Exploration et Exploitation des Hydrocarbures:

Eléments Techniques et non Techniques pour mieux comprendre et cerner ce secteur de l'industrie Minière

Cameroonians GeoPetroMiners in Germany

Prepared & Presented by M.Sc. E. Atangana-Eloundou

Structure

- Objectives
- About Myself
- Overview of the Oil & Gas Industry
- Focus on the Upstream
- Upstream: The workers…
- The Reservoir…
- Conclusions
- Discussions

Objectives:

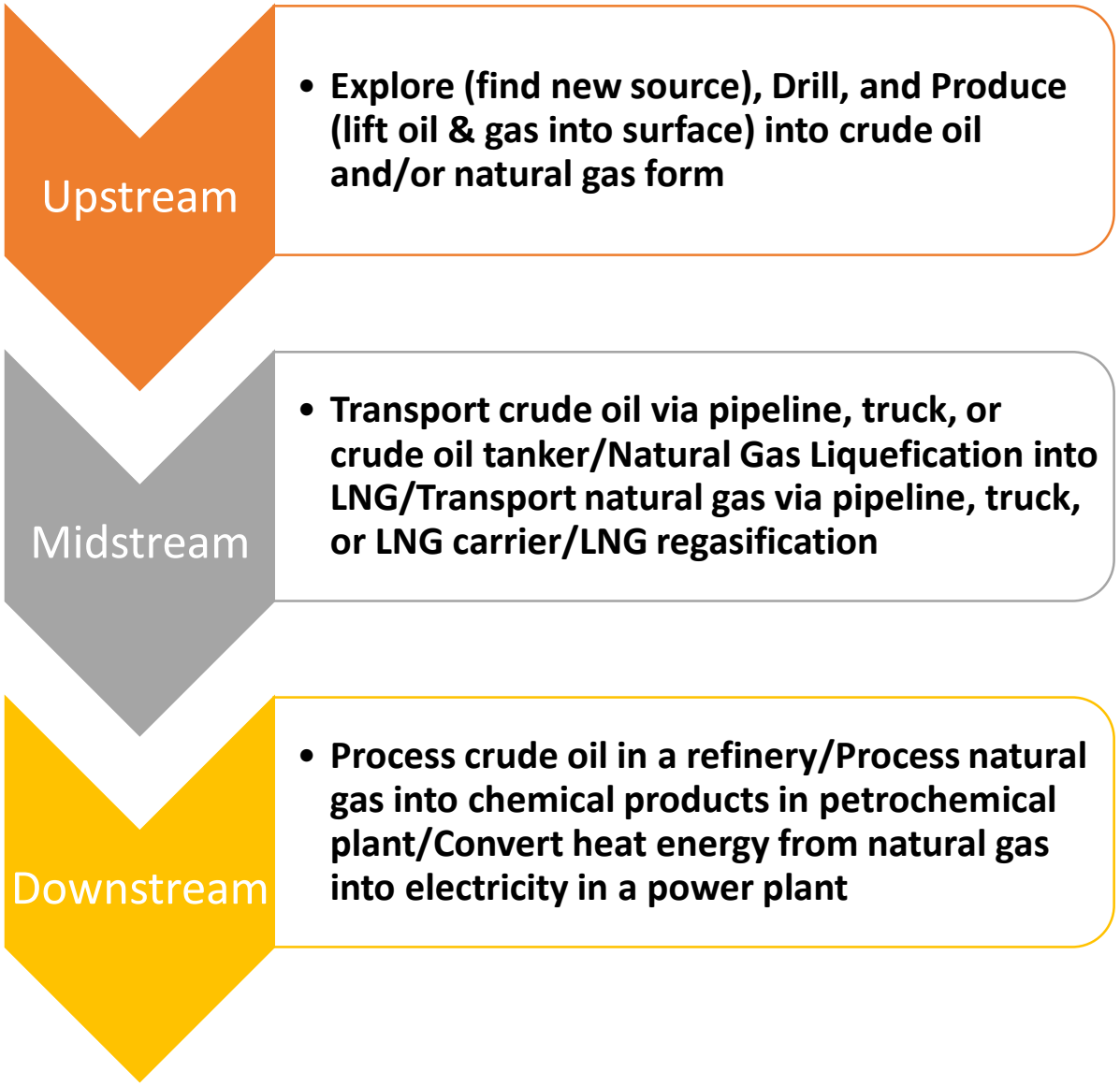
- Needs of clarification in our minds
  - Society, Students and Academicians
- Present and Discuss
  - why we should build our petroleum (Reservoir) Engineers
- Opportunity to
  - Make connections and
  - Built a wordwide network of
  - Geoscientists/Mining/Petroleum Engineers

About the Myself:

- Cameroonian...
- Clausthal University of Technology
  - Lower Saxony/Germany
  - Bachelor of Sciences Energy & Rohmaterials
  - Focused on Petroleum Engineering
- Freiberg University of Technology & Mining Academy
  - Saxony/Germany
  - Master of Sciences Engineering & Industrial Management
  - Focused on Petroleum Engineering/Reservoir Management
- Berlin university of Technology
  - Research & Scienstist Worker
  - PhD Student
  - Focused on Mechanical Assisted Production Optimization & Reservoir Simulation

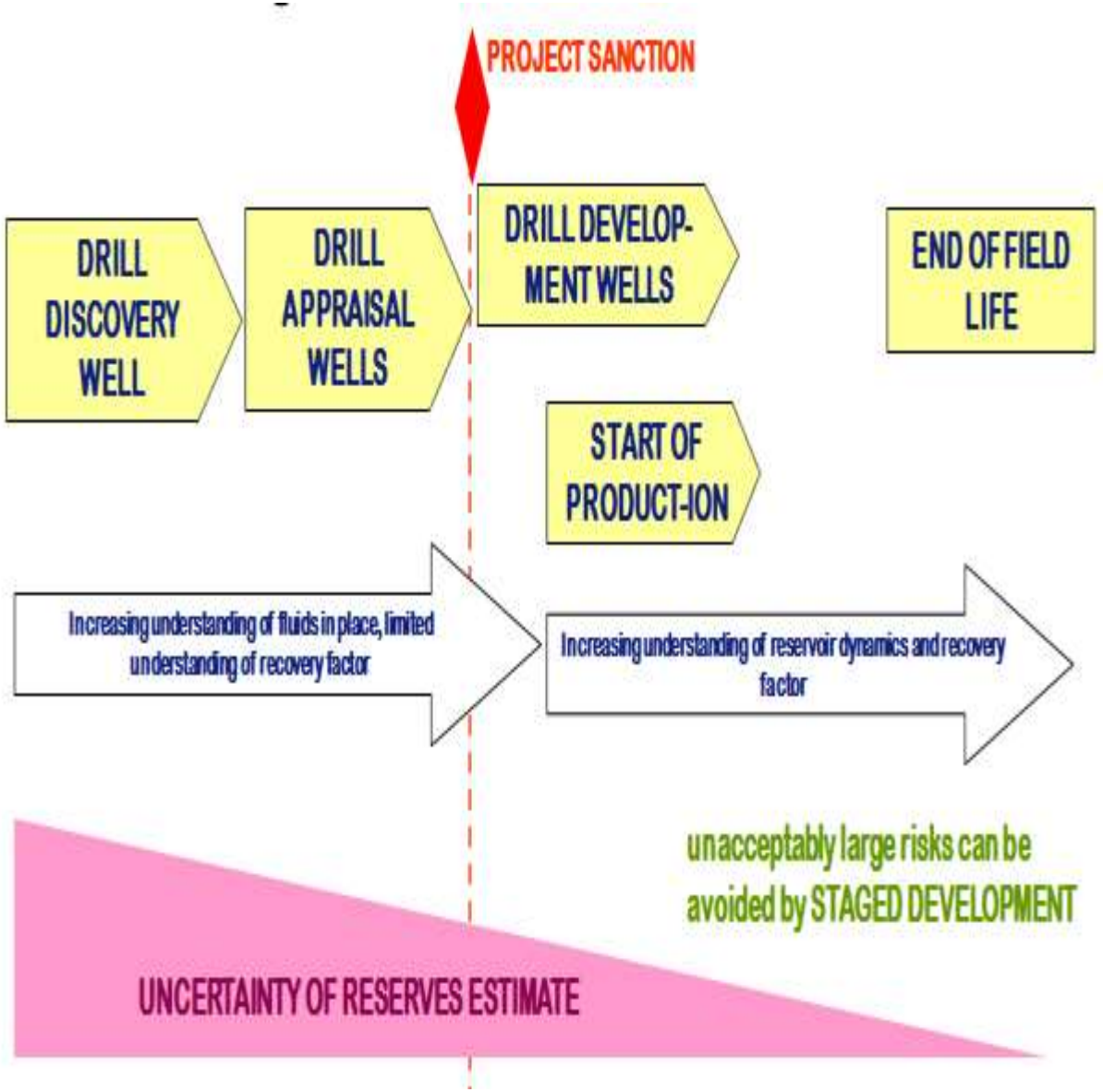
Oil & Gas Industry: Overview

- ***Upstream :***
  - Explore (find new source),
  - Drill, and Produce (lift oil & gas into surface) into crude oil and/or natural gas form
- ***Midstream :***
  - Transport crude oil via pipeline, truck, or crude oil tanker/Natural Gas Liquefication into LNG/Transport natural gas via pipeline, truck, or LNG carrier/LNG regasification
- ***Downstream :***
  - Process crude oil in a refinery/Process natural gas into chemical products in/petrochemical plant/Convert heat energy from natural gas into electricity in a power plant



Upstream Industry: Overview

- ***Exploration :***
  - Find a new oil & gas reservoir
- ***Appraisal :***
  - Ensure new finding is commercially feasible
- ***Development :***
  - Develop surface facilities to extract & process oil & gas from the reservoir
- ***Production :***
  - Produce oil & gas and maintain the facilities until end of field life / contract period
- ***Abandonment :***
  - Close the production and return the field into original condition



Persons Involved in the Upstream Industry: Finders vs. Movers...

Who will discover future oil & gas?

The Finders: **Geoscientists**

- Study the Earth for clues to where oil & gas might be hidden.
- Evaluate subsurface structures to find oil & gas fields

The Movers: **Petroleum Engineers**

- Work with geoscientists to understand the geologic formation & properties of the reservoir rock & the fluids therein, help determine the drilling methods to be used, & monitor production operations.
- Design equipment & processes to achieve the maximum profitable recovery of oil & gas.
- As only a small proportion of oil & gas in a reservoir will flow out under natural forces, PEs implement various enhanced recovery methods:
  - injecting water, chemicals, gases, or steam into a reservoir to force out more of the oil,
  - Geo-steered drilling or hydraulic fracturing to connect a larger area of a reservoir to a single well.

