인하대학교 INHA UNIVERSITY

2018 인하대 **K-MOOC** 강의 교재

인류의 그림자, 에너지 바로알기

신 현돈 교수
(hyundon.shin@inha.ac.kr)

인하대학교 에너지자원공학과

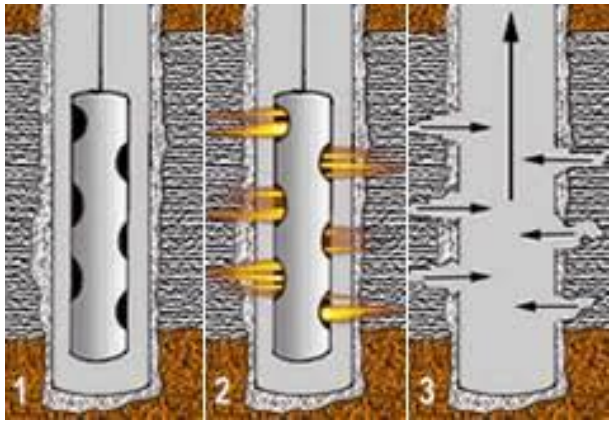
2018

5: 석유 생산기술의 발달

5-1: 지하의 석유를 어떻게 생산할까?

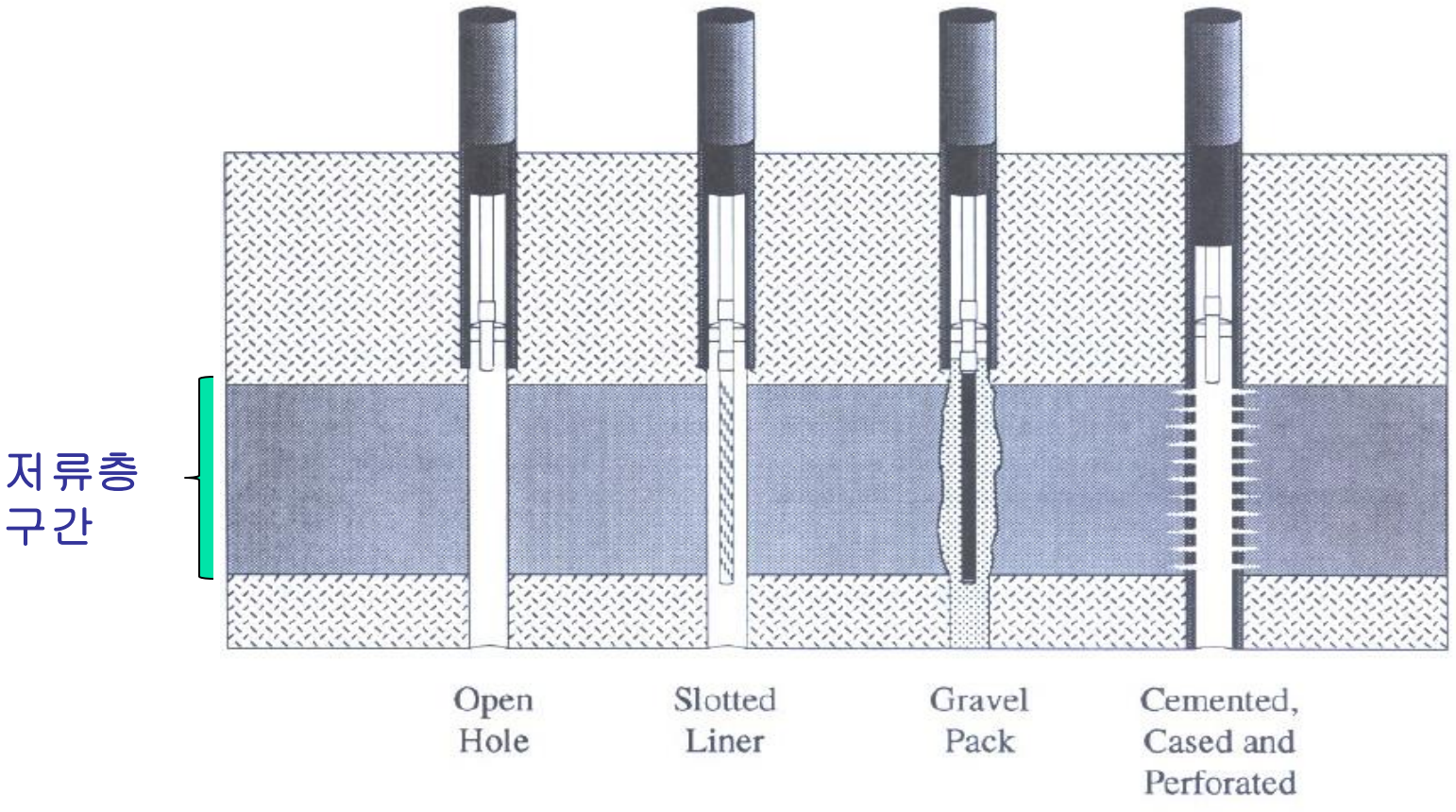
석유 생산 단계

- 지하 저류층의 석유를 지상으로 끌어올림
- 지하 저류층 – 생산파이프 - 지상 저장소
  - 저류층과 생산파이프 연결: 천공
  - 지상 저장소로 수송: 펌프



