PGE-251

Introduction to Petroleum and Natural Gas Engineering

PGE 251
Introduction to Petroleum Engineering

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Chapter Three
Origin and Geology of Petroleum Reservoirs

Chapter Three: Origin and Geology of Pet. Reservoirs

Introduction and Origin of Petroleum

The most popular theories for petroleum origin are the organic and the inorganic theories.

The organic theory is believed to be the most realistic one.

Organic Origin Theory

Organic matter from the remains of plants, animals and microorganisms were buried by rocks and volcanic materials, then was decomposed over millions of years by pressure, temperature and chemical reaction in the absence of oxygen and formed petroleum.

Inorganic Origin Theory

Hydrogen and Carbon come together under pressure and temperature below earth's surface, where chemical reactions occurred and formed oil and gas.

Generation Of Hydrocarbon (Requirements)

- Need a Source (Plants Or Animal Remains).
- Proper Conditions.
- A Long Time Period.

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Geology of Petroleum Reservoirs

Geology is the science that deals with the history and structure of the earth and its life forms, especially as recorded in the rocks.

Geology is so essential to the petroleum industry.

Knowledge of the basic principles of this science is desirable for anyone associated with oil or natural gas.

Many decades of prospecting for oil have convinced the participants that there are certain basic geologic requirements for oil and gas accumulation.

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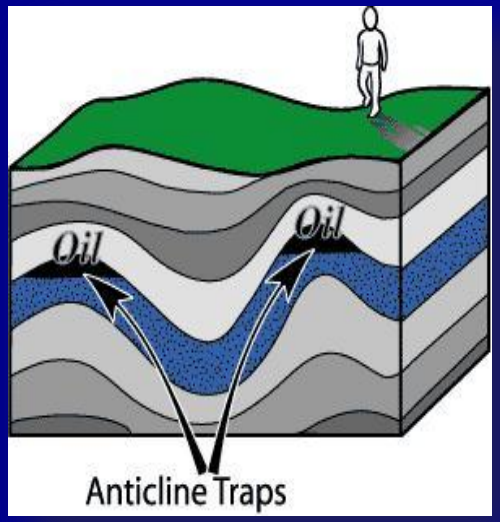
Geology of Petroleum Reservoirs

These pre-requisites concern:

- the quality of the oil bearing reservoir rocks
- and the presence of a barrier that will trap the oil in underground pools.



Thus,

the commercial production ultimately depends upon the pressure, porosity, and permeability of the reservoir rock as much as on the rock's having a proper trap or a good seal to keep the petroleum in the reservoir.

All of these factors are part of the petroleum geologist's concern in searching for a commercial petroleum deposit.

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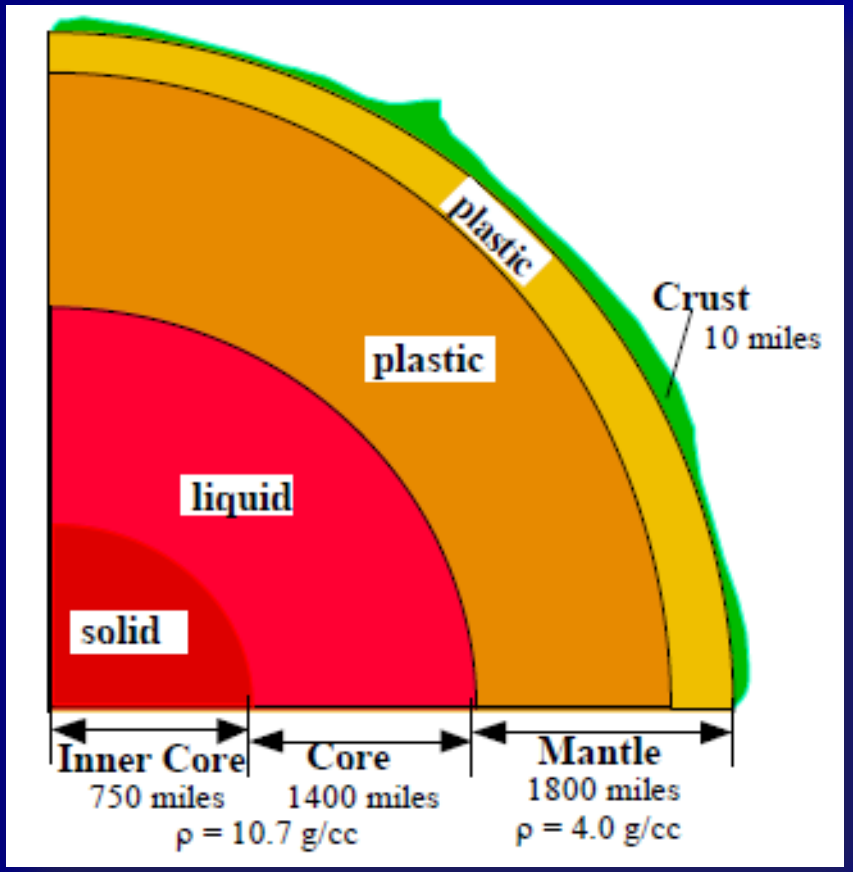
Types of Rocks

The rocks forming the earth's crust are broken down into three major classes reflecting their origins.

