Field Life Cycle

Field Life Cycle

- 5 phases in Petroleum Projects

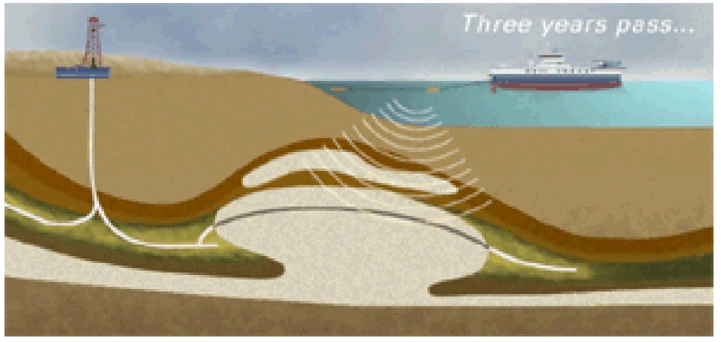
  - Exploration
  - Appraisal
  - Development Planning
  - Production
  - Decommissioning

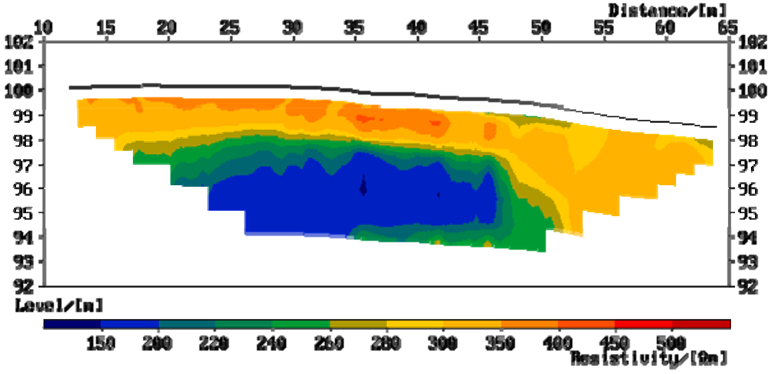
광구권 확보
Lease

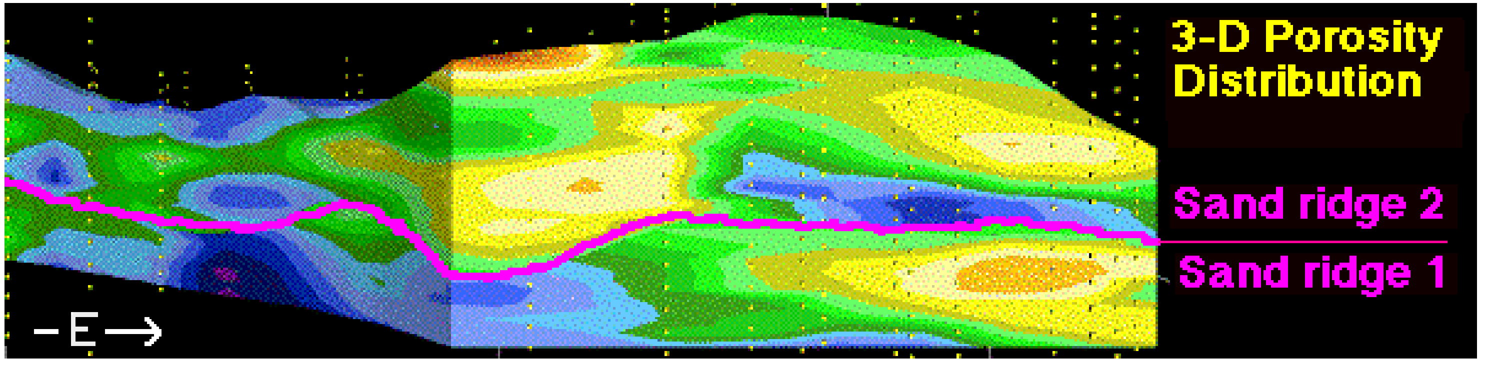
→

석유탐사
Prospecting

→



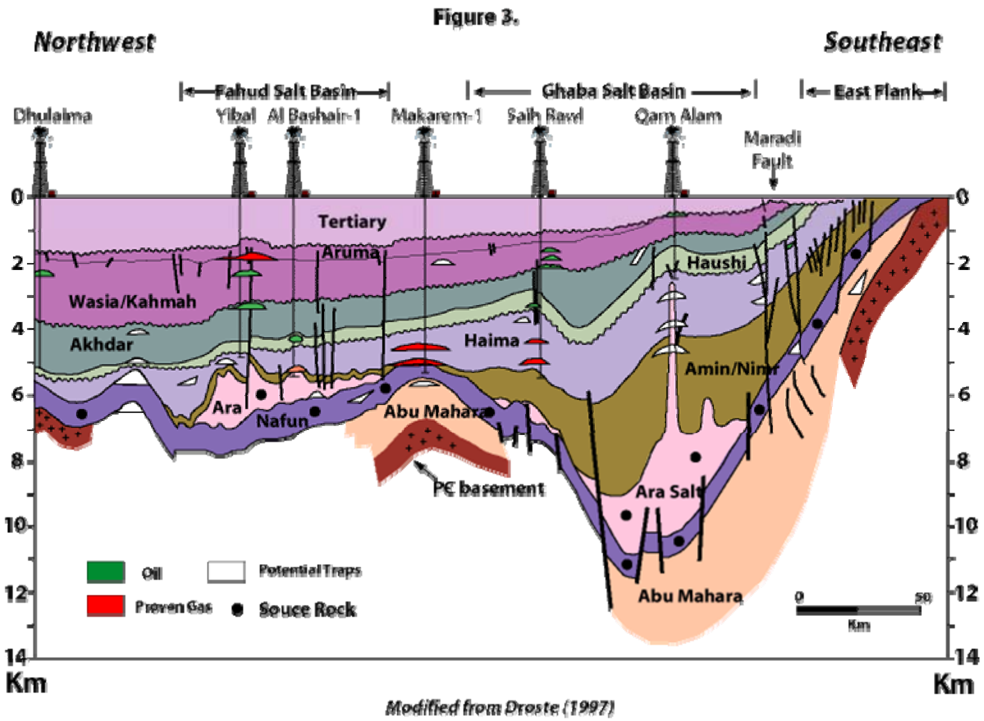




Field Life Cycle

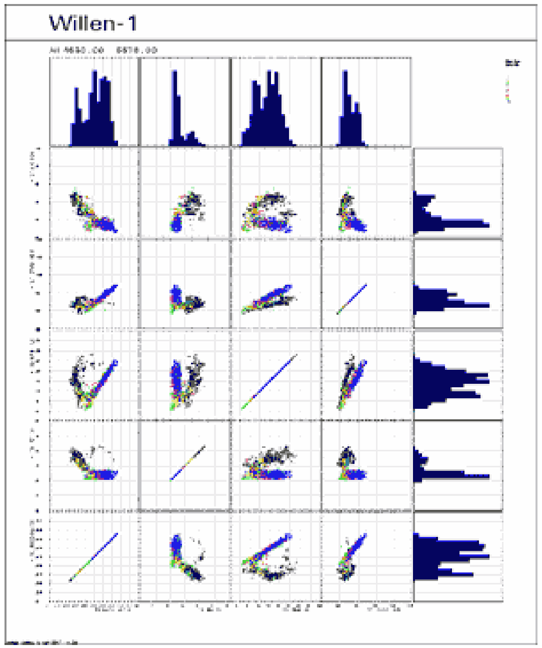
석유 시추
Drilling

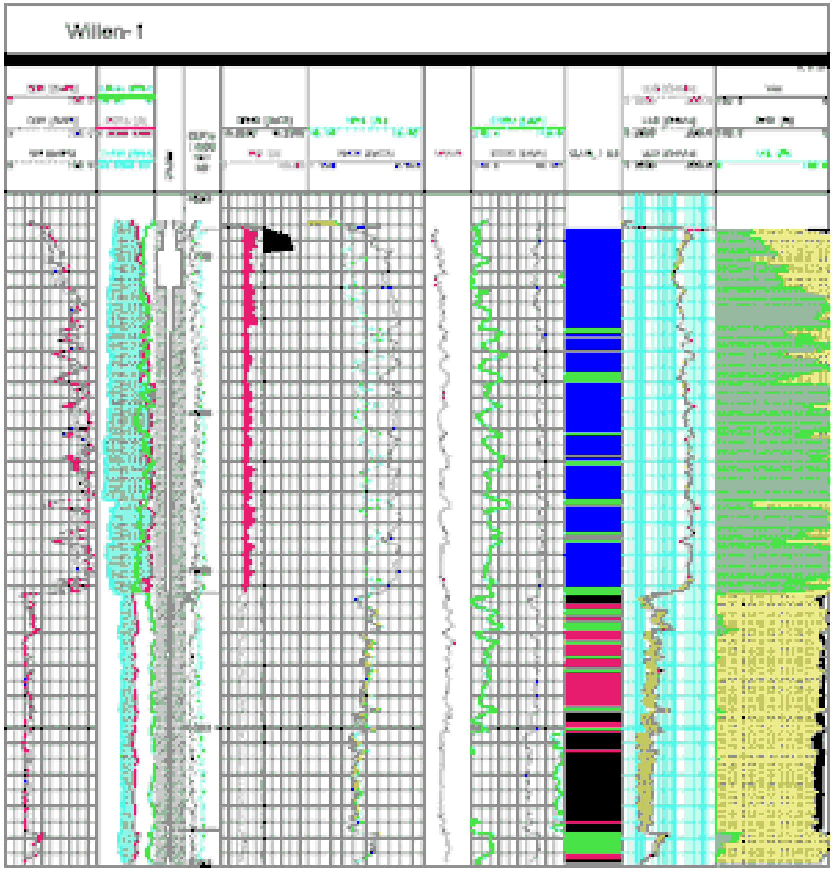
- ❑ 탐사 시추
- ❑ 개발 시추



유정 평가
Well evaluation

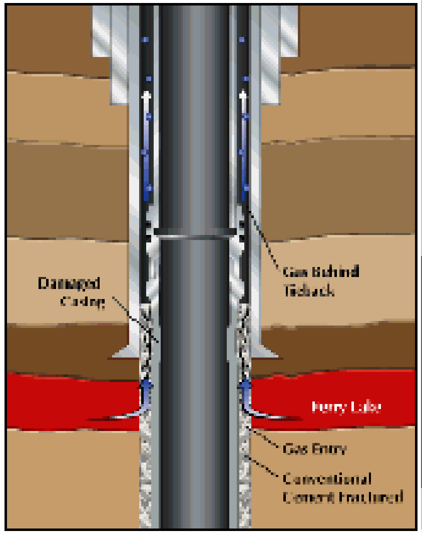
- 검층(well logging)
- 코아분석(core analysis)

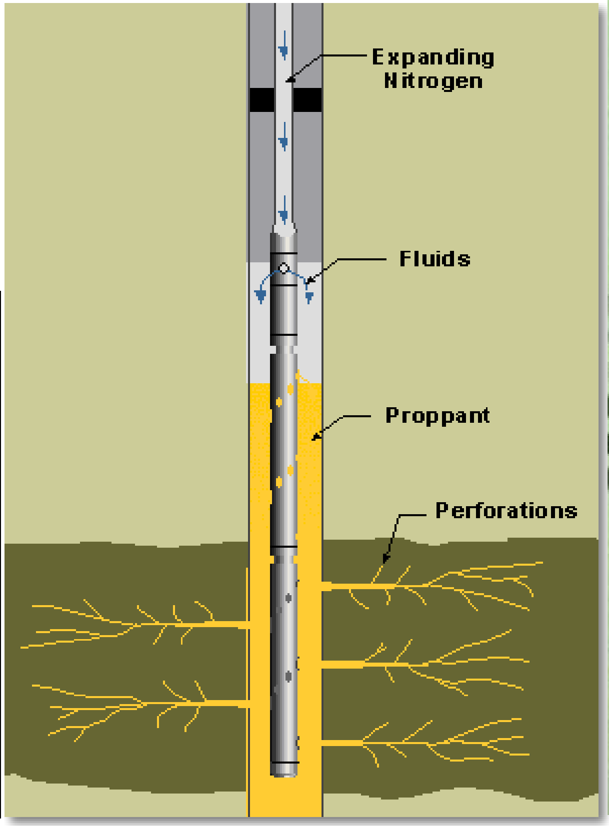


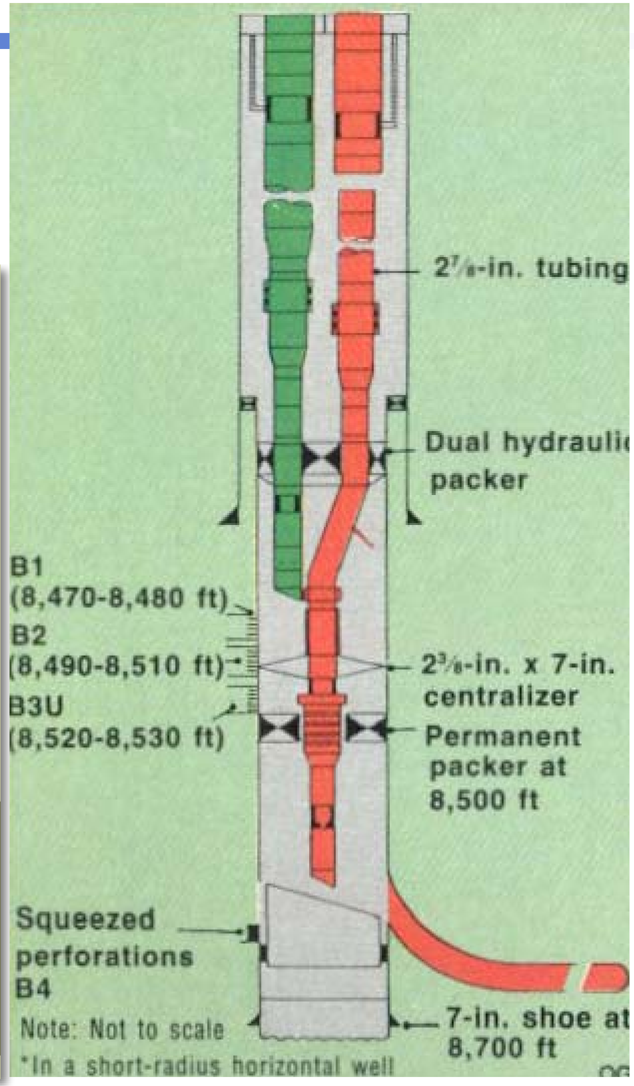


유정 완결
Well completion

- 공벽보호관(casing) 설치
- 시멘팅(cementing)
- 천공(perforation)





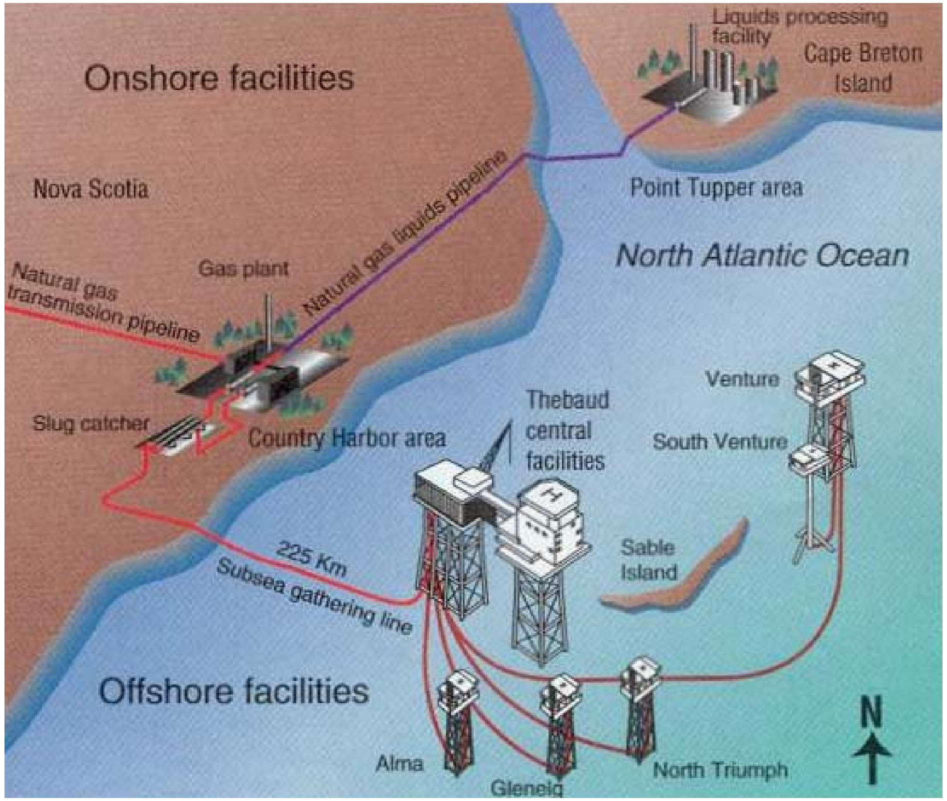


석유 생산
Production

- 1차 생산
- 2차 생산
- 3차 생산(EOR)