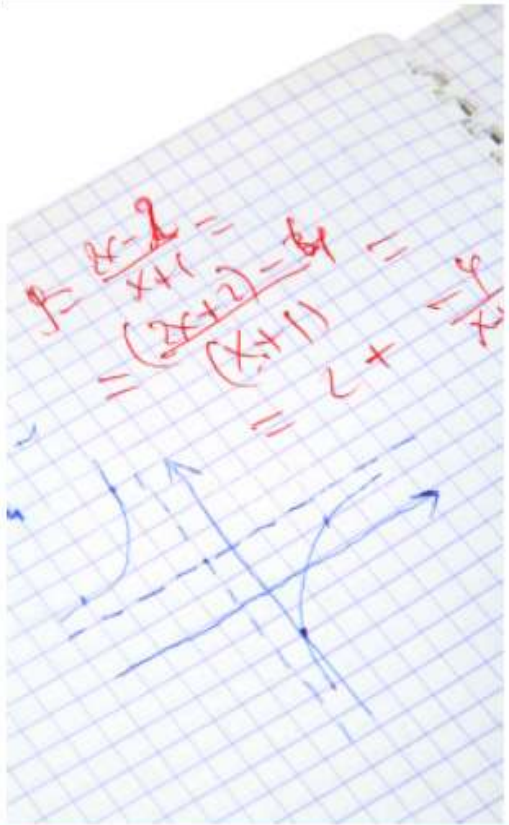
Petroleum Engineers:

work in teams to ...

- Use creative solutions to find oil & gas.
- Understand rock formations & reservoir fluids.
- Analyze oil & gas fields' qualities.
- Monitor drilling & production.
- Design equipment, processes so maximum amount of oil & gas is recovered.
- Manage drilling of oil & gas wells.
- Ensure operations run smoothly & safely, while respecting the environment.

The Petroleum engineers: Areas of Speciality & Daily Life

Petroleum Engineers:
Areas of speciality …



Petroleum Engineers
- reservoir engineer
- production engineer
- completions engineer
- drilling engineer
- economist
- HS&E engineer
- & more!

Allied careers
- petrophysicist
- geologist
- geophysicist
- information technologist

Petroleum Engineers:
A day in the life …

- While most PEs work directly for oil & gas production companies, many join the service sector in the employment of the large contractors.
- PEs have a broad focus & cross over many industries, working on a wide range of projects & activities.
- A 'production' PE will focus on production challenges, identifying, testing, & implementing methods for improving oil & gas production. Whilst an 'operational or wellsite' PE may focus on safety issues, or maintenance support, identifying and planning upgrades of equipment or systems.
- A 'reservoir' PE will focus on building models for production forecasts and booking reserves, with a likely to be focus on economics, helping a team determine the optimum number of wells for a given development. These PEs often move into new business groups, advising on acquisitions & divestments, & may become consultants to investors, banks, or other financial services firms.

Persons Involved in the Upstream Industry… Interdiciplinarity and Team Work!!!

- Geoscientists
- Drilling engineers
- Production Engineers
- Reservoir Engineers
- Others Scientists
  - Informaticians/Computer Scientists
  - Mathematicians
  - …

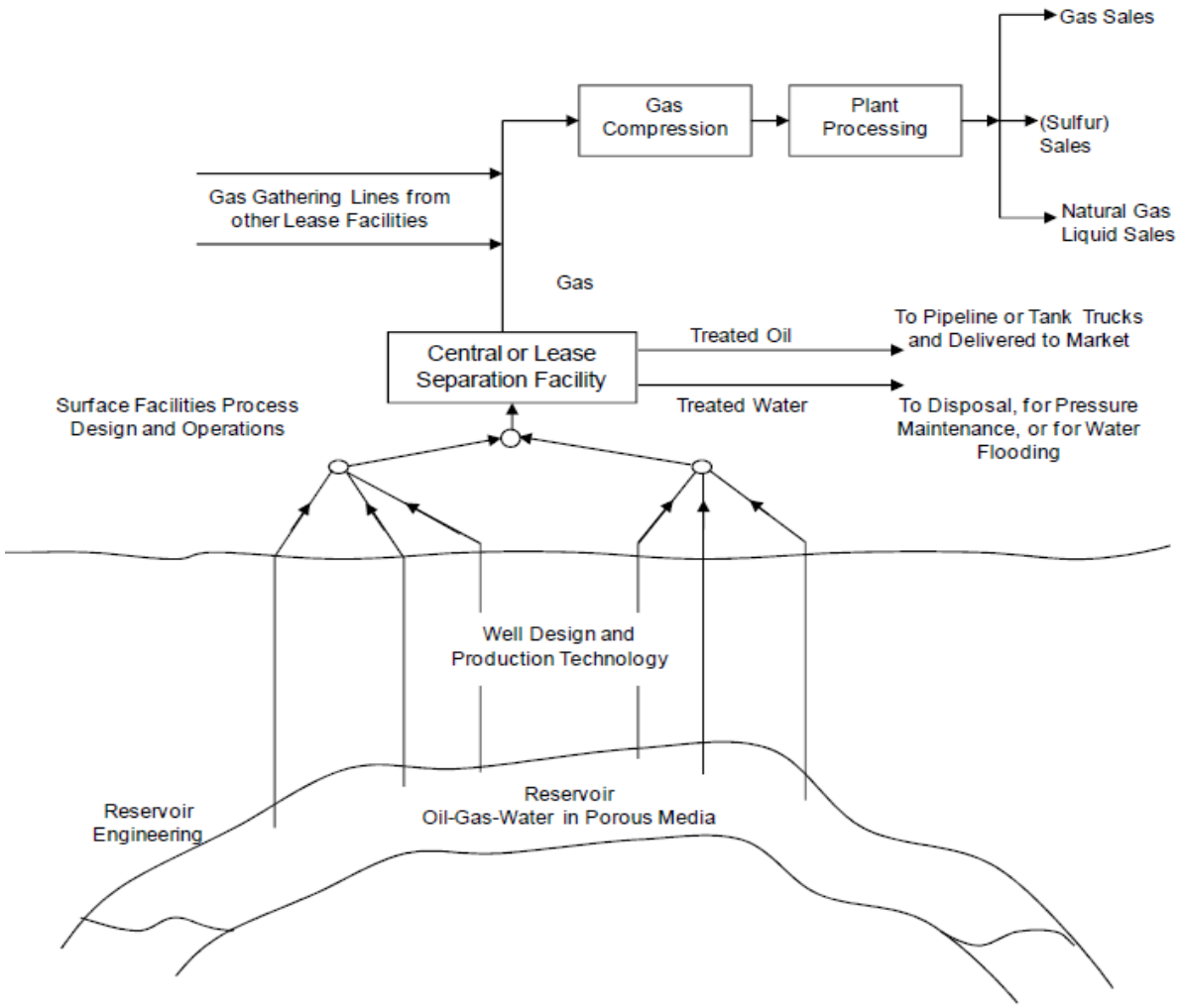
The Production Engineer

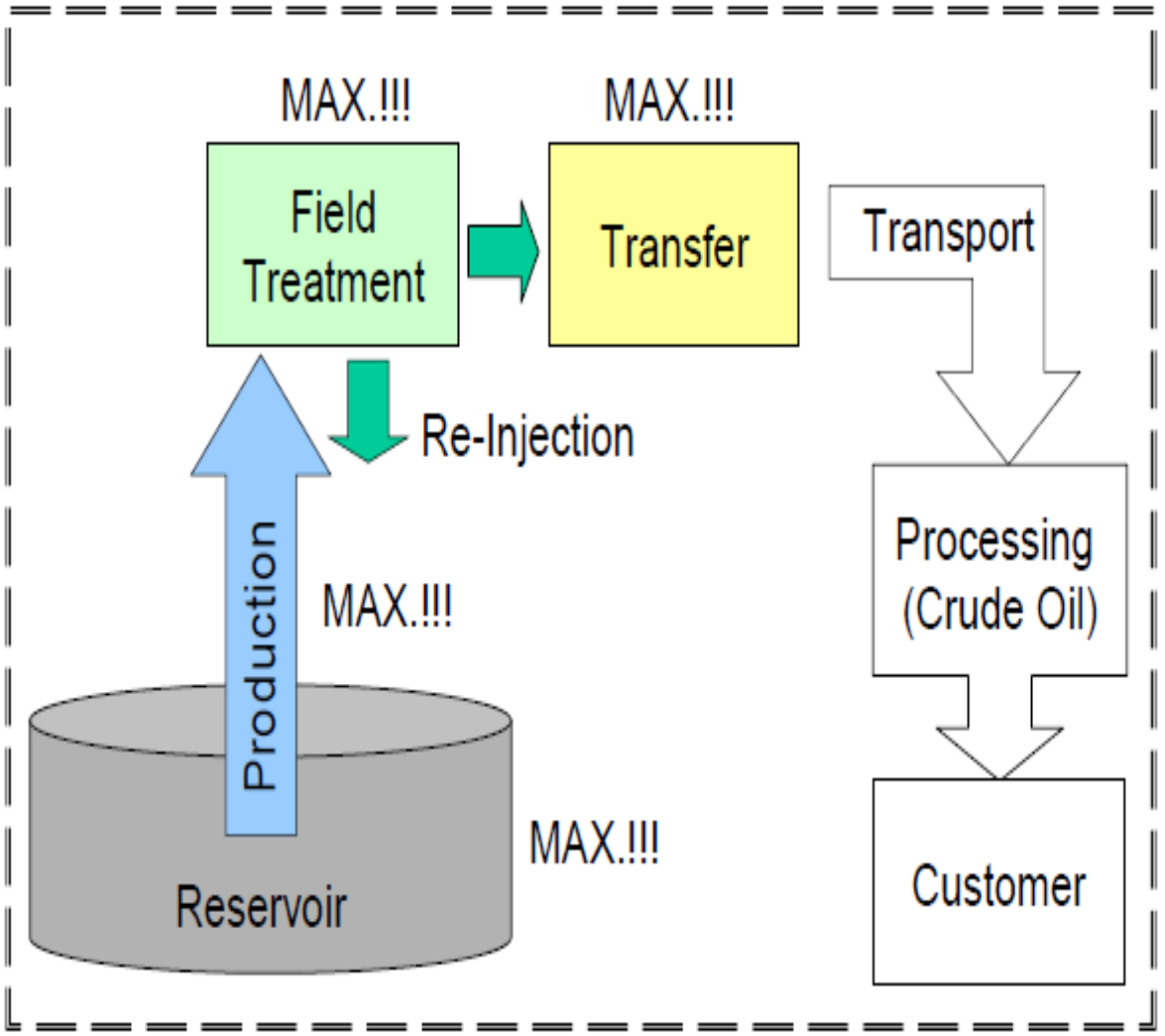
- ***„Production engineering is that part of petroleum engineering that attempts to maximize production (or injection) in a cost-effective manner."*** after Economides & al. [1]
- Focused on the „Well" but Involves two connected systems:
  - ***The Reservoir***
    - Flow caracteristics (transport) and Storage capacities
  - ***Artificial structures (Surface facilities)***
    - Well/Bottomhole & Wellhead assemblies
    - Surface Gathering and Facilities (Separation & Storage)
- Directly related & interdependently with other major areas, such as
  - Formation evaluation (Petroleum Geosciences)
  - Drilling Engineering
  - Reservoir Engineering

The Production Engineer: Typical Duties

- Production monitoring and evaluation
- Asset management planning
- Workover design and execution
- Production equipment design
- Cost estimating and budgeting
- Interfacing with
  - working interest partners,
  - service companies
  - and regulatory agencies
- Implementing safe and environmentally sound practices in field operations and maintenance
- Determining appropriate equipment for facilities and construction operations.
- Performing procedures in drilling, workover, snubbing and coiled tubing operations.
- Determining and applying electric line, slickline, remedial and P&A operations.