- **Igneous,**
- **sedimentary, and**
- **metamorphic.**



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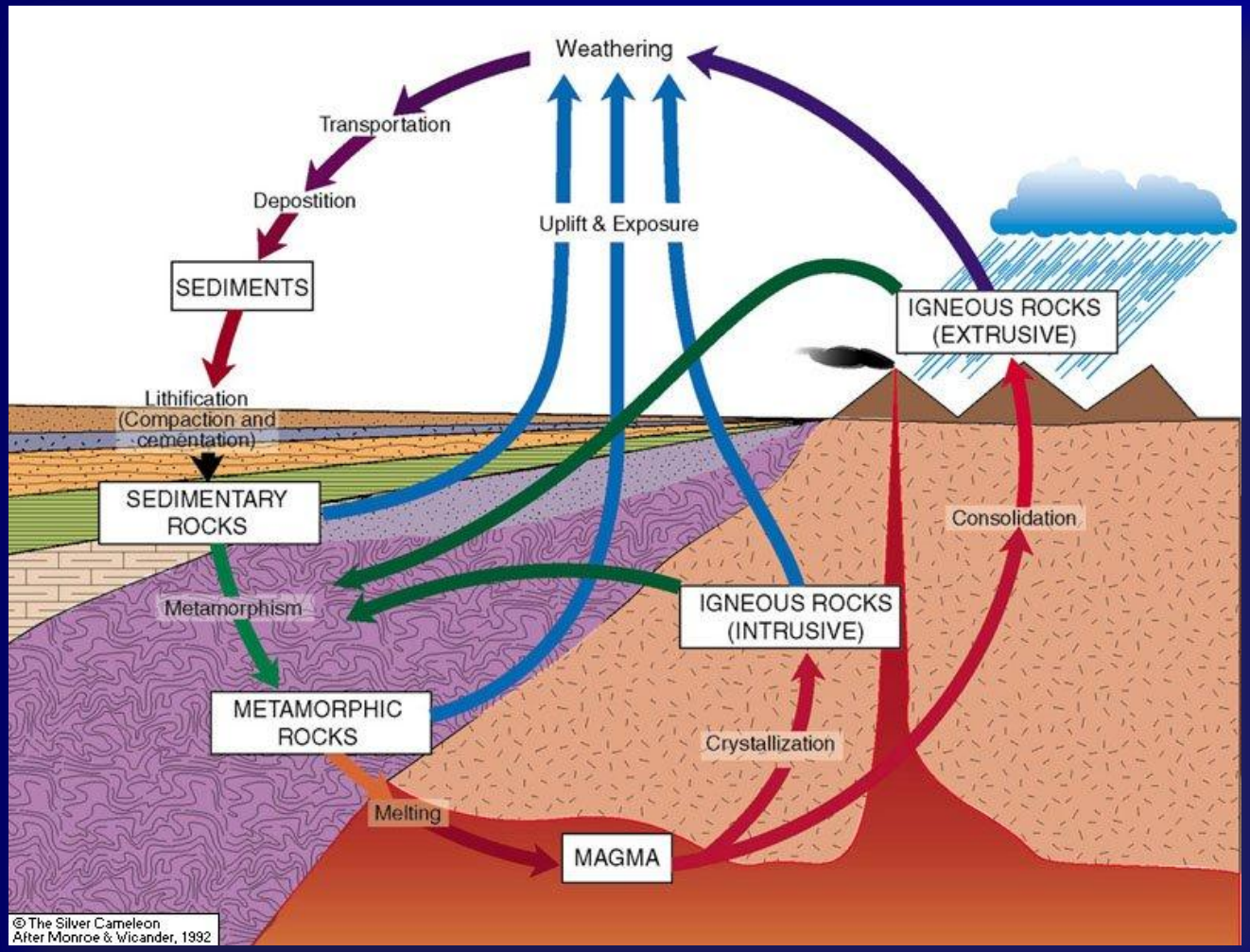
Types of Rocks



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Types of Rocks

Igneous are rocks that have solidified from a molten or liquid state. These rocks can be formed deep in the earth or at the surface from cooling of volcanic lava. Igneous rocks usually do not contain hydrocarbons because they have no porosity.

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Types of Rocks

Sedimentary are formed from the deposition of particles (sediments) in seas, rivers or lakes. The accumulate sediments are cemented together to form sedimentary rocks. Sedimentary rock are those rocks where hydrocarbons are formed (source rock) and accumulated (reservoir rock). Sandstone, limestone, dolomite, shale, and evaporates are the most important sedimentary rocks for petroleum engineers.

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Types of Rocks

metamorphic are formed by the metamorphosis of other existing rocks by extreme temperature and pressure.
These two factors cause recrystallization of the minerals in the rocks. Metamorphic rocks normally do not contain hydrocarbons.

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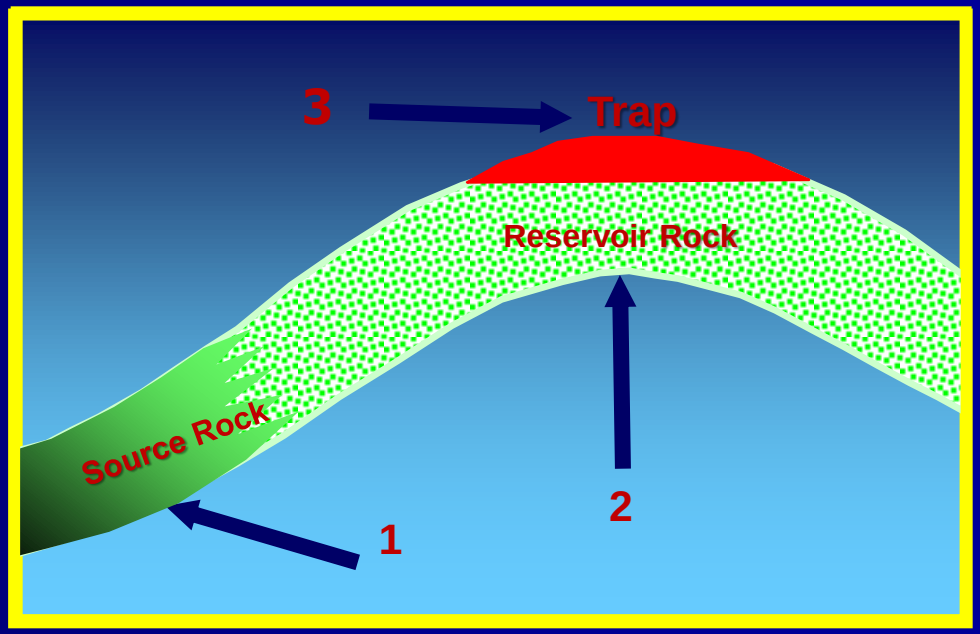
Petroleum Accumulation Requirements

Petroleum is found in sedimentary basins in sedimentary rocks. Several geologic elements are necessary for oil and gas to accumulate in sufficient quantities to create a reservoir large enough to be worth producing.

