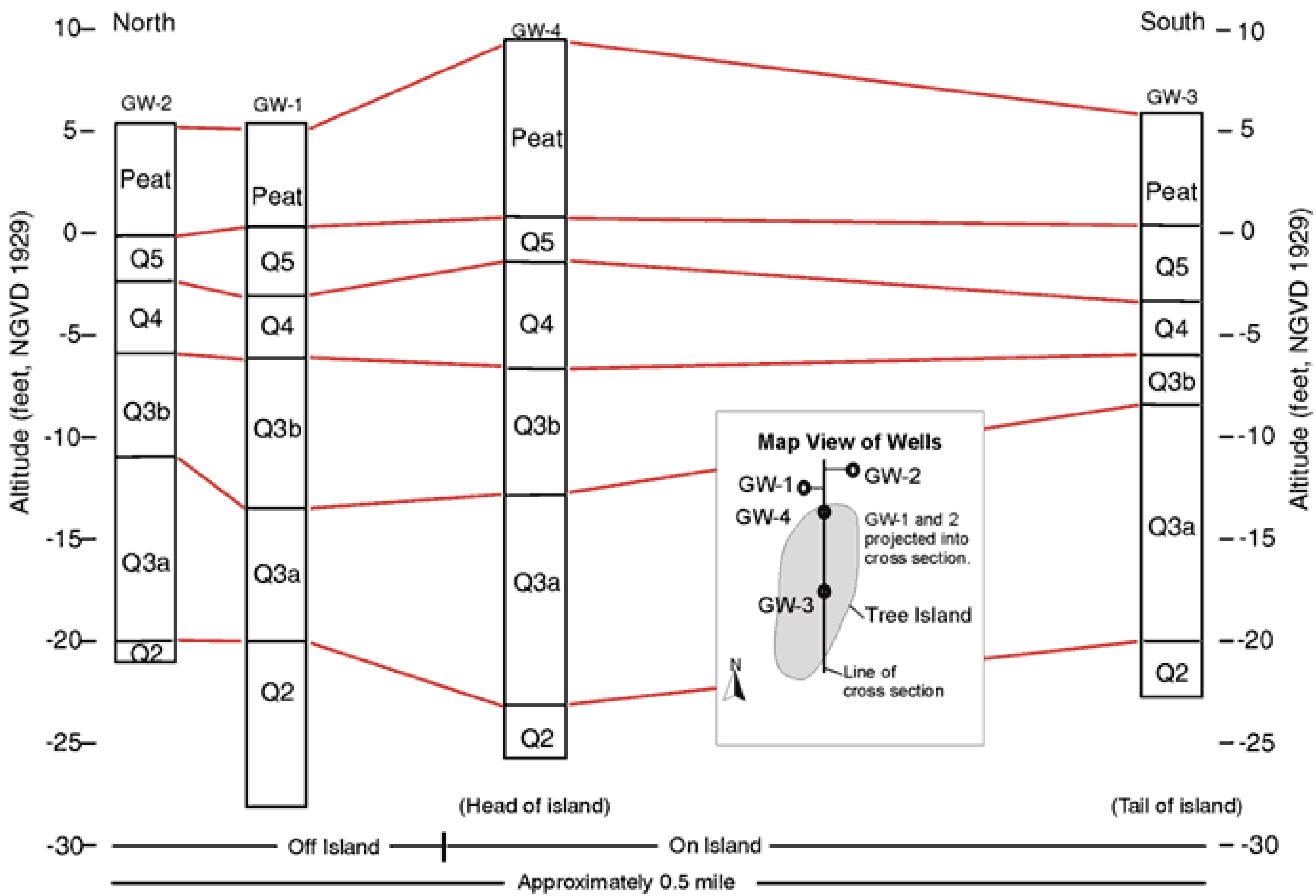
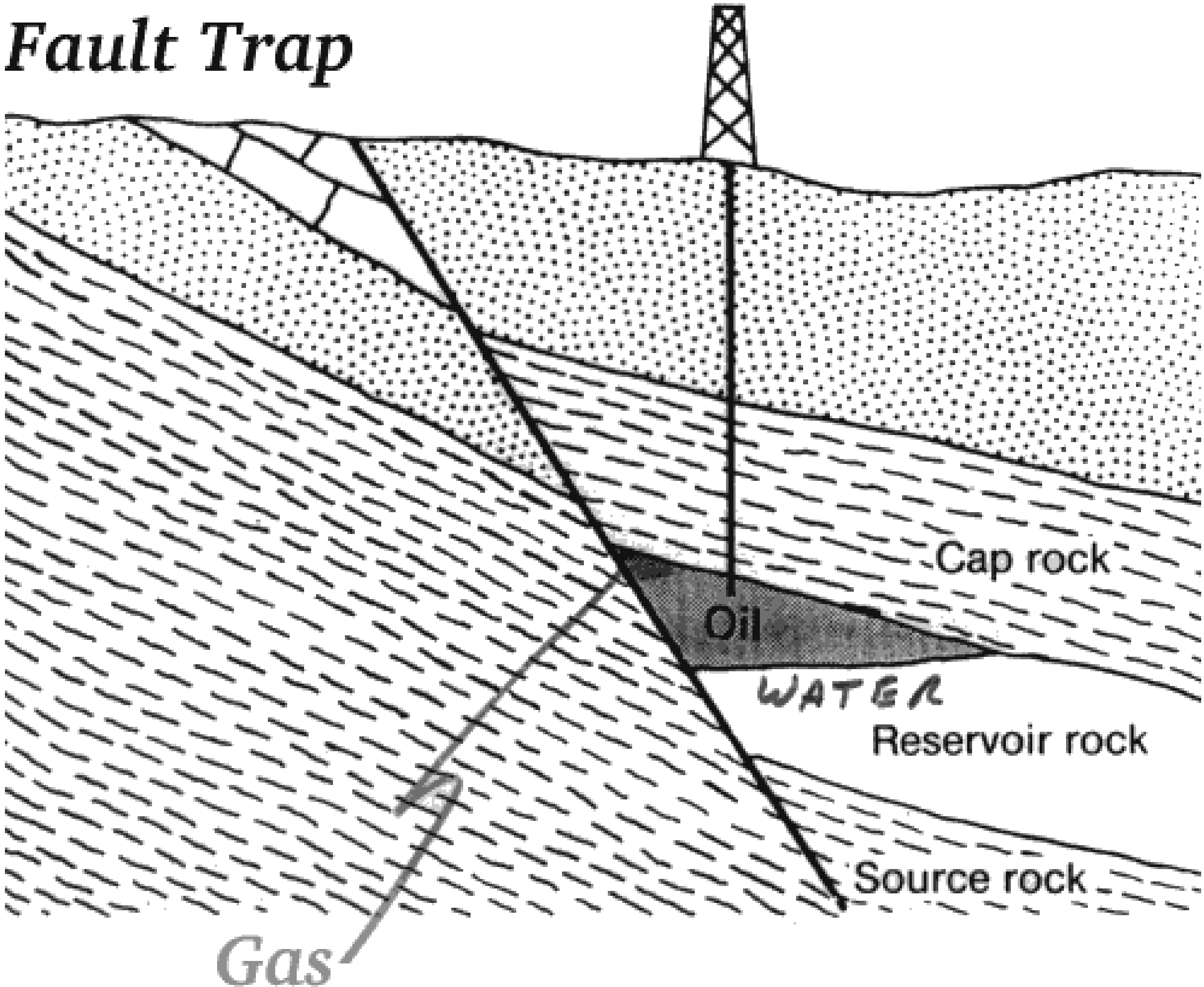
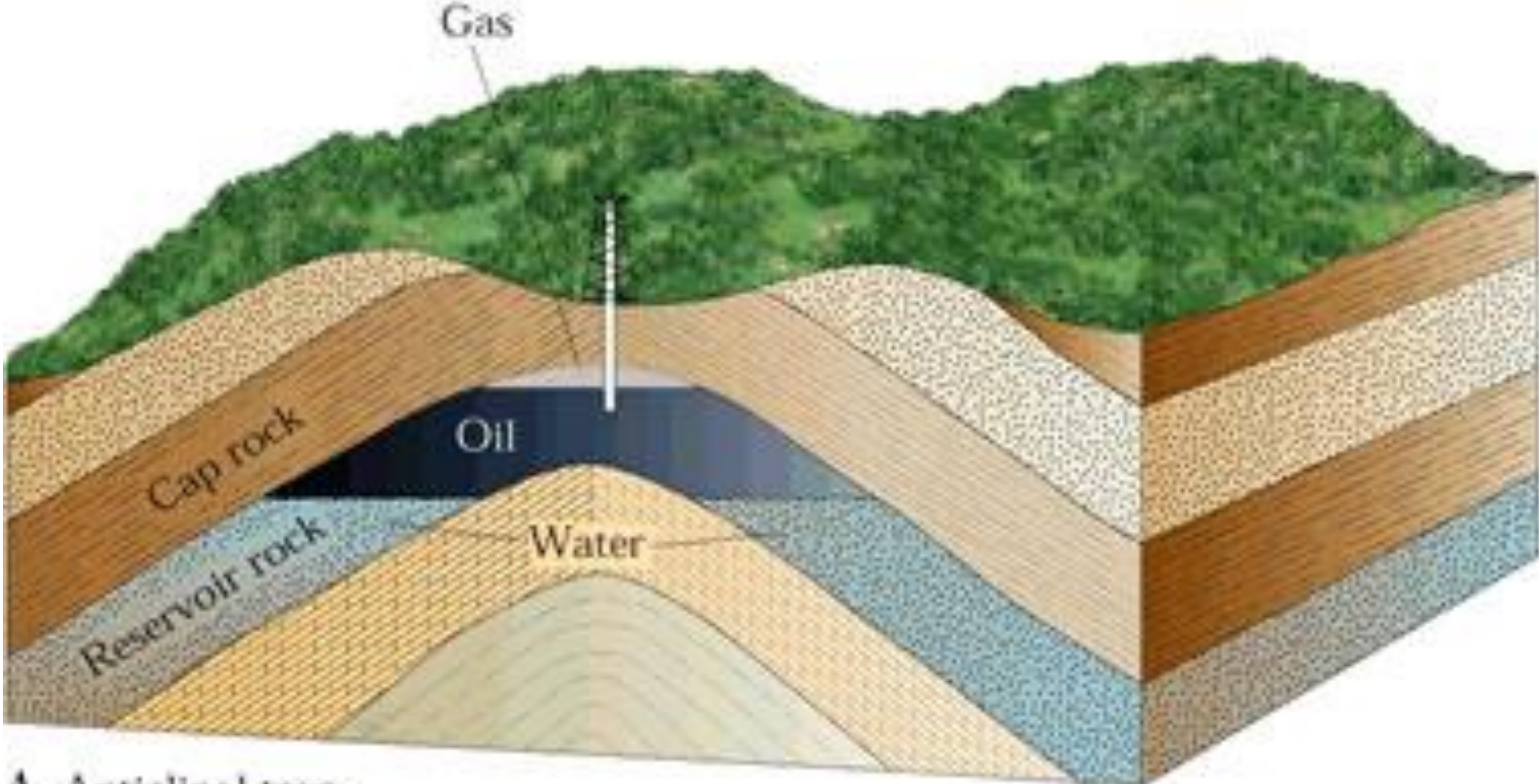
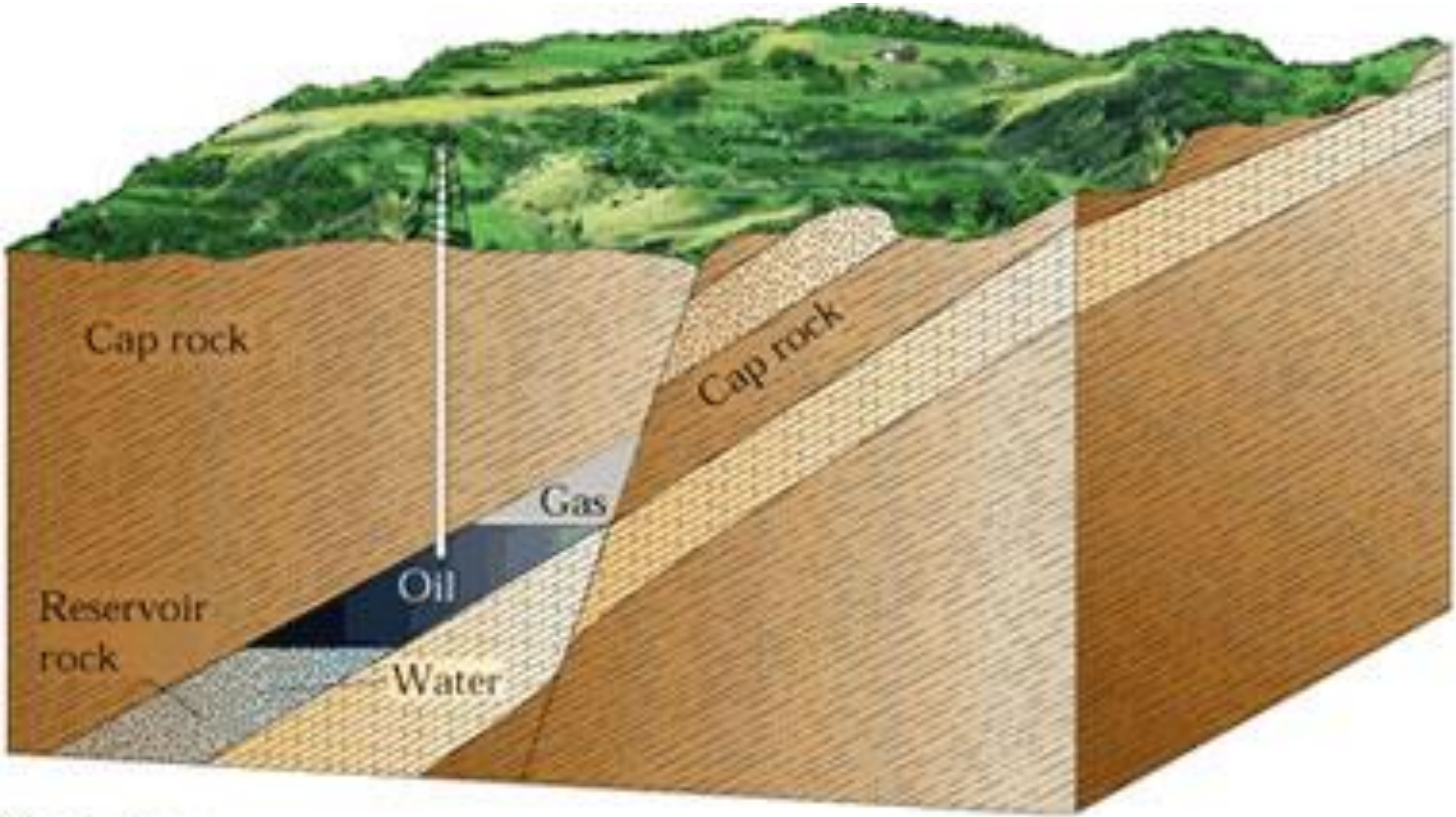

North
South
Altitude (feet, NGVD 1929)
10
5
0
-5
-10
-15
-20
-25
-30
GW-2
GW-1
GW-4
GW-3
Peat
Q5
Q4
Q3b
Q3a
Q2
Map View of Wells
GW-1
GW-2
GW-4
GW-3
GW-1 and 2 projected into cross section.
Tree Island
Line of cross section
N
(Head of island)
(Tail of island)
Off Island
On Island
Approximately 0.5 mile