The Petroleum Production-System





- *The Petroleum Production-Systems (a)Sources: Dr.-Ing. J. Holzmann [2]*
- *The Petroleum Production-Systems (b)Sources: Dr.-Ing. J. Holzmann [2]*

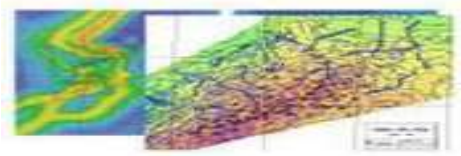
Reservoir Engineering: The Definition

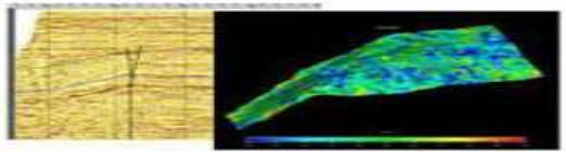
- is a branch of petroleum engineering that applies scientific principles to the drainage problems arising during the development and production of oil and gas reservoirs so as to obtain a high economic recovery.
- Is the art of forecasting future performance of a geologic oil and gas reservoir from which production is obtained according to probable and pre-assumed condition .
- Functions Of Reservoir Engineering
  - To continuously monitor the reservoir and collect relevant data and interpret it to be able to:
  - Determine (present conditions)
  - Estimate (future conditions) and
  - Control the movement of fluids through the reservoir
  - so that we can
    - ***enhance (increase recovery factor) and***
    - ***accelerate (increase production rate) the oil recovery***

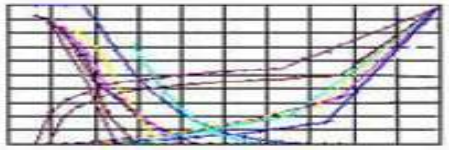
Reservoir Engineering: The Workflow

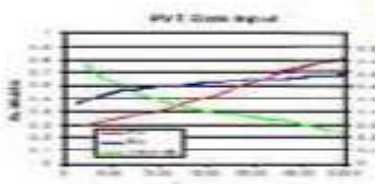
- ***RESERVOIR CHARACTERIZATION***
  - Shape of the Reservoir- Length, Width-
  - Thickness Distribution
- ***GROSS ROCK VOLUME***
  - Fluids and Contacts
  - Saturation Distribution
  - Non- Reservoir Zones
  - Porosity
- ***NET IN- PLACE HYDROCARBONS***
  - Permeability Distribution
  - Capillary Pressure
  - Relative Permeability
- ***FLOW CHARACTERISTICS***
  - Fluid Properties
  - Rock Compressibility
  - Aquifer Size
  - Pressure Distribution
- ***RESERVOIR ENERGY***
  - Well Locations
  - Production/Injection Constraints
- ***RESERVOIR PERFORMANCE***
  - Prediction Scenarios
  - Redevelopment Scenarios
  - Cash Flow Predictions

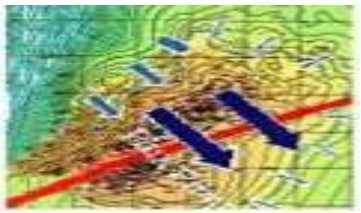
Reservoir Engineering: Multidisciplinary approach

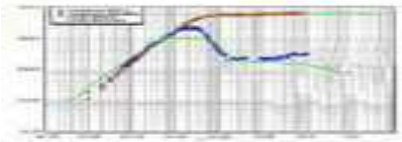












Geology (Maps)

Geophysics (Seismic)

Petrophysics

Saturation function

Fluid property

Reservoir Engineering

Production history

Drive mechanism

Well Testing

Reservoir Model

Reservoir Development Plan

Prediction of Reservoir Performance

The primary Functions of Reservoir Engineer

- To calculate the volume of the initial hydrocarbon present in the reservoir
- To predict the derivability of the wells producing from the reservoir (production versus time)
- To suggest strategies for increasing an individual or the productivity of the entire reservoir .
- During the whole life cycle of the Field Development, he has to answer the following question:
  - ***How can we increase the HC recovery economically????***

Reservoir Engineering: Most Used Terms

- ***Porosity:*** this is the ration of pore volume to bulk volume. It is expressed in fraction
- ***Permeability:*** this is the property of a reservoir that enables the movement of fluid (Darcy)
- ***Effective Permeability:*** this is the permeability of a reservoir when 100% saturated with a particular fluid
- ***Relative Permeability:*** this is the ration of effective permeability to absolute permeability
- ***Effective Porosity:*** this is the ratio interconnected pore volume to bulk volume
- ***Water Saturation:*** this is the ratio of the volume occupy by water to the pore volume
- ***Critical water saturation:*** critical water saturation defines the maximum water saturation that a formation with a given permeability and porosity can retain without producing water.
- ***Irreducible water saturation:*** This is the minimum water saturation at which water will remain immobile
- ***Formation volume factor:*** this is the ration of the volume of fluid in the reservoir to the volume at the surface
- ***Shrinkage factor:*** this is the inverse of formation volume factor

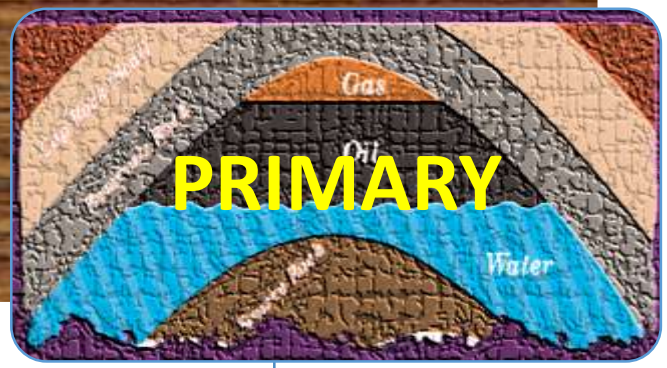
Calculating Original Oil in Place (OOIP)

- **OOIP = 7,758*A*h*ϕ*(1-Sw)/Bo**
- Where:
  - OOIP = Original Oil In Place [STB]
  - 7,758 = Factor Converting acre-Feet to Barrels
  - A = Reservoir Area [acres]
  - h = Average Reservoir Thickness [feet]
  - ϕ = Average Reservoir Porosity /Fraction of Bulk Volume [%]
  - S_w = Average Water saturation/Fraction of Pore Volume [%]
  - B_o = Oil Formation Volume Factor, [RB/STB]

OIL RECOVERY PROCESSES

- ***Primary Recovery***
  - Production using only natural reservoir energy (natural water drive, gas cap expansion, solution gas drive and pressure depletion drive).
- ***Secondary Recovery*** ***Improved Oil Recovery (IOR)***
  - Water or gas injection to maintain reservoir pressure (water flooding and immiscible gas injection to supplement natural reservoir energy).
- ***Tertiary Recovery*** ***Enhanced Oil Recovery (EOR).***
  - An EOR process is any process which does a better job of recovering oil than conventional technology (primary and secondary recovery processes).
  - In an EOR process conventional water or gas is replaced by a more effective (more expensive) recovery agent.