These elements include:

- ✓ **Source Rock**
- ✓ **Reservoir Rock**
- ✓ **Geological Structures (Traps)**



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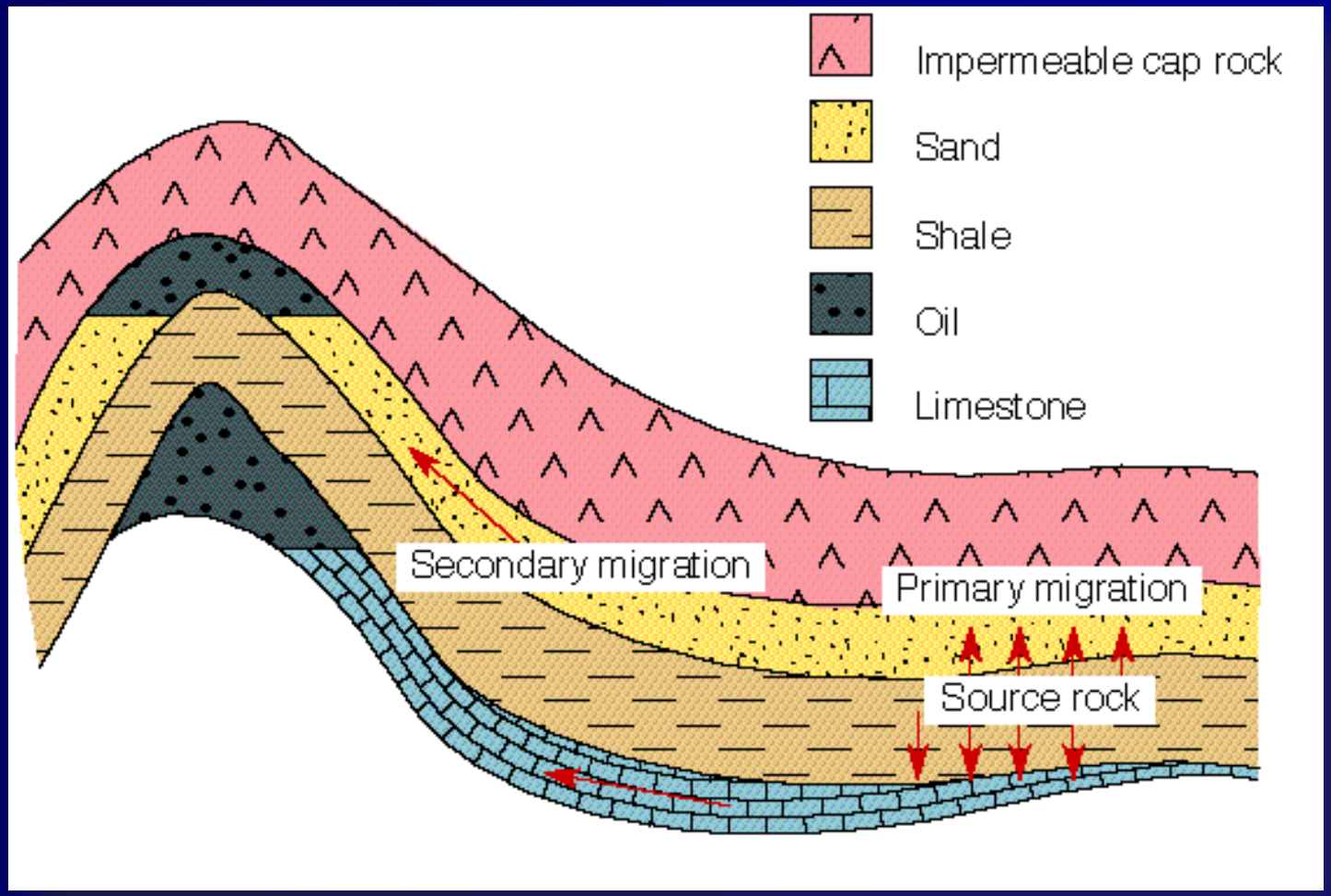
Petroleum Accumulation Requirements



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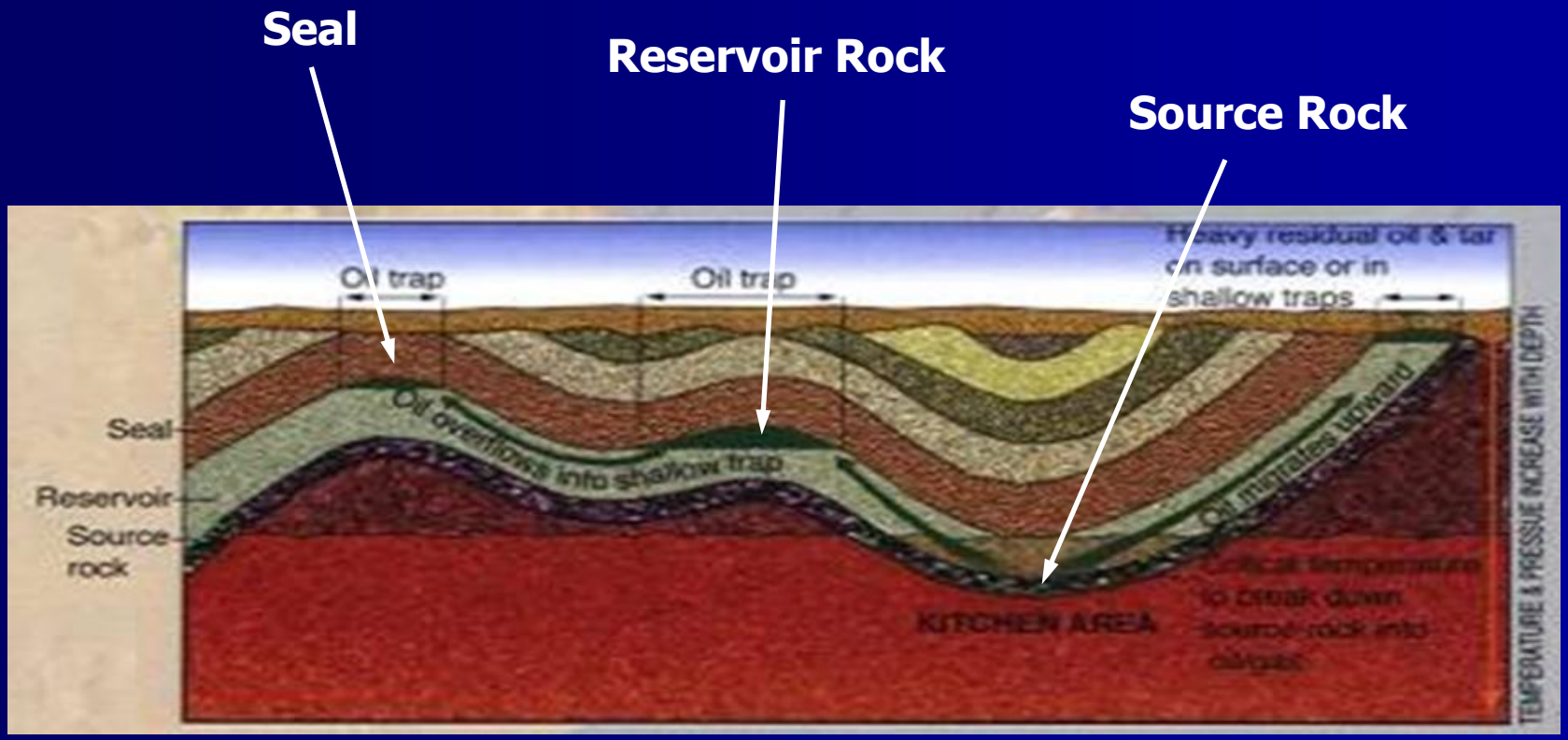
Petroleum Accumulation Requirements