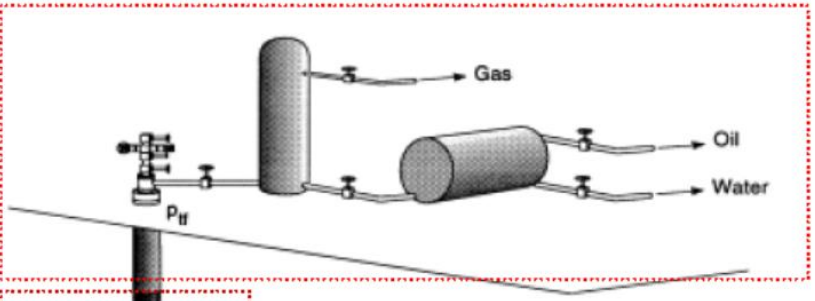
유정완결 (Well completion)

- 유정완결: 생산 준비 과정



석유 생산 시스템(production system)

Surface Production
(from wellhead to downstream)

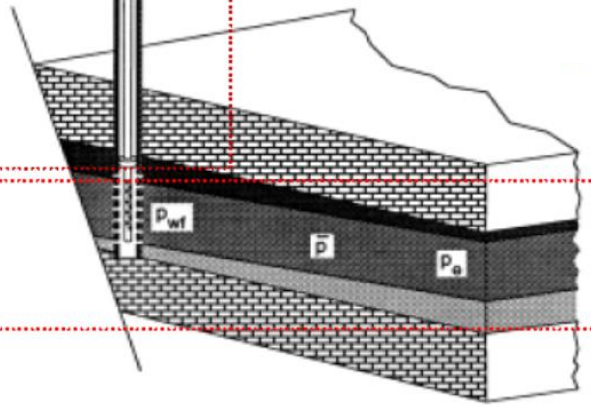


지상생산설비

Vertical flow Performance
(from wellbore to Wellhead)

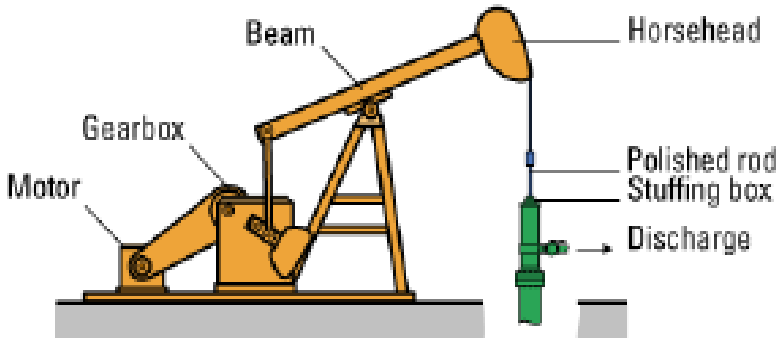
파이프유동

Inflow Performance
(from reservoir to wellbore)