Fault Trap

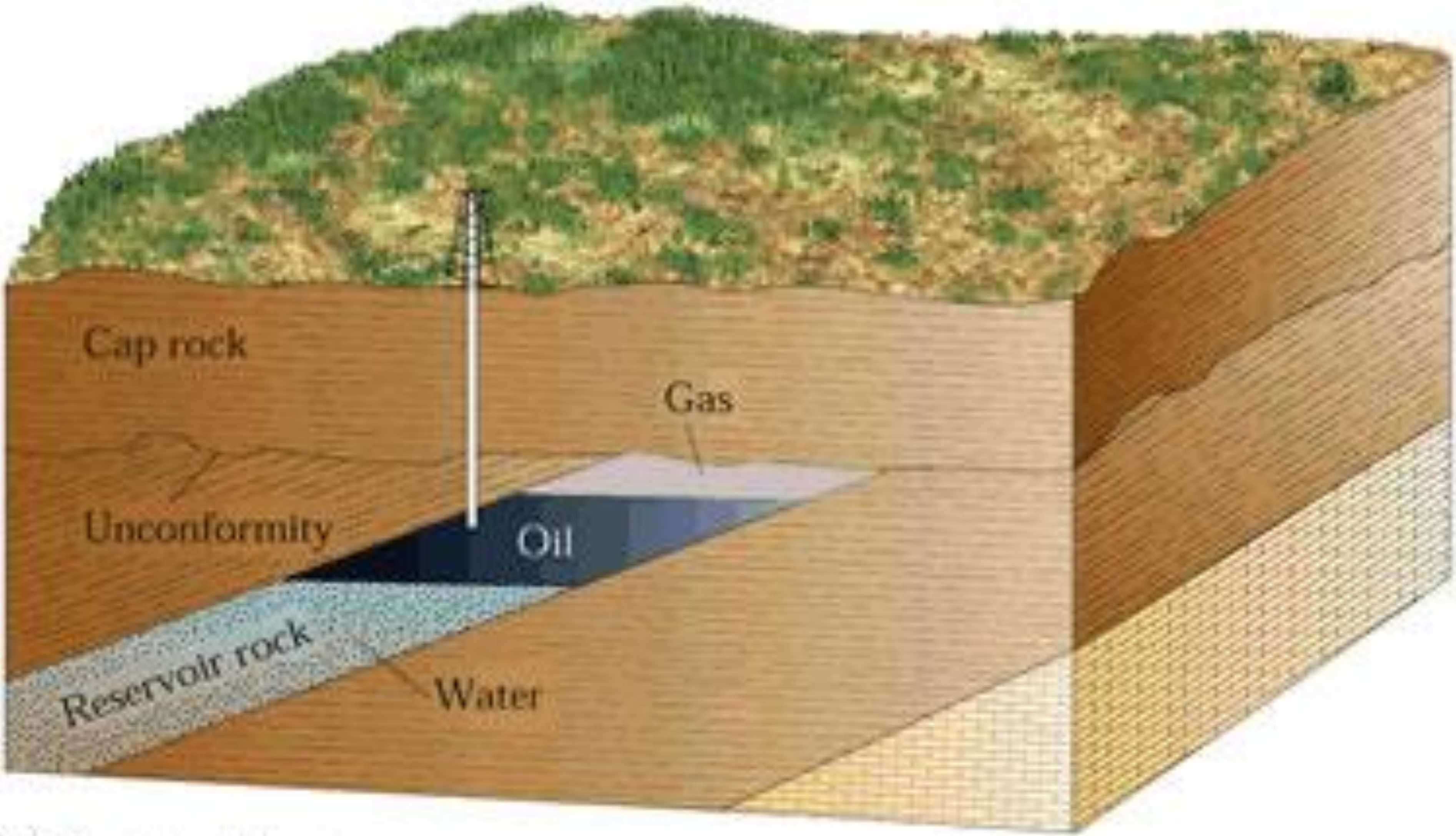




A. Anticlinal trap



B. Fault trap



C. Stratigraphic trap

Geologic Resources

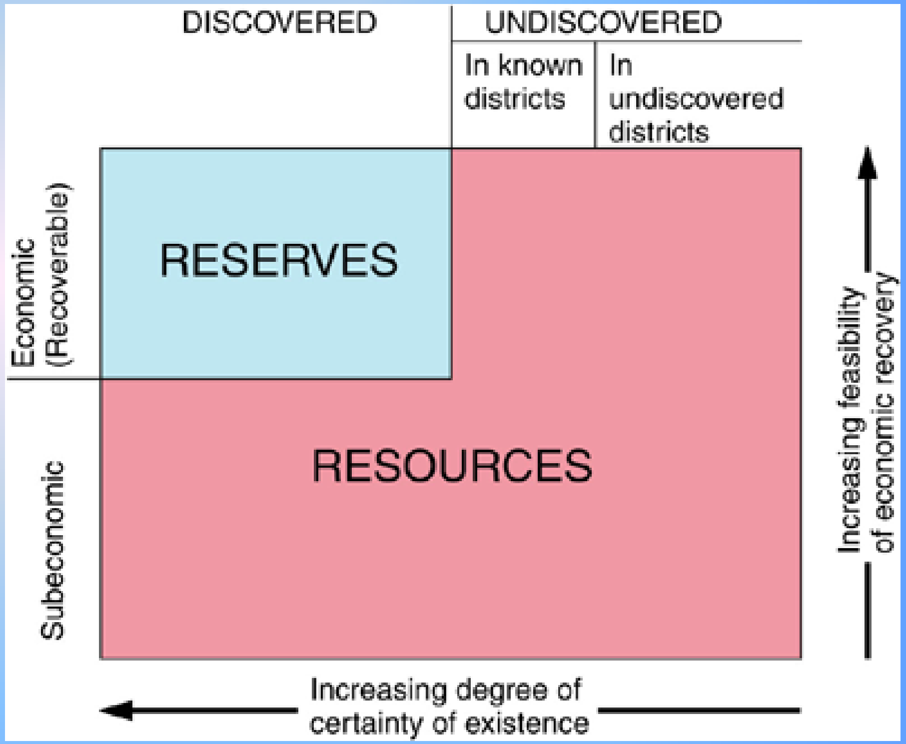
- ***Geologic resources*** are valuable materials of geologic origin that can be extracted from the Earth
  - Many geologic resources originate in the hydrosphere
    - Petroleum and coal come from organisms that lived and died in *water*
    - Halite (salt) and other evaporite minerals come from dry lake beds
  - Weathering interactions between geosphere, atmosphere and hydrosphere produce metal oxide *ores*
  - Humans (***biosphere***) interact directly with the geosphere, the hydrosphere, and the atmosphere when extracting and utilizing resources
  - Even ***water***, when found beneath the Earth's surface, is a geologic resource (renewable)

Types of Geologic Resources

- Geologic resources can be grouped into three major categories:
  - *Energy resources* - petroleum (oil and natural gas), coal, uranium, geothermal resources
  - *Metals* - iron, copper, aluminum, lead, zinc, gold, silver, platinum, etc.
  - *Non-metallic resources* - sand and gravel, limestone, building stone, salt, sulfur, gems, gypsum, phosphates, etc.
    - Groundwater is included in this category

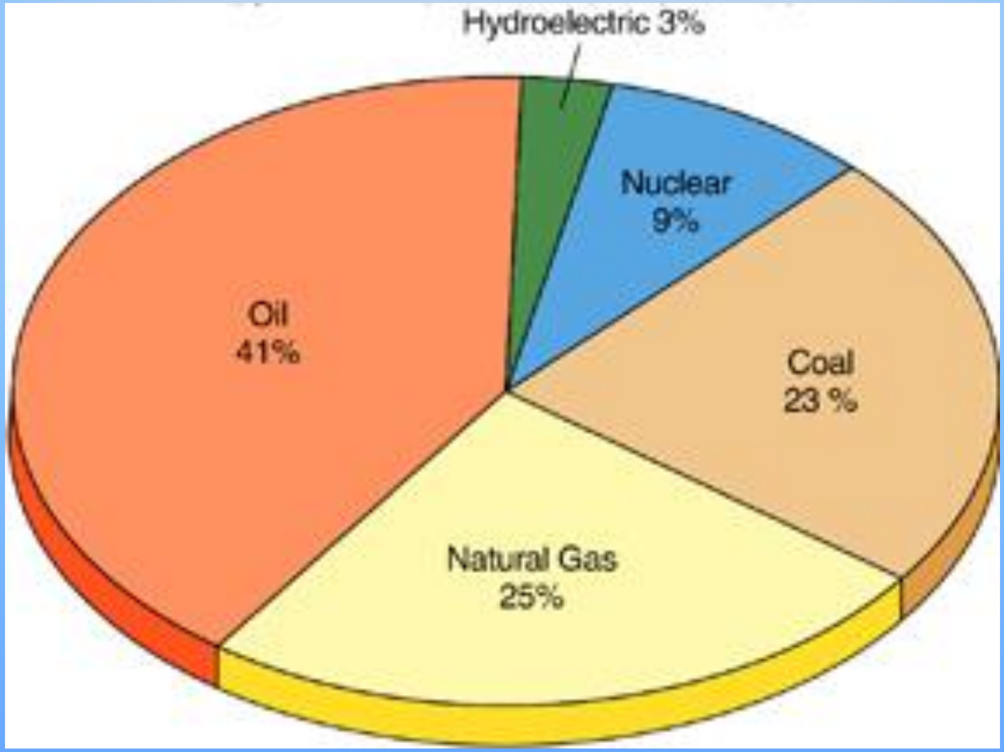
Resources and Reserves

- ***Resources*** - the total amount of a valuable geologic material in *all deposits*, discovered and undiscovered
- ***Reserves*** - discovered deposits of geologic resources that can be extracted *economically* and *legally* under present conditions
  - The *short-term* supply of a geologic materials



Energy Resources

- *Fossil fuels* (*oil*, *natural gas*, and *coal*) account for nearly 90% of U.S. energy



Petroleum

- The broad term used for oil and natural gas.
- Many geologists use the term petroleum is synonymous with crude oil.
- These are **nonrenewable resources** because they form so slowly that, at the present rapid rates of consumption, they easily become exhausted.
- **Petroleum**: The liquid mixture of naturally occurring hydrocarbons. It can be distilled to yield a great variety of products.
- **Natural Gas**: A *gaseous* mixture of naturally occurring hydrocarbons. Many wells that yield oil also recover natural gas.

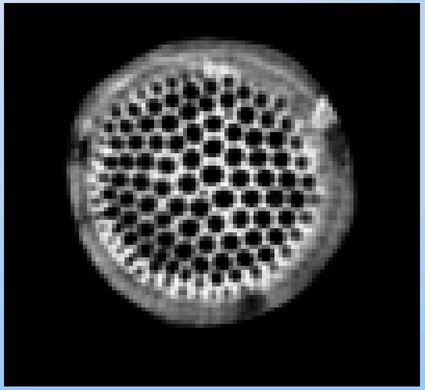
The Origin of Oil and Gas

- Originate from organic matter in marine sediment

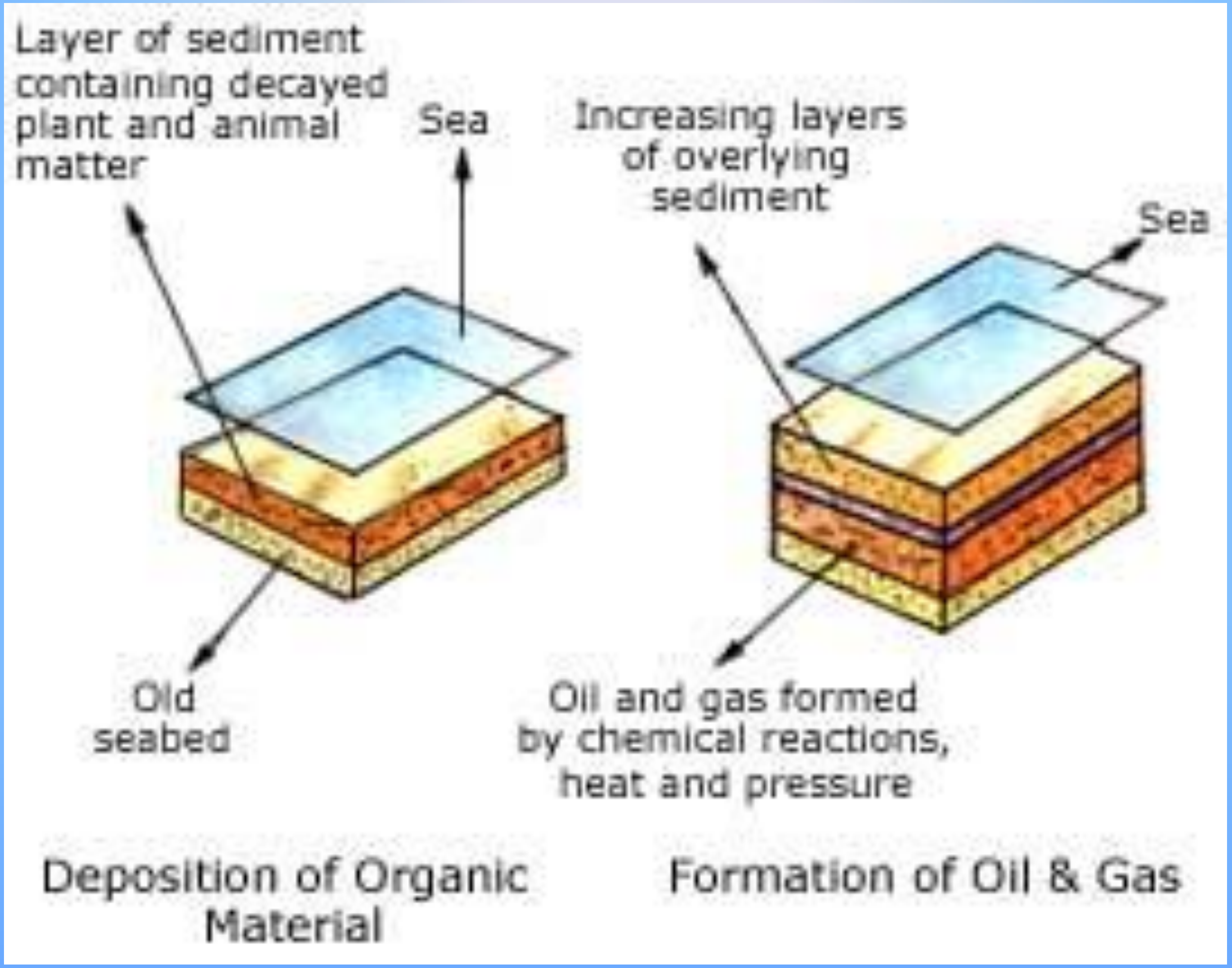
Microscopic organisms accumulate in the marine muds.

Diatoms

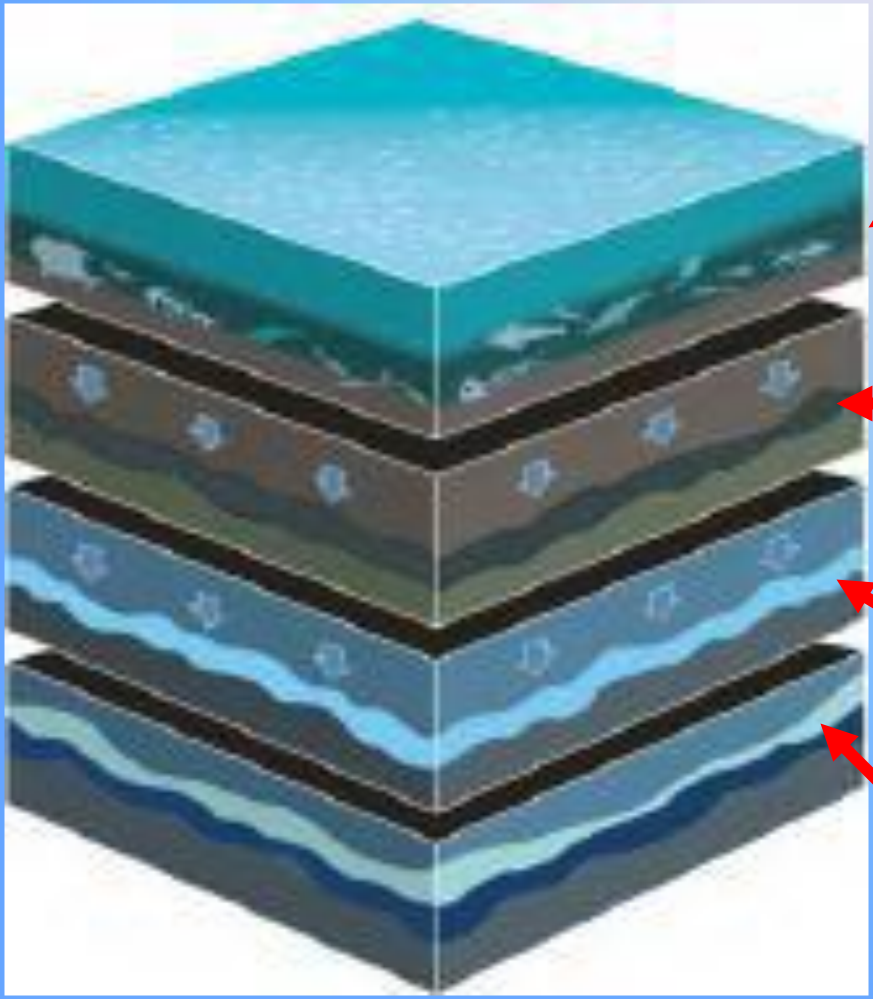
- Photosynthetic algae
- Opaline silica tests
  - Silt-sized
  - Round or oval-shaped
  - Two valves fit together like a box and lid



Oil Formation



Oil Formation



Marine plants and animals are buried and are broken down by anaerobic bacteria

Increasing heat and pressure converts fats into fatty acids, which are then changed into karagen, an asphaltic matieral

Further increases in temperature and pressure cause petroleum to form

Natural gas collects above the oil

The Occurrence of Oil and Gas

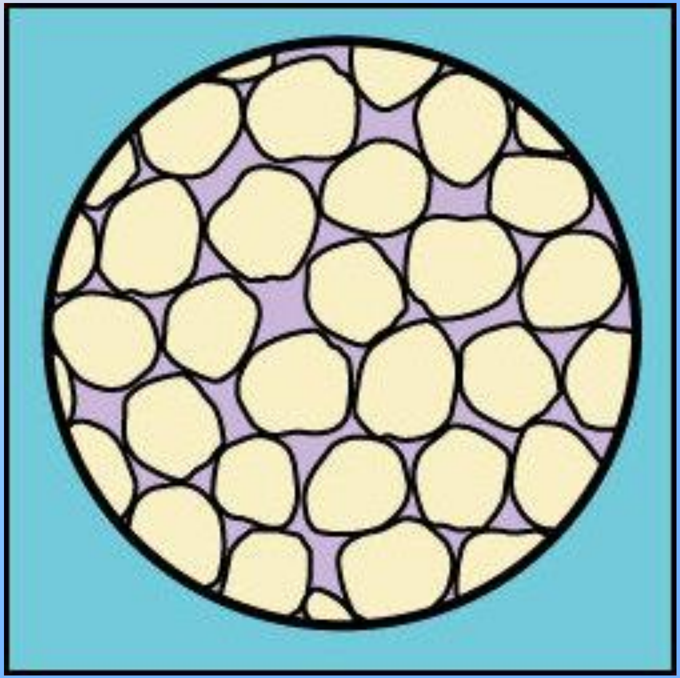
- **Valuable underground accumulations of oil found when the following four conditions occur together**