Geology Of Saudi Arabia Meets All Requirements



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Petroleum Accumulation Requirements

✓Source Rock

Hydrocarbon originates from minute organisms in seas and lakes. When they die, they sink to the bottom where they form organic-rich "muds" in fine sediments.

These "muds" are in a reducing environment or "kitchen", which strips oxygen from the sediments leaving hydrogen and carbon.

The sediments are compacted to form organic rich rocks with very low permeability.

The hydrocarbon can migrate very slowly to nearby porous rocks, displacing the original formation water.

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Petroleum Accumulation Requirements

- ✓ **Reservoir Rock**

Reservoir rocks need two properties to be successful:

Pore spaces able to retain hydrocarbon.

Permeability which allows the fluid to move.

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Petroleum Accumulation Requirements

✓Geological Structures (Traps)

Traps generally exist in predictable places such as at the tops of anticlines, next to faults, in the up-dip pinch-outs of sandstone beds, or beneath unconformities.

Petroleum reservoirs contain interconnected pores filled with water and hydrocarbons (oil and gas).

Because most oils are lighter than water, they migrate upward through the pores, or along faults and fractures, and make their way to the surface to discharge as oil seeps.

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Petroleum Accumulation Requirements

✓Geological Structures (Traps)

The exception is when a seal exists, some sort of impermeable barrier that prevents the upward migration of oil.

Shale, salt, and cemented sandstones are all potential seals. If the geometry is such that a seal forms a trap, such as in an anticline, then oil accumulates behind the trap to form a reservoir that, if large enough, can be commercially produced.

Oil will continue to migrate into the trap until the base of the reservoir reaches a spill point, where the excess oil escapes to renew its upward migration to the surface or to another trap. Traps may also be formed by faults, pinch-outs and unconformities.

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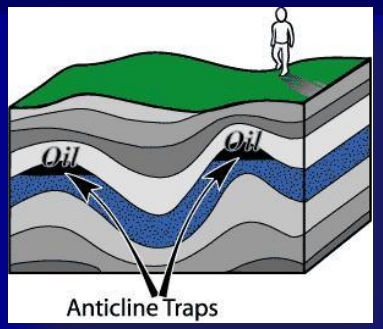
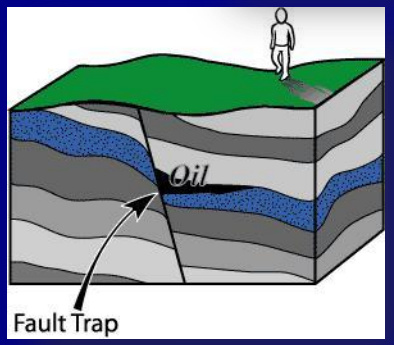
Types of Reservoir Traps

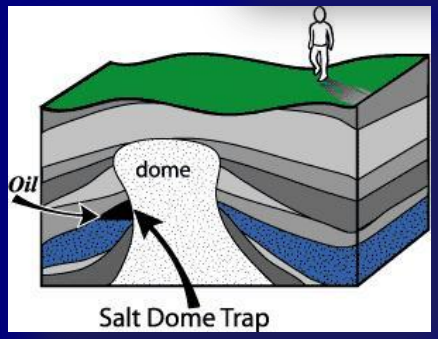
✓ **Structural Traps**

A structural trap is formed by the folding or faulting of the rock layer that contains the hydrocarbons.

Structural traps vary widely in size and shape. Some of the more common structural traps are **anticline** traps, **fault** traps, and **salt dome** traps







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Types of Reservoir Traps

✓ **Structural Traps**

These **anticline** traps were filled with petroleum when it moved in form its source below.

Fault traps are formed by breaking or shearing and offsetting of strata. The oil is confined in traps of this type because of the tilt of the rock layers and the faulting.

Salt dome and plug traps are porous formations on or surrounding great plugs or masses of salt or serpentine rock that have pierced, deformed, or lifted the overlying
layers.