저장 및 운반
Storing and transportation

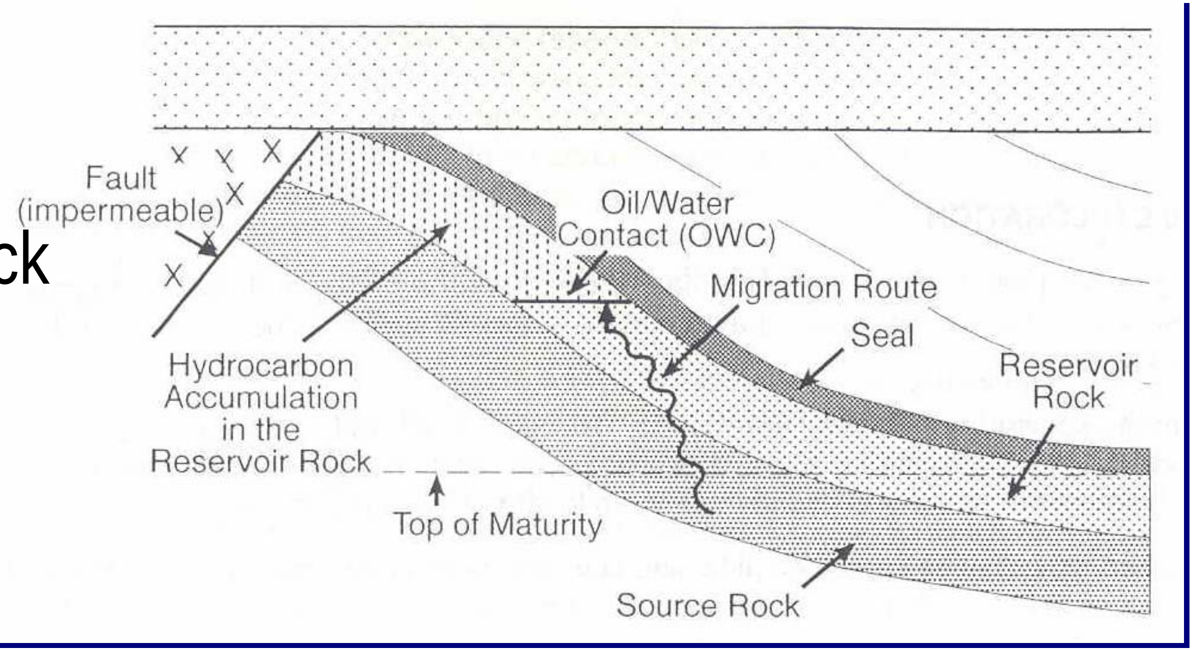
- ❑ 석유 가스 분리기
- ❑ 수송



Exploration

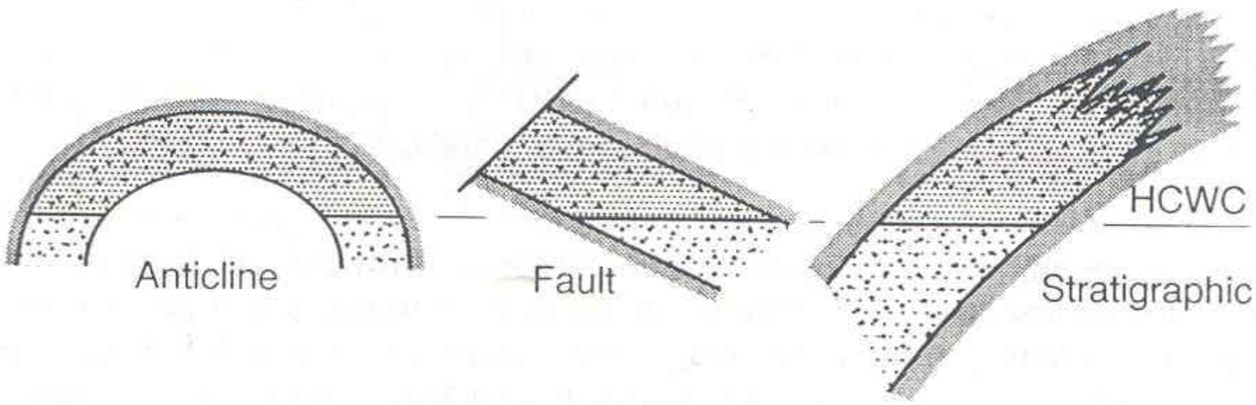
Hydrocarbon Accumulations

- Sedimentary basins
- Source rocks
- Maturation
- Migration
- Reservoir rock
- Traps



Traps

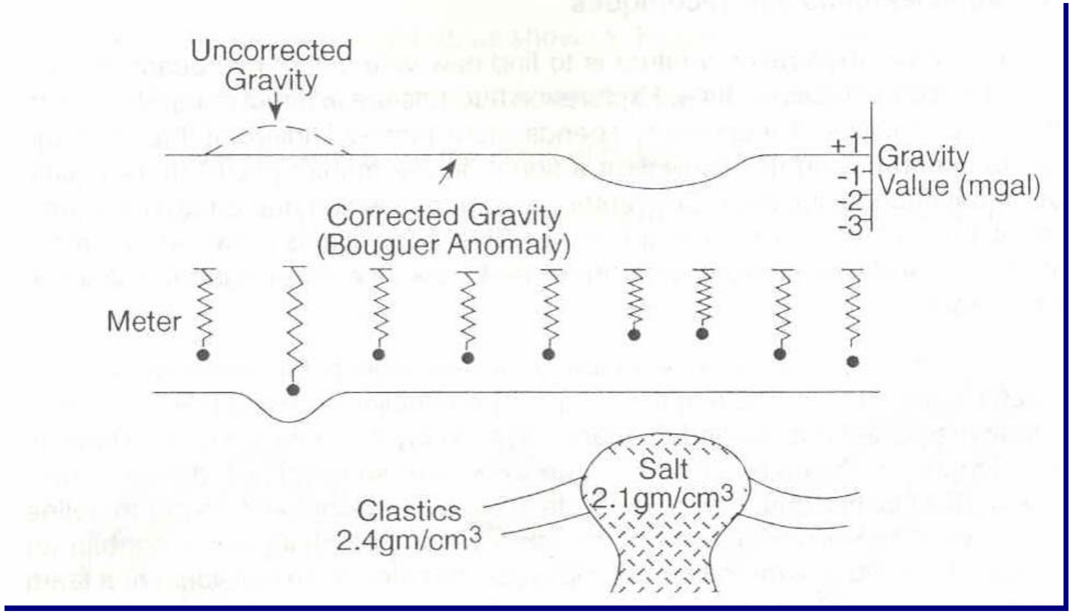
- Anticline
- Fault
- Stratigraphic



Exploration Methods and Techniques

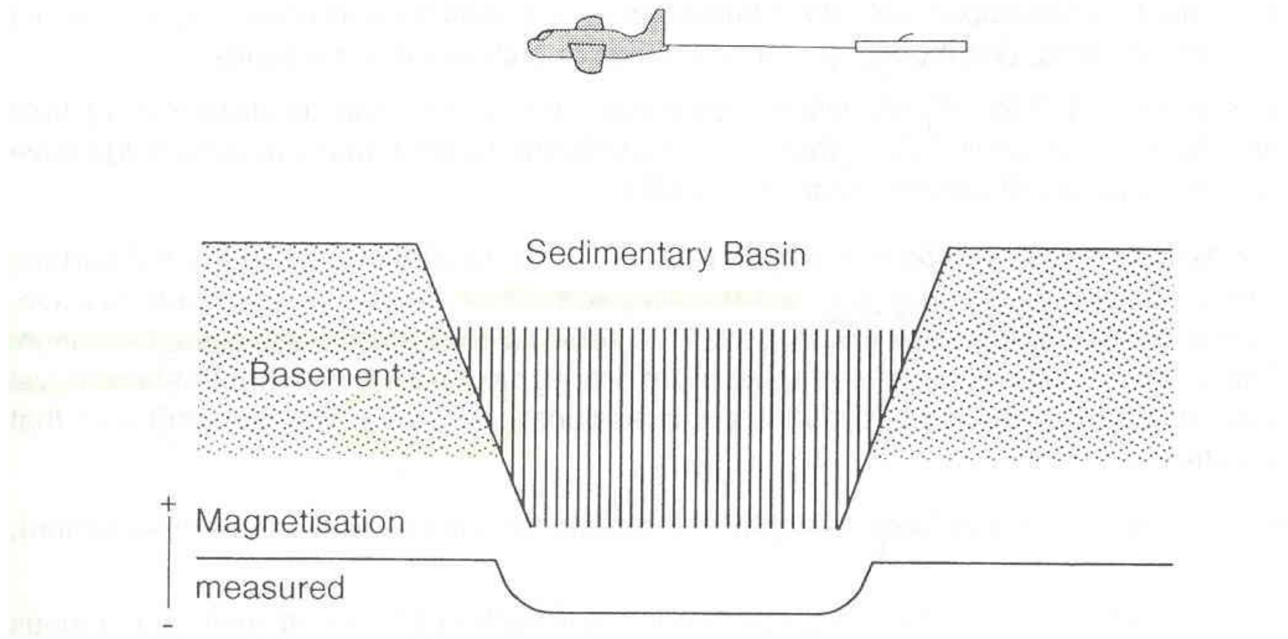
Gravity Surveys

- Measures small variations of the earth's gravity



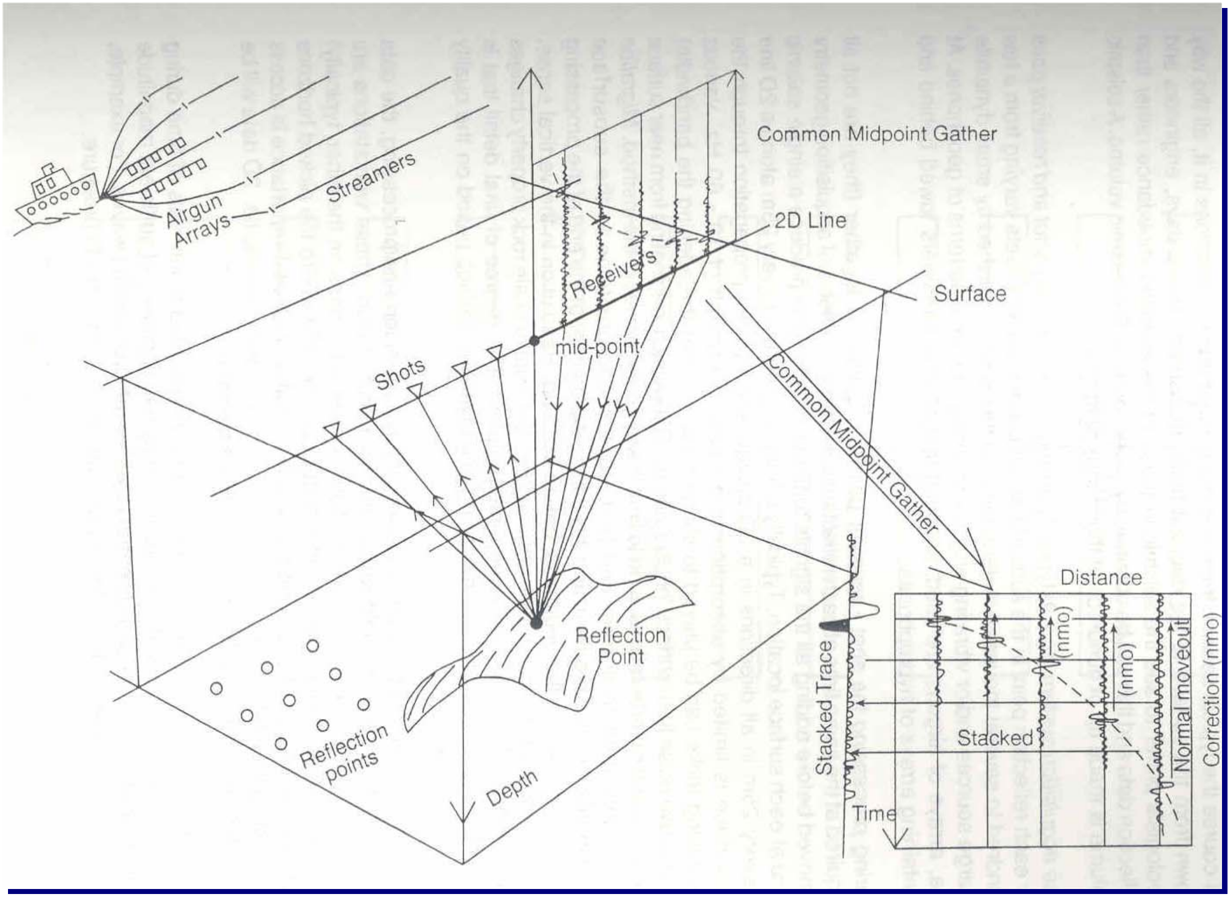
Magnetic Surveys

- Detects changes in the earth's magnetic field
- Basement and igneous rocks – highly magnetic
- Define large scale structures (basins)



Seismic Surveys

- Generation of artificial shock waves, reflected back to receivers
- Pressure pulse (in hydrophone – offshore)
- Acceleration (in geophone - onshore)
- Produce an acoustic image of the subsurface


Common Midpoint Gather
Streamers
Airgun Arrays
2D Line
Receivers
Surface
mid-point
Shots
Common Midpoint Gather
Distance
Reflection Point
Reflection points
Stacked Trace
Stacked
Normal moveout
Correction (nmo)
(nmo)
Depth
Time

- In *exploration* for determining structures and stratigraphic traps to be drilled
- In *field appraisal* and *development* for estimation of reserves and formulation of field development plans
- During *production* for reservoir surveillance purposes such as observing movement of contacts, distribution of reservoir fluids and changes in pressure

Mudlogging

- One of the first direct evaluation methods available during the drilling of an exploration well
- Gives qualitative information about the lithology being drilled

Summary of Exploration Objectives & Methods

Objective / Method	Basin	Source Rock	Maturation	Migration	Reservoir Rock	Trap	Fluids oil, gas, water
Seismic	(X)			(X)	X	X	(X)
Gravimetry	X						
Magnetometry	X						
Drill / Log		X	X	X	X	X	X
Field Studies & Analogues	(X)	X	X	X	X	(X)	
Geochemistry		X	X	X			

Drilling Engineering

Well Planning

Objectives of wells

- To gather information
- To produce hydrocarbon
- To inject gas or water
- To relieve a blowout

Objectives of well planning

- To drill a quality well at the minimum cost without compromising safety or environmental standards

- Required information

  - Geologist: type and depth of the different rock formation
  - Petrophysist: fluid distribution
  - Reservoir engineer: a prognosis of pressures along the well trajectory

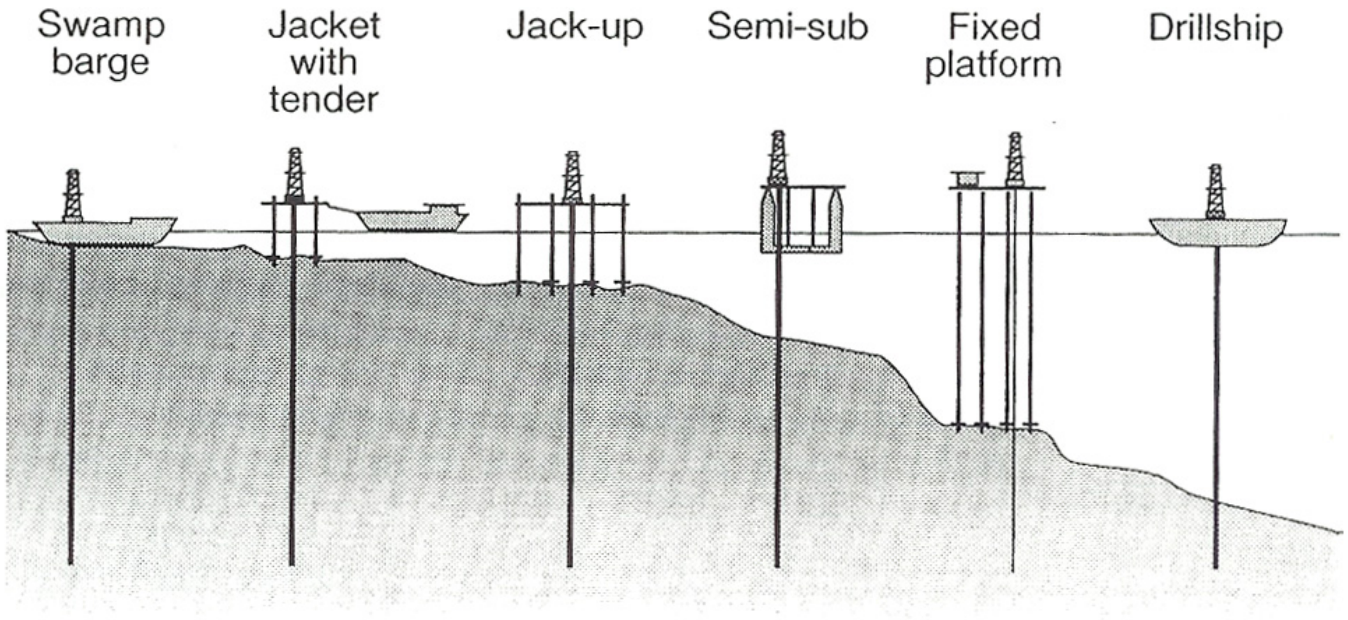
- Well proposal->drilling program

- What to be planned

  - The setting depth and ratings for casings
  - Mud weights and mud types
  - Selection of an appropriate rig and related hardwares

Rig Types and Rig Selection

- Factors affecting a selection of the rig type
  - Cost and availability
  - Water depth of location (offshore)
  - Mobility/transportability (onshore)
  - Depth of target zone and expected formation pressures
  - Weather conditions
  - Quality of the drilling crew