Source Rock

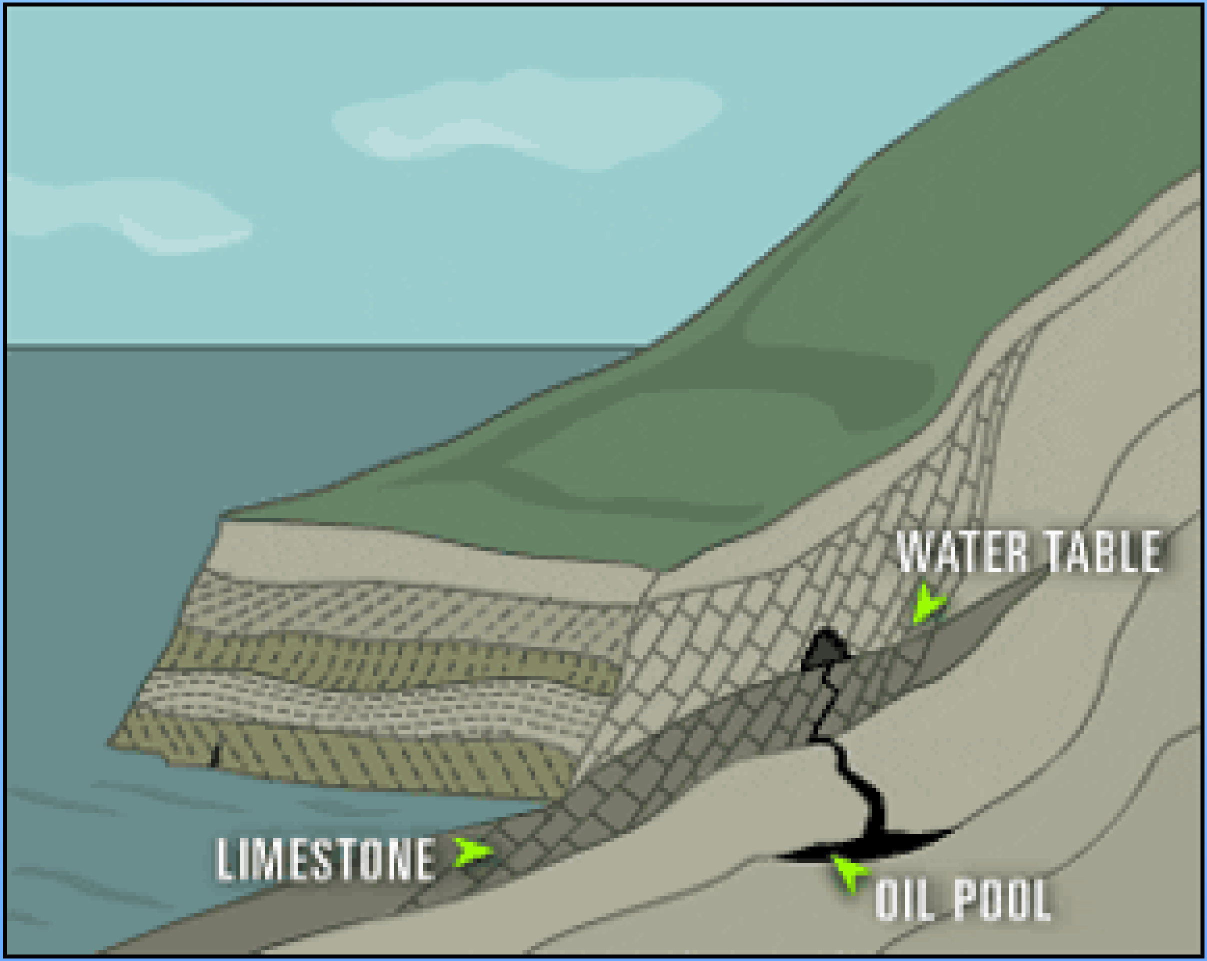
- Contains organic matter that is converted to oil and gas.
- It is often shale.

Reservoir Rock

- Must be
  - Porous: Able to store the petroleum
  - Permeable: Capable of allowing the petroleum to move throughout the rock
- Usually sandstone or limestone



Limestone and an Oil Pool



Thermal Maturity

- Burial must be deep enough to “cook” the oil and gas out of the organic matter

Oil Traps

- A set of conditions to hold petroleum in a reservoir rock
- Prevents oil from escaping by migration
- A trap rock is often shale, which is considered to be impermeable

Structural Traps

Geologic Structures

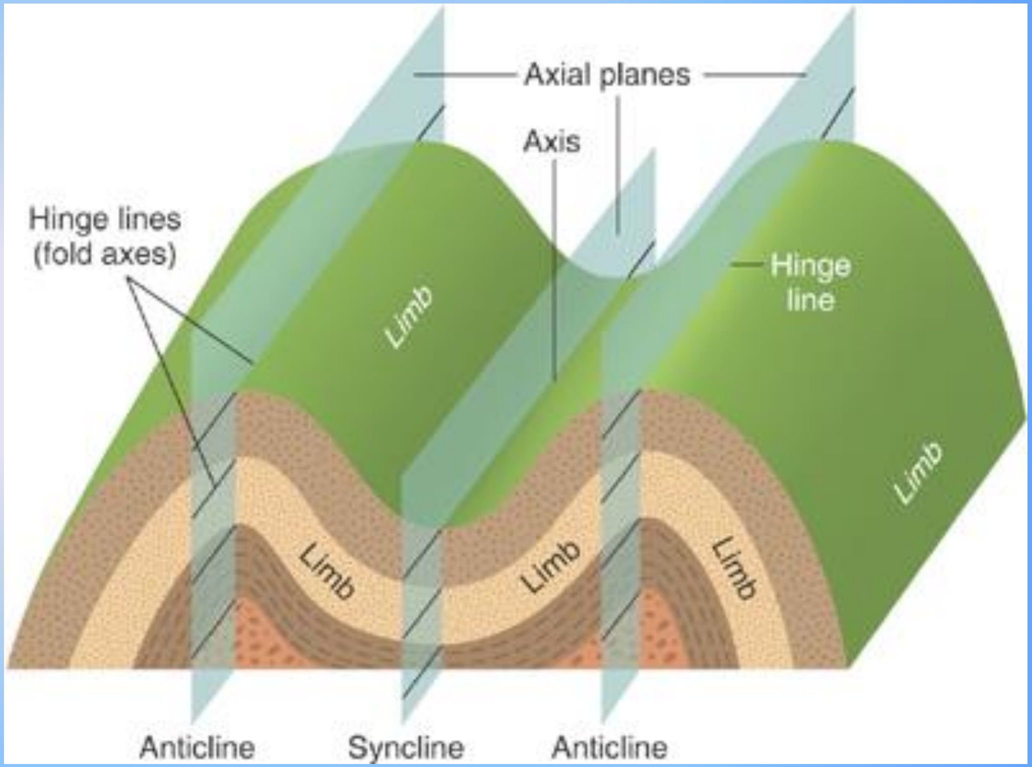
- Dynamically-produced patterns or arrangements of rock or sediment that result from, and give information about, *forces within Earth*
  - Produced as rocks change shape and orientation in response to applied stress

Folds

Wavelike bends in layered rock

•The *axial plane* divides a fold into its two *limbs*

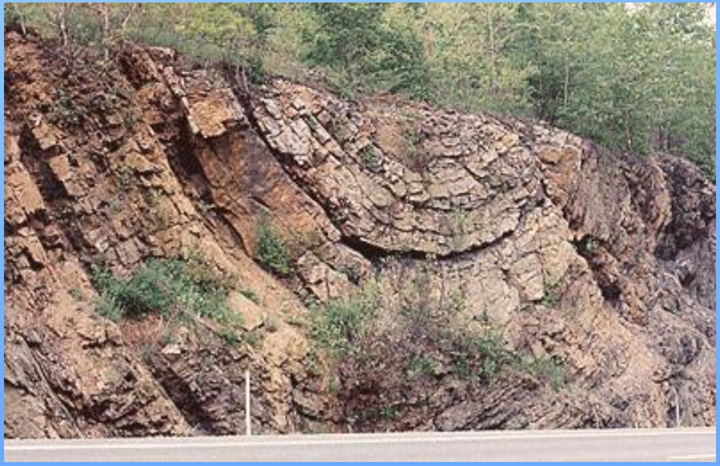
–The surface trace of an axial plane is called the *hinge line* (or *axis*) of the fold



- *Folds* represent rock strained plastically
  - Bending without breaking and not returning to their original shape
  - Usually under *compression*

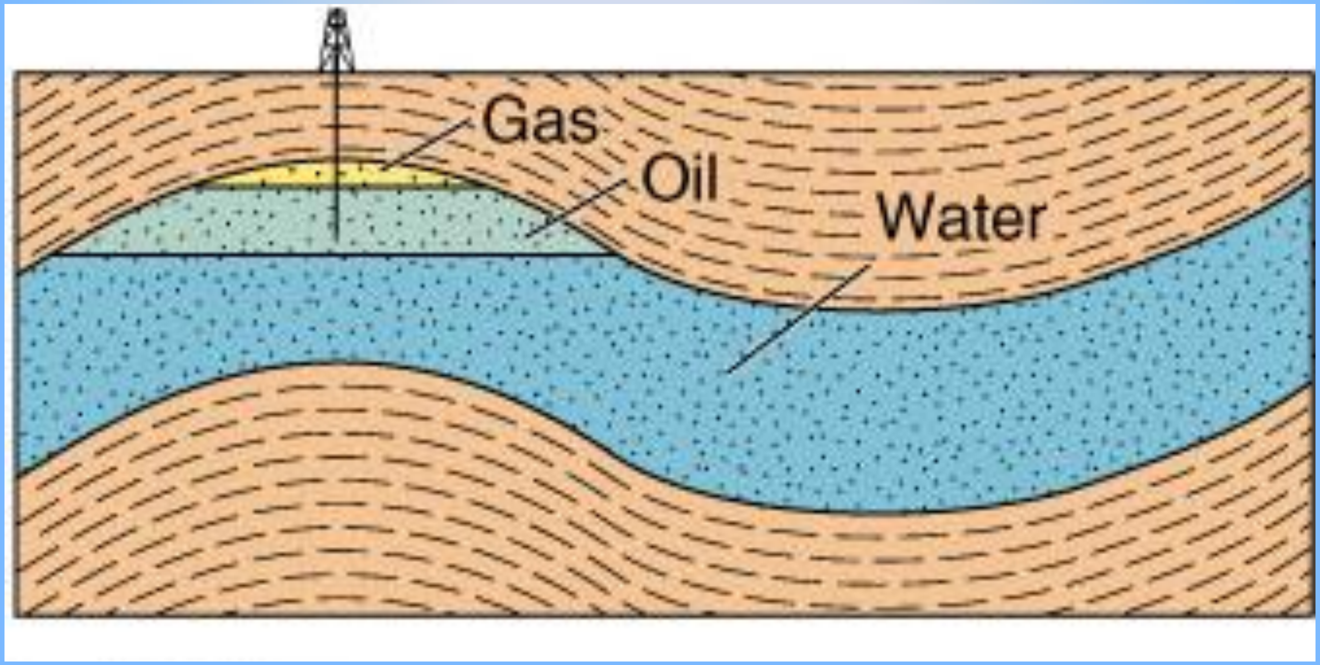
Types of Folds



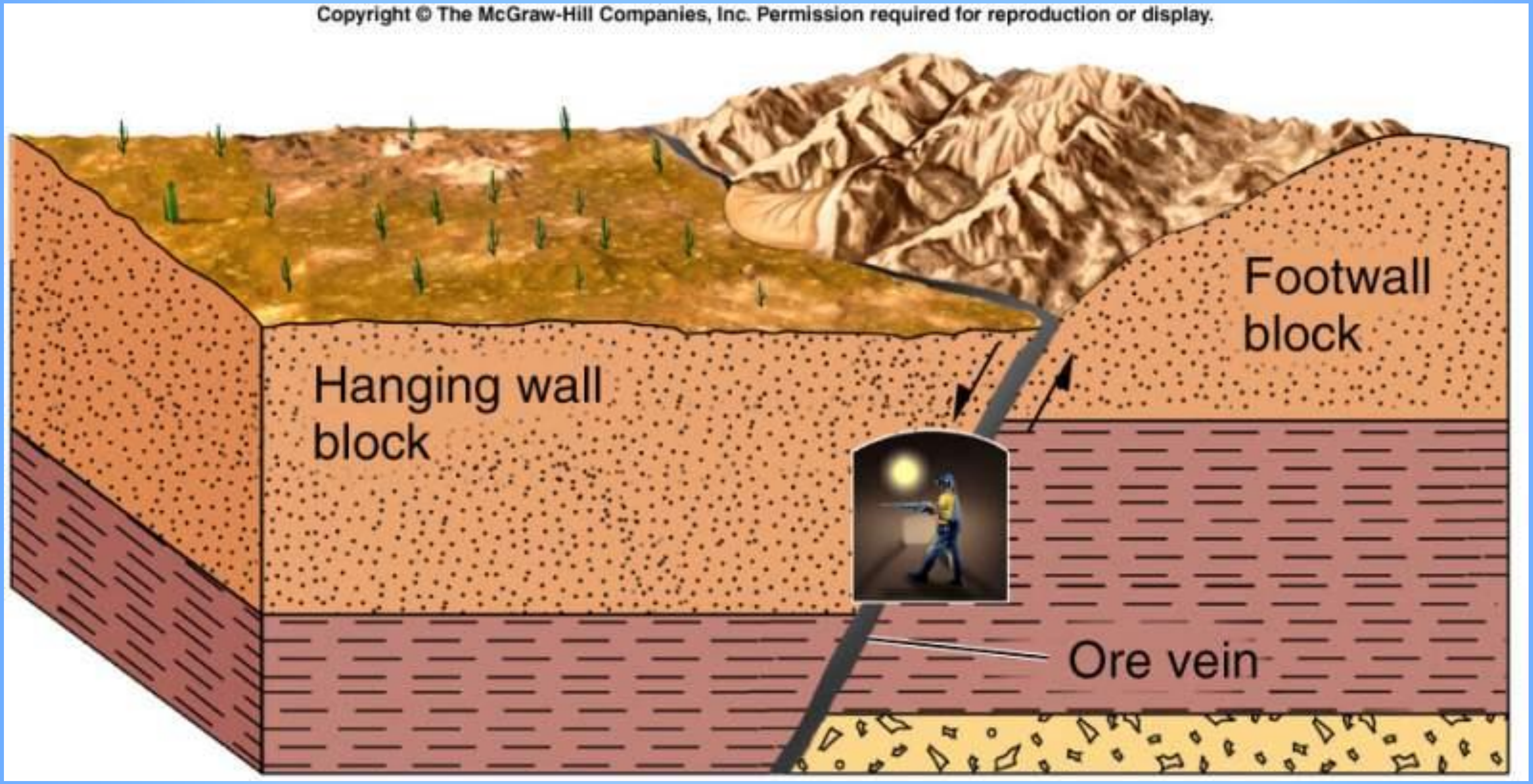
Anticlines

The Most Common Oil Trap



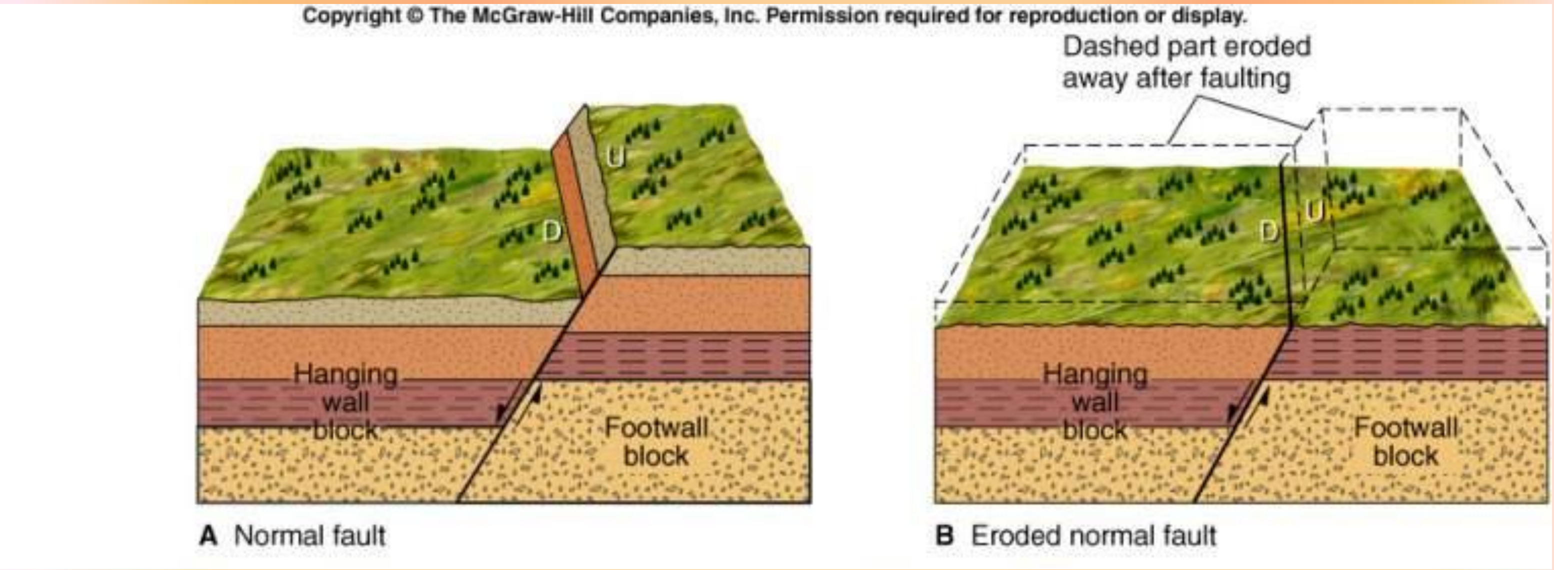
- Oil rises to the top of the fold
- Impermeable shale traps the oil