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Types of Reservoir Traps

- ✓ Structural Traps

Surface Outcrops Of Sedimentary Beds

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Types of Reservoir Traps

- ✓ Structural Traps

Anticline

Syncline

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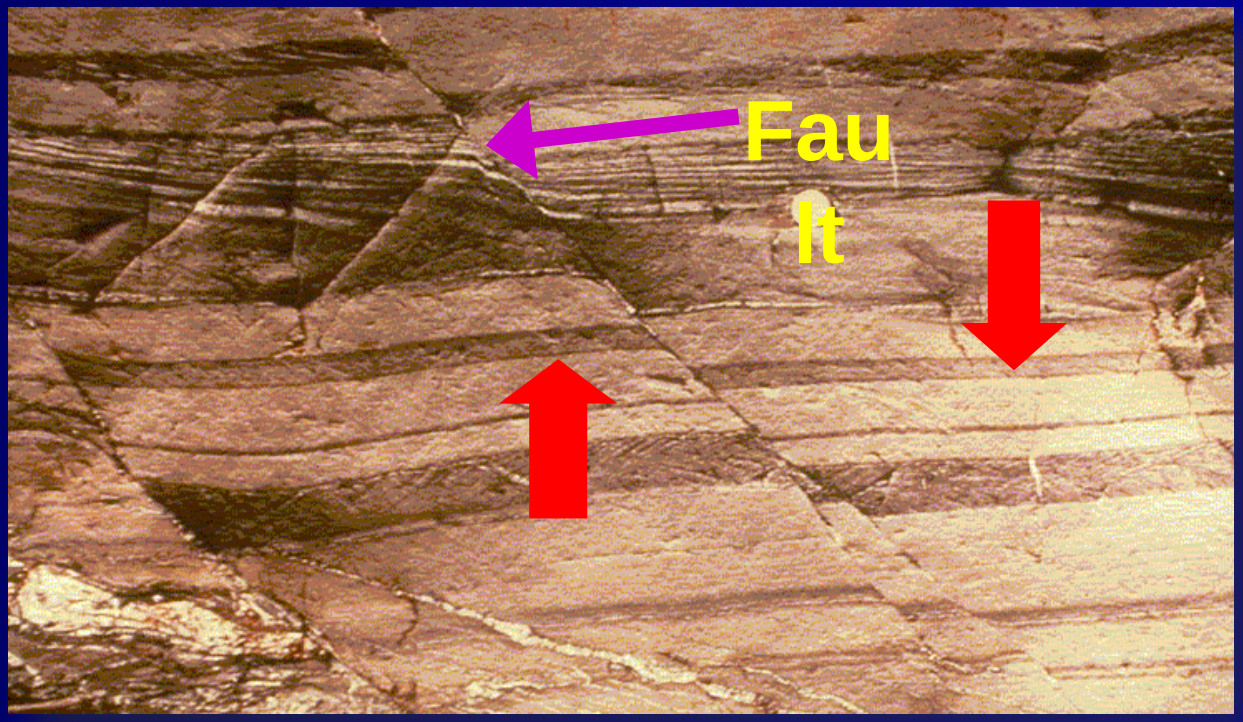
Types of Reservoir Traps

- ✓ Structural Traps

Surface Exposure Of Faulted Rock



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Types of Reservoir Traps

- ✓ **Stratigraphic Traps**

Stratigraphic traps are caused either by a nonporous formation sealing off the top edge of a reservoir (porous) bed or by a change of porosity and permeability within the reservoir bed itself.

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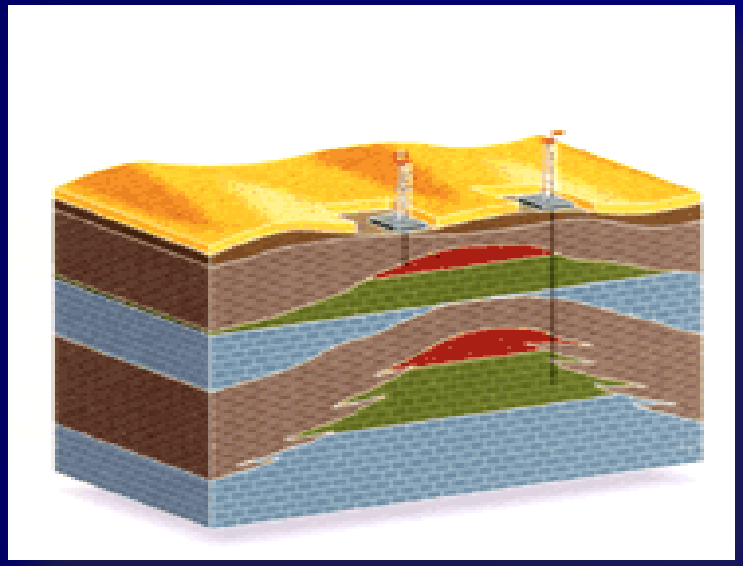
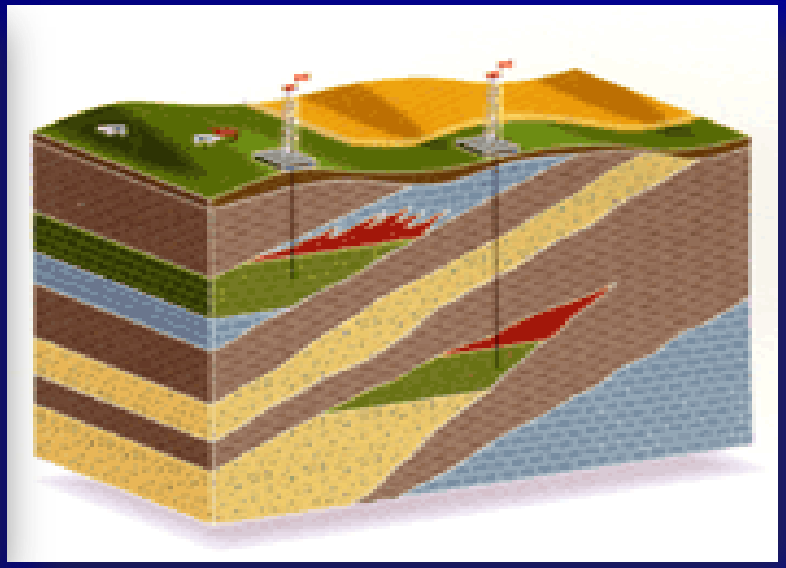
Types of Reservoir Traps