OIL RECOVERY PROCESSES



PRIMARY

SECONDARY

TERTIARY

Natural reservoir energy

Water flooding

Enhanced Oil Recovery

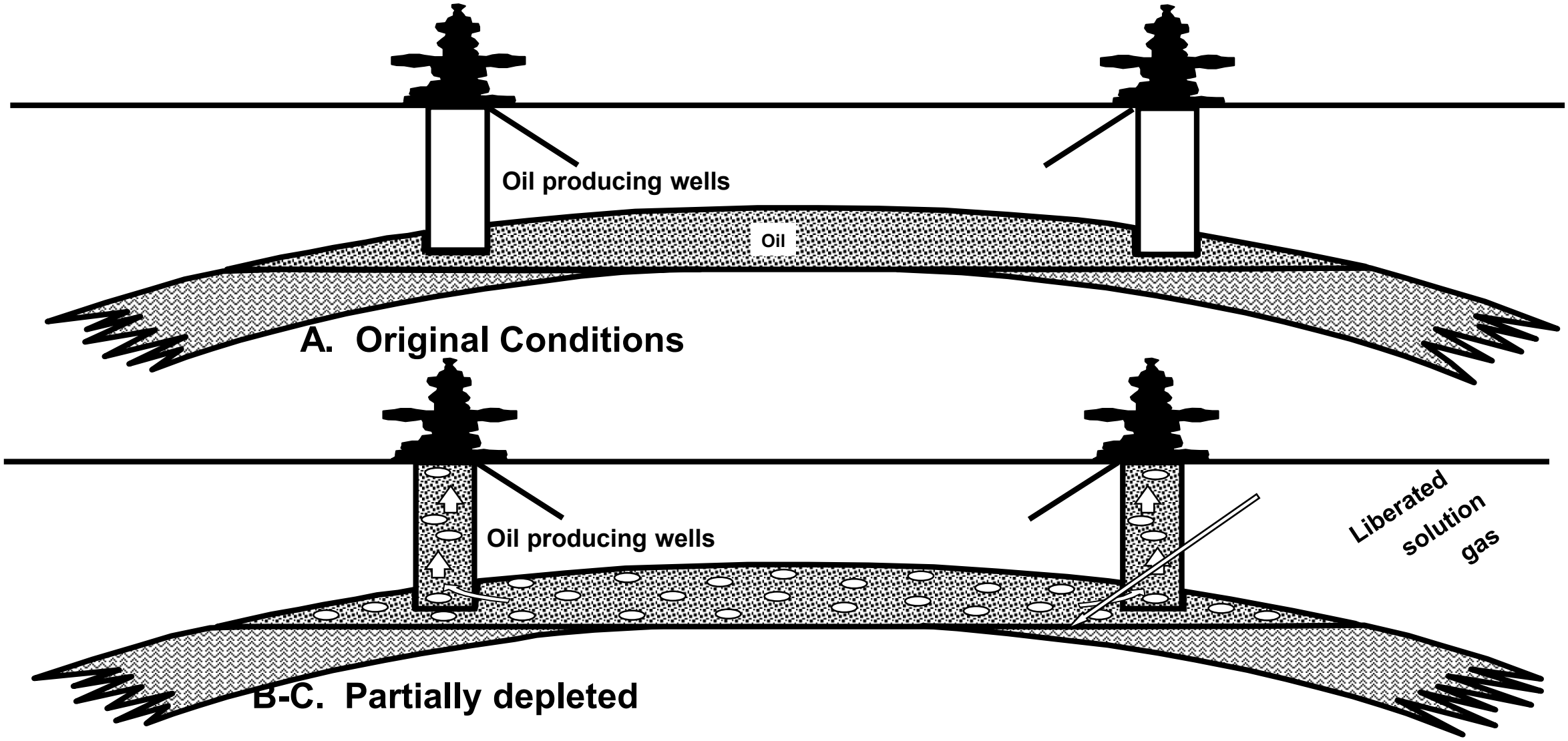
OIL RECOVERY PROCESSES

PRIMARY RECOVERY	**By: PRESSURE DEPLETION** ***→Development wells are all producers***	**Normal for GAS but poor for OIL (5-12% recovery)**
SECONDARY RECOVERY	**By: FLUID DISPLACEMENT** ***→Some development wells inject water or gas into the reservoir***	**Good for OIL (30-40% recovery)**
TERTIARY RECOVERY (Enhanced Recovery)	**By: DISPLACEMENT USING SPECIAL FLUIDS** ***→injection of surfactants, carbon dioxide or steam***	**Improves OIL recovery but expensive to carry out**

PRIMARY RECOVERY MECHANISMS

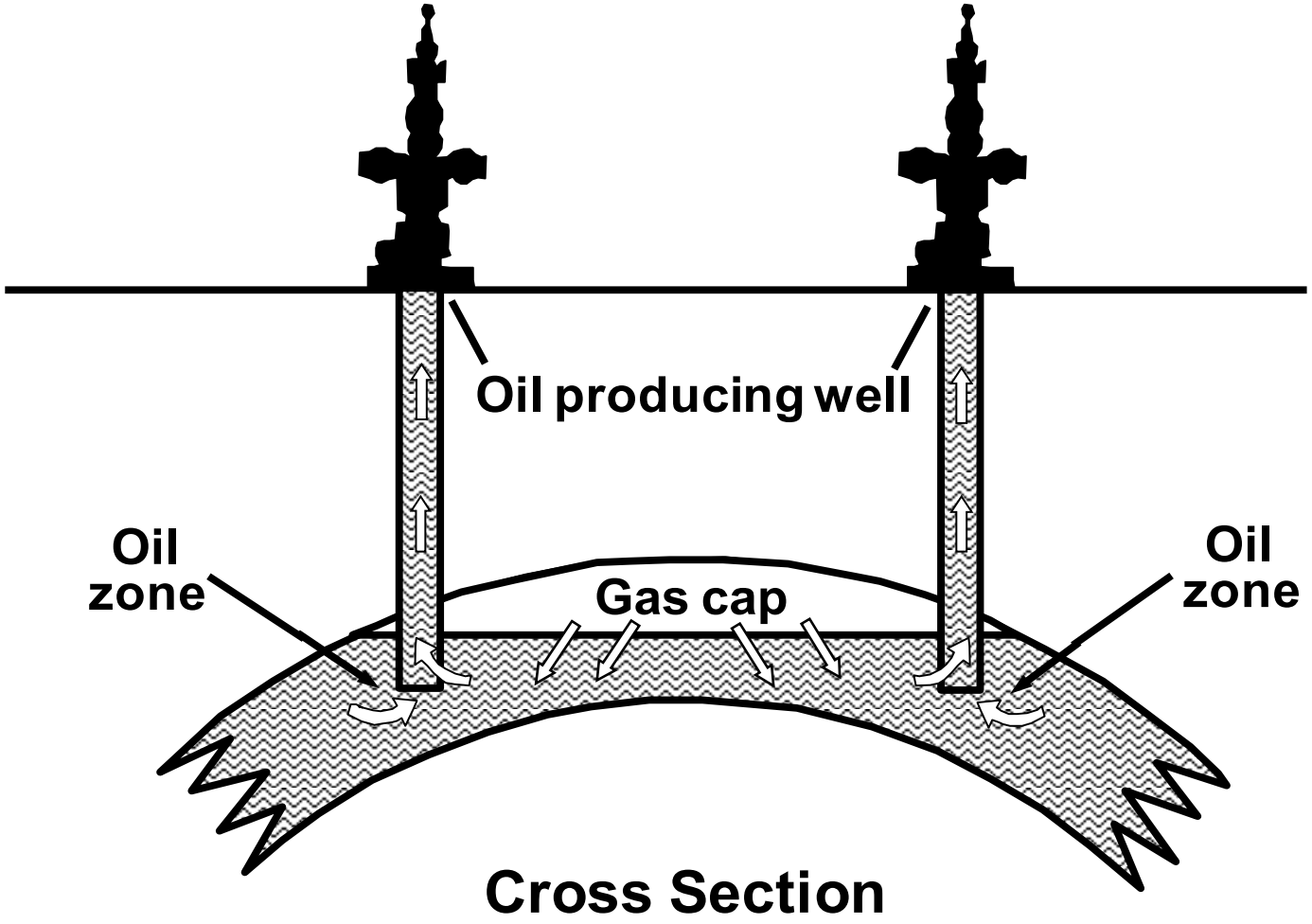
- The ***natural energy*** of the reservoir is used during the ***initial*** production of hydrocarbons
- ***Solution Gas Drive/Depletion Drive***
  - Liberation and expansion of dissolved gas
- ***Water Drive***
  - Influx of aquifer water (Water Drive)
- ***Compaction Drive***
  - Contraction of reservoir rock skeleton
- ***Gas Cap Drive***
  - Expansion of original reservoir fluids
  - Free gas, if present
  - Interstitial water
  - Oil, if present
- ***Gravity Drainage***
  - Gravitational forces (Gravity Drainage)
- ***Combination Drive***