Dip-slip faults



Movement of blocks is parallel to the dip of the fault plane

Normal Faults

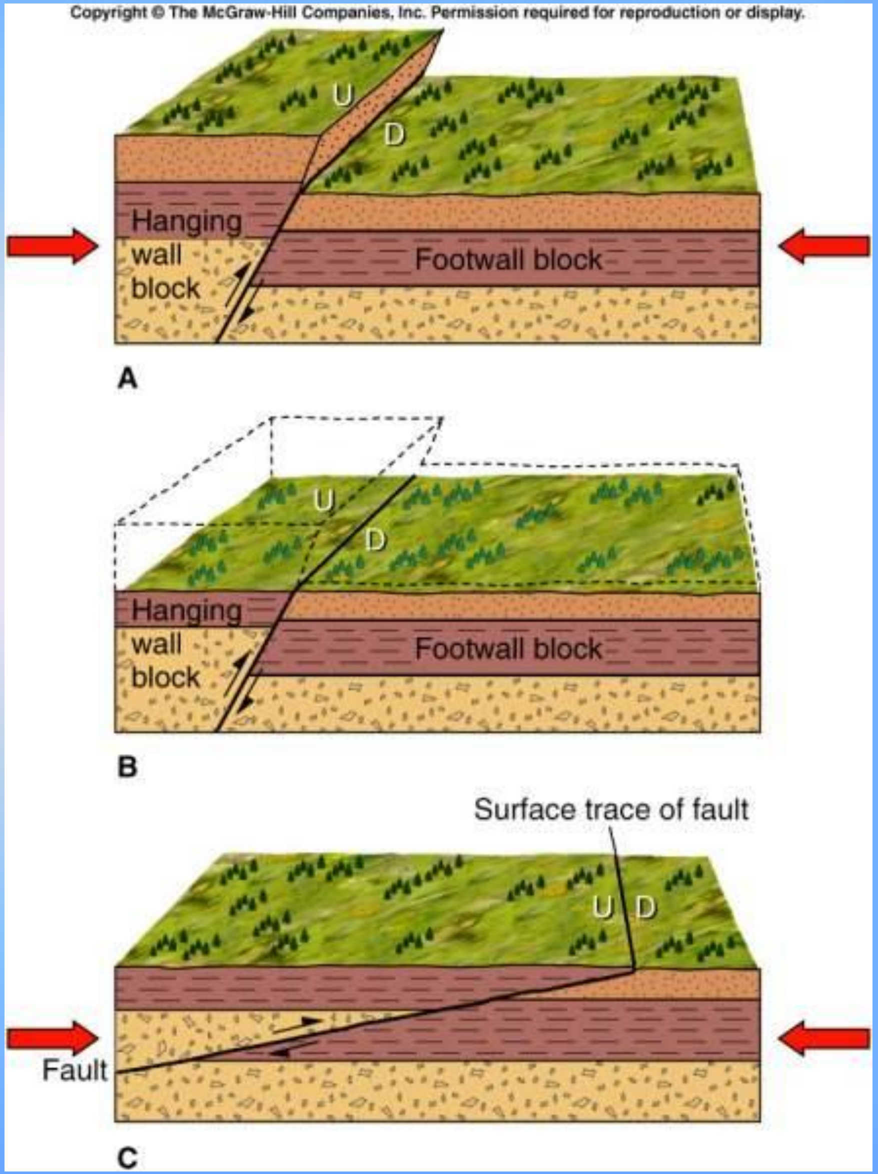


- In *normal faults (gravity faults)*, the *hanging-wall block* has moved down relative to the *footwall*
  - Associated with *tensional* forces

Reverse Faults

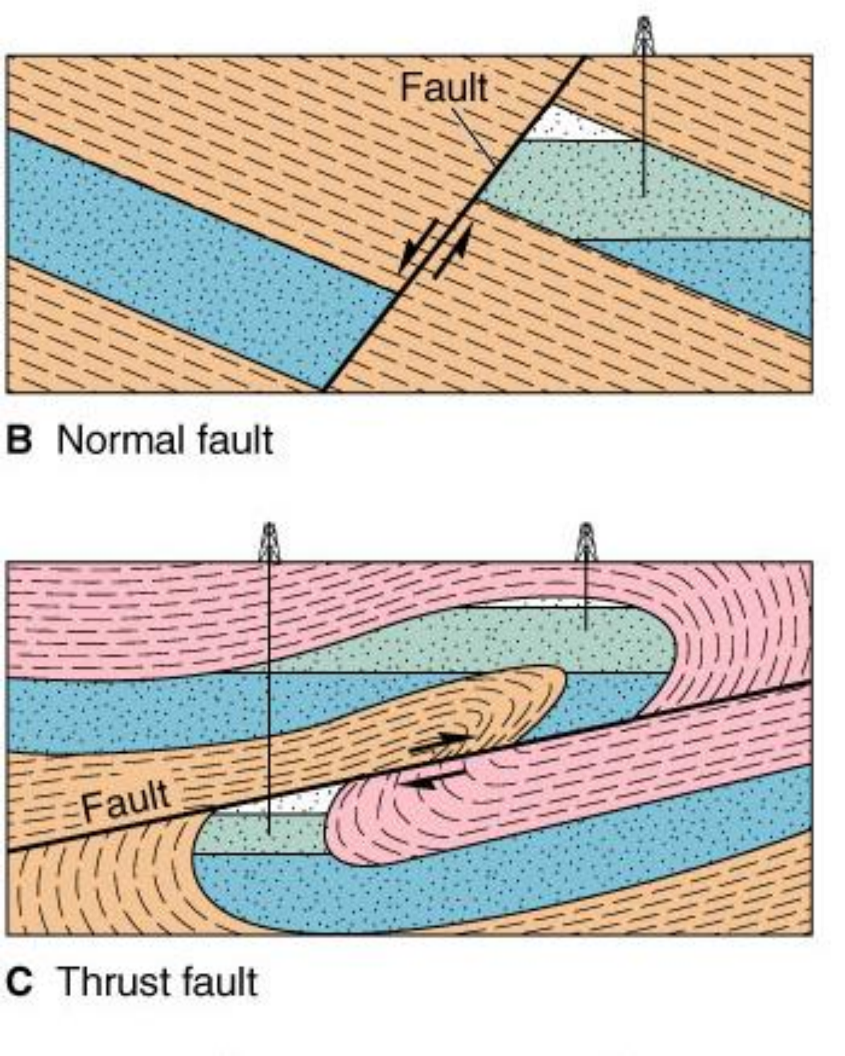
- The hanging-wall block has moved up relative to the footwall block

- *Thrust faults* are reverse faults with dip angles *less than 30°* from horizontal



Faults

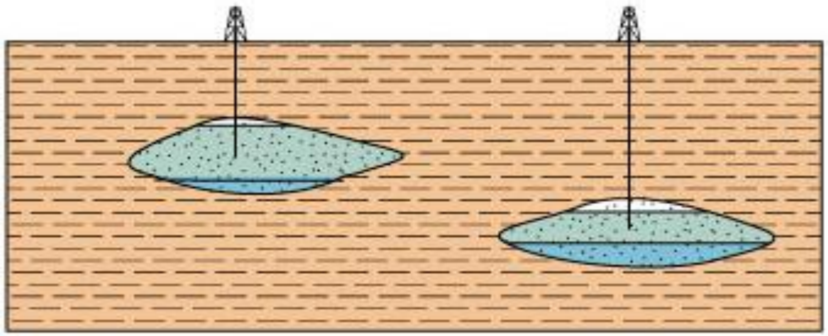
Faults



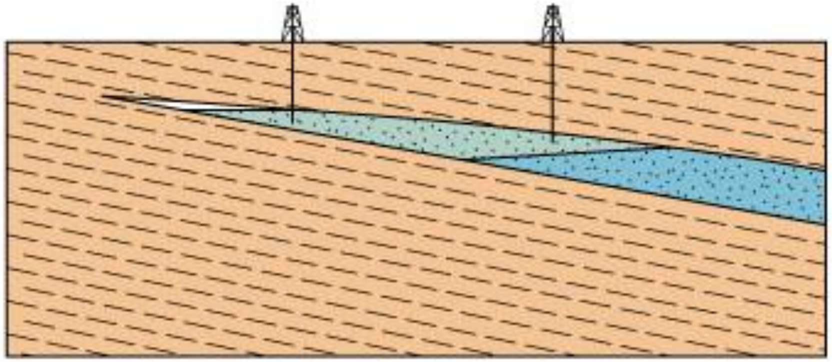
- Permeable reservoir rocks
  - Break
  - Slide next to impermeable rocks