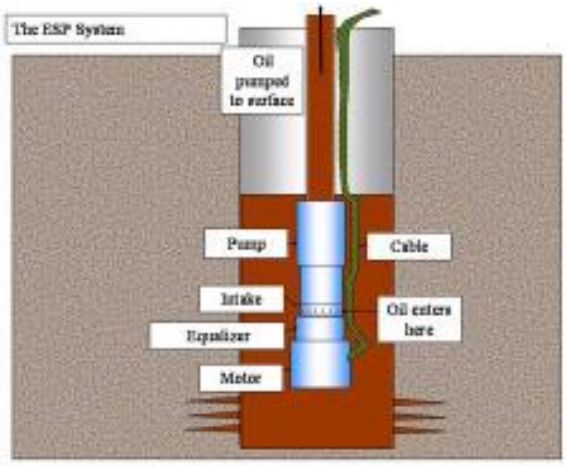


지하유입

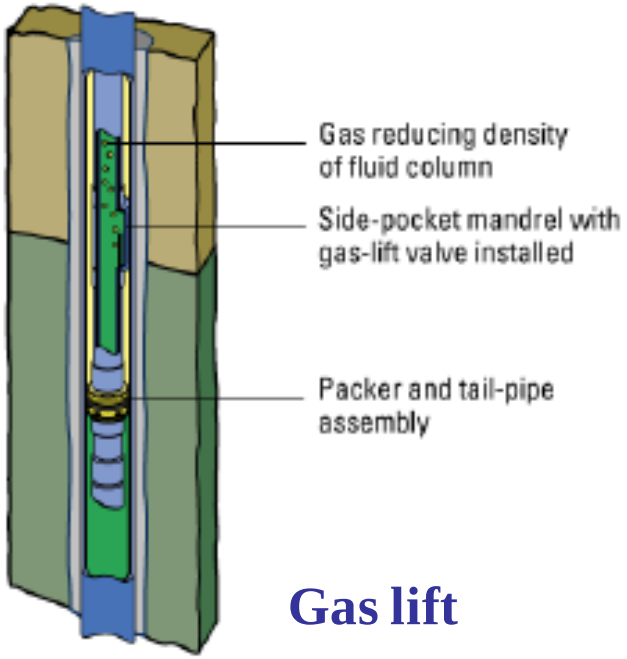
생산 펌프(Production pumps)