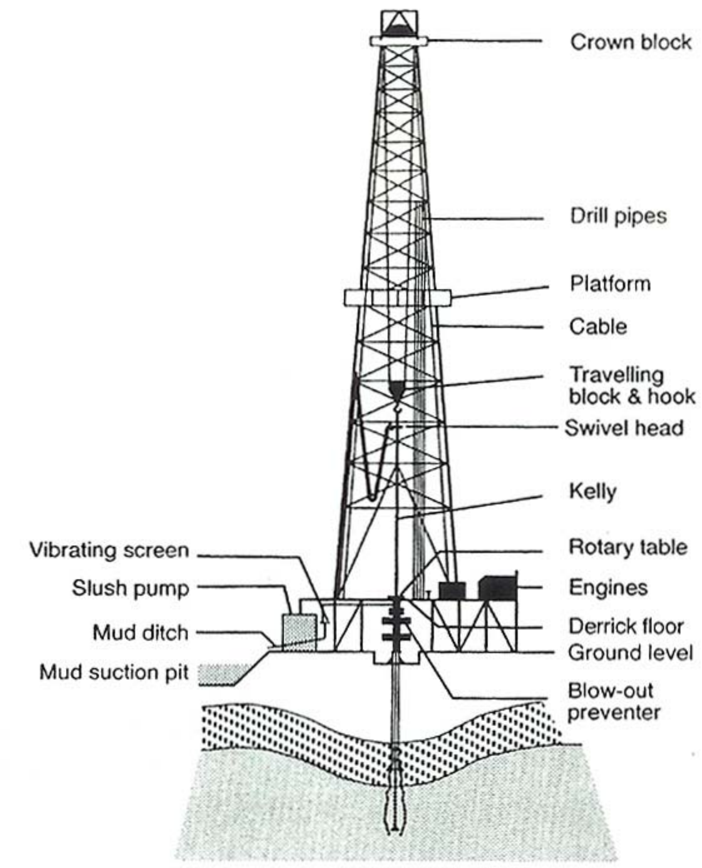

Swamp barge
Jacket with tender
Jack-up
Semi-sub
Fixed platform
Drillship

Types of rig

- Swamp Barges: shallow water (less than 20ft)
- Drilling jackets: many wells may be drilled from one jacket
- Jack-up rigs: in water depth up to 650ft and as shallow as 15ft
- Semi-submersible rigs: in too deep water
- Drill ships: in deep water and remote areas/ dynamic positioning by computer controlled thrusters
- Tender assisted Drilling: in shallow and calm water/ all the supporting functions are located on the tender

Drilling Systems and Equipment

- Rotary rig



Bit

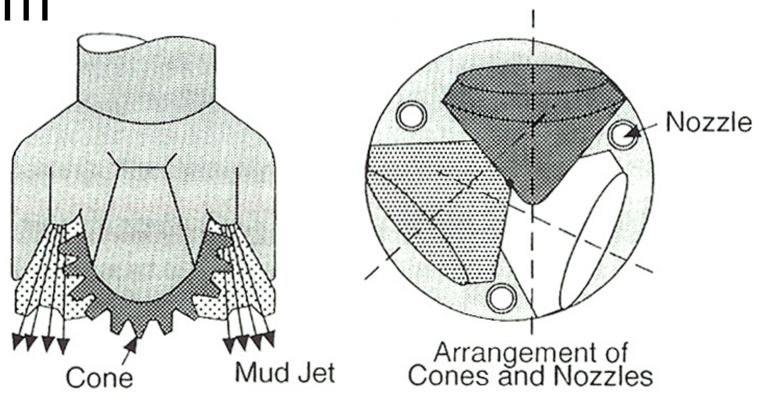
- Rock bit
- PDC bit:

  industrial diamond cutters

  better ROP (Rate Of Penetration)

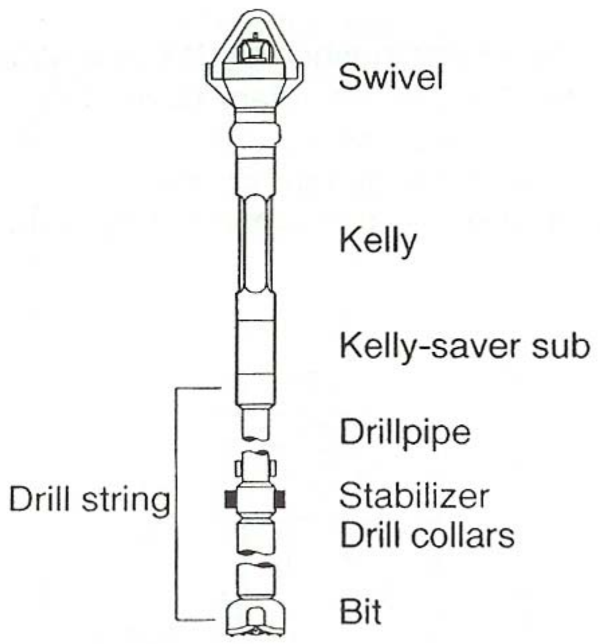
  longer life time

  suitability for drilling with high rpm



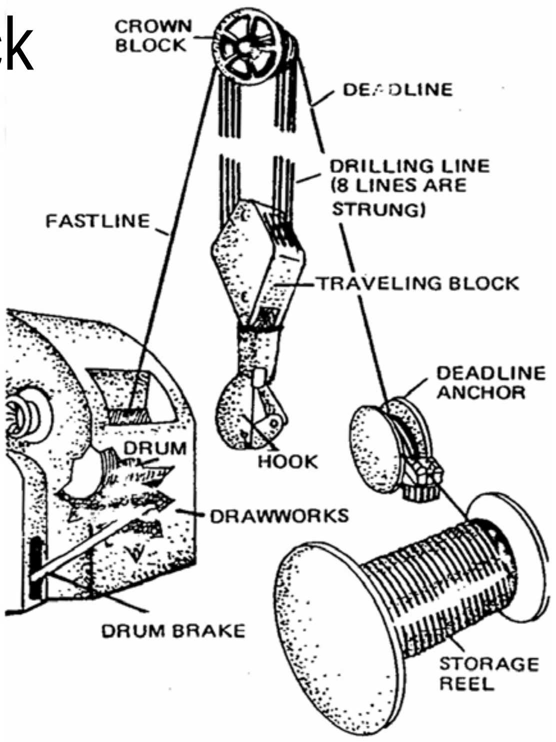
Drill string

- Drill collars: to provide weight onto the bit
- Stabilizer: to increase or decrease the hole angle
- Kelly
- Kelly-saver sub
- Drill pipe



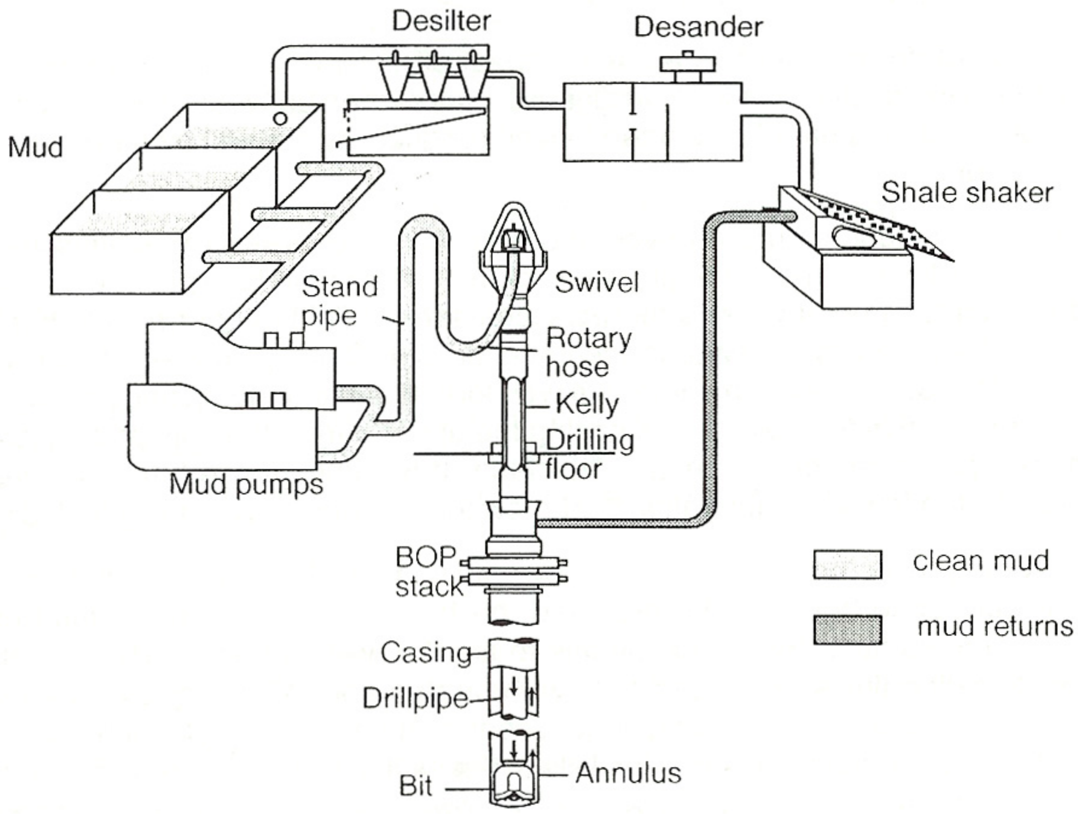
Hoisting system

- Drawworks: to provide the power required to raise or lower the heavy strings of pipe
- Block: crown block / traveling block
- Steel cable



Circulating system

- Mud: WBM/OBM
- Shale shaker
- Desilter
- Desander
- Stand pipe
- Rotary hose

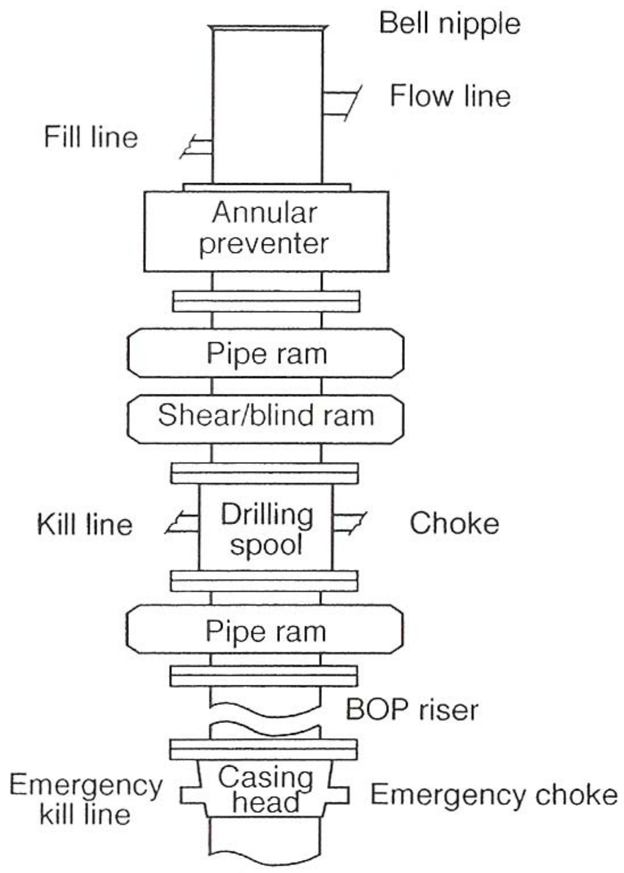


Blowout Preventer (BOP)

- Shut in
- Killing the well:

  annular preventer, blind ram

  shear ram



Personnel

- Roughneck
- Derrickman
- Specialists

  mud eng., logging, fishing etc
- Tool pusher

Site Preparation

Environmental Impact Assessment (EIA)

- Meeting the legal requirement
- Ensuring that the drilling activity is acceptable to the local environment
- Quantifying risks
- Concerning factors:
  noise, air emission, waste disposal, traffic, emergency response

Onshore

- Determining the size of rig from the site survey
- Cleared of vegetation and levelled
- Coated with plastic lining
- Required accommodation

Offshore

- See-bed survey: to recognize features such as pipelines, reefs and wreckage
- Shallow seismic survey: to detect indications of shallow gas pockets
- Soil boring

Drilling Techniques

Top hole drilling

- Usually drilled with a large diameter bit
- To cement a cellar in a conductor or stove pipe
- Removal of vast quantities of formation cuttings

Intermediate and reservoir section

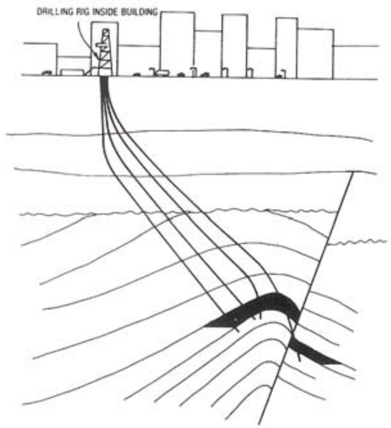
- Deviation angle is often increased in this interval
- Setting an intermediate casing
- In reservoir section, drilling not to impair the formation

Directional drilling

- Cases used directional drilling:

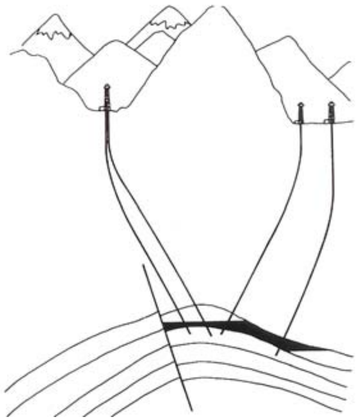
  field under a city, natural obstructions,

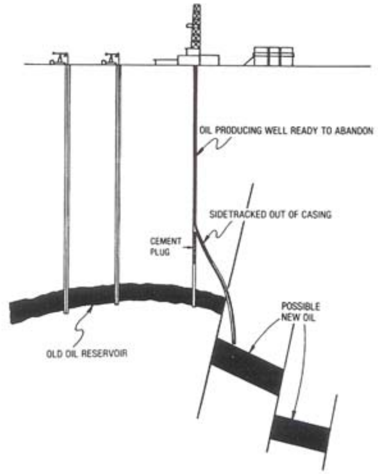
  sidetracking or multiple targets



- Types of directional drilling:

  tangent, S-shape, horizontal





Directional drilling

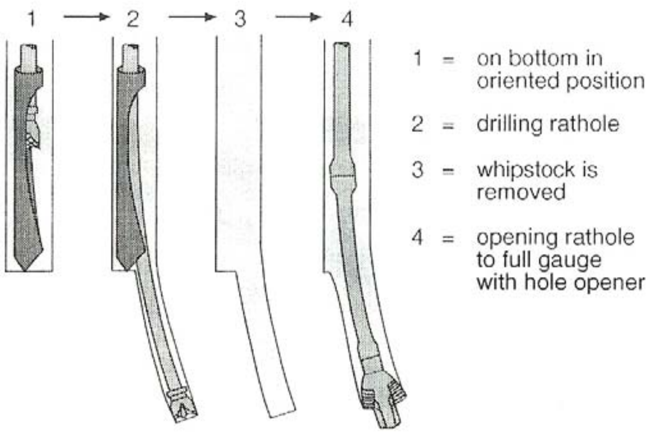
- Equipment to deflect:

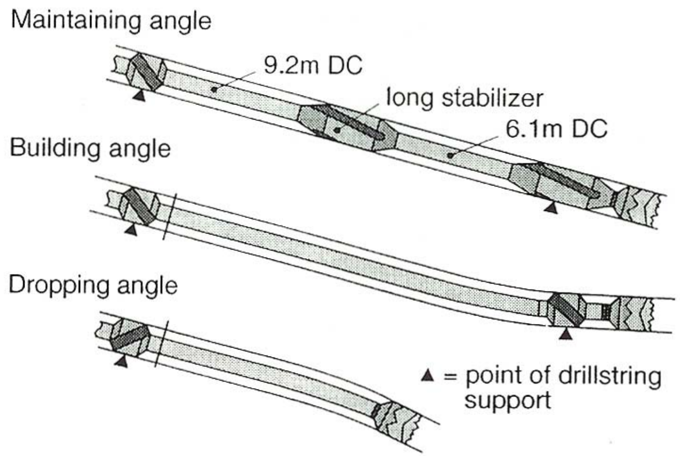
(1) whipstock: a slightly asymmetric steel joint

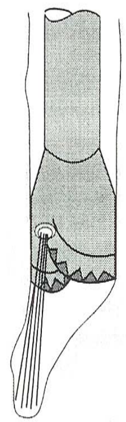
(2) jet bit: in shallow kick off in soft formation

2 small and 1 large jet

(3) mud motor or mud turbine







Horizontal drilling

- Given the lateral distribution of reservoir rock or reservoir fluids
- Accurate directional surveys are crucial
- Measurement While Drilling (MWD)
- Petrophysical data gathering: gamma-ray, resistivity, density and porosity
- Geo-steering

Extended Reach Drilling (ERD)

- The ratio of horizontal displacement and depth is more than 2

Slim hole drilling

- Slim hole: a well in which 90% or more of the length has a diameter 7 inches or less

- Greatly reduced cost:

  (1) less site preparation

  (2) easier equipment mobilization

  (3) reduction in the amount of consumables

  (4) less cuttings to dispose of

  (5) smaller equipment

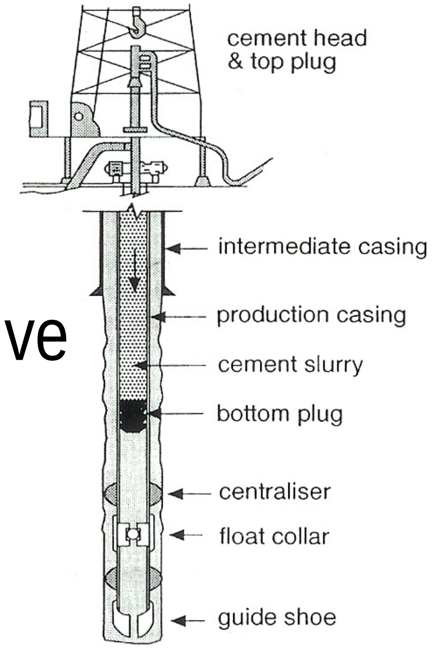
Coiled Tubing Drilling (CTD)

- A special version of slim hole drilling
- The drill string (seamless tubular) is reeled onto a large diameter drum

Advantages	Disadvantages
- nearly no pipe handling	- limited to slim hole
- less environmental impact	- reliability of drill string components
- lower cost for site preparation	
- easier completion	

Casing and Cementing

- Casing cementation
  - Running casing
  - Guide shoe: a protective cap with one way valve
  - Plug: to prevent contaminant of the cement
  - Float collar: to catch the plug
  - Centralizer: in the increasing deviation angle part