Stratigraphic Traps

The result of natural sedimentation

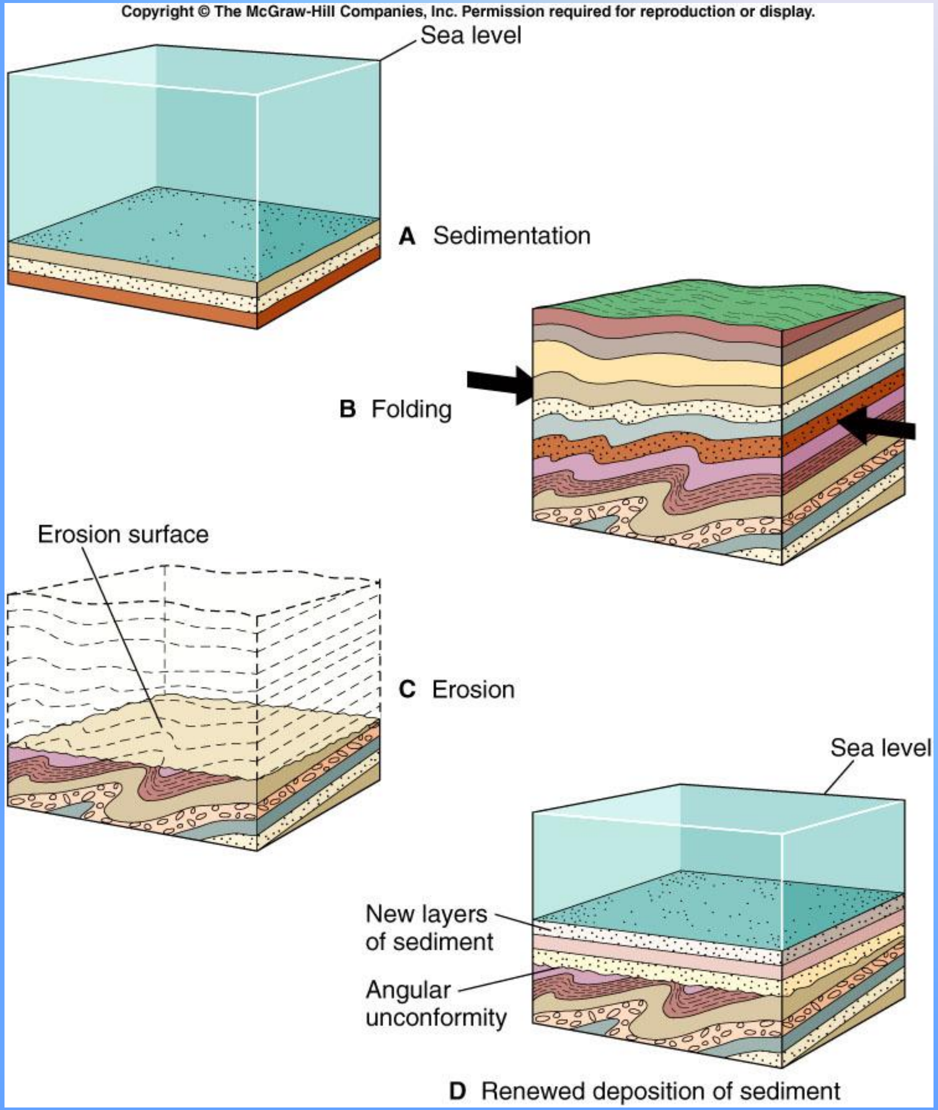


D Sandstone lenses



E Sandstone pinchout

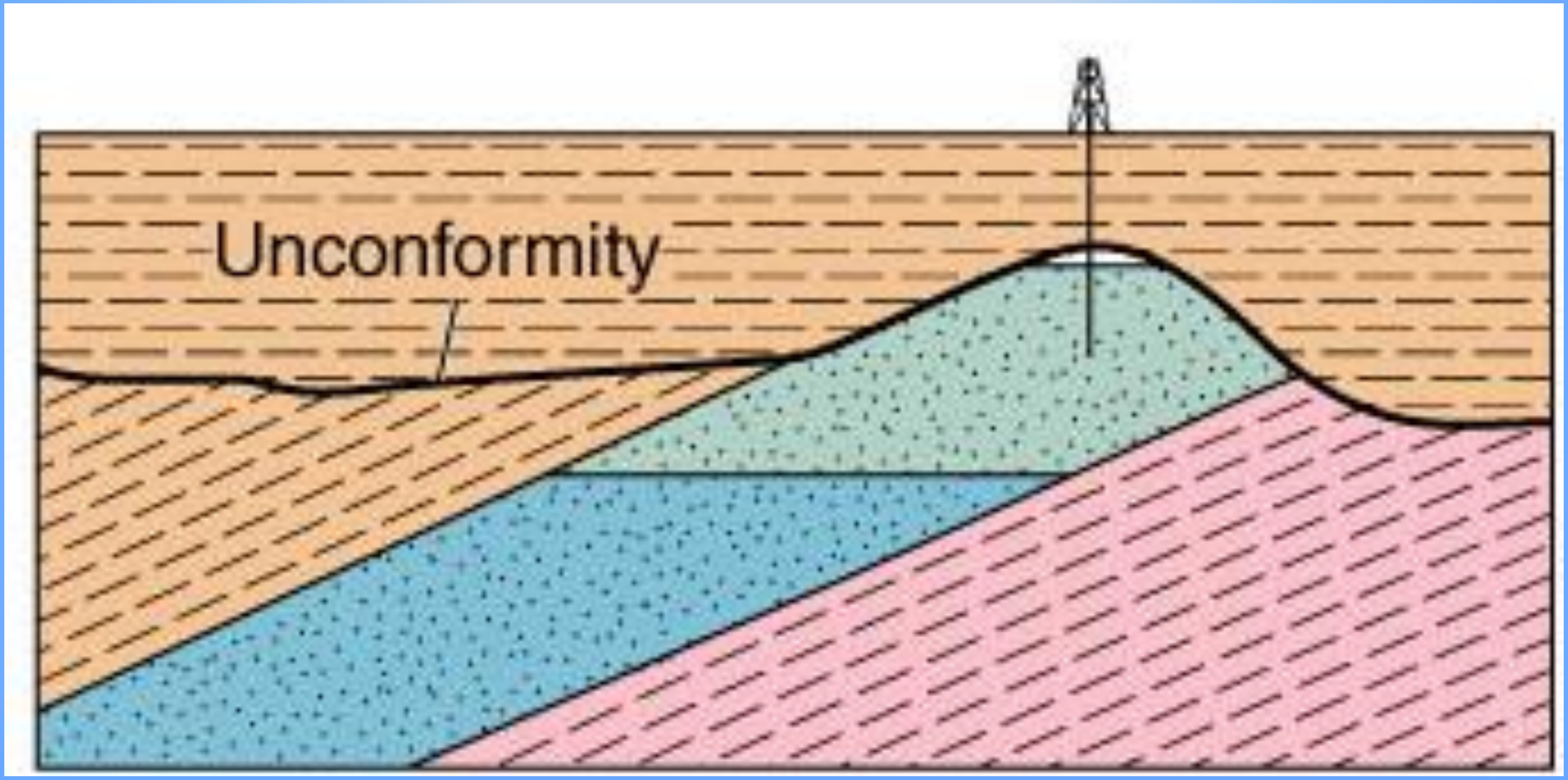
Unconformity-Related Traps



An erosional surface buried by younger sedimentary rocks

Unconformity-Related Traps

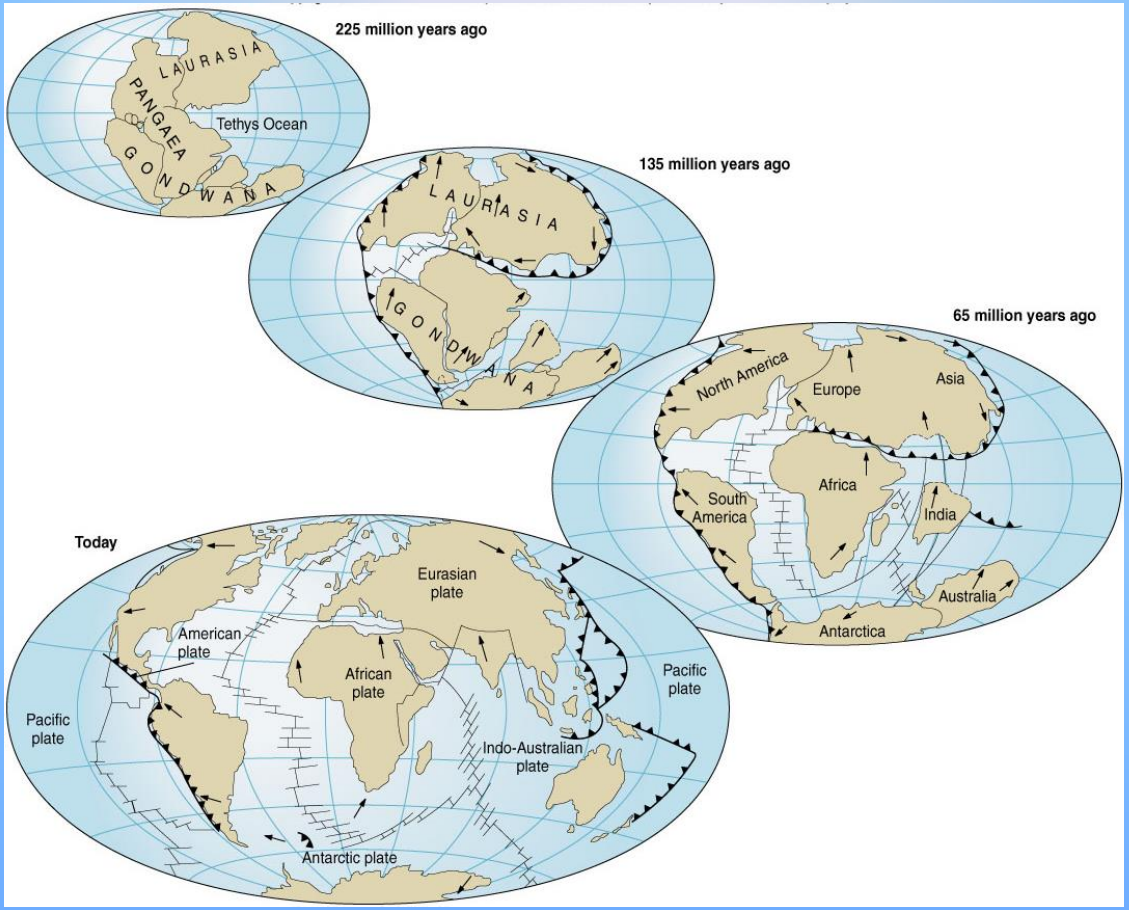
An impermeable shale cap rock has been deposited on top of the sandstone reservoir rock



So, Why Has Sea Level Changed in the Geologic Past?

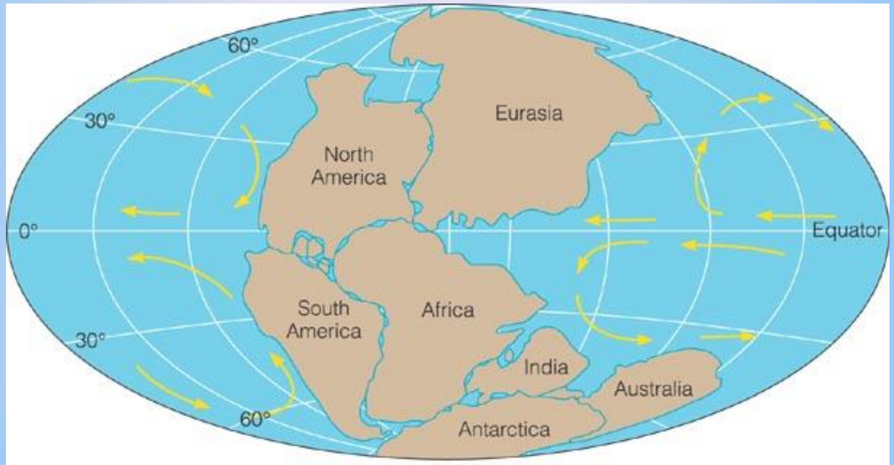
A few possible explanations . . .

Plate Tectonics and Continental Drift

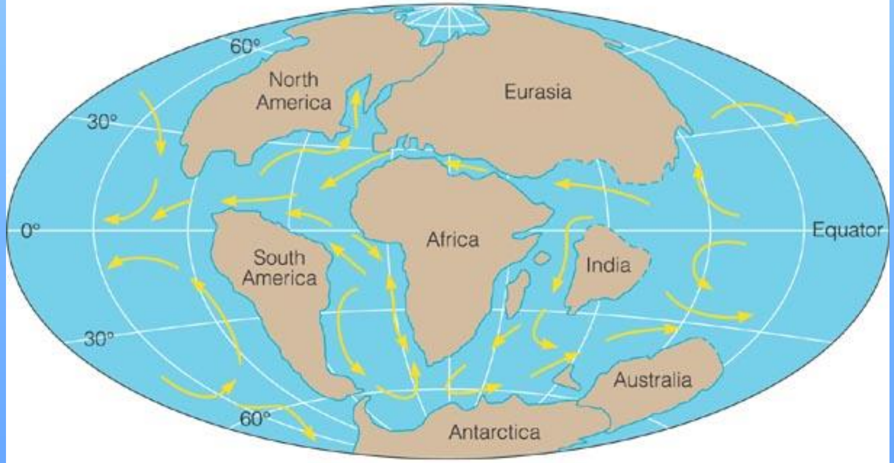


- **Change in distribution of land and water**
- **Change in precipitation patterns**

Change in Oceanic Circulation



(a) Triassic Period

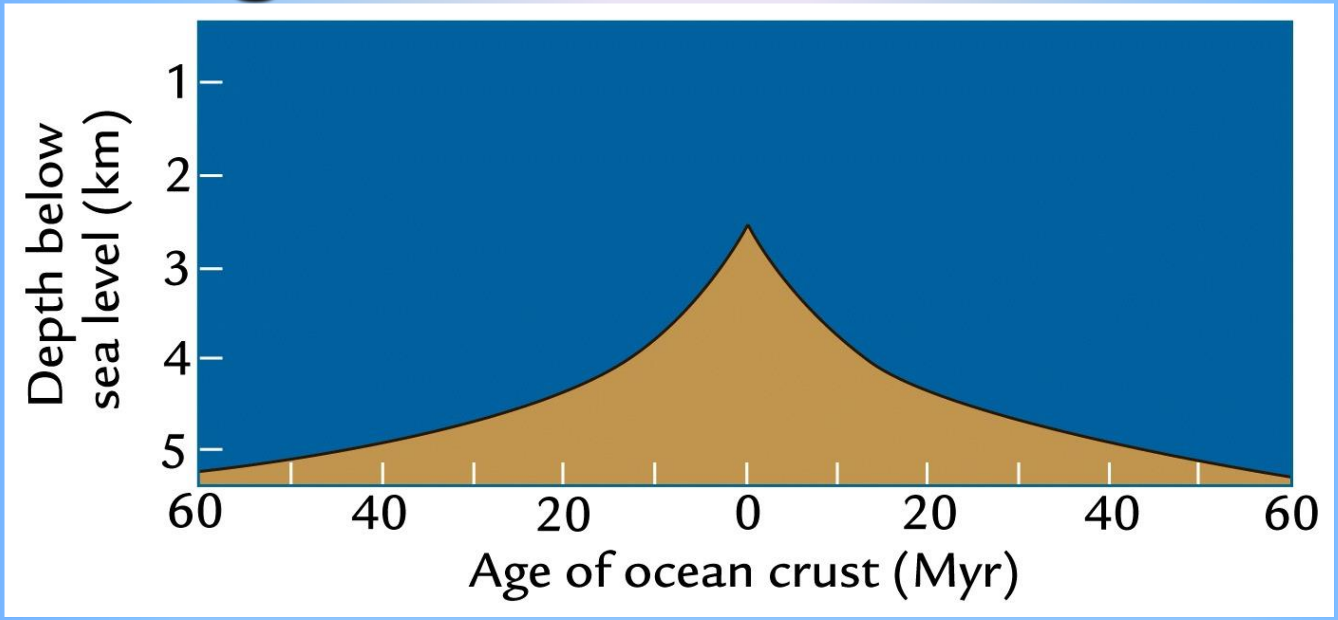


(b) Cretaceous Period

The Greenhouse Era 100 Myr Ago
The Cretaceous Period of the Mesozoic Era

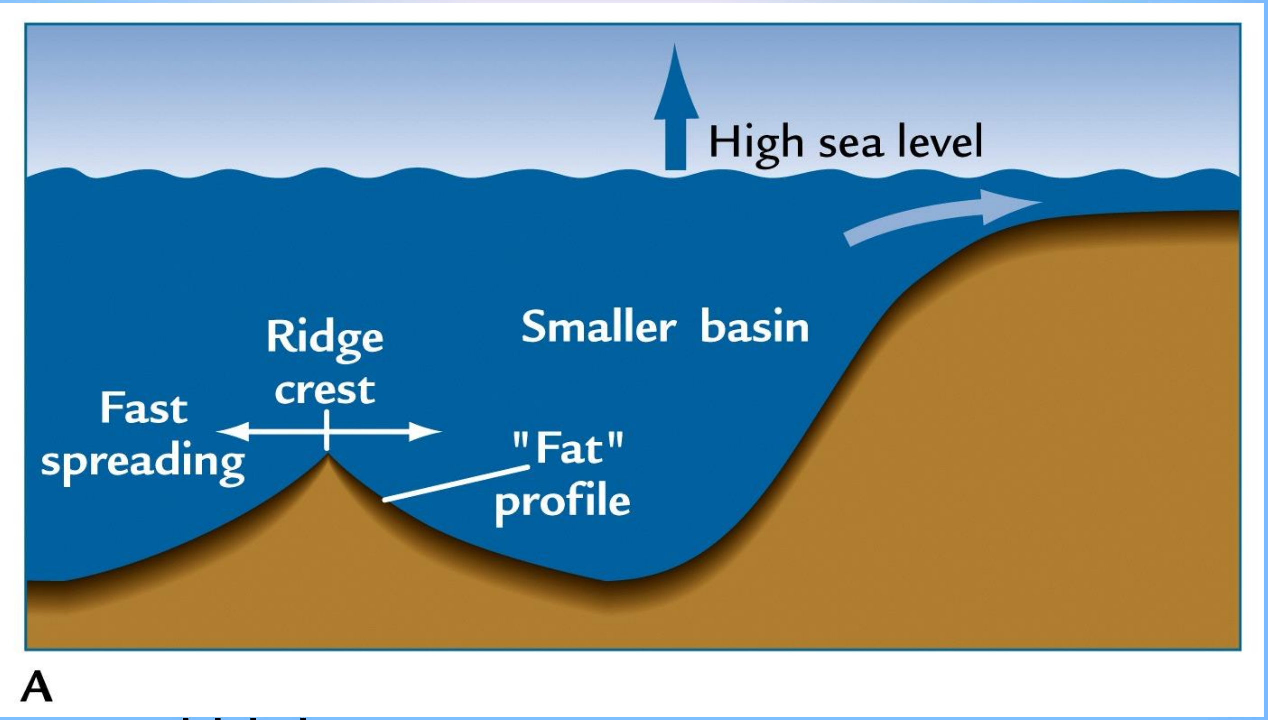
- Global Sea Level – 200 m higher than today
- Shallow seas flooded continental interiors
- Cretaceous is from the Latin word *creta* which means chalk

Ridges Subside with Time



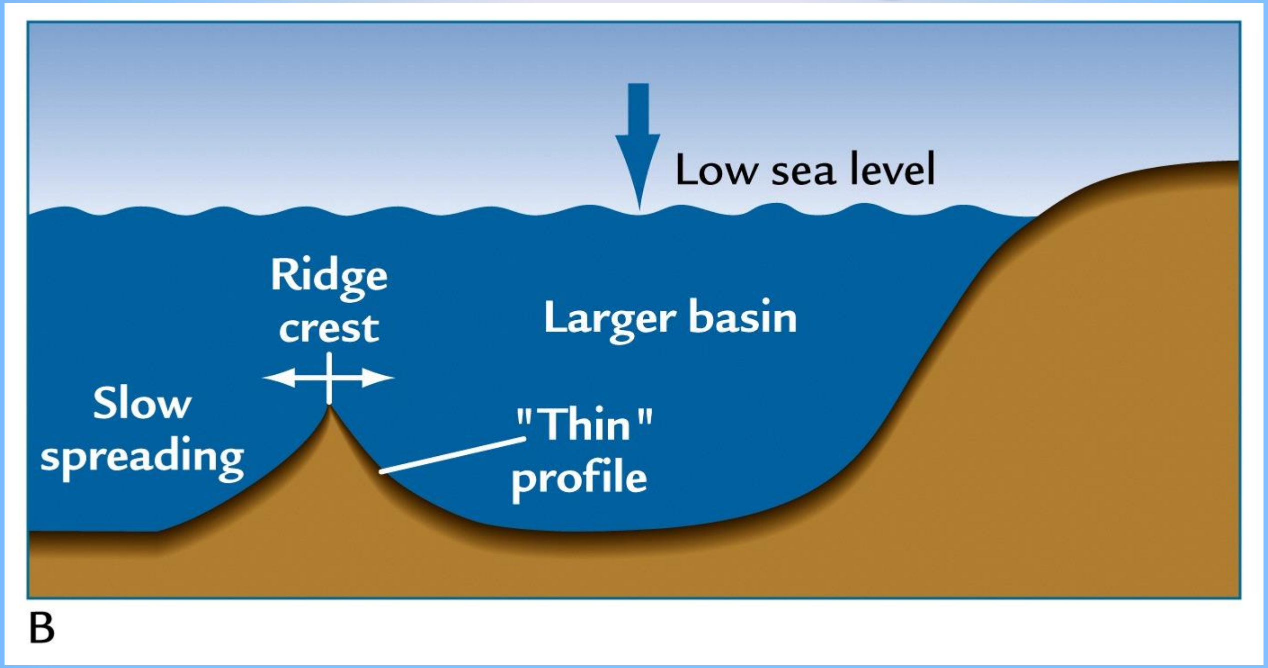
- Initially anomalously high heat flow causes ridges to stand high above the seafloor
- As rock moves away from the crest
  - Rapid subsidence due to heat loss
- As rock continues to move along the ridge flanks
  - Rate of heat loss is more gradual
- After 60 Myr
  - All excess heat is lost
  - Ridge elevations are a stable depth of 5500 m (average value)

Fast Spreading Rates



- Ridges stand higher
  - Less time to cool and contract
- Produce a wider, high elevation ("fat") profile
- Reduces the volume of ocean basins displacing water onto the continents
- *Transgressions* occur resulting in eustatic sea level changes.

Slow Spreading Rates

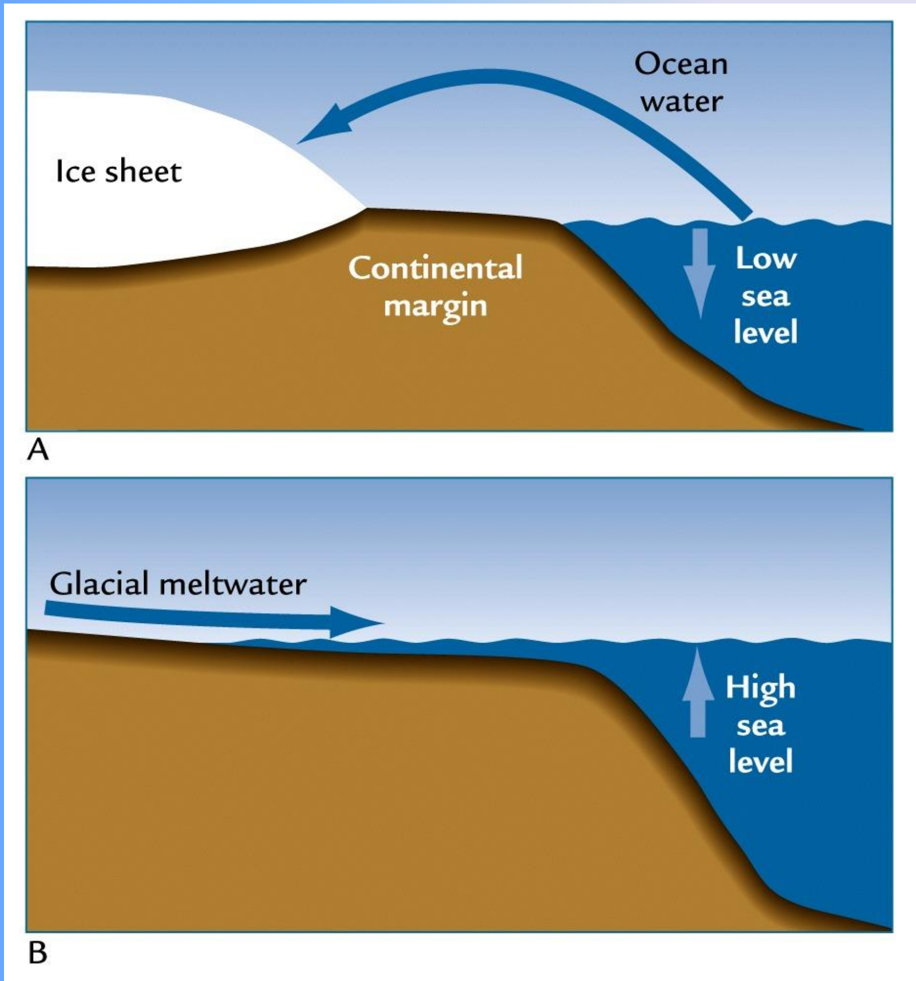


- More time for crustal rocks to cool and contract
- A narrower (“thin”) profile results
  - Ocean basins are deeper
  - Less water is displaced
- *Regressions* occur resulting in eustatic seal level change

Sea Level During the Cretaceous Period

- Average spreading rates were at least 50% faster than today
- Evidence of marine transgressions
- Ocean basins had a lower capacity
- Sea level was 200 to 300 m lower than today

Glacial Ice

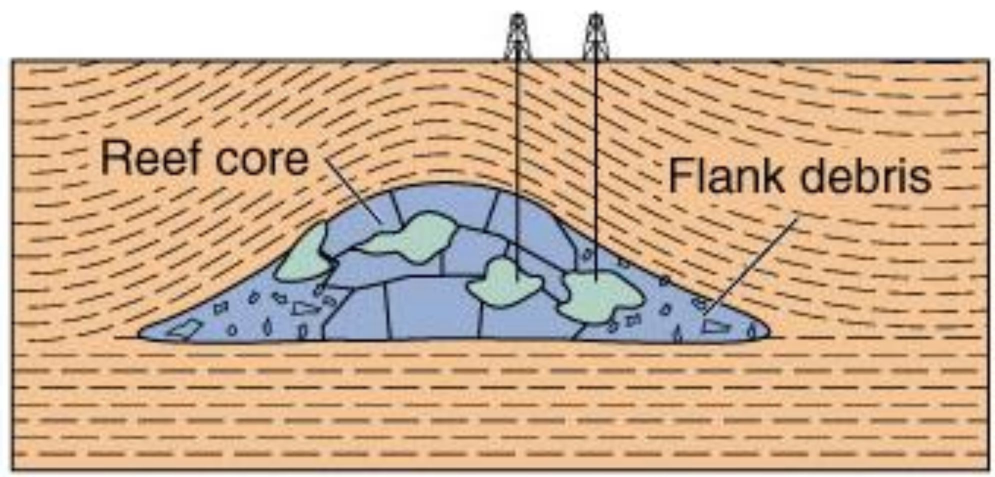


- Huge amounts of water stored on land
  - Sea Level is lower during ice ages
- Water returns to the sea during interglacial periods
  - During the last ice age sea level was about 300 m lower than today

Sea Level Today . . .