Rod pump



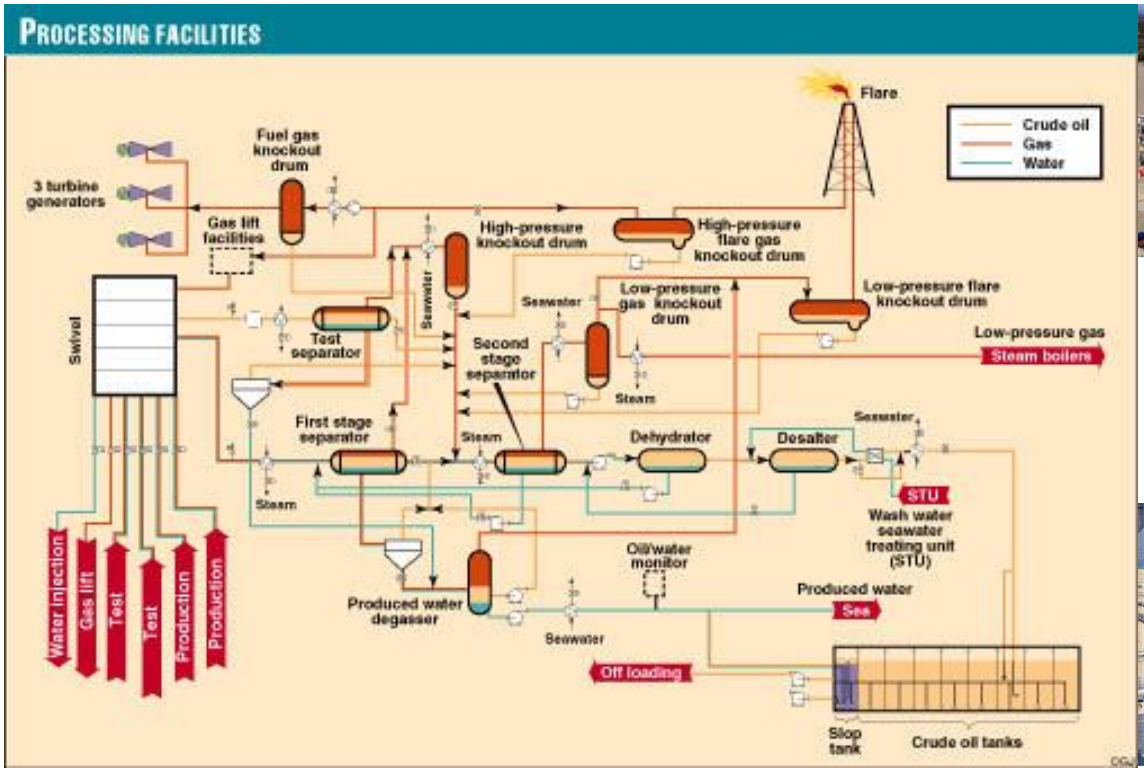
Downhole pump

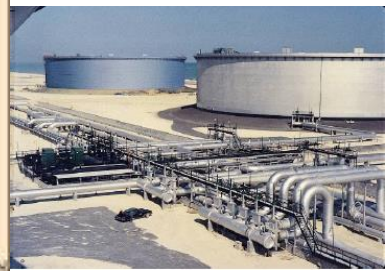


Gas lift

지상 생산 설비

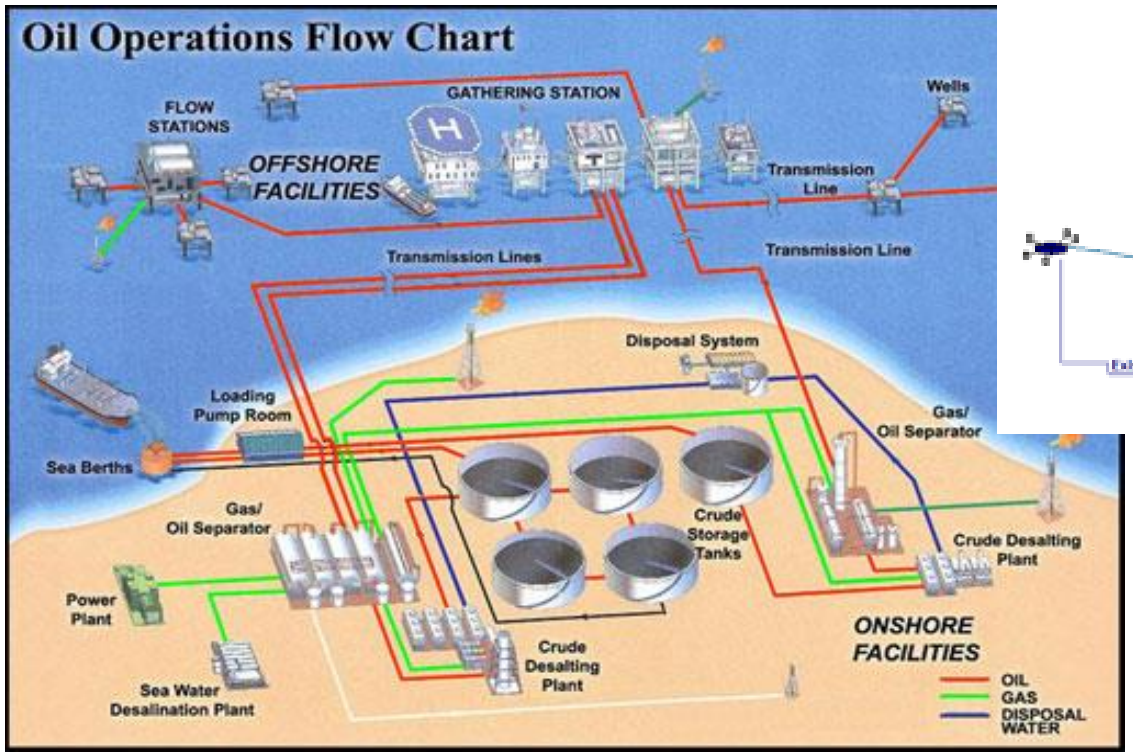
- 정두(Wellhead) – 유체분리기(Separator) – 운송(Transport)