- Purpose of a primary cementation

  - Bond the casing to the formation

  - Prevent the casing from buckling

  - Prevent fluid movement between permeable formations

  - Seal off trouble horizons

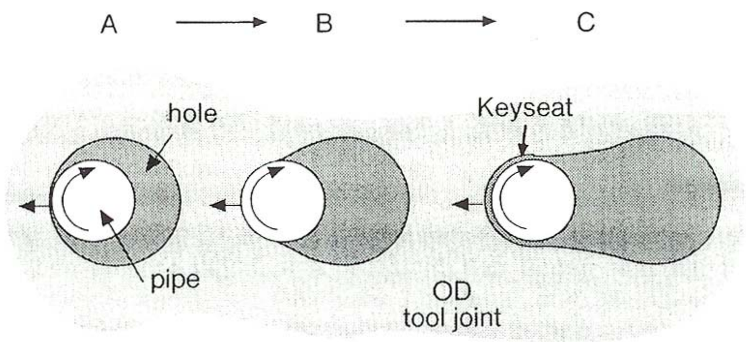
- Purpose of a secondary cementation

  - When primary cemetations are not successful

Drilling Problems

Stuck pipe

- A situation whereby the drill string cannot be moved up or down or rotated anymore



Stuck pipe

- Most common reasons for stuck pipe:

  (1) excessive pressure differentials between the borehole and the formation

  (2) swelling of clay minerals

  (3) unstable formations or a badly worn drill bit

  (4) residual stresses in the formation

  (5) when the well trajectory shows a severe dogleg

- Back-off
- Explosive or chemical charge
- Need to fish

- Fishing

  - The retrieval of a foreign object from the borehole

  - Junk: bit nozzle, rock bit cones, or broken off parts of equipment

  - Need a cost-benefit assessment

Lost circulation

- Cases of lost circulation:

(1) a highly porous, coarse or vuggy formation

(2) karst structure

(3) a densely fractured intervals

(4) a low strength formation

Lost circulation

- By adding Lost Circulation Materials (LCM) to the mud system
- By squeezing cement slurry
- In hydrostatically pressured interval: drill with surface water
- In over-pressured interval: shut-in is prohibited.
- In normally pressured zone, the well is overbalanced to prevent the influx of formation fluid

Lost circulation

- Reliable of indications of over-pressed zone

(1) gas readings

(2) porosity-depth trends

(3) ROP

(4) Shale density measurement

- Indications of kick fluids

(1) increase of total mud volume

(2) increase in ROP

(3) decrease in pump pressure

Lost circulation

- Removal of kick fluids

(1) shut-in

(2) circulating heavier mud

(3) squeezing out kick adjusting a choke

Costs and Contracts

Contracts

- Turkey contract: paying a fixed amount, quality problem
- Footage contract: providing an incentive to make hole quickly, prospective reservoir
- Incentive contract: providing a bonus for better than average performance
- Day-rate contract: renting the rig and crew on a per day basis, less favored by most oil companies
- Partnering and alliances: a long term relationship, merging of joint business objectives

Reservoir Description

Reservoir Geology

- Depositional Environment

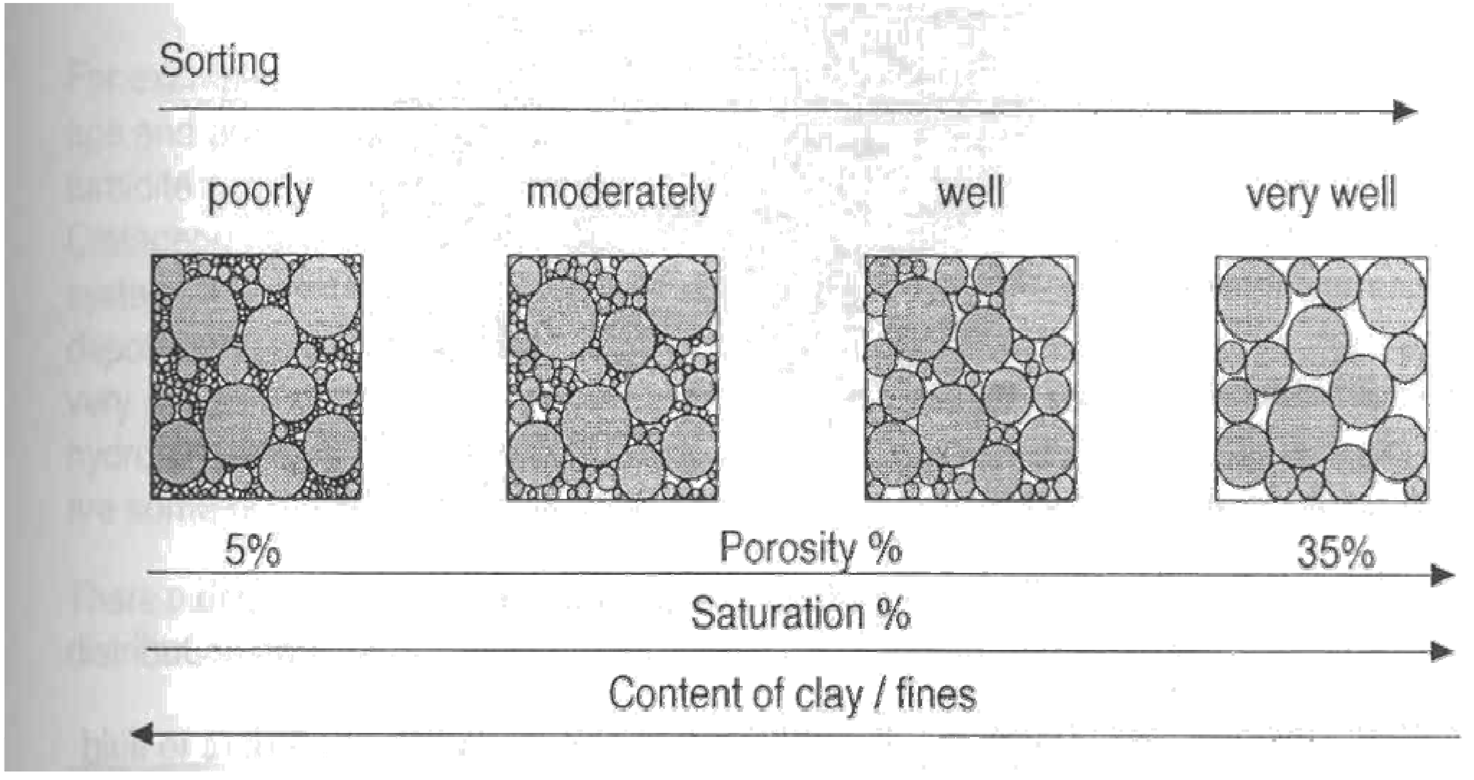
  - Clastics (Sandstones)

    (1) The Gulf of Mexico and North Sea

    (2) Weathering and transport

    mechanical weathering, chemical weathering

- Impact on sorting on reservoir quality



- Carbonate rocks

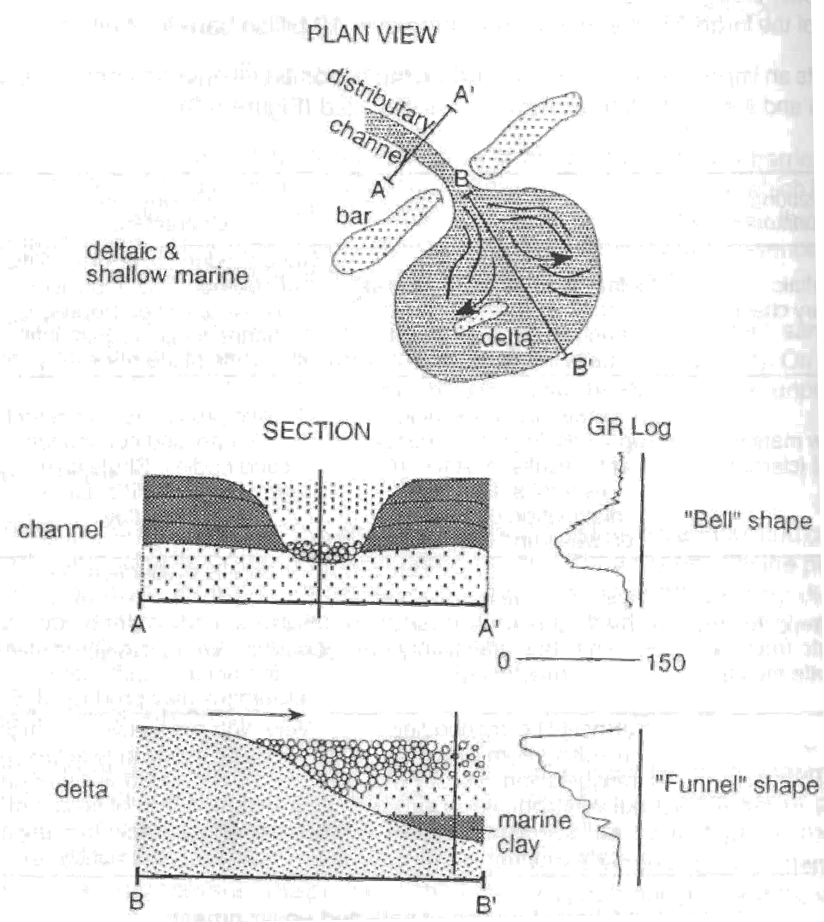
  (1) In situ

  (2) Severely affected by diagenetic processes

  (3) Middle East

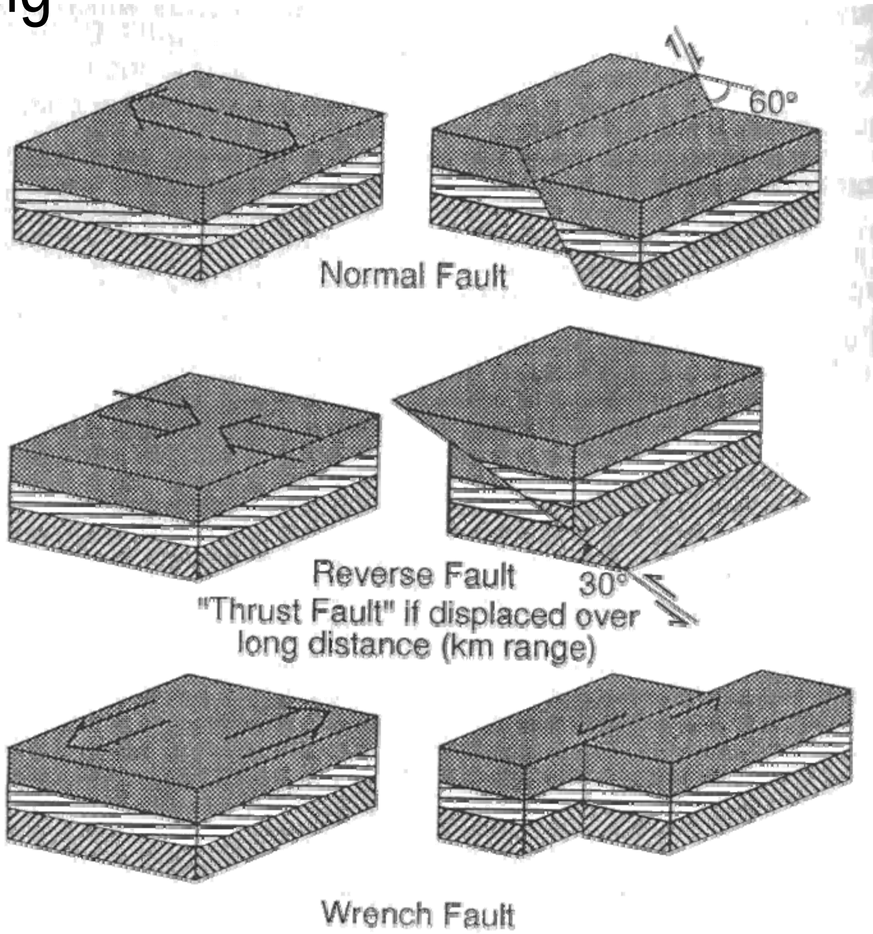
  (4) Fractures

- GR log response : capture in energy during deposition



Reservoir structure

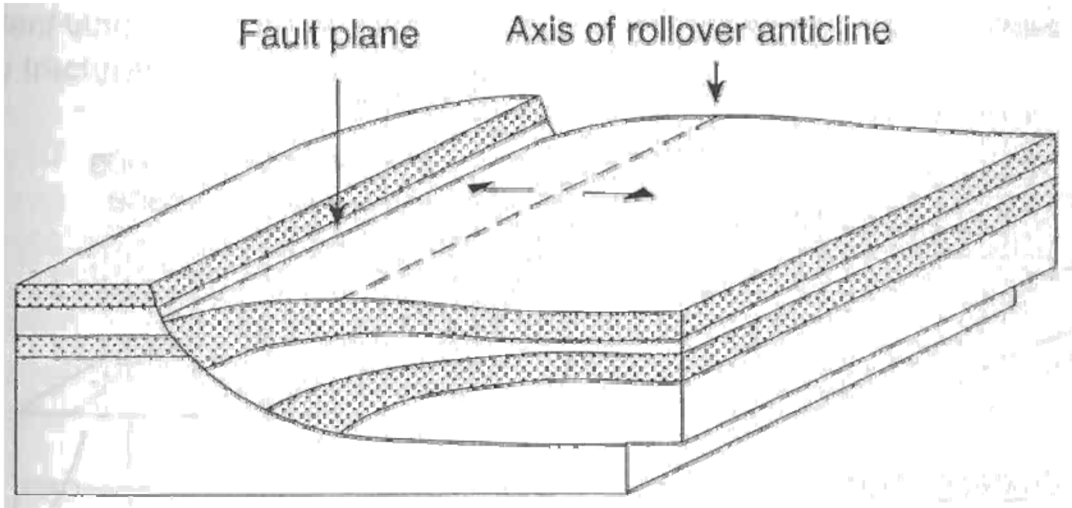
- Types of faulting



- Growth fault:

(1) deltaic sequences

(2) rapid deposition of large quantities of water-saturated sediments



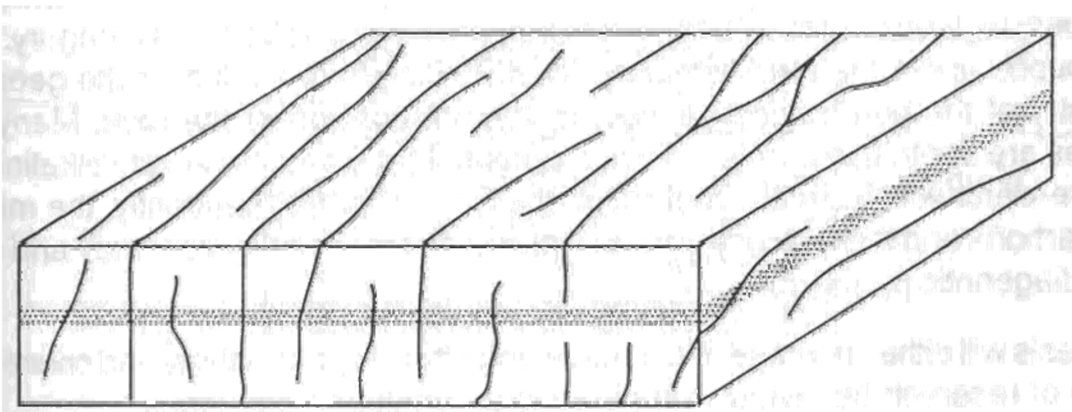
- Fracture

(1) Normal to bedding planes

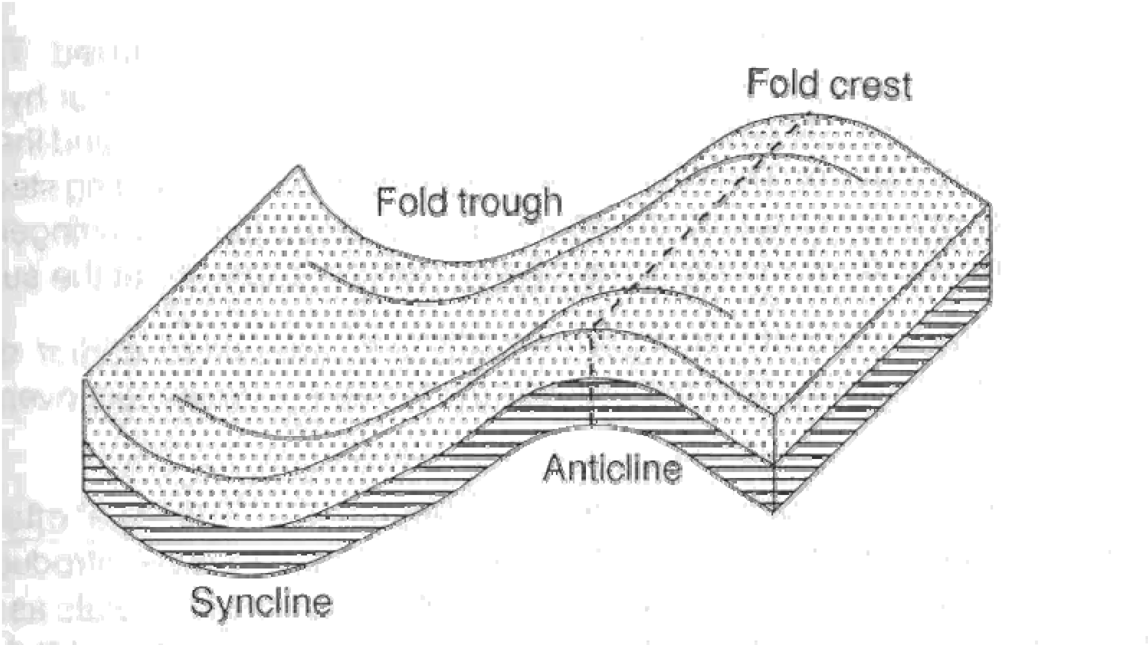
(2) Carbonate rocks > sandstones

(3) High porosity / high perm.