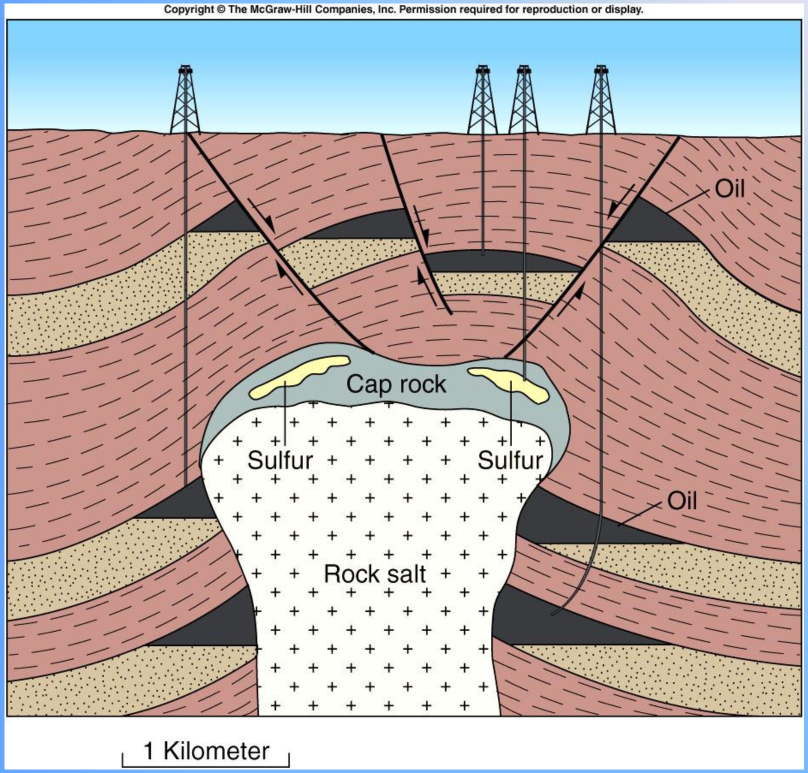
- Antarctica's Ice
  - Holds enough water to raise sea level 66 meters
- Greenland's Ice
  - Holds enough water to raise sea level 6 m
- If all the ice on these continents melted, there would be a eustatic sea level increase of 72 meters

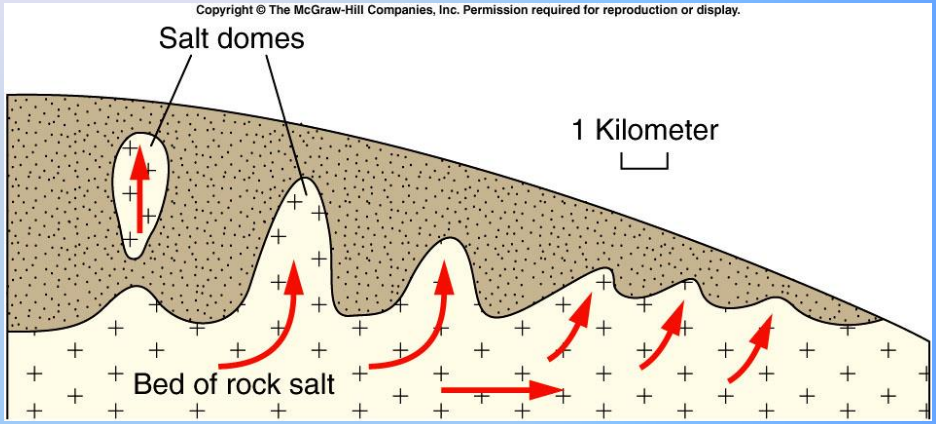
Limestone Reefs



G Reef (a small "patch" reef)

Salt Domes



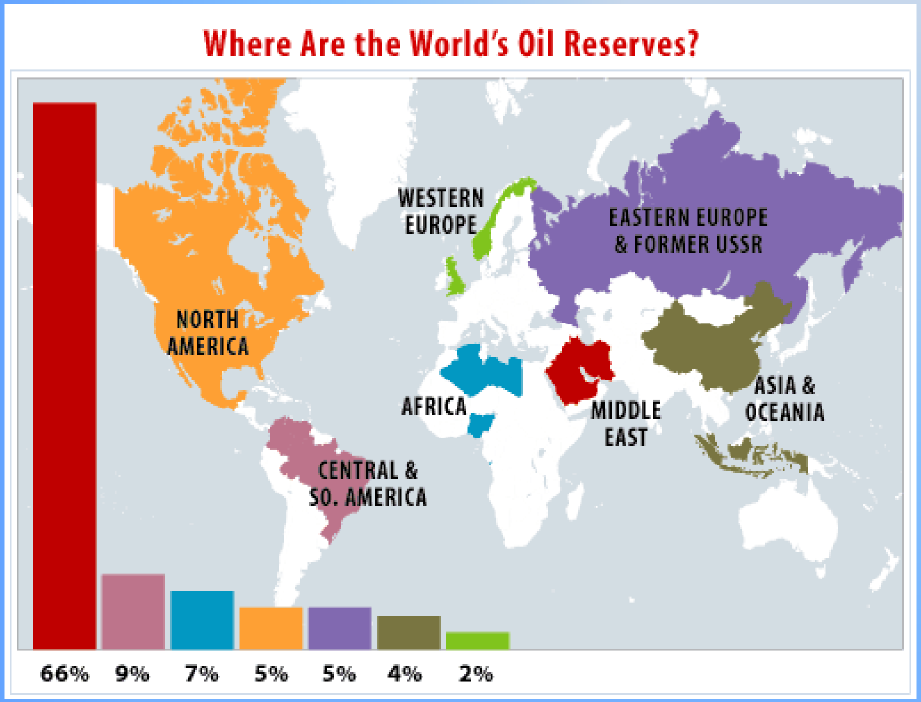


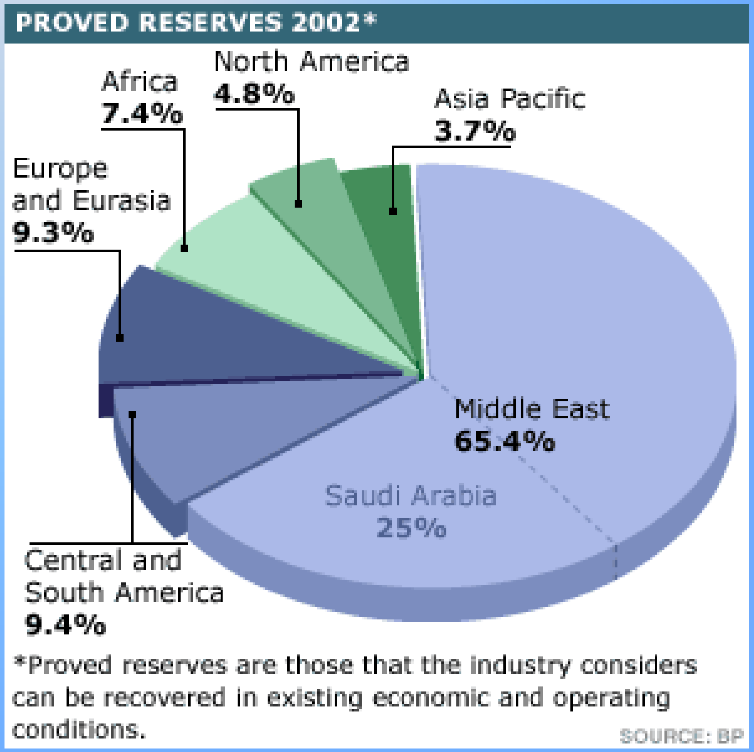
Oil and gas are trapped:

•In folds and along faults above the dome

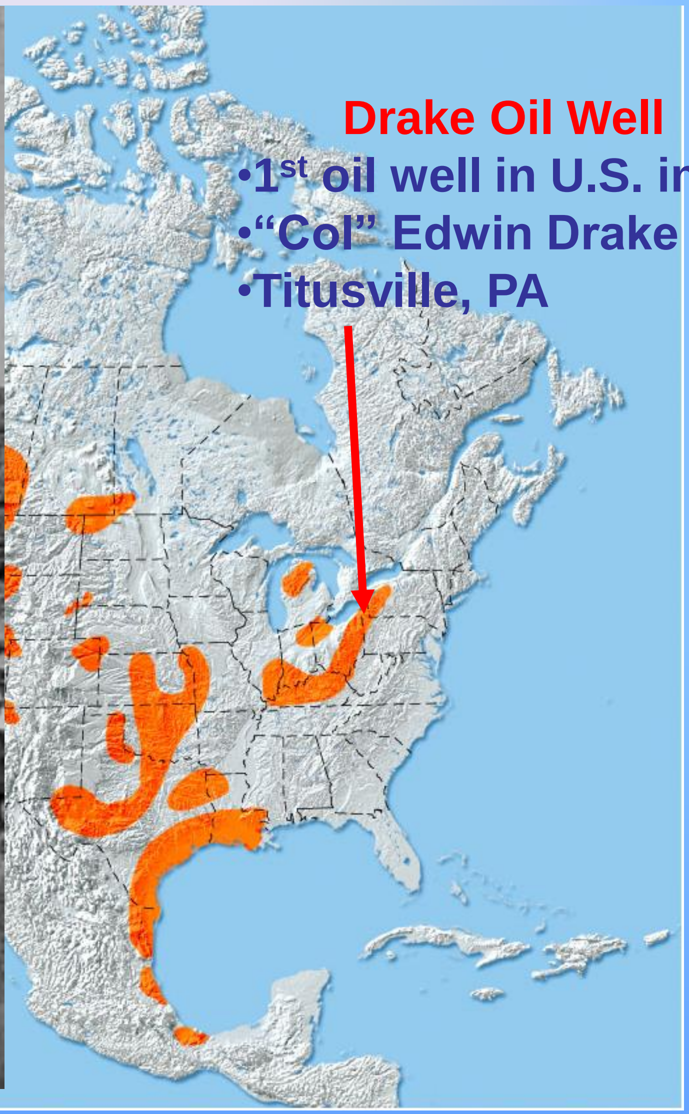
•Within upturned sandstones on the sides of the dome.

The World's Oil





Oil Fields

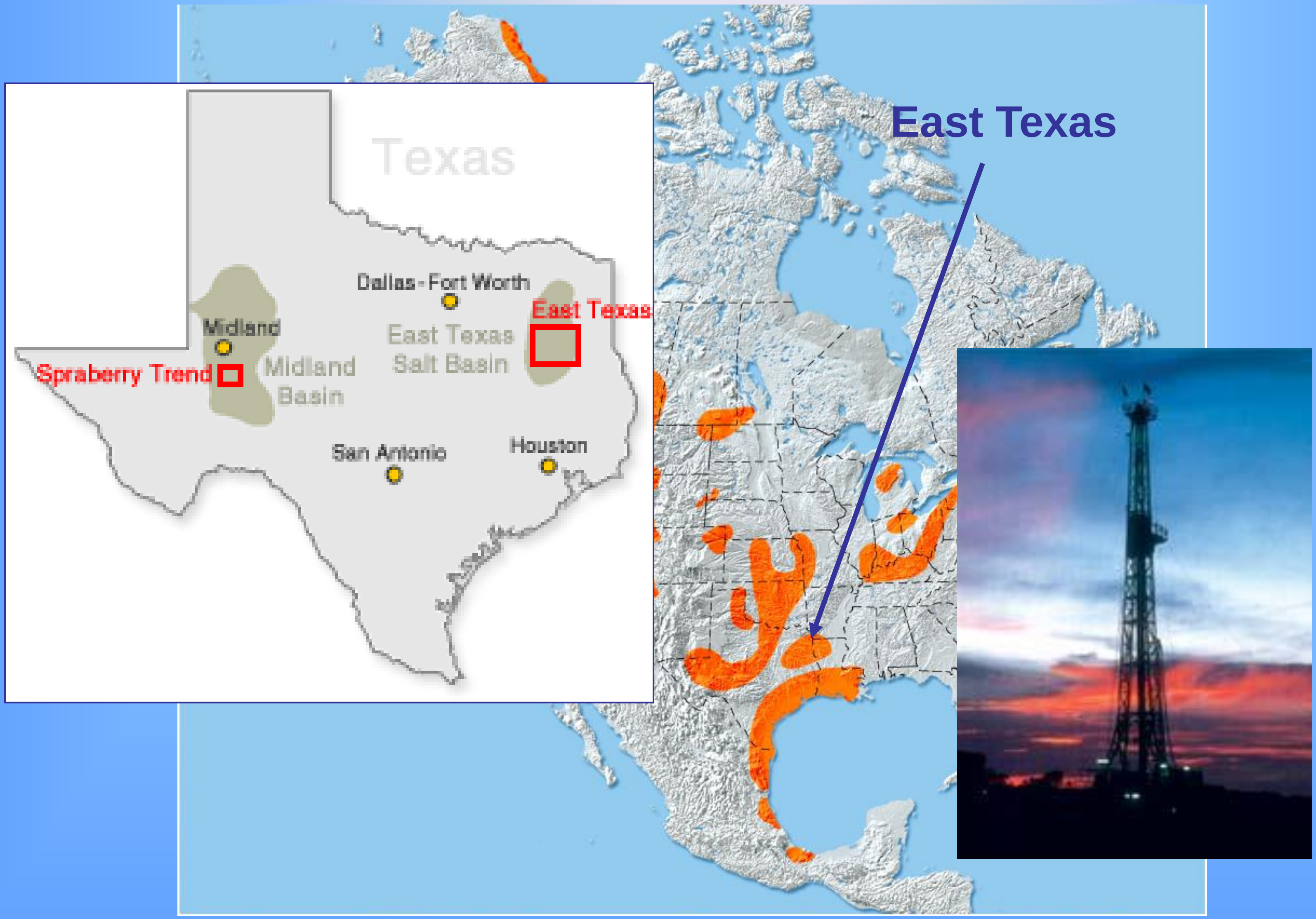


Drake Oil Well

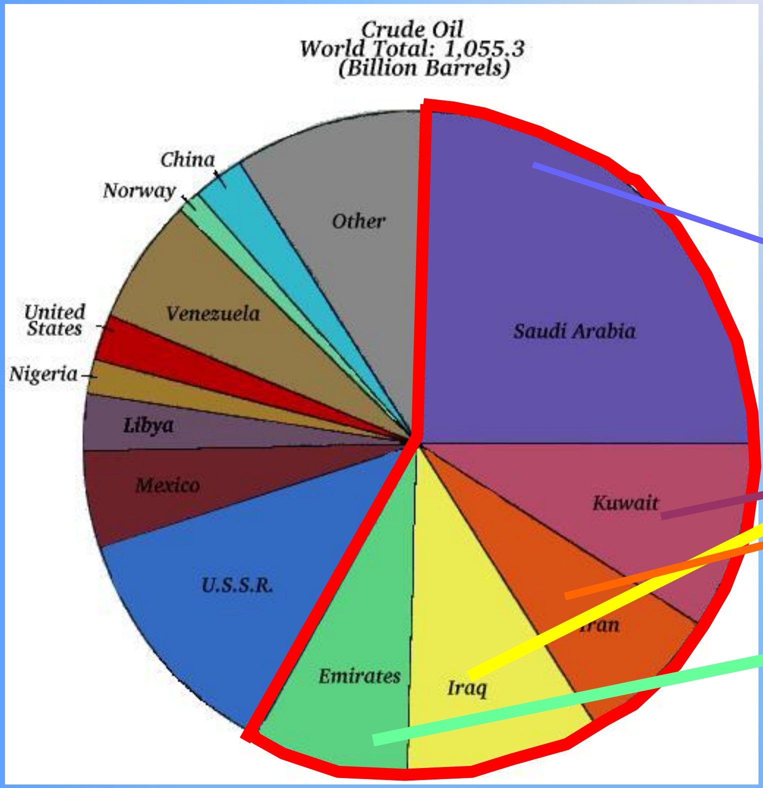
- 1st oil well in U.S. in 1859
- "Col" Edwin Drake
- Titusville, PA