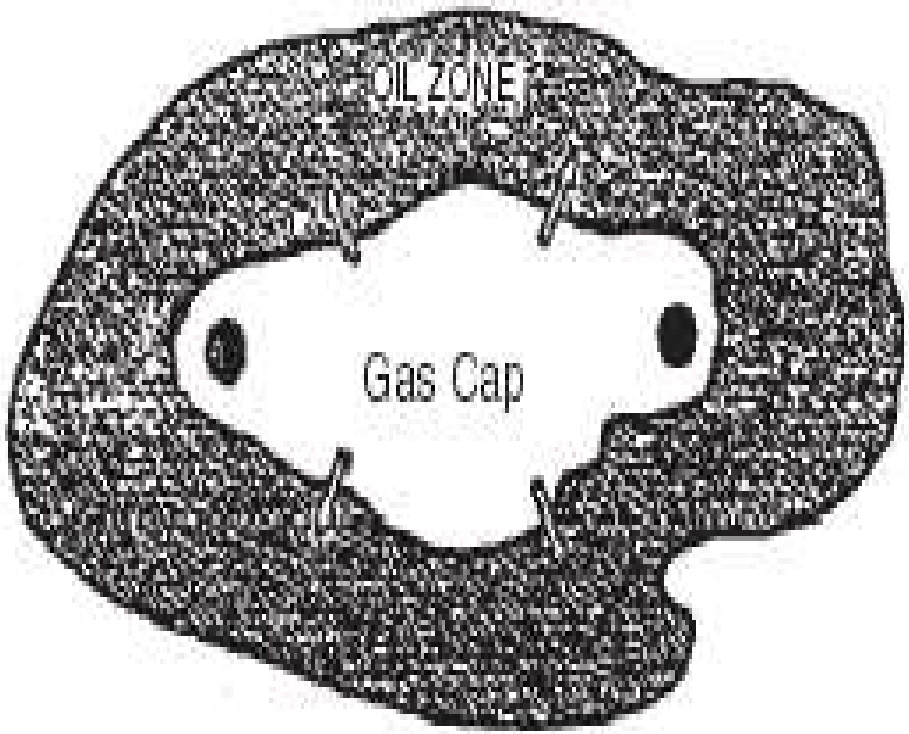
SOLUTION GAS DRIVE



GAS CAP DRIVE MECHANISM

- **Expansion of gas cap and solution gas as it is liberated!!!**





GAS CAP DRIVE MECHANISM

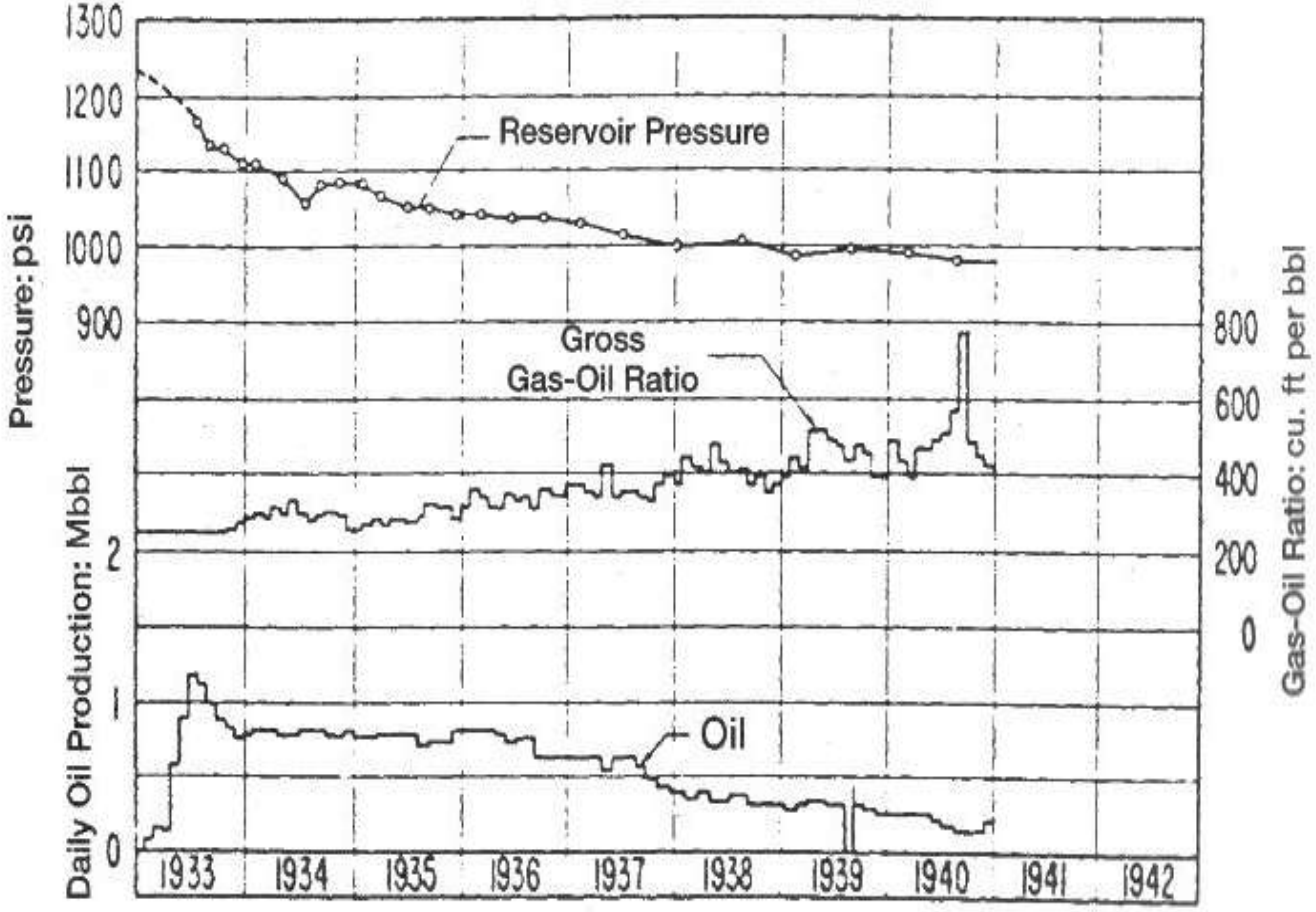
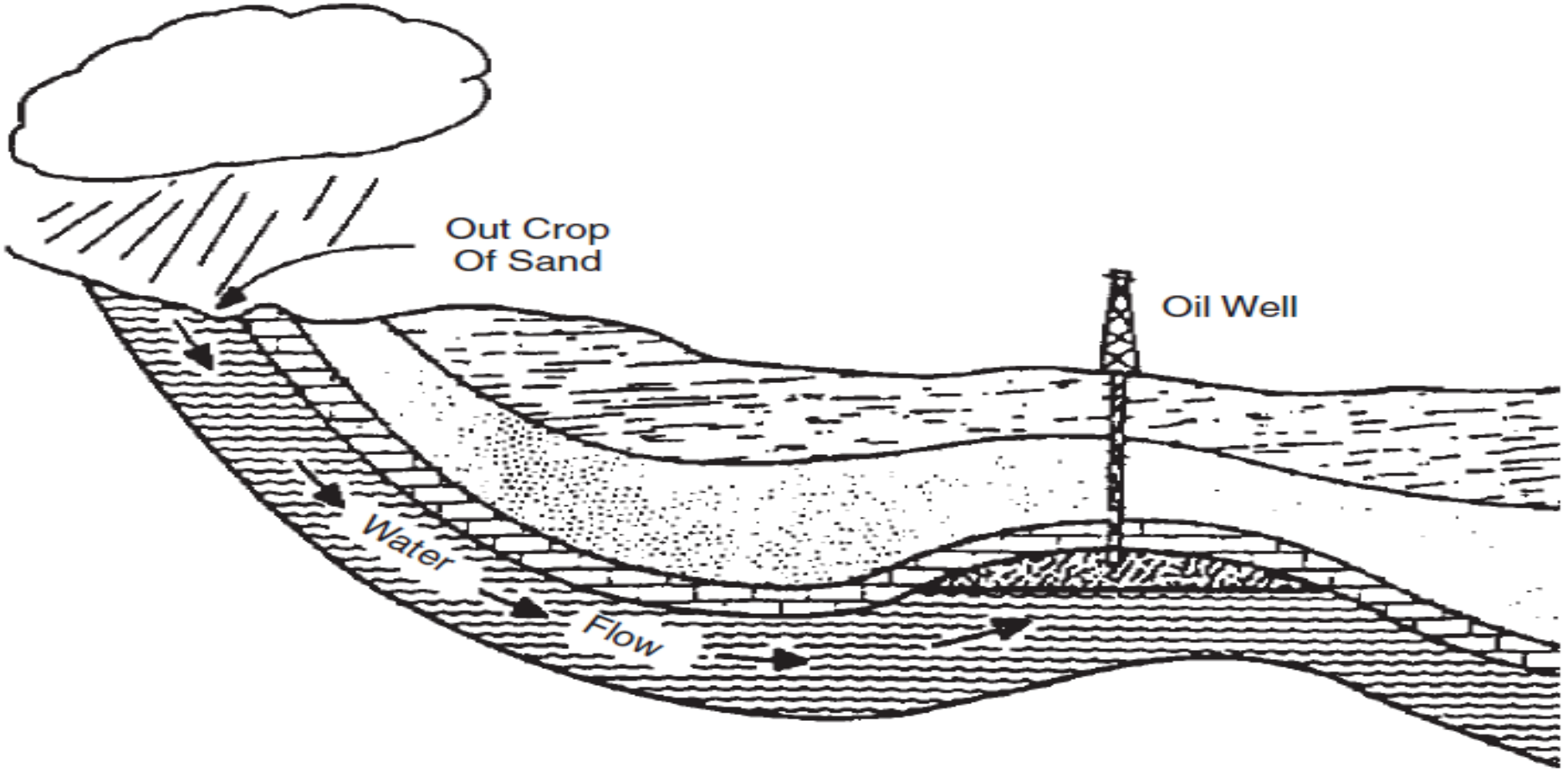


Figure 11-6. Production data for a gas-cap-drive reservoir. (*After Clark, N. J. Elements of Petroleum Reservoirs, SPE, 1969. Courtesy of API.*)

Characteristic	Trends
Oil Recovery	20% to 40% OOIP
Reservoir pressure	Declines slowly and constantly
Gas-Oil ratio	Rises constantly
Water Production	None
Well Behavior	Reservoir pressure maintained

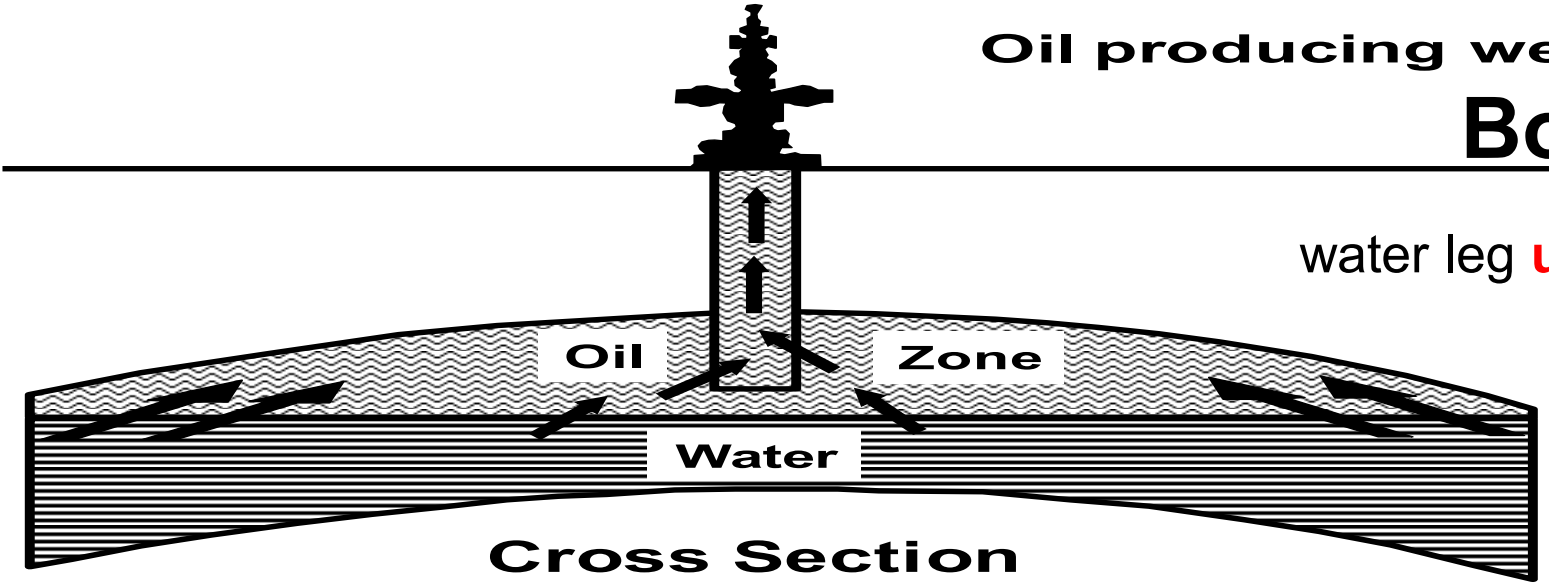
NATURAL WATER DRIVE MECHANISM

✓ An **aquifer** provides the energy for hydrocarbon production. Both water expansion, as a result of pressure reduction, and inflow are involved.