- ✓ Stratigraphic Traps

Reef



Pinch-out



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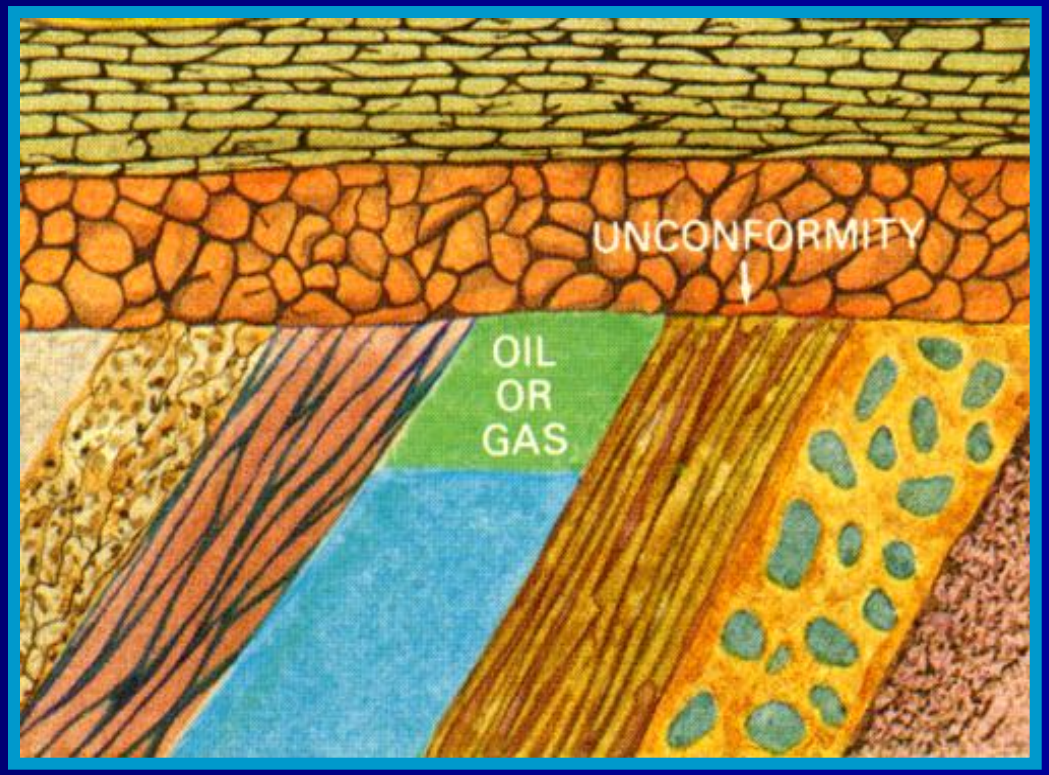
Types of Reservoir Traps

- ✓ Stratigraphic Traps



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Types of Reservoir Traps

- ✓ Stratigraphic Traps

Surface Exposure Of Erosional Unconformity

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Types of Reservoir Traps

- ✓ **Complex (Combination) Traps**

When stratigraphic and structural traps are located in the same place, the whole group is named as a complex trap.

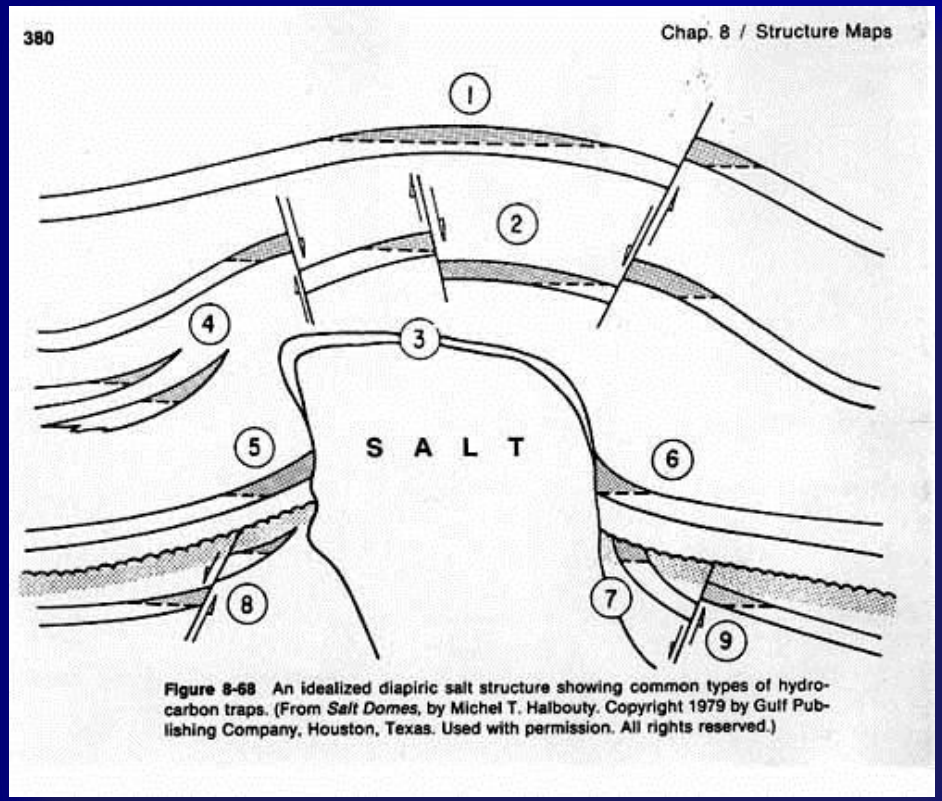

Figure 8-68 An idealized diapiric salt structure showing common types of hydrocarbon traps. (From *Salt Domes*, by Michel T. Halbouty. Copyright 1979 by Gulf Publishing Company, Houston, Texas. Used with permission. All rights reserved.)

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Petroleum Accumulation Requirements

In summary, the geological features necessary for accumulation of and recovery of oil and natural gas in commercial reservoirs are:

1. A porous (at least ϕ = 10%) and permeable zone of sufficient thickness (at least h = 10ft) to contain large quantities of oil and natural gas called reservoir rock.
2. An overlaying bed of impermeable rock such as shale that is normally called cap rock.
3. An underlying seal such as water saturated zone or a confinement by water down dip below the oil and gas in the reservoir horizon.
4. Some type of structure feature, or discontinuity of the porous and permeable beds (i.e. stratigraphic or structural traps).
5. Sufficient pore fluid pressure (energy) to perform flow into the production wellbore.
6. Organic rich source rock.