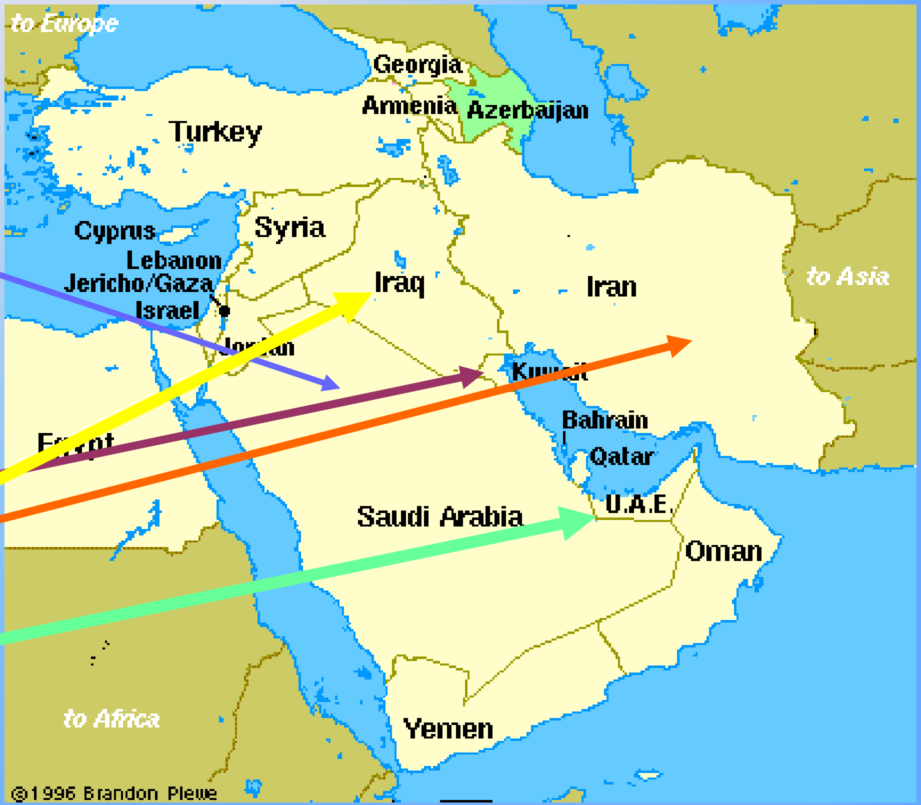
Oil Fields

Oil Fields


Texas
Dallas - Fort Worth
East Texas
Midland
East Texas
Salt Basin
Spraberry Trend
Midland
Basin
San Antonio
Houston
East Texas

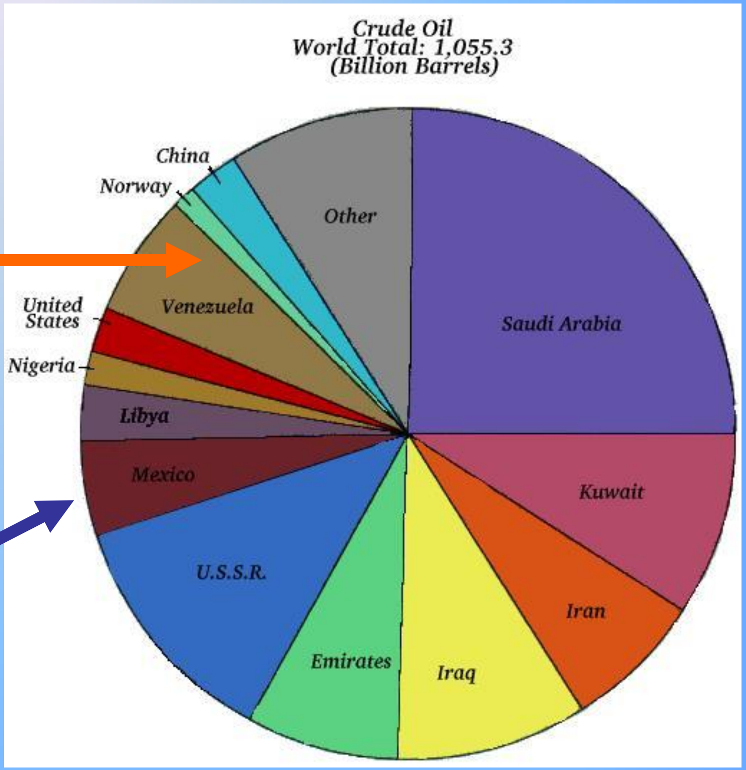
Middle East Oil





Russia and Azerbaigan

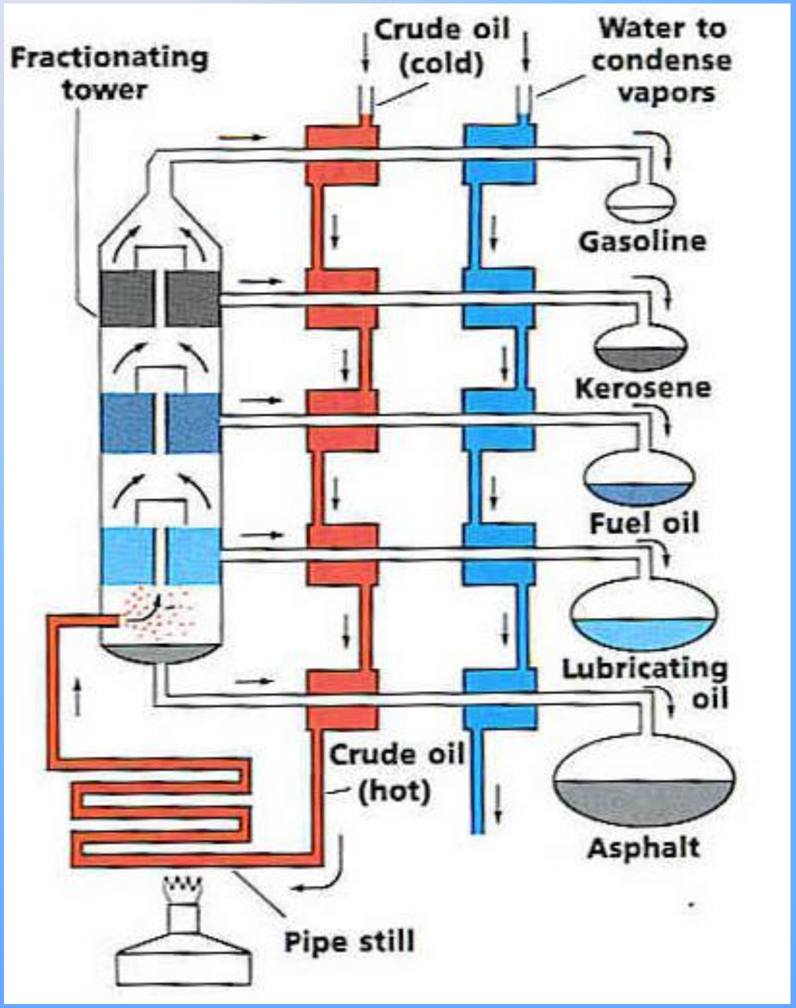
Venezuela and Mexico



Recovering Oil

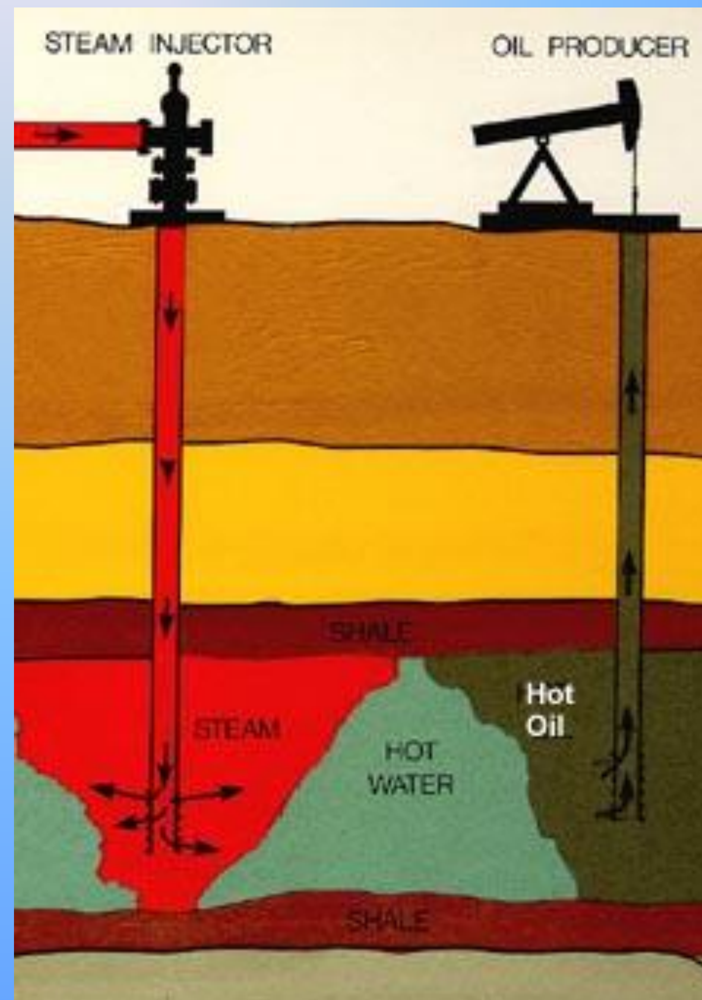



Refining Crude Oil



Heavy Crude

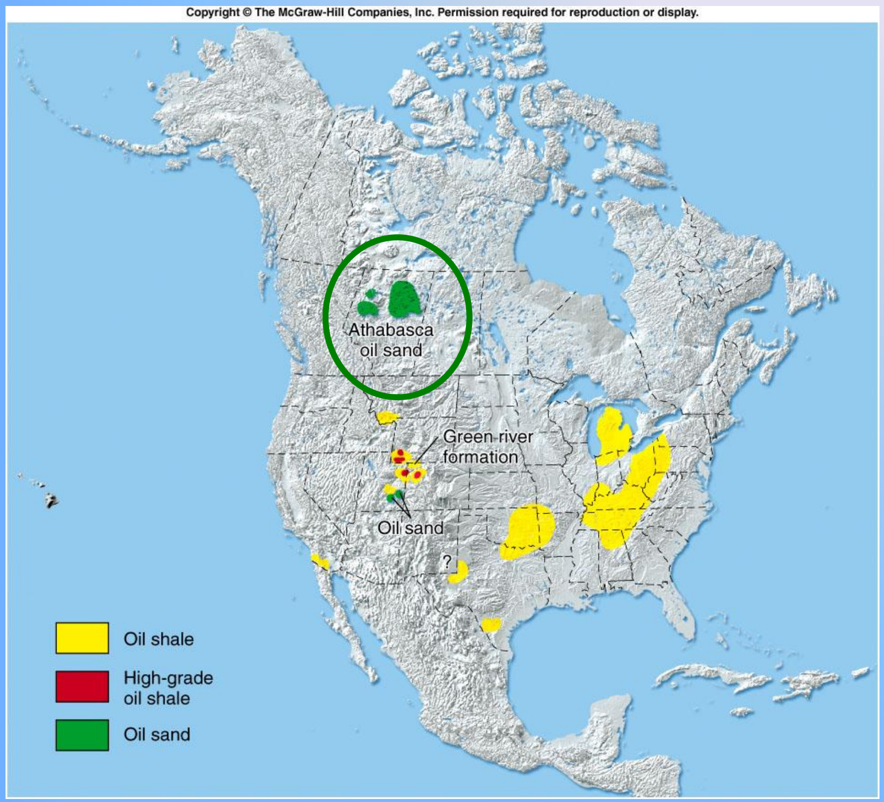
- Dense and viscous
- Flow rate very slow to be economical
- Flow can be mad faster by steam or solvent injection into wells
- Most California oil



Oil Sands

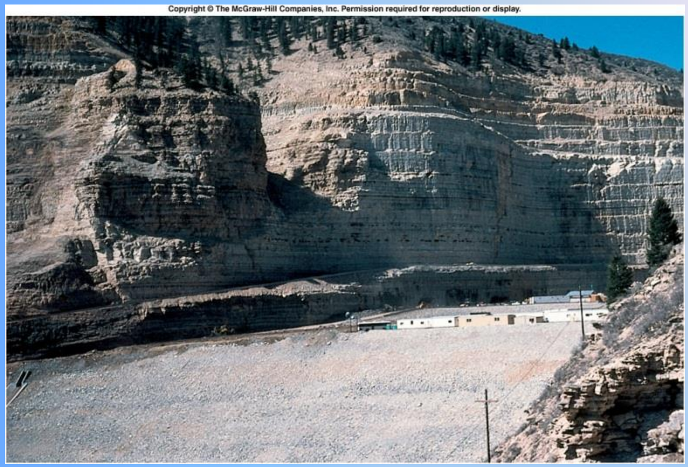
- Also called *Tar Sands*
- Asphalt-cemented sand or sandstone deposits
- Some are 4,000 m deep
- *Rancho La Brea Tar Pits* in Los Angeles

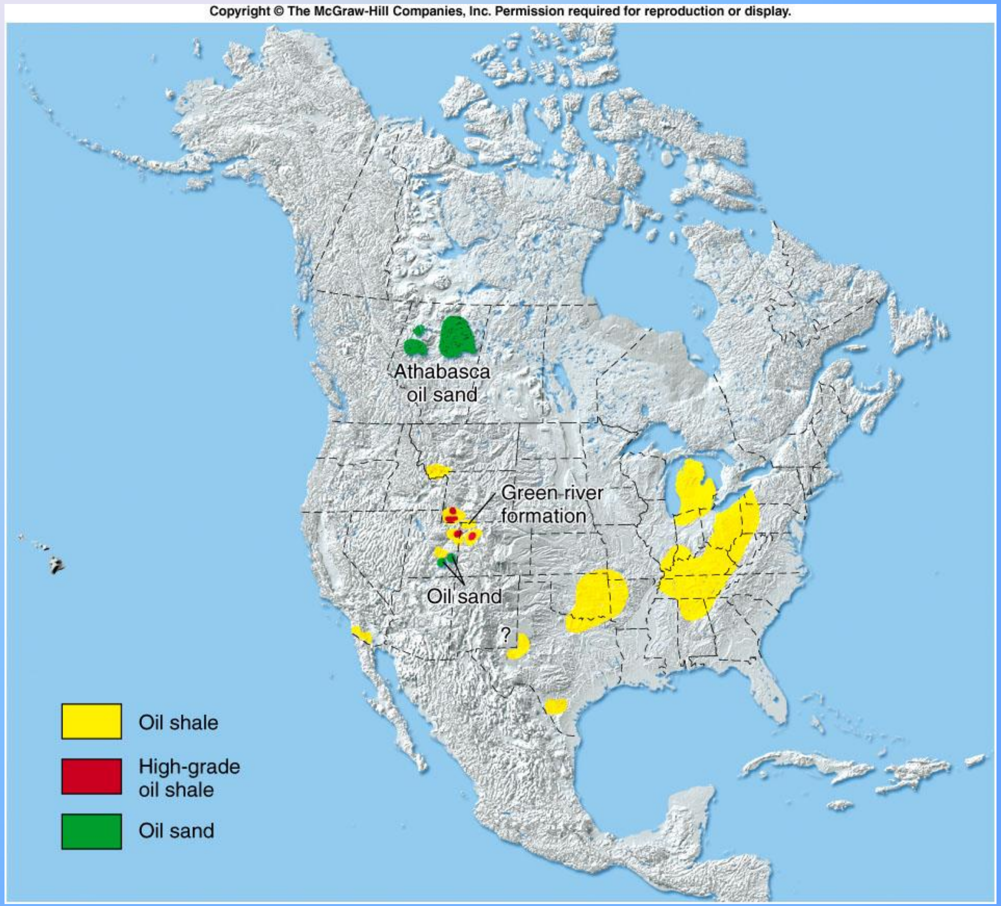
Athabasca Oil Sand



- Best known deposit of oil sand in North America
- 10% of Canada’s present oil production