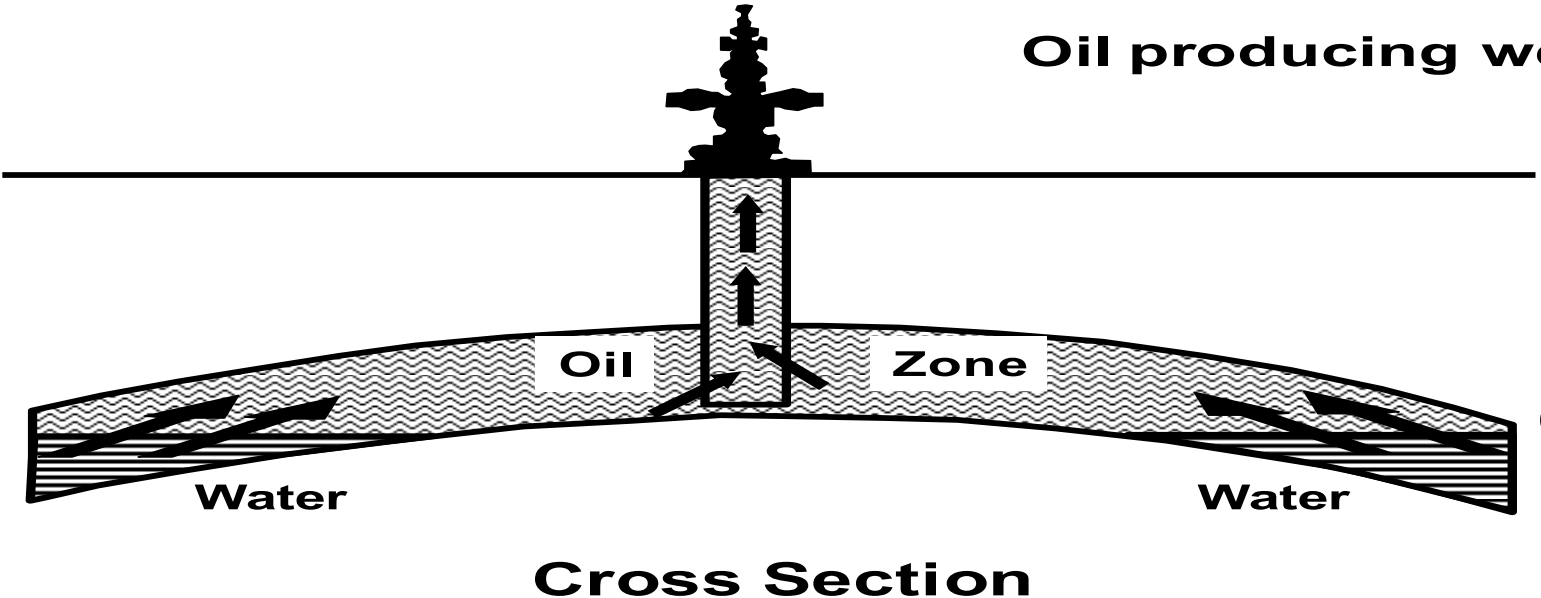
Reservoir having artesian water drive (After Clark, N.J., Elements of Petroleum Reservoirs, SPE, 1969).

Different Water Drive Mechanisms



Bottom Water Drive

water leg **underlies** the entire reservoir



Edge Water Drive

only **part** of the areal extent is contacted by water,

WATER DRIVE MECHANISMS

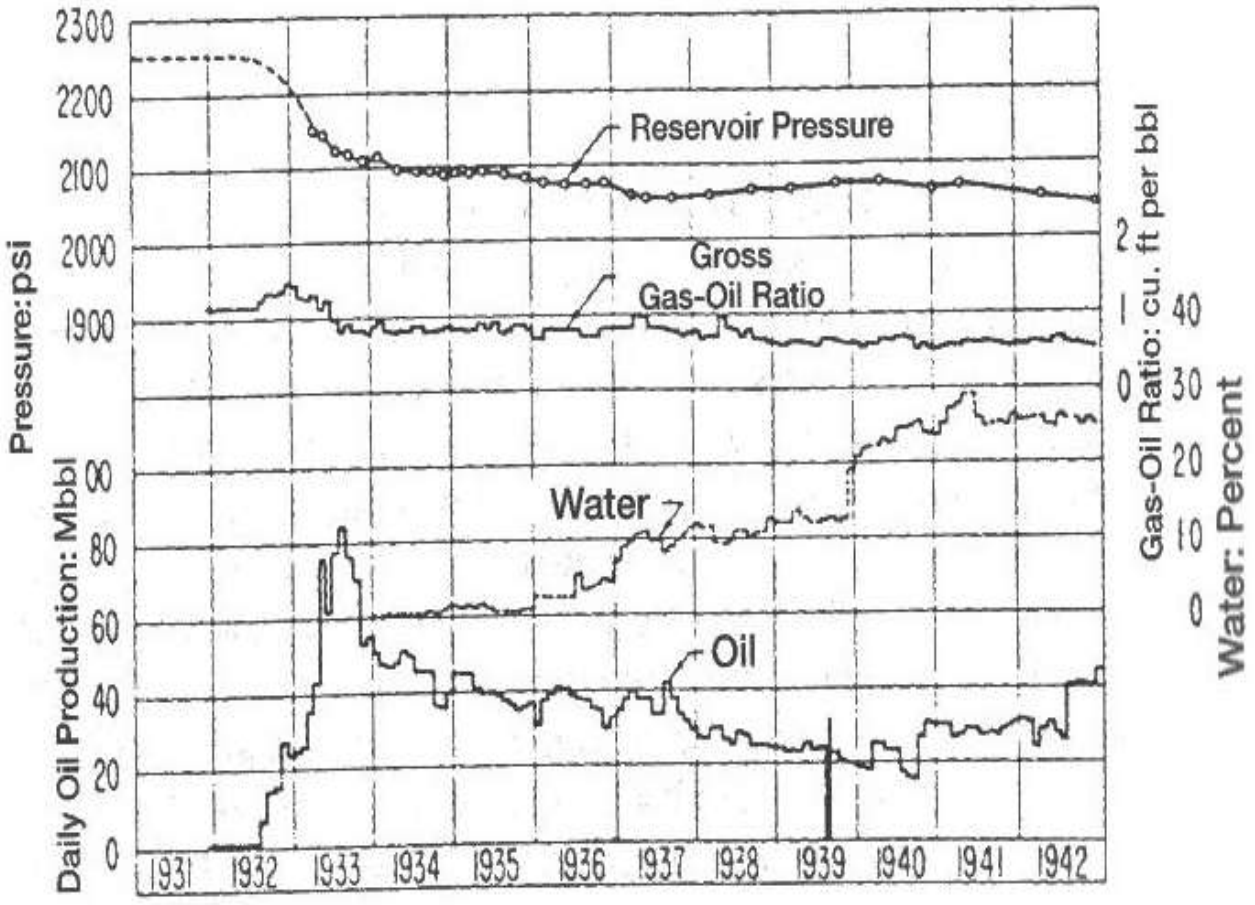
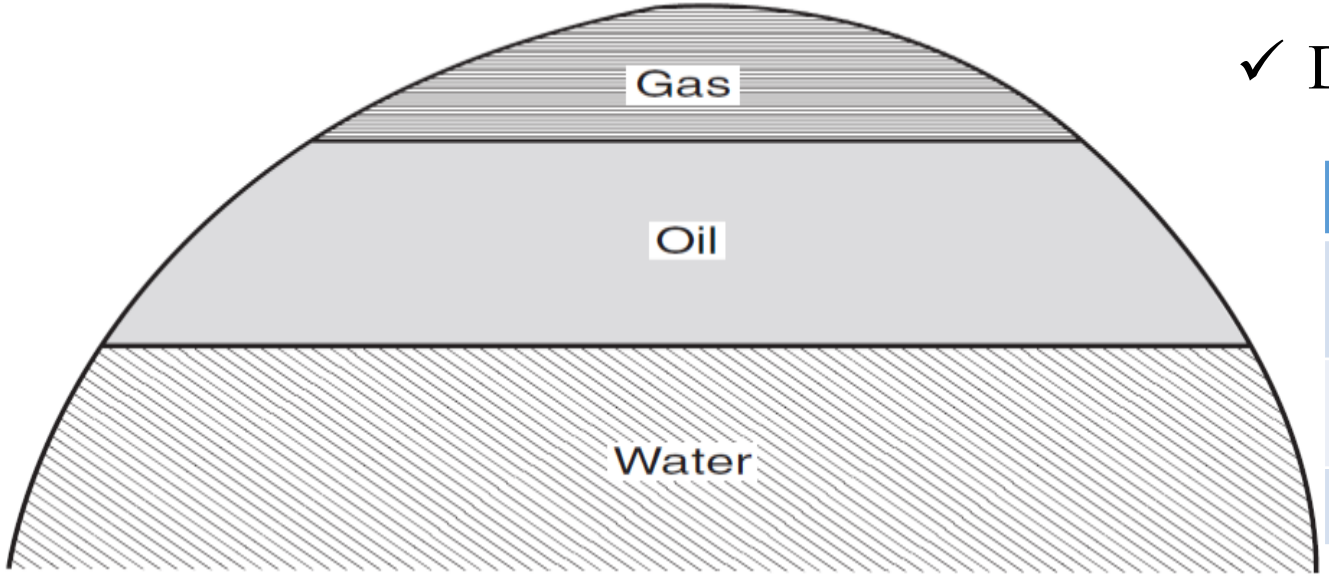


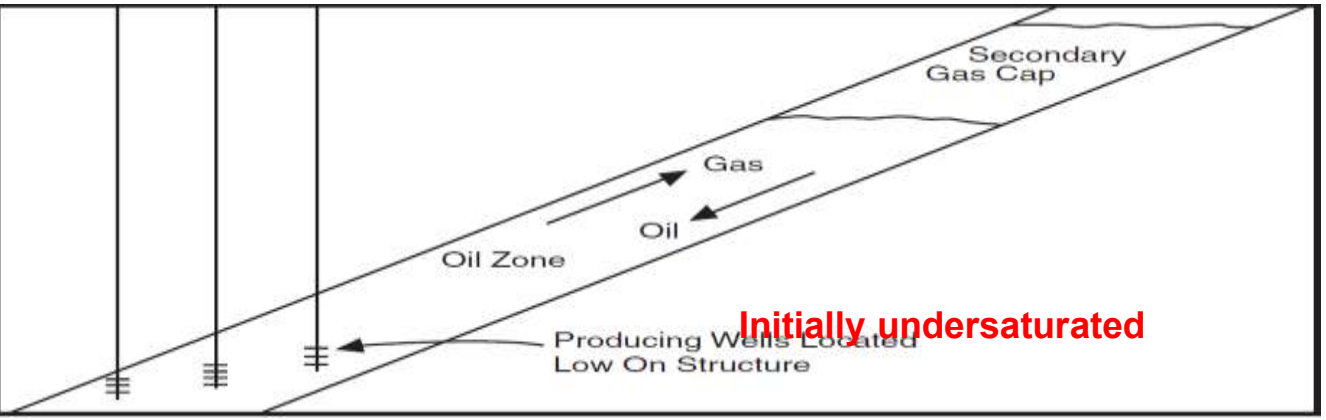
Figure 11-10. Production data for a water-drive reservoir. (*After Clark, N. J., Elements of Petroleum Reservoirs, SPE, 1969. Courtesy of API.*)

CHARACTERISTIC	TRENDS
Reservoir pressure	Remains high
Gas-Oil ratio	Remains low
Water Production	Starts early and increases to appreciable amounts
Well behavior	Flows until water production is excess
Oil recovery	35 to 70% OOIP

GRAVITY-DRAINAGE DRIVE MECHANISM



Initial fluids distribution in an oil reservoir



Gravity drainage secondary gas cap

✓ Difference in **densities** of the reservoir fluids.

Characteristic	Trend
Secondary gas cap	Initially **Undersaturated**
Reservoir pressure	Rapid pressure decline without gas cap
Gas-Oil ratio	Low due to gravity **segregation**

✓ **Ultimate recovery**

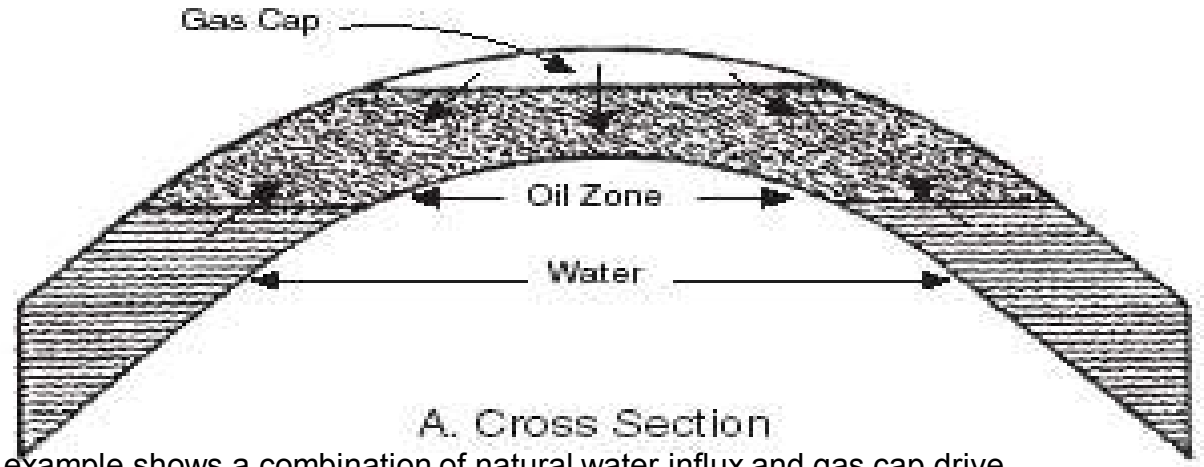
- **High vertical**
- **Production rate similar to the gravity drainage rate**
- **Low viscosity**

COMBINATION DRIVE

In combination-drive reservoirs,

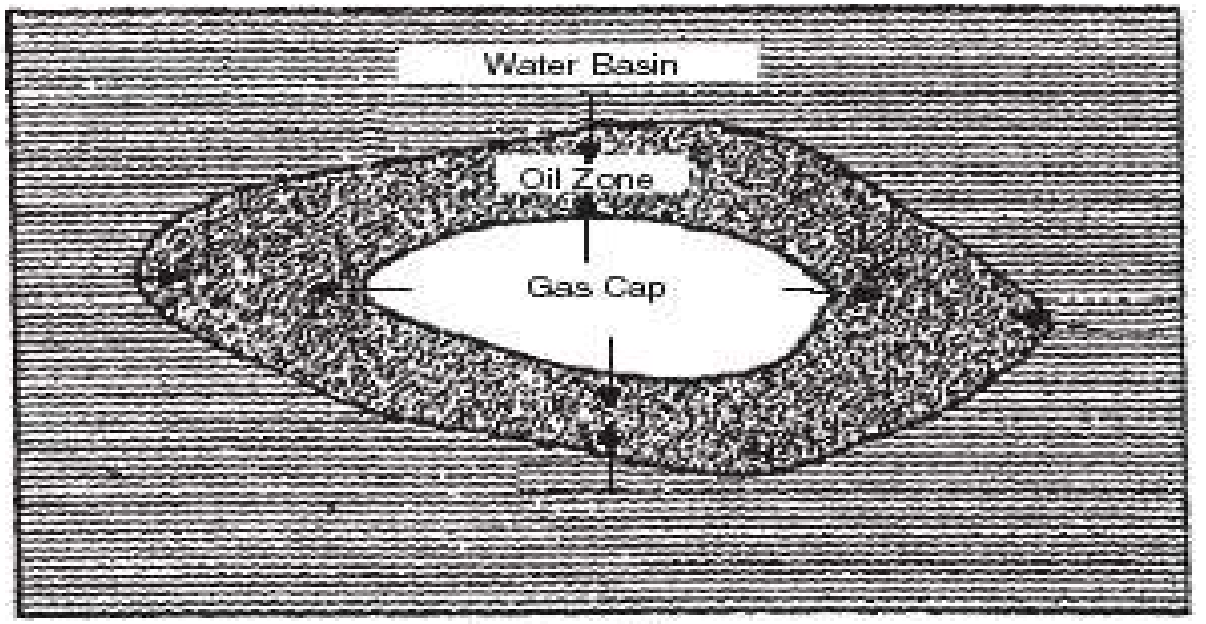
- Depletion drive and **a weak water drive**,
- Depletion drive with a small gas cap and **a weak water drive**.

Water production	Increasing water production rates
Reservoir pressure	Increasing water production
Gas-Oil ratio	Continually increasing Gas-Oil ratio



A. Cross Section

The example shows a combination of natural water influx and gas cap drive.

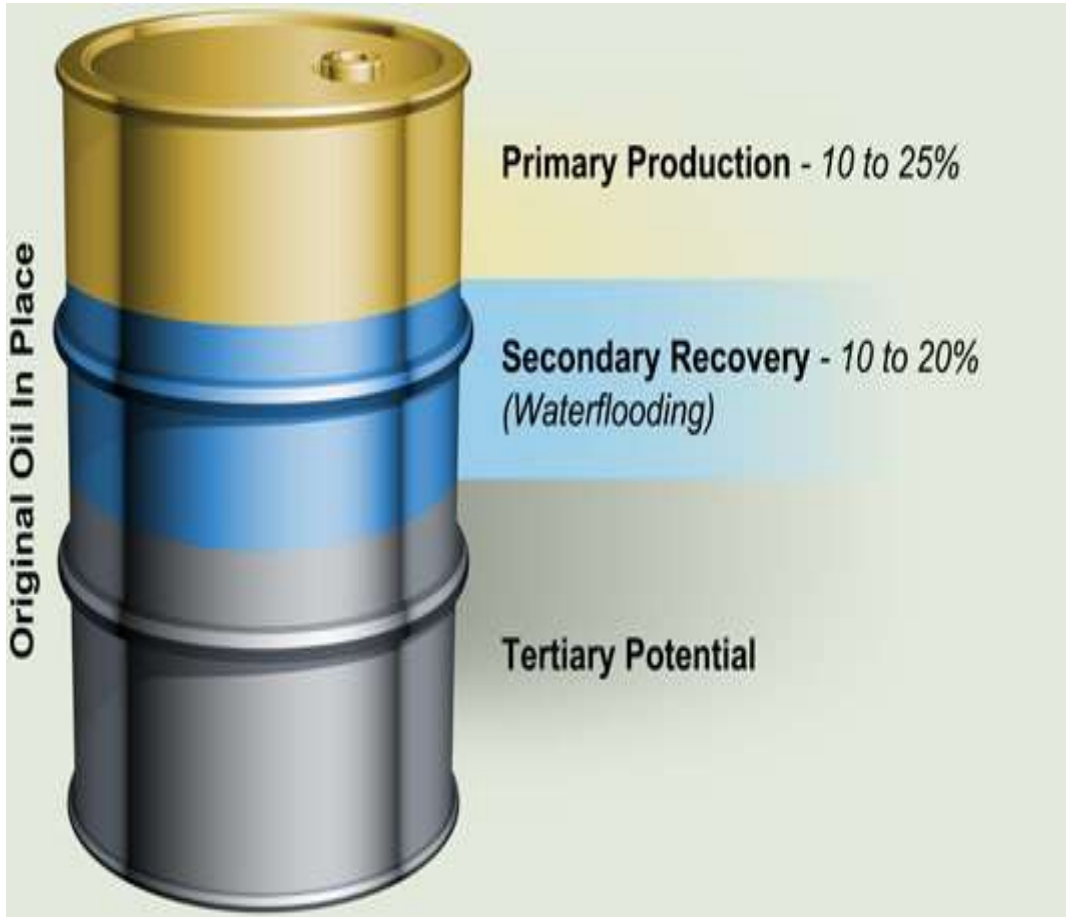


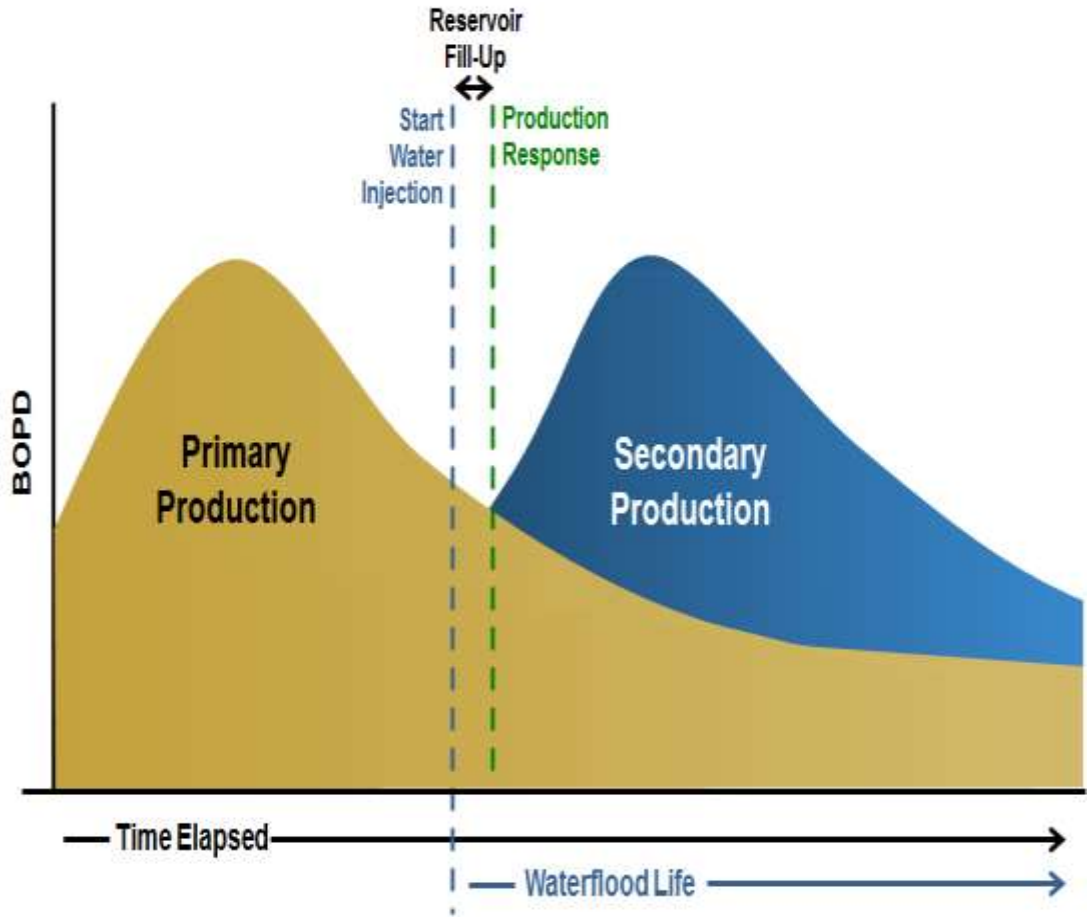
B. Map View

Secondary Recovery

- Over the lifetime of the well the pressure will fall, and at some point there will be insufficient underground pressure to force the oil to the surface.
- If economical, as often is, the remaining oil in the well is extracted using secondary oil recovery methods *(see: energy balance and net energy gain)*.
- Secondary oil recovery uses various techniques to aid in recovering oil from depleted or low-pressure reservoirs.
- Sometimes pumps, such as beam pumps and electrical submersible pumps (ESPs), are used to bring the oil to the surface.
- Other secondary recovery techniques increase the reservoir's pressure by water injection, natural gas reinjection and gas lift, which injects air, carbon dioxide or some other gas into the reservoir.
- Together, primary and secondary recovery generally allow **25% to 35%** of the reservoir's oil to be recovered.

From Primary to Secondary… Summary



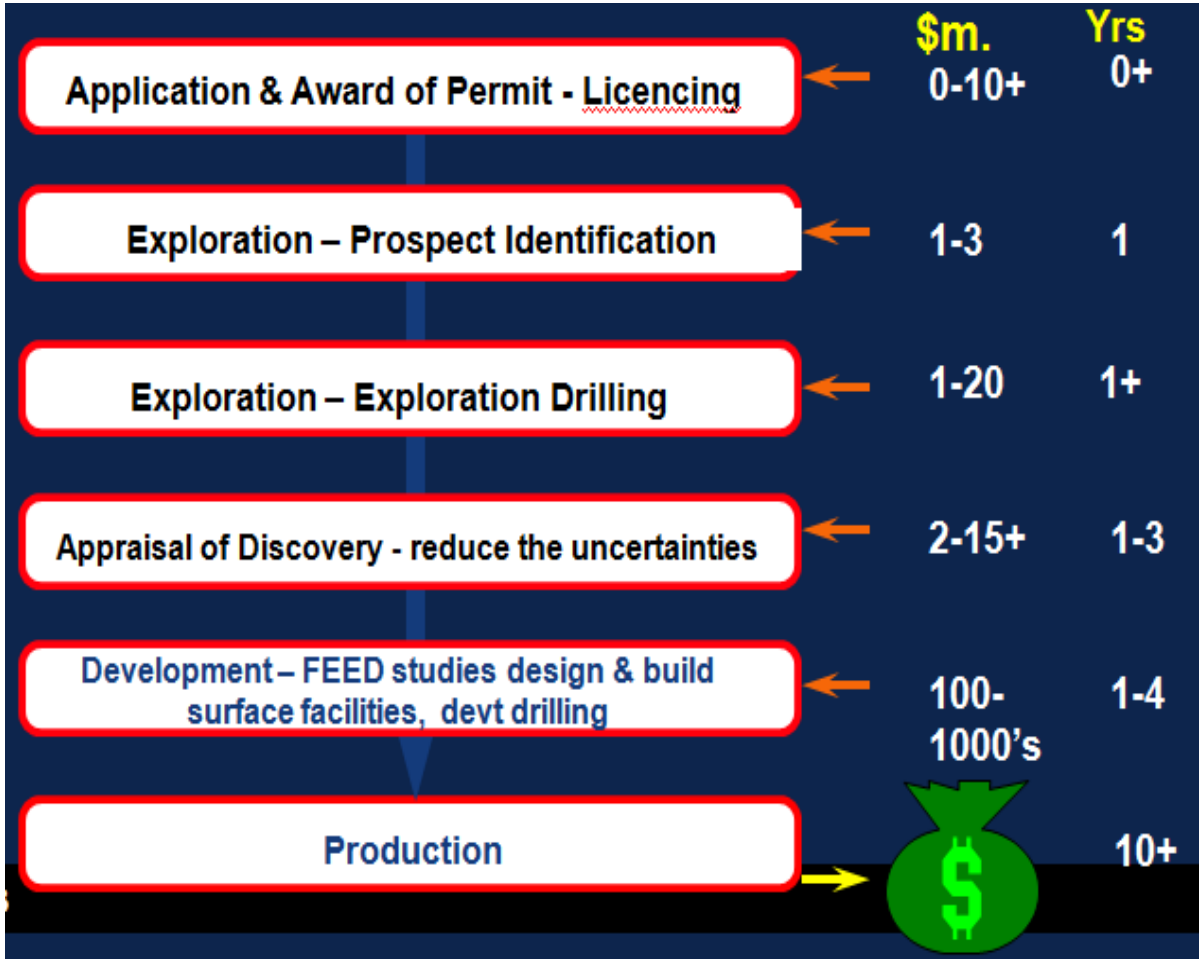


Tertiary Recovery

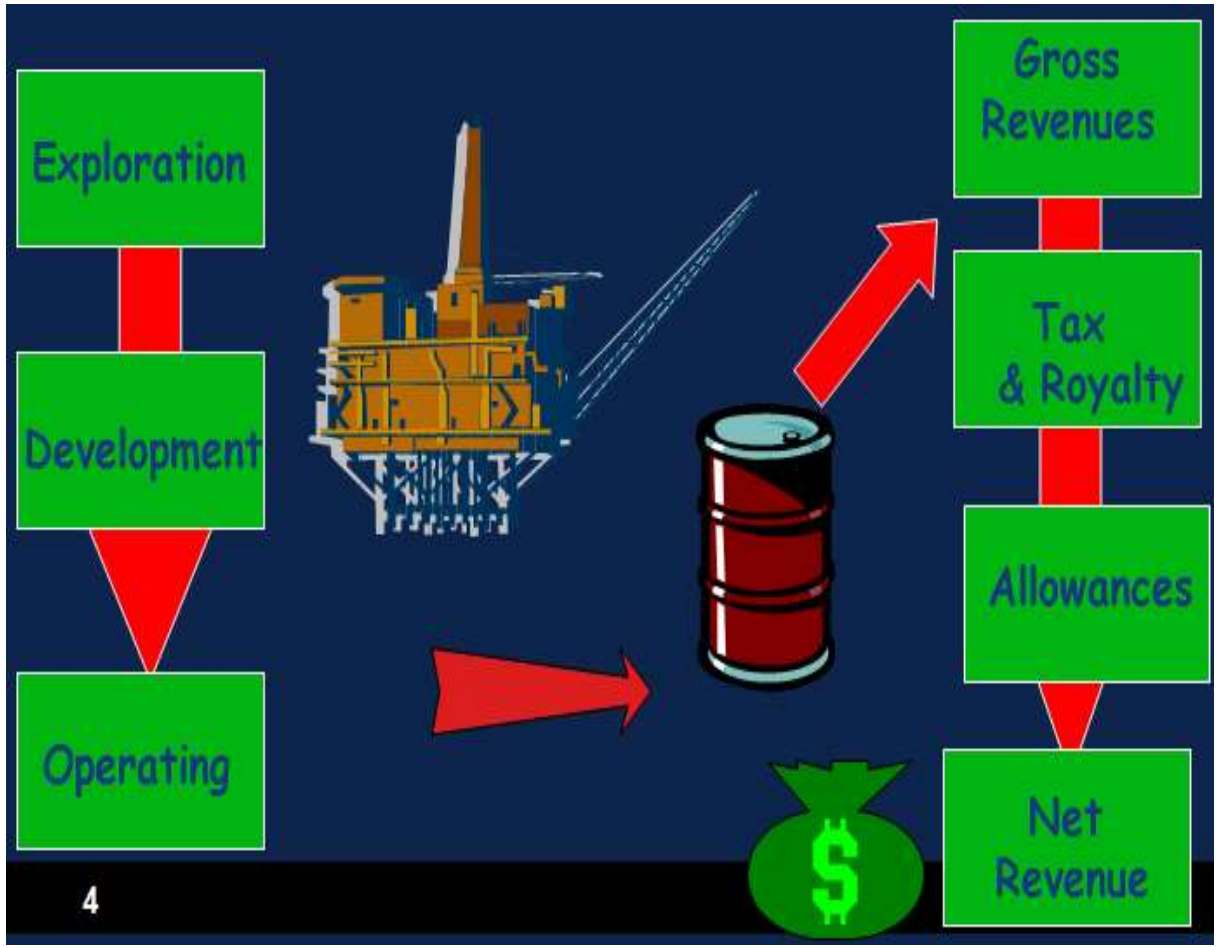
- In these processes the nature of the rock and HC have to be modified in order to improve the displacement efficiency of oil
- For exemple: the Viscosity of the oil can be reduced so that it can move faster...
- Some EOR Processes:
  - Thermal Flooding
  - Chimical Flooding
  - Microbial EOR
  - CO_2 Sequestration

Upstream Industry: Development Sequences & Economics

Exploration & Production Sequences



Cash Flow in Upstream Operations



Conclusion

- Petroleum Engineering
  - Team Work
  - Interdiciplinarity
  - Multicultural
- Reservoir Engineering
  - The Driller...
  - The Production Engineer
  - The Geoscientist
- The Reservoir Engineer
  - Reservoir Simulation
  - Reservoir Management
  - Reserves Evaluation
  - Well Testing
- Strategic Functions
  - ...

Any Questions???

- Thank You
- For your...