(4) Need to be planned to intersect as many fractures as possible (drilling horizontal wells)



- Fold



Diagenesis

- All chemical and physical processes affecting a sediment after deposition
- Alter the geometry and chemistry of the pore space as well as the composition of the rock
- Compaction

(1) By increasing overburden pressure

(2) Severe in clay

(3) Subsidence during production: reducing porosity and permeability

(4) Growth faults

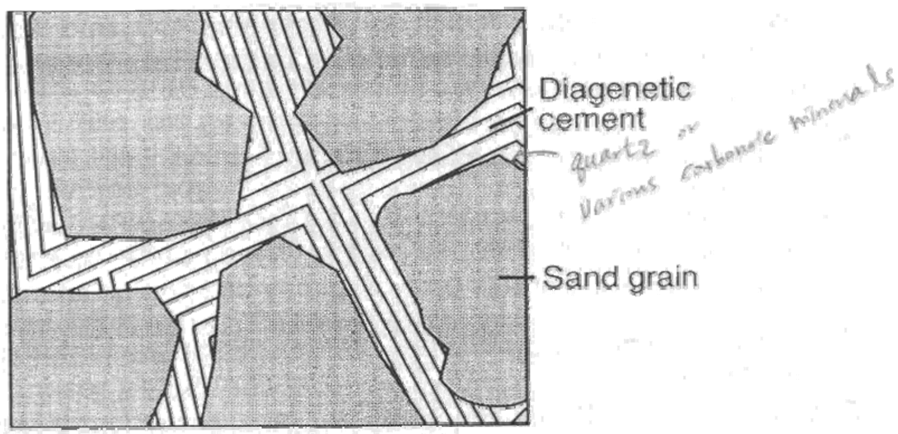
- Cementation
- Dissolution

  Karstification -> reservoir

  $CaCO_3+H_2O+CO_2$ -> $Ca(HCO_3)_2$
- Replacement

  $2CaCO_3+Mg^{2+}$ -> $CaMg(CaCO_3)_2+Ca^2$

  Increase in effective porosity (13%)



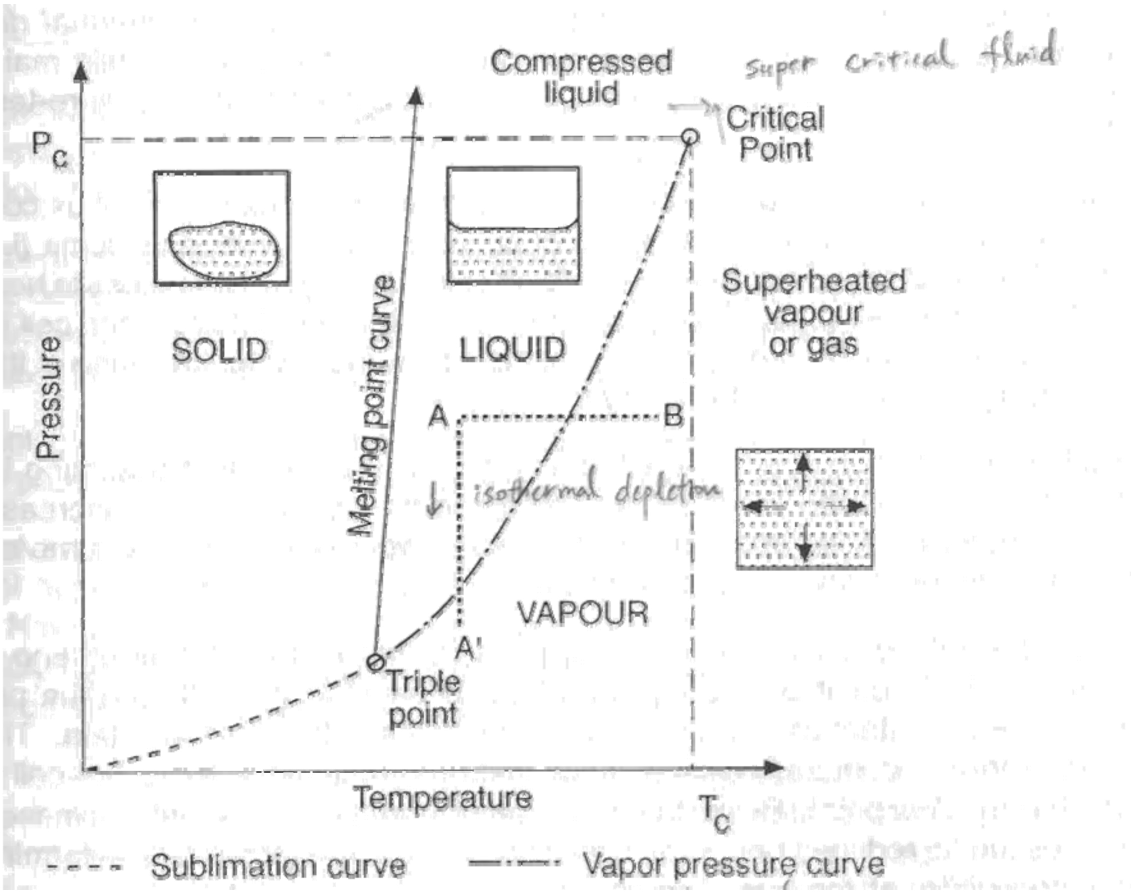
Reservoir Fluids

- Crude oil (by weight)

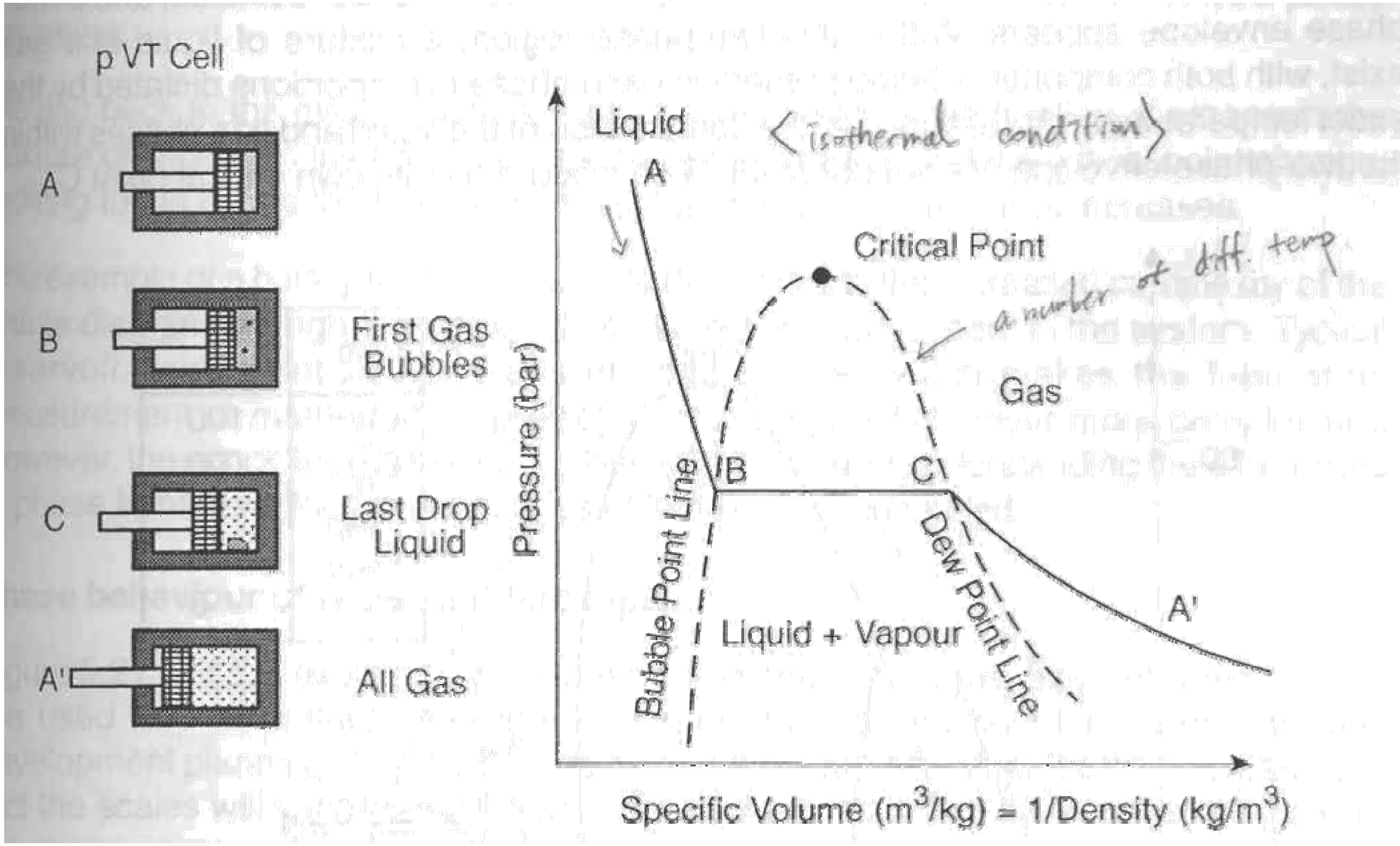
  - Carbon 84-87%
  - Hydrogen 11-14%
  - Sulphur, nitrogen, oxygen, metal 1%

The physical properties of hydrocarbon fluids

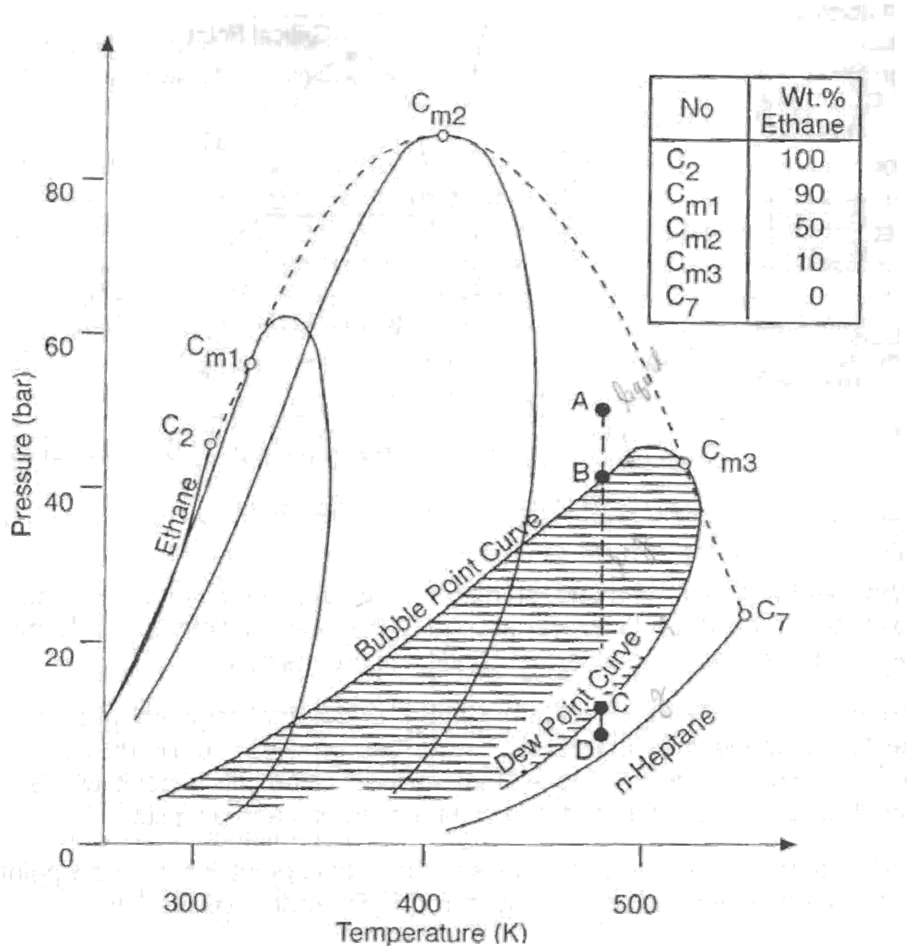
- Phase behavior (single component, p-T)



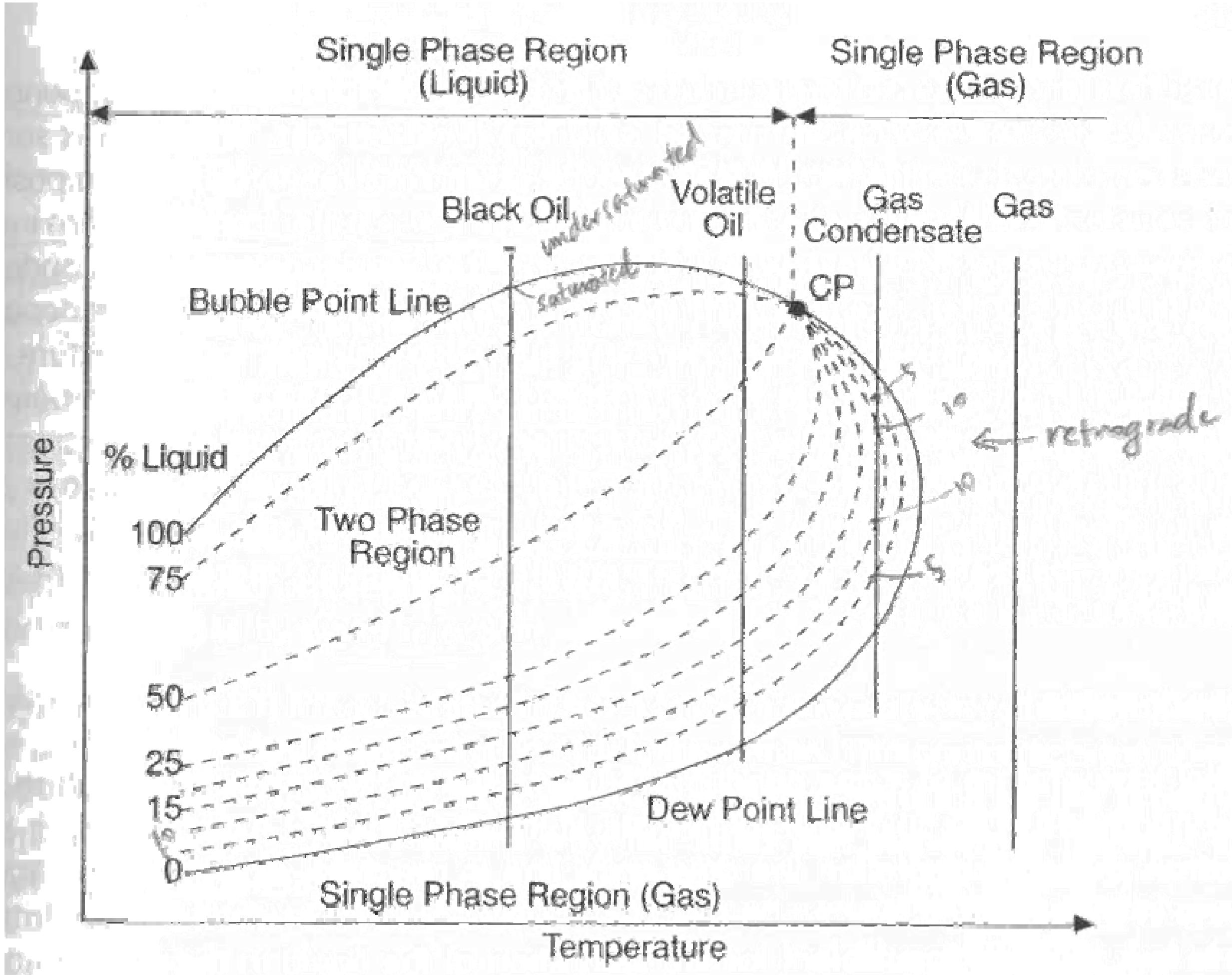
- Phase behavior (single component, p-V)



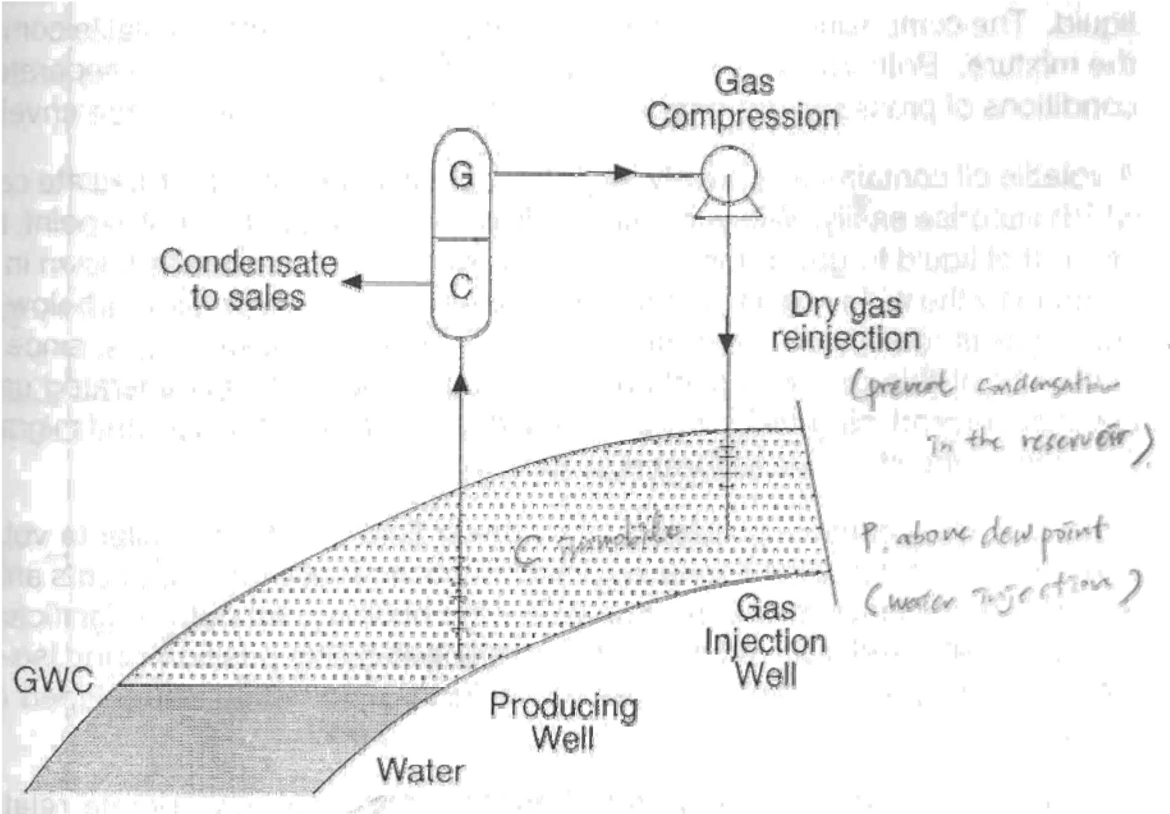
- Phase behavior (binary component)



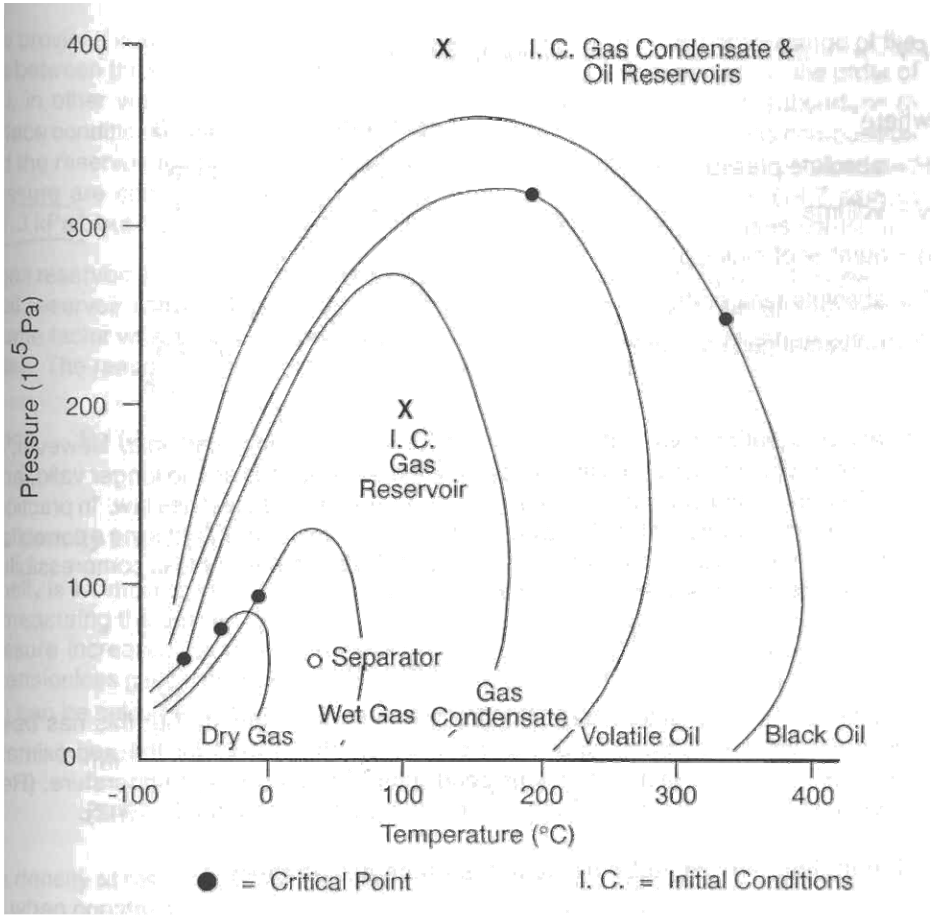
- Phase behavior of reservoir fluid types



- Gas recycling process



- Comparison of phase envelopes for different hydrocarbon types



Properties of hydrocarbon gases

- Ideal gas law

$$pV = nRT$$

Ignore volume, attractive force and conserve energy

- Real gas law

$$pV = ZnRT$$

- Relationship between subsurface and surface gas volumes

Expansion factor

E = volume of gas at STD/volume of gas at RVD

$E = 35.37\ P/ZT$

B_g (rb/scf) = 1/5.615E

- Gas density and viscosity

  D = MP/zRT

- The typical range of gas viscosity in the reservoir: 0.01-0.05 cp
- Poise: if a force of one dyne, acting on one sq. cm ,maintains a velocity of 1 cm/s over a distance of 1 cm

- Surface properties of hydrocarbon gases

  Wobbe index: measurement of the quality of a gas

  = Gross calorific value of the gas/(specific gravity of the gas)$^{0.5}$

- Hydrate formation

  (1) Solid form

  (2) Blockages in pipelines and other vessels

  (3) Control the conditions or add a chemical

Properties of oils

- Compressibility of oil

$c = -1/V\ dV/dp\ (psi^{-1})$

- Viscosity

(1) Typically 0.2-50 cp

(2) viscosity $\propto$ p/T

- Density

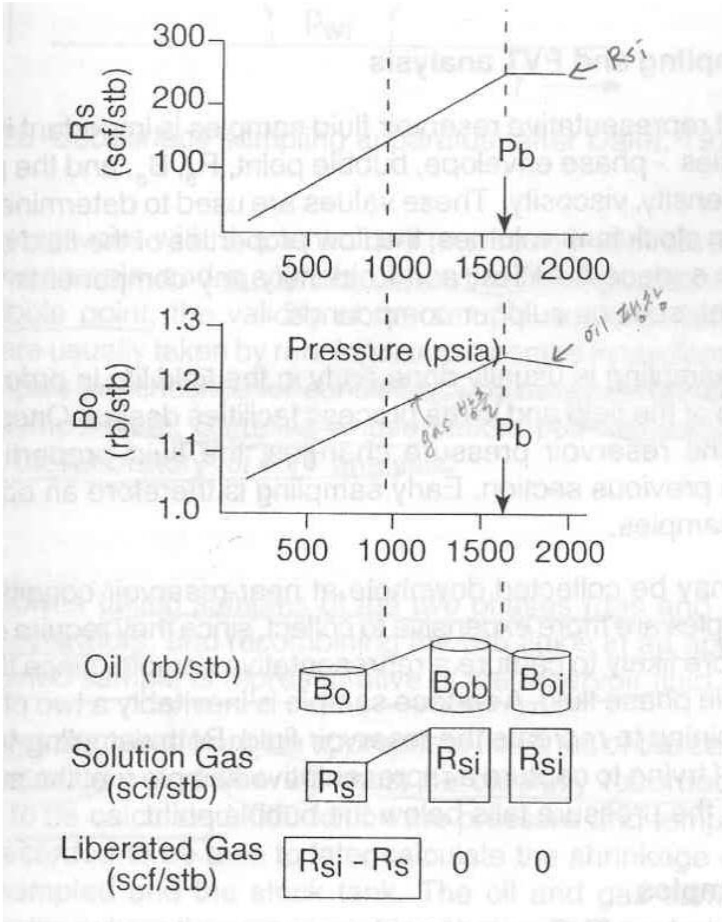
API = 141.5/specific gravity of oil(STD)-131.5

$$\rho_{orc} \cdot B_o = \rho_o + R_s \cdot \rho_g$$

where

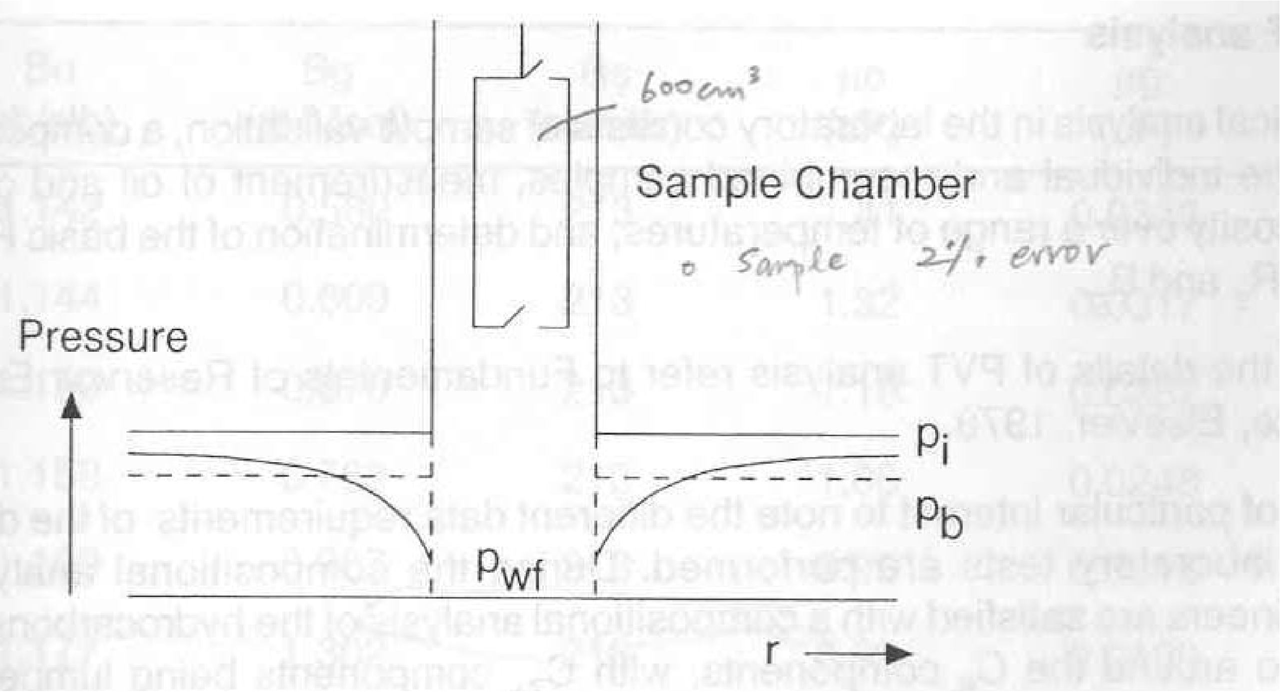
ρ_{orc}	=	oil density at reservoir conditions	(kg/m^3)
B_o	=	oil formation volume factor	(rm^3/stm^3)
ρ_o	=	oil density at standard conditions	(kg/m^3)
R_s	=	solution gas : oil ratio	(sm^3/stm^3)
ρ_g	=	gas density at standard conditions	(kg/m^3)

- Oil formation volume factor and solution gas oil ratio



Fluid sampling and PVT analysis

- Subsurface sampling



- Surface samples

(1) Taking samples of the two phase flowing through the surface separators

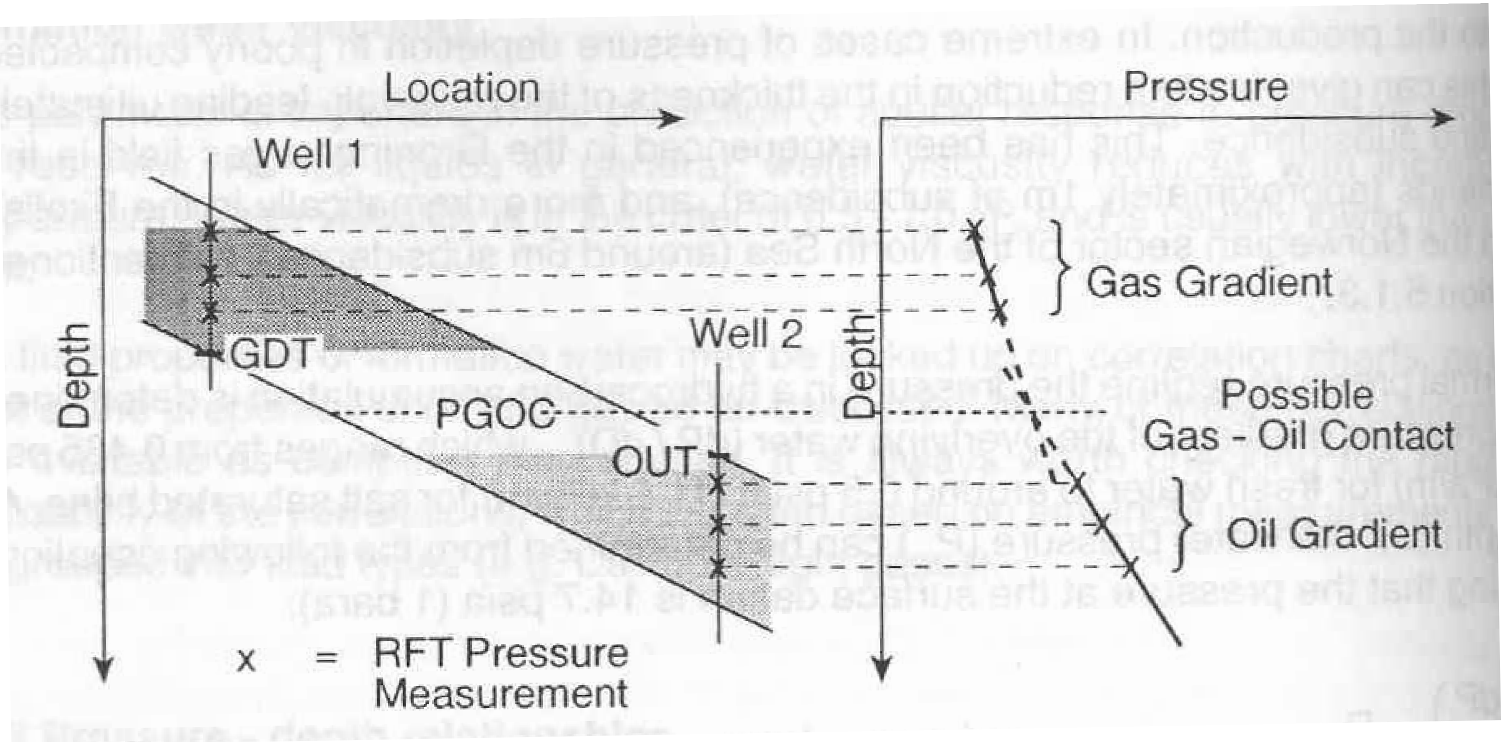
(2) Recombining the two fluids in an appropriate ratio such that the recombined sample is representative of the reservoir fluid

(3) A quality check on the sampling technique:

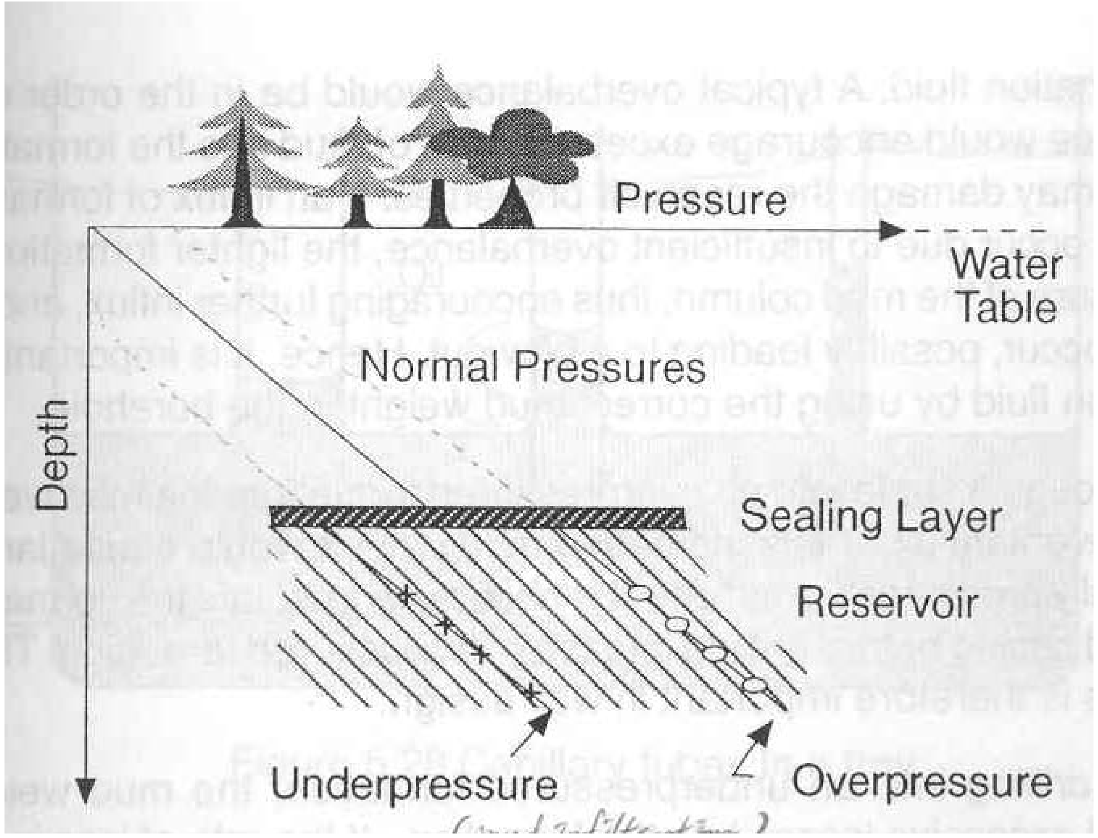
check p_b (at separator T) = separator p

Pressure – depth relationships

- GOC: intercept between gas and oil gradient
- FWL (Free water level): intercept between oil and water gradient

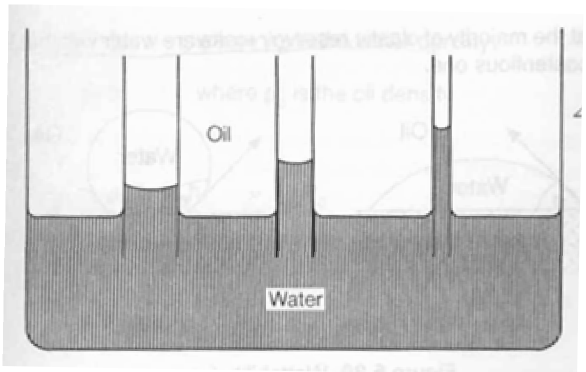


- Normal and abnormal pressure regimes

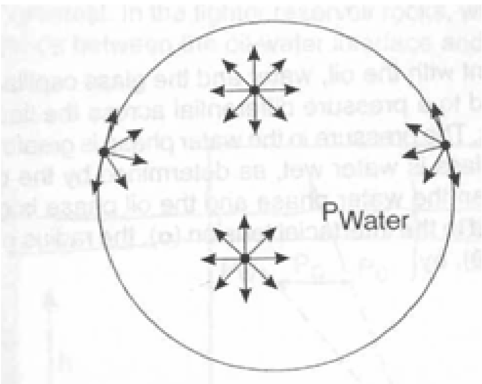


Capillary pressure

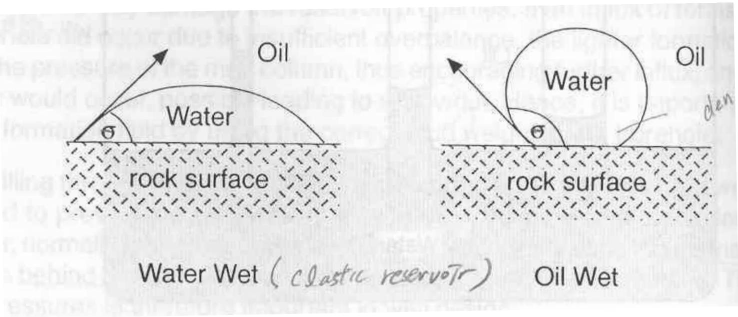
- An equilibrium exist between buoyancy forces and capillary forces
- A result of the interaction of attractive forces between molecules in the two liquids (surface tension effects), and the fluids and the solid surface (wettability effects)
- Capillary tubes in a tray (non-miscible fluids are in contact)



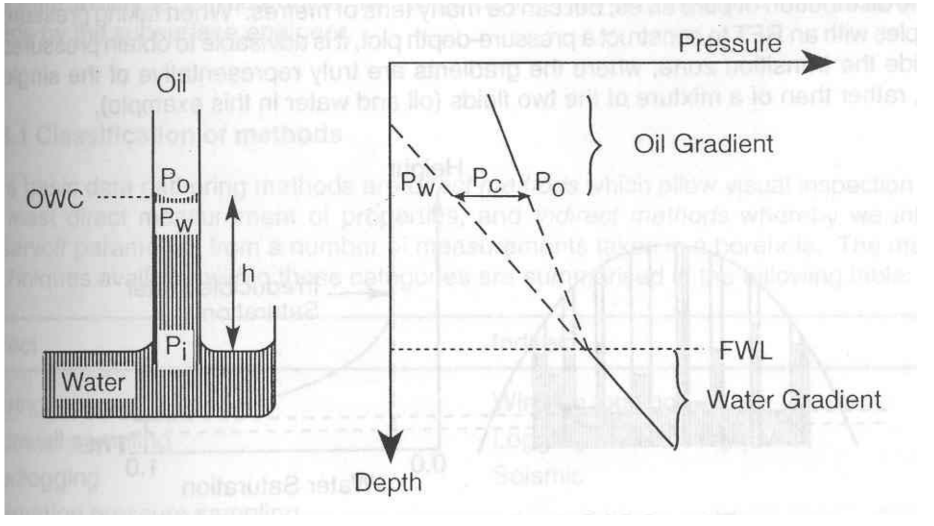
- Water droplet with attractive forces



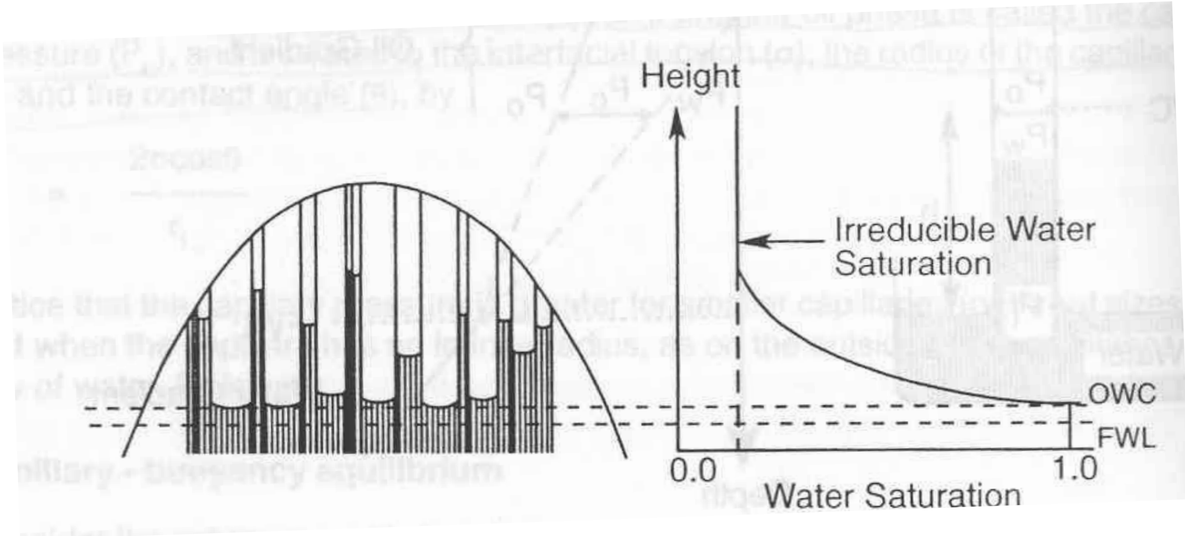
- Wettability



- Capillary – buoyancy equilibrium



Saturation – height relationships



Data Gathering

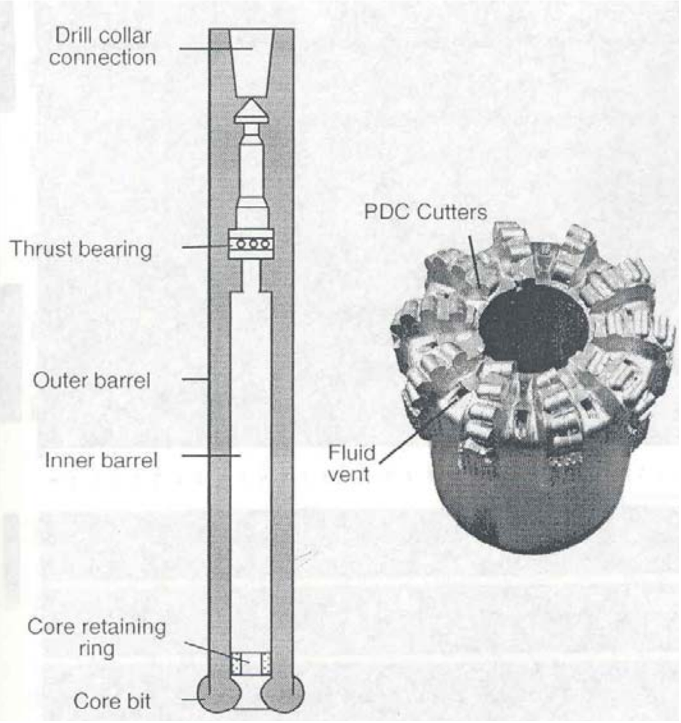
Classification of methods

- Direct: visual inspection or direct measurement
- Indirect: inference of reservoir parameters from the borehole data

Direct	Indirect
Mudlogging	Wireline logging
Coring	Logging while drilling (LWD)
Sidewall sampling	Seismic
Formation pressure sampling	
Fluid sampling	

Coring and core analysis

- Coring



- Cores

(1) Direct measurement of physical rock properties in a laboratory

(2) Description of the depositional environment, sedimentary features and the digenetic history of the sequence

- Core analysis

(1) Photograph under normal and UV light

(2) Plug(D:2cm, L:5cm) analysis

Standard: porosity, horizontal air permeability, grain density

Special: vertical air permeability, relative permeability, capillary pressure, cementation exponent and saturation exponent

- Cost factor

(1) Rig time

(2) Coring is only used in selected intervals

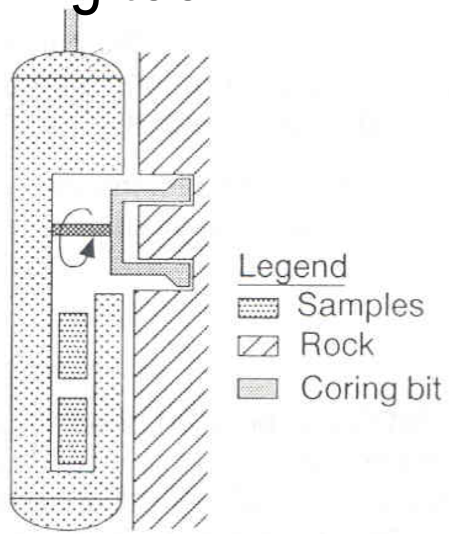
Sidewall sampling (SWS)

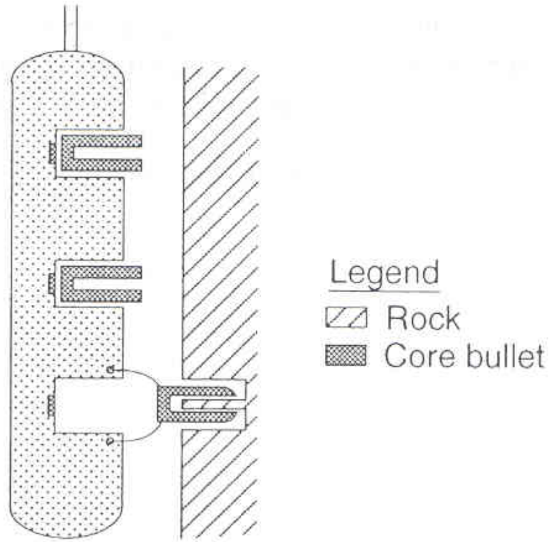
- SWS tool: small plugs

(1) Direct indications of HC under UV light

(2) Stratigraphic analysis: age dating, correlation, depositional environment

- Sidewall coring tool





Wireline logging

- Logging tools

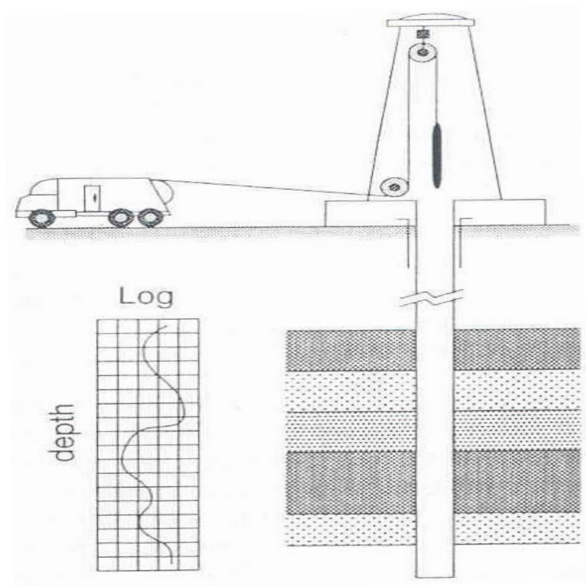
Tools	Uses
Gamma ray log	bed boundaries, correlation, zonation of sand and shale
Gamma spectroscopy	clay mineral identification
Sonic log	porosity indication
Resistivity log	fluid content
Density log	formation density, porosity, shale content and lithology identification
Neutron log	porosity evaluation (most reliable but dangerous)
Dipmeter log	structural and sedimentary dip

- Complicating factor

(1) Mud cake

(2) Open hole time increase

(3) Cost: 5 ~ 15% of total well cost



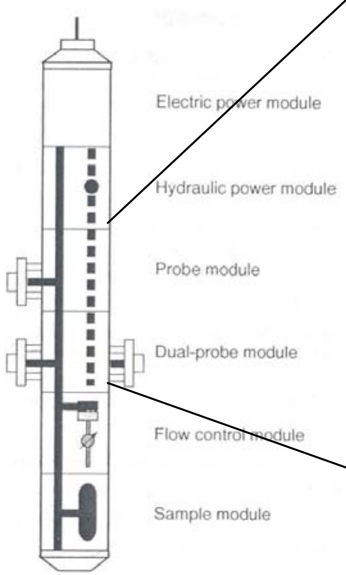
Pressure measurement and fluid sampling

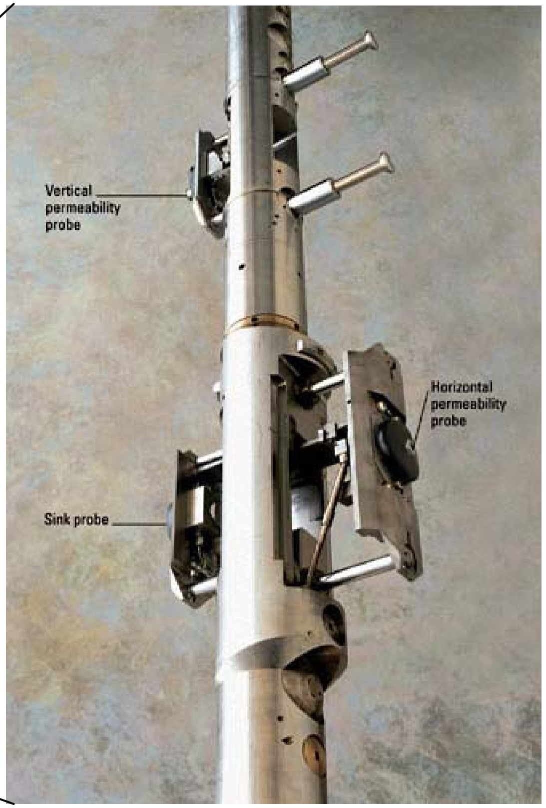
- Wireline formation tester

(1) RFT (Repeat Formation Tester) &

FMT (Formation Multi Tester)

(2) MDT (Modular Dynamic Tester)





Measurement while drilling(MWD)

- Real time data

(1) Correlation for picking coring and casing points

(2) Overpressure detection in exploration wells

(3) Logging to minimize ‘out of target’ sections

(4) Formation evaluation to facilitate stop drilling decisions

- MWD tool

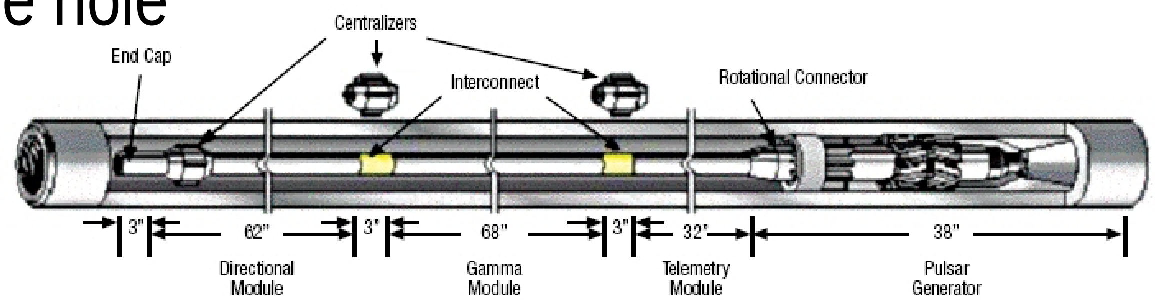
(1) Telemetry module: gathering data from the gamma and directional modules, formatting and storing

(2) Gamma module: measuring naturally occurring gamma radiation

(3) Pulsar/generator: generating electrical power, controlling drilling mud flow

(4) Battery module: providing power

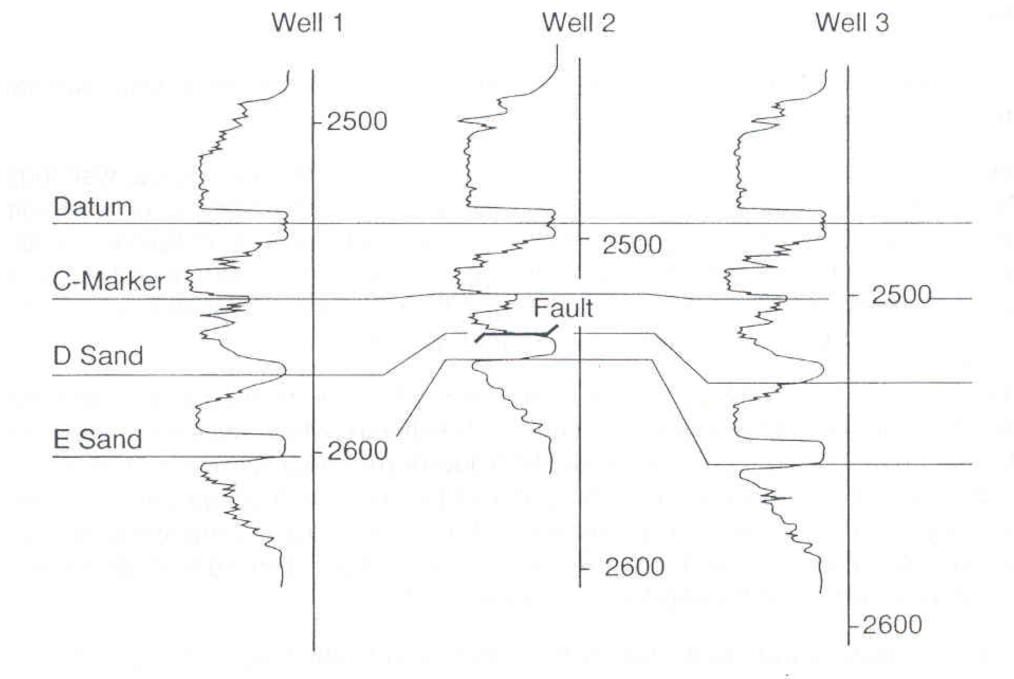
(5) Directional module: measuring the compass direction of BHA and the angle of the hole



Data Interpretation

Well correlation

- Establishing lateral and vertical trends of reservoir parameters
- Datum plane correlation

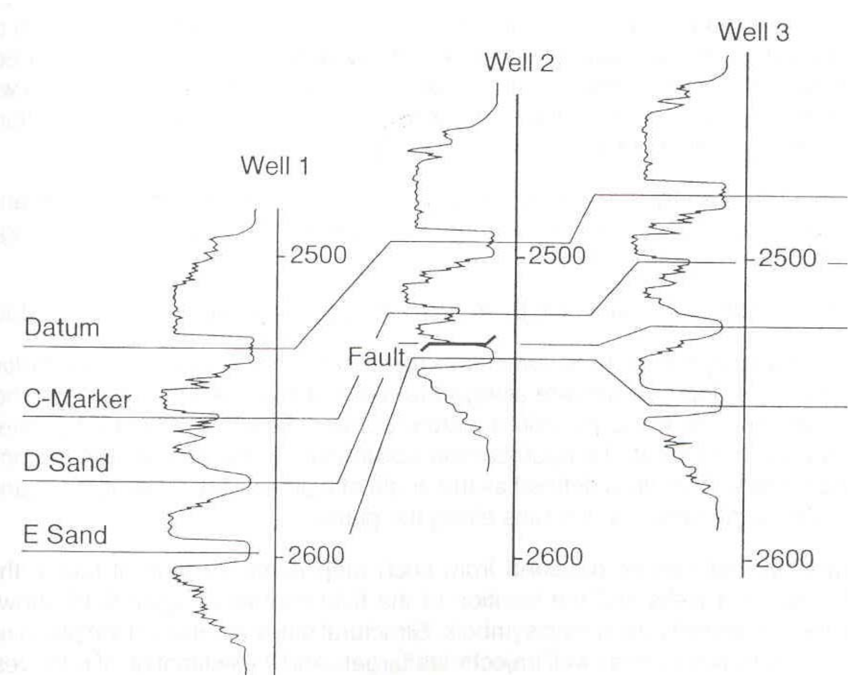


- Ambiguity of correlations:

  As many correlation options are possible

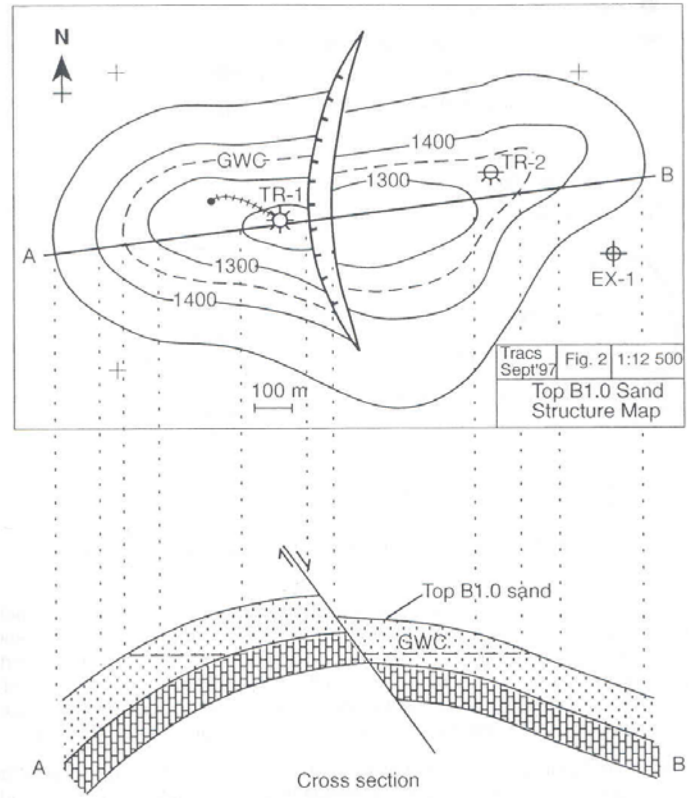
- If correlation is 'lost': faulting or unconformity

- Structural correlation



Maps and sections

- Maps only describe the surface of an area
- Sections are cuts through the surface



- Structural maps

(1) The top/bottom of the reservoir surface below the datum level

(2) Depth: true vertical sub sea

(3) Displaying the shape and extent of a hydrocarbon accumulation, the status and location of wells, faults, and the fluid contacts

(4) Indicating the dip and strike of the structure

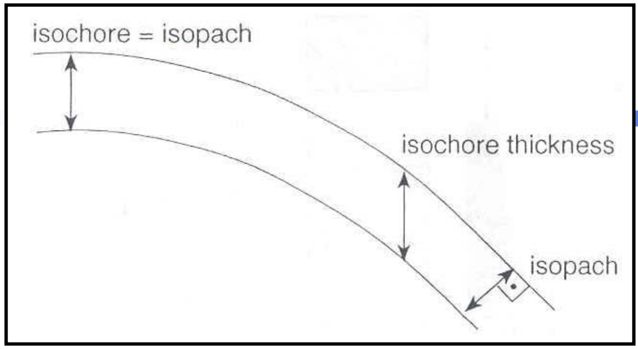
(5) Planning well trajectories/targets and the estimation of reserves

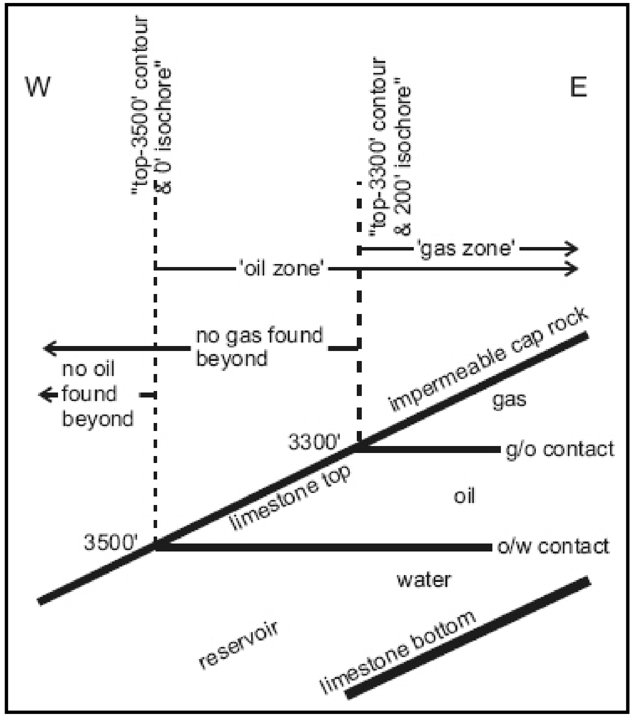
- Reservoir quality maps

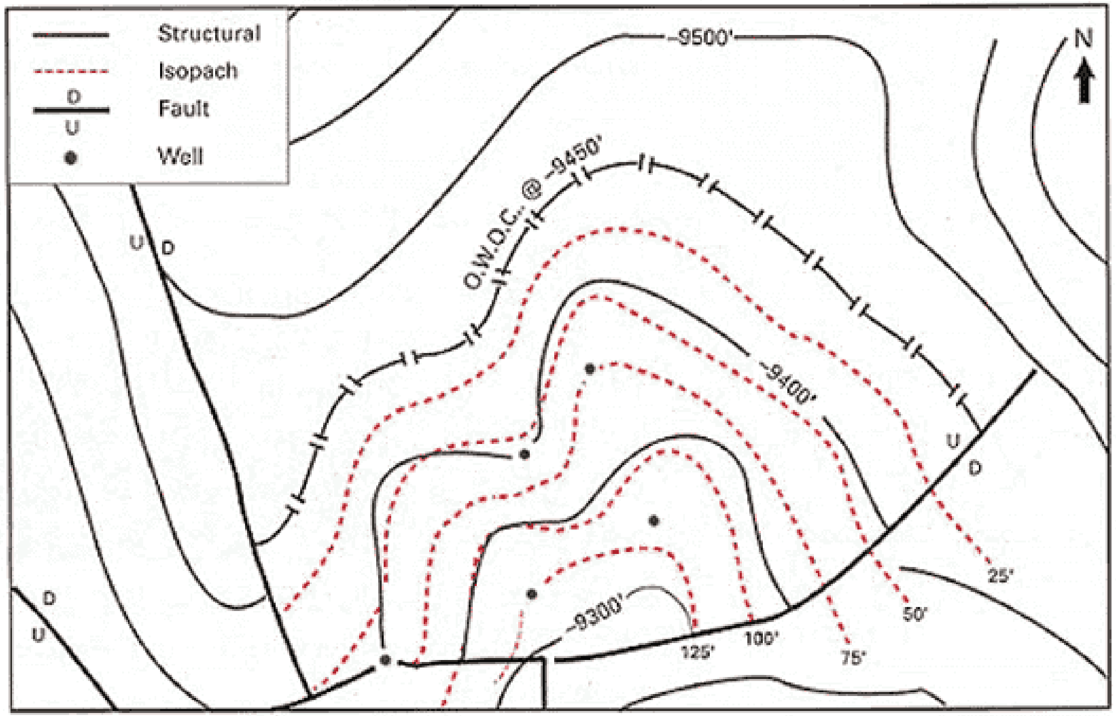
(1) Illustrating the lateral distribution of reservoir parameters

(2) Isochore maps: Contour the difference in depth between top and bottom

(3) Isopach maps: Contour points of equal stratigraphic thickness of rock unit


isochore = isopach
isochore thickness
isopach


W
E
"top-3500' contour & 0' isochore"
"top-3300' contour & 200' isochore"
'gas zone'
'oil zone'
no gas found beyond
no oil found beyond
impermeable cap rock
gas
3300'
g/o contact
limestone top
oil
3500'
o/w contact
water
reservoir
limestone bottom


Structural
Isopach
Fault
D
U
Well
N
-9500'
O.W.O.C. @ -9450'
-9400'
-9300'
25'
50'
75'
100'
125'

Net to gross ratio (N/G)

- Definition

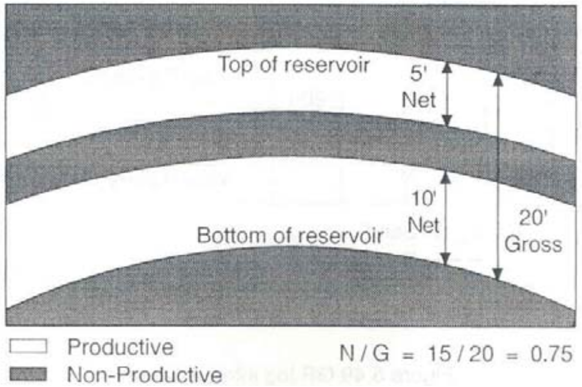
(the thickness of productive reservoir rock)

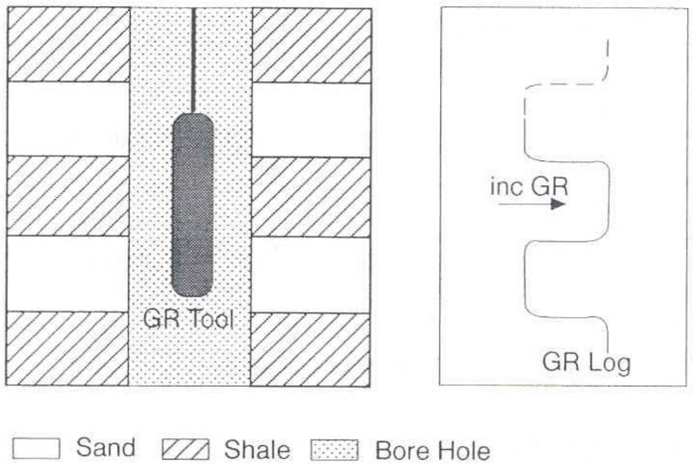
/ (the gross reservoir thickness)

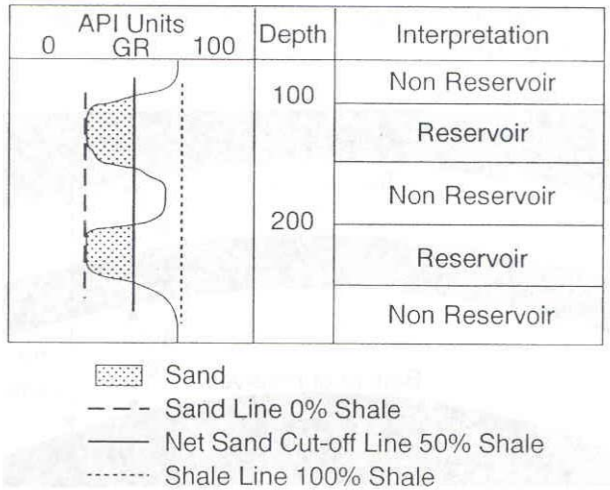
- Tool: Gamma ray log

(1) Shale: high level of radioactivity

(2) Sand: low level of radioactivity


Top of reservoir
5'
Net
10'
Net
Bottom of reservoir
20'
Gross
Productive
Non-Productive
N / G = 15 / 20 = 0.75


GR Tool
inc GR
GR Log
Sand
Shale
Bore Hole


API Units
0
GR
100
Depth
Interpretation
100
200
Non Reservoir
Reservoir
Non Reservoir
Reservoir
Non Reservoir
Sand
Sand Line 0% Shale
Net Sand Cut-off Line 50% Shale
Shale Line 100% Shale

Porosity

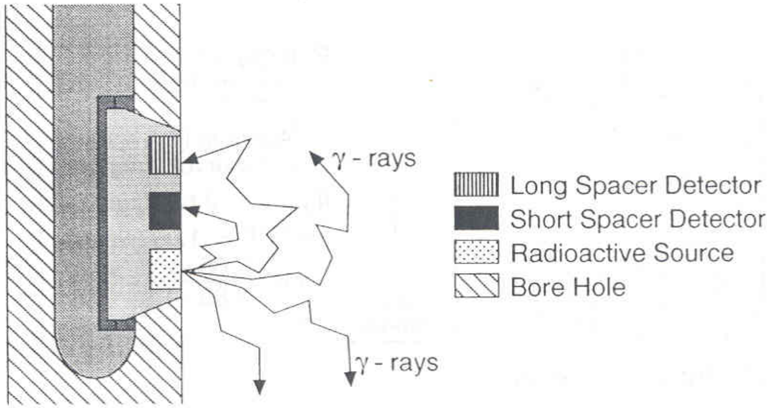
- Tools

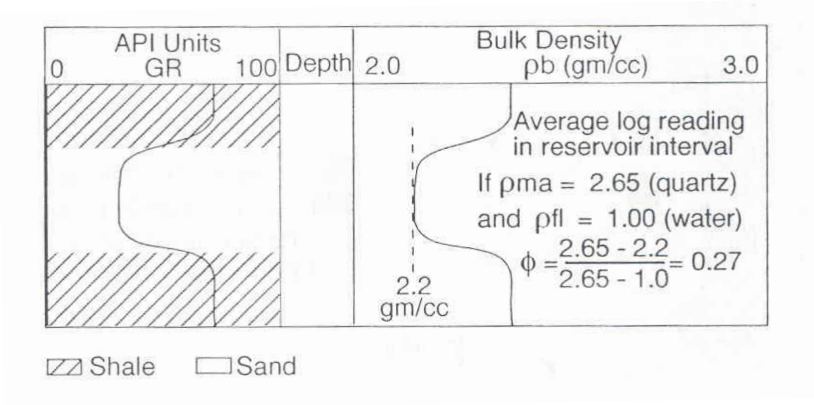
(1) Formation density log

$$\rho_b = \rho_f \phi + \rho_{ma}(1-\phi)$$

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

$$\left(\begin{array}{l} \rho_b = \text{formation bulk density} \\ \rho_{ma} = \text{matrix density} \\ \rho_f = \text{fluid density} \end{array} \right)$$





(2) Neutron log

(3) Sonic log

$$\Delta t_b = \Delta t_f \phi + \Delta t_{ma}(1-\phi)$$

$$\phi = \frac{\Delta t_{ma} - \Delta t_b}{\Delta t_{ma} - \Delta t_f}$$

Hydrocarbon saturation

- Archie's formula (1942)

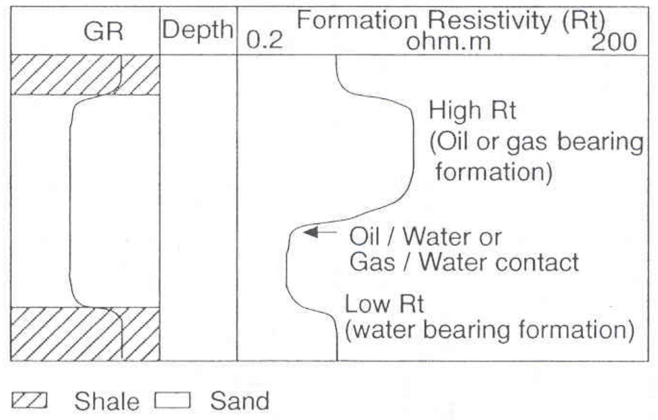
$$C_o = \phi^m C_w$$

$$C_t = S_w{}^n \phi^m C_w$$

$$R_t = S_w{}^{-n} \phi^{-m} R_w$$

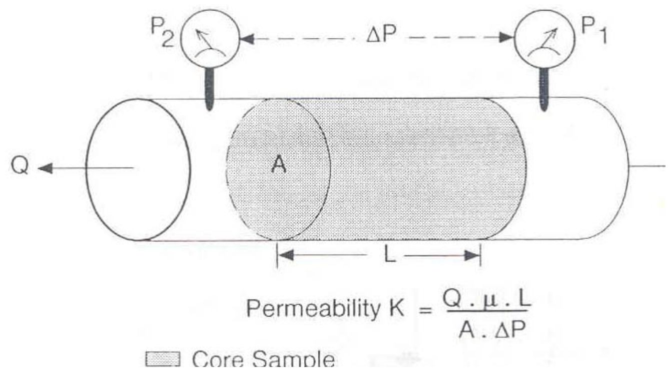
$$S_w = \sqrt[n]{\frac{R_w}{\phi^m R_t}}, \quad S_h = 1 - S_w$$

$$\left(\begin{array}{l} R_t = \text{formation resistivity (ohm.m)} \\ S_w = \text{water saturation (fraction)} \\ R_w = \text{water resistivity(ohm.m)} \\ m = \text{cementation exponent} \\ n = \text{saturation exponent} \end{array} \right)$$



Permeability

- Darcy equation



- Caliper log