Oil Shale



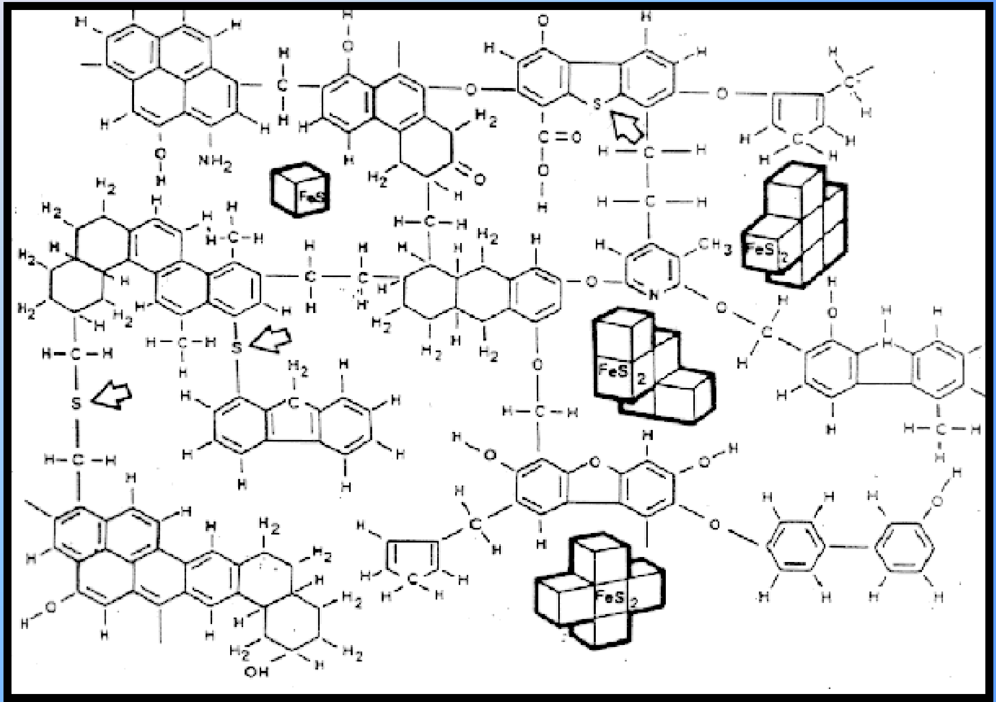


- Black or brown shale
- Extraction of oil by distillation
- Best know U.S. oil shale is the **Green River Formation** in Wyoming, covering 15,000 mi^2

Green River Formation

Coal

Bituminous Coal

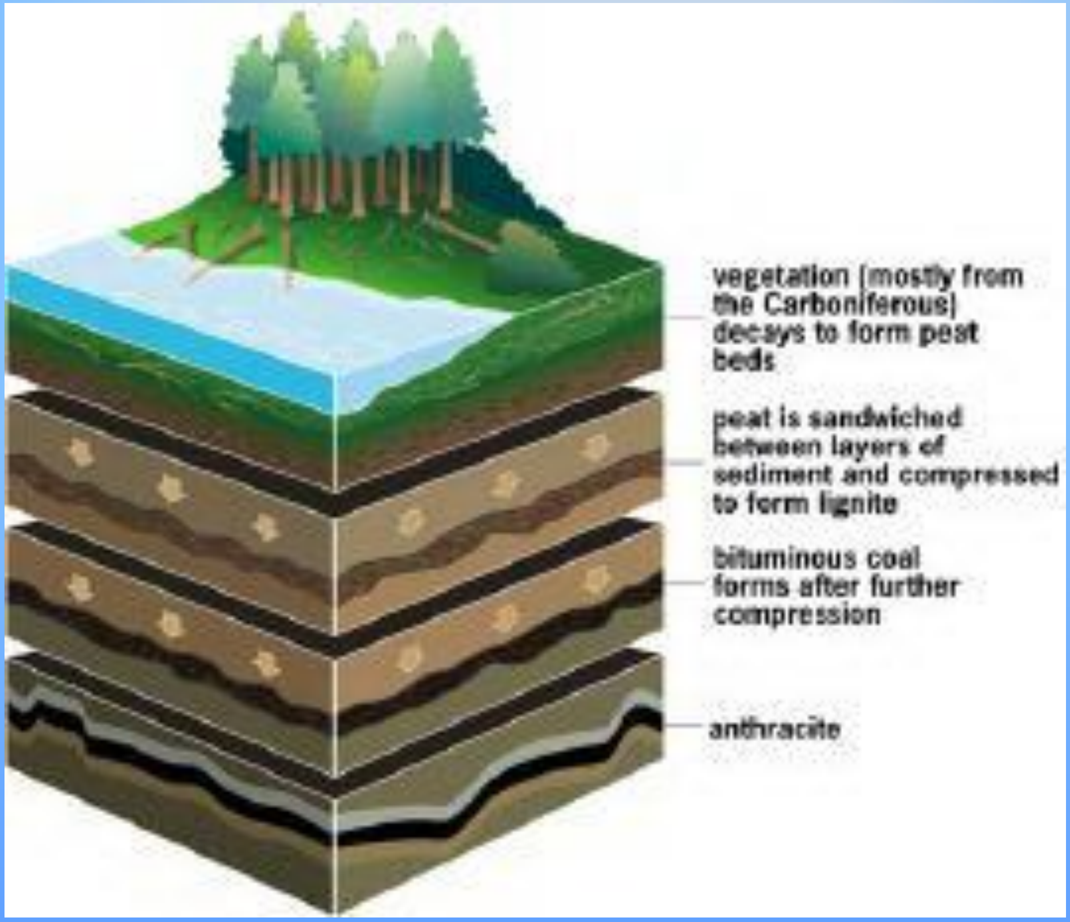


Representative structure of bituminous Coal showing sulfur linkages and the presence of iron pyrite FeS_2

- Forms from the compaction of plant material that has not completely decayed.

Coal Formation

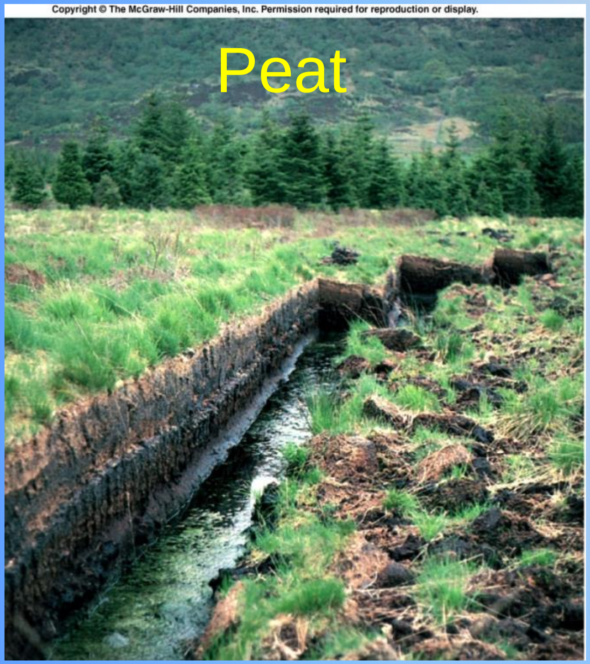
Environment of deposition: Shallow swamps in a temperate or tropical climate that have rapid plant growth and water with a low oxygen content.



Varieties of Coal

ii Several … of original plant material and the degree of compaction (peat, lignite, bituminous). Anthracite is a metamorphic grade of coal

Coal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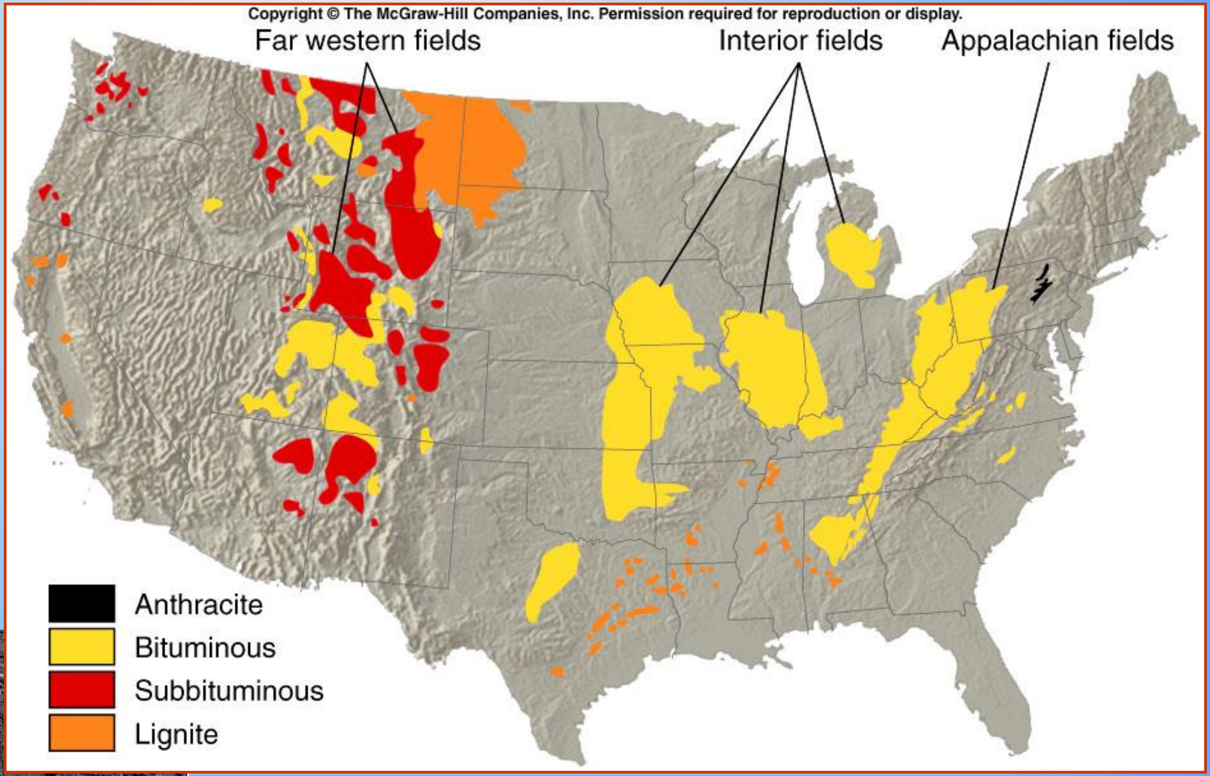
Peat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Far western fields
Interior fields
Appalachian fields
Anthracite
Bituminous
Subbituminous
Lignite


Bituminous


Coal Seams

Ranks of Coal

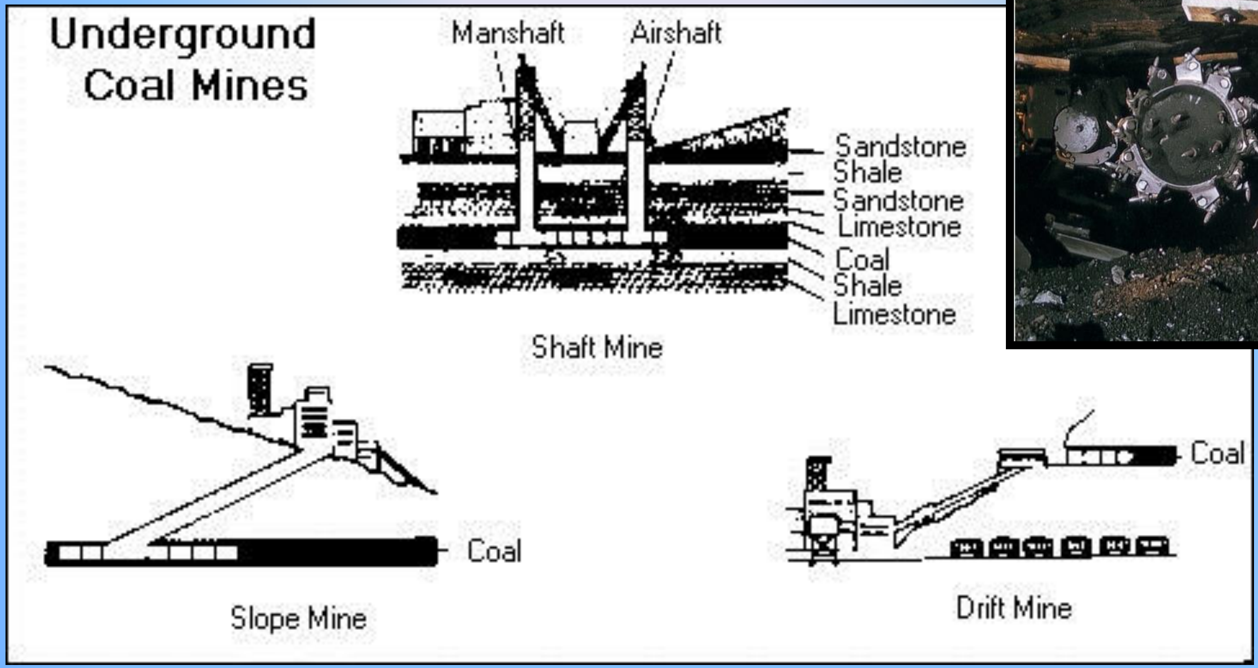
Table 21.1

Varieties (Ranks) of Coal

	Color	Water Content (%)	Other Volatiles (%)	Fixed Carbon[2] (%)	Approximate Heat Value (BTUs of heat per pound of dry coal)
Peat[1]	Brown	75	10	15	Varies
Lignite	Brown to brownish-black	45	25	30	7,000
Subbituminous coal	Black	25	35	40	10,000
Bituminous coal (soft coal)	Black	5 to 15	20 to 30	50 to 75	12,000 to 15,000
Anthracite (hard coal)	Black	5	5	90	14,000

1. Peat is not a coal.
2. "Fixed carbon" means solid combustible material left after water, volatiles, and ash (noncombustible solids) are removed.

Mining Coal Underground



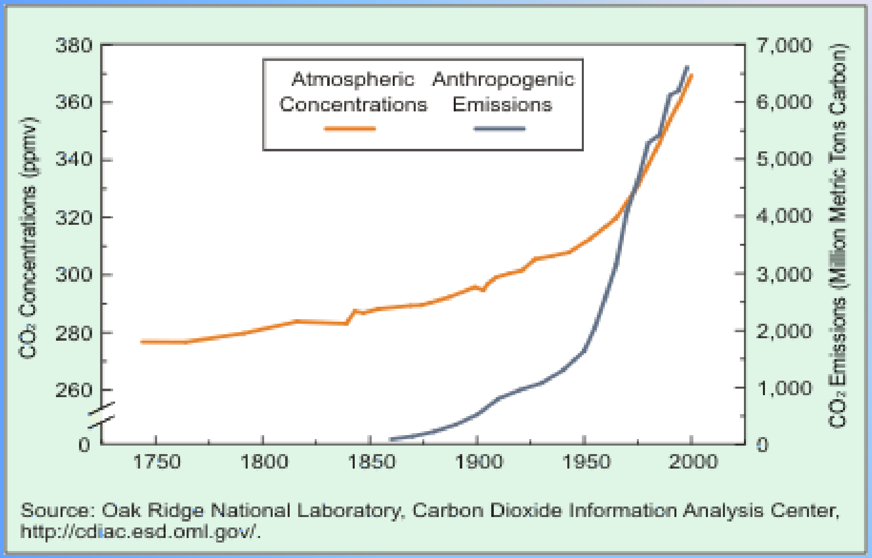
- **Drift mines** have horizontal entries into the coal seam from a hillside.
- Slope mines, which usually are not very deep, are inclined from the surface to the coal seam.
- **Shaft mines**, generally the deepest mines, have vertical access to the coal seam via elevators that carry workers and equipment into the mine.
- Almost all underground mines are less than 1,000 feet deep, but some mines reach depths of about 2,000 feet. Miners in Nova Scotia actually mine coal beneath the Atlantic Ocean.

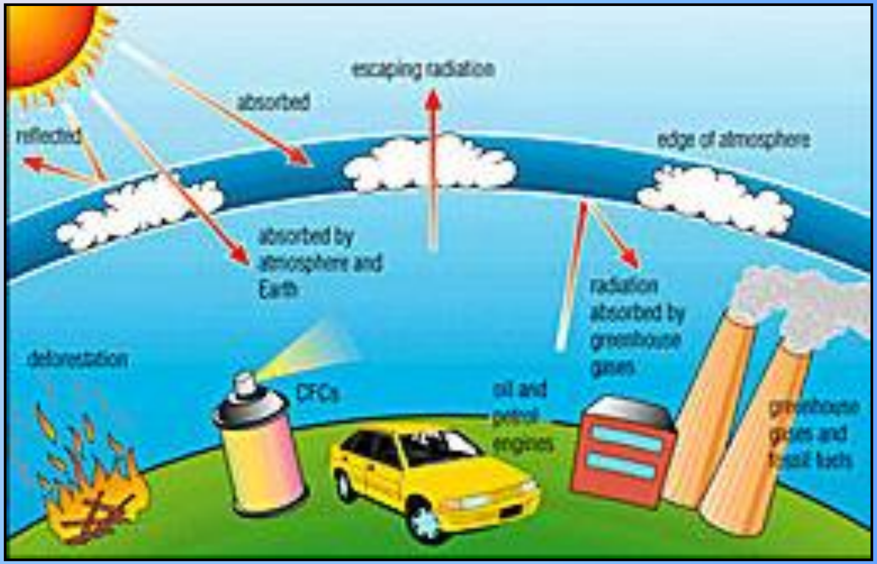
Strip Mining Coal

- Surface mining of coal
- Coal beds are close to the surface
- Trenches in which coal has been removed are filled with the overburden of the adjoining strip

Environmental Problems – Oil Spills

Environmental Problems-
Burning Fossil Fuels





Environmental Problems – Acid Rain