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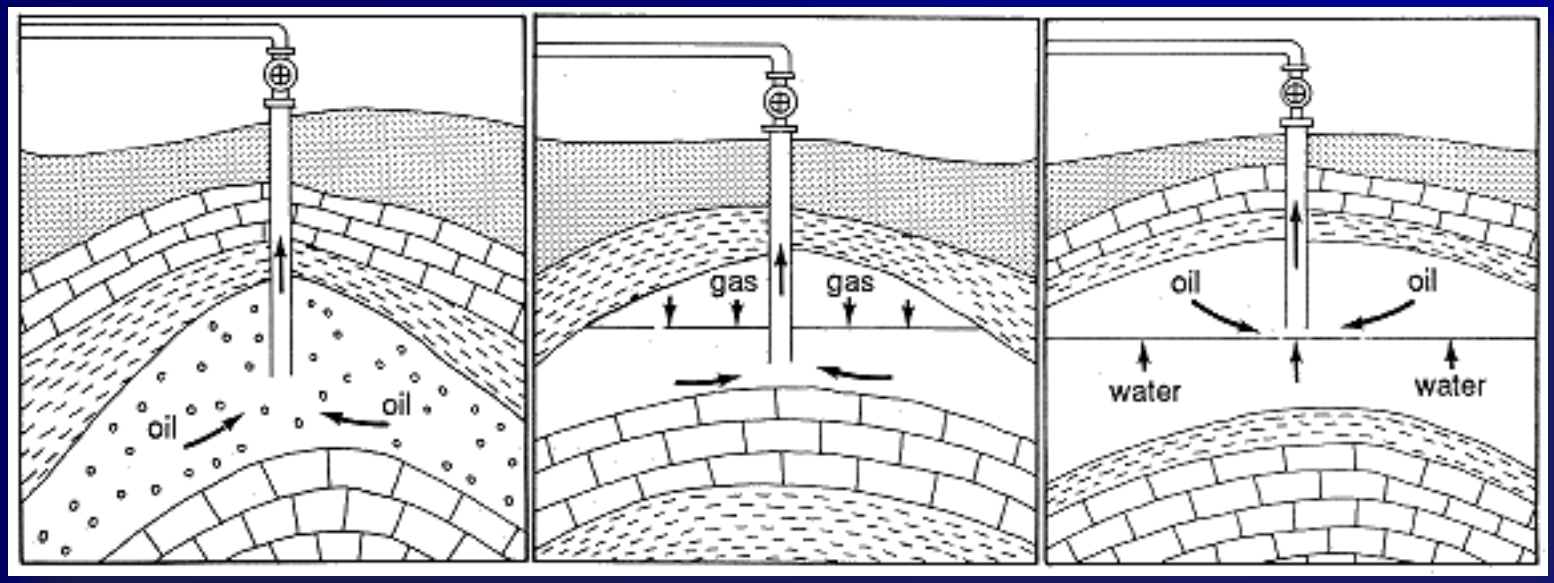
✓ Reservoir Energy Mechanisms

Reservoir-drive mechanisms. **Solution gas drive** is the result of the expansion of gas that is dissolved in the oil. **Gas-cap drive** is the result of the expansion of gas which is contained in the reservoir above the oil. **Aquifer drive** is the result of the upward pressure of water as it expands and moves into the regions of lowered pressure as oil is produced.



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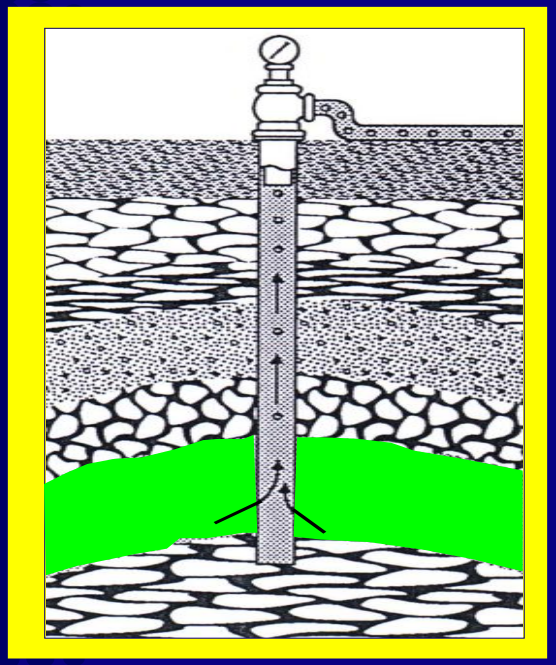
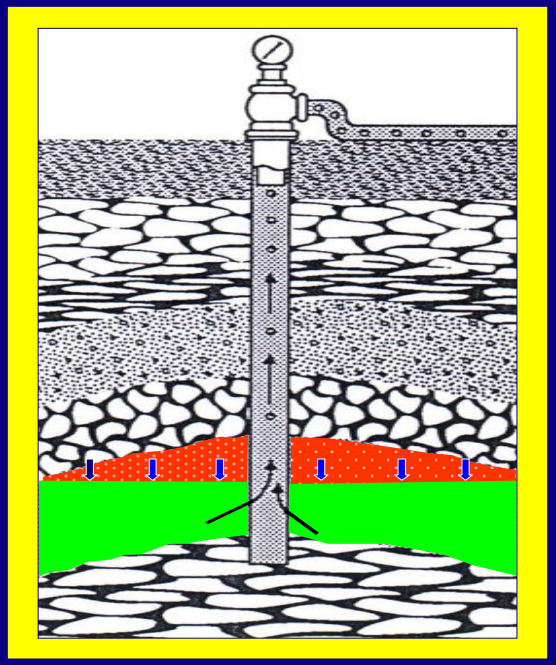
✓ Reservoir Energy Mechanisms

Primary Oil Recovery



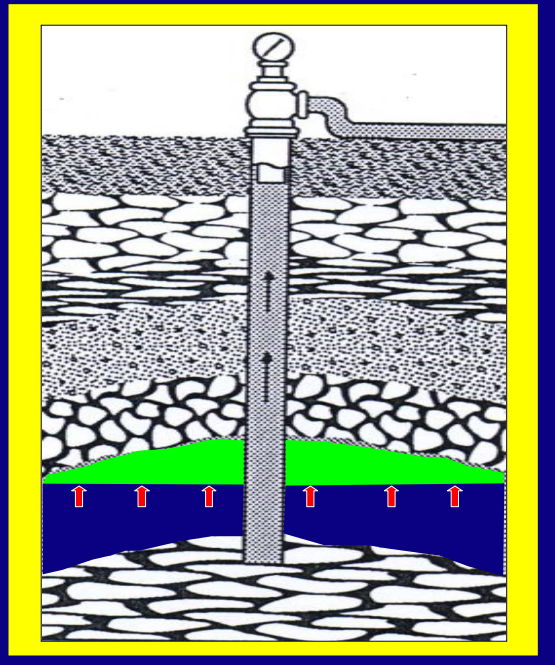
Solution Gas

RE = 5 – 30%



Gas Cap Drive

20 – 60%



Water Drive

35 – 80%

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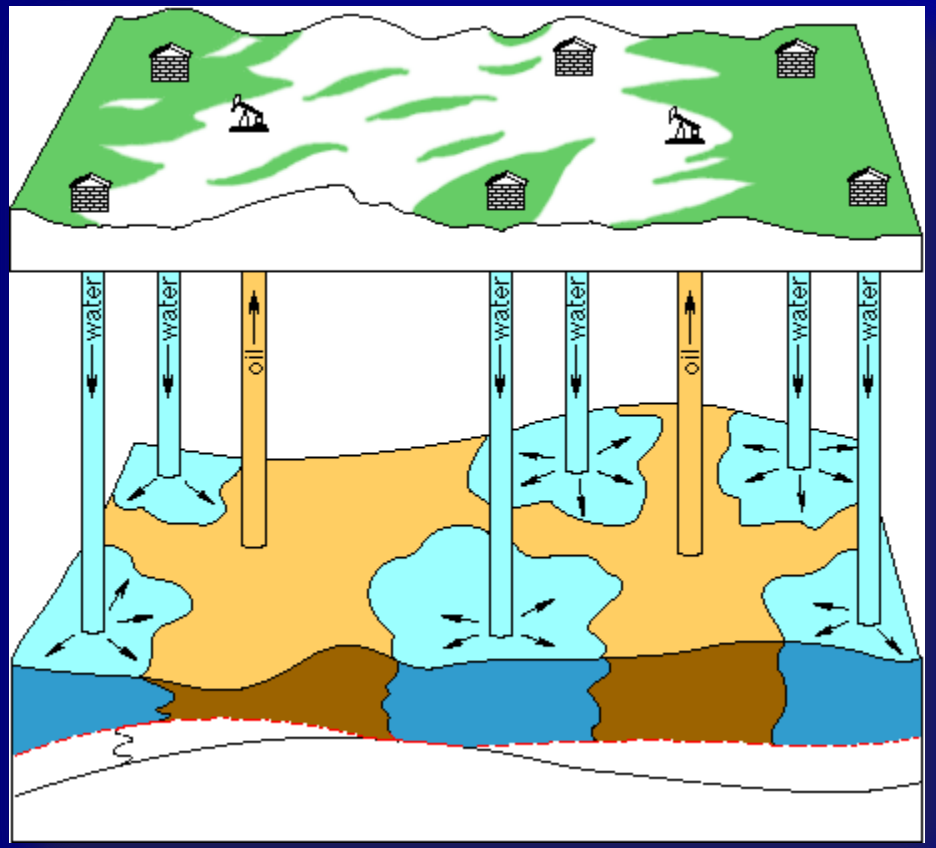
✓Improved Recovery Mechanisms

The use of **natural** reservoir energy to produce oil and natural gas generally results in a recovery of less than 50% of the original hydrocarbon in place.

If the natural drives are insufficient, as they very often are, then the pressure can be artificially maintained by applying **secondary** recovery methods by injecting **water** into the aquifer or **gas** into the gas cap.



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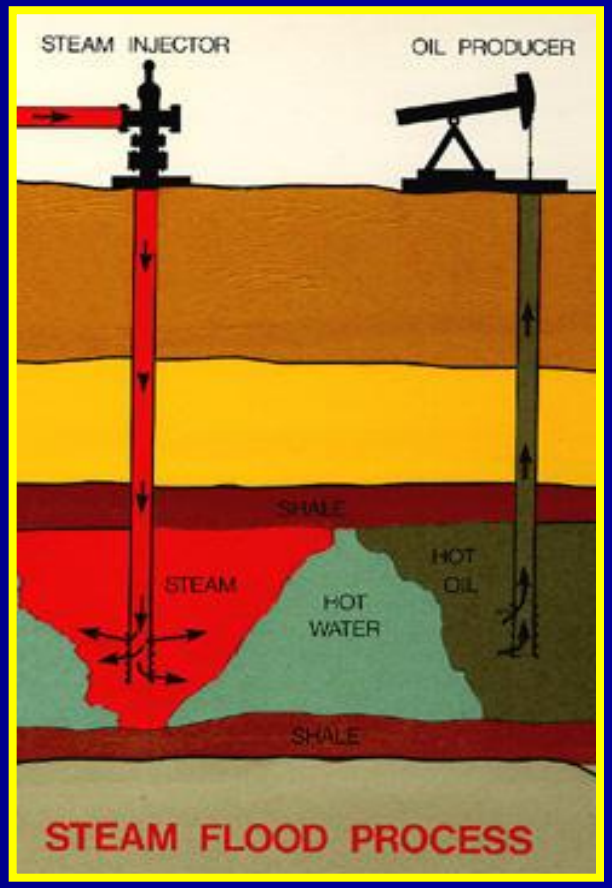
✓Improved Recovery Mechanisms

If the reservoir productivity is still low, then the tertiary or enhanced oil recovery techniques are applied.

Tertiary recovery methods are the mechanisms of changing either the reservoir rock properties or the reservoir fluids properties by chemical recovery, thermal recovery, miscible and immiscible recovery processes.

Thermal



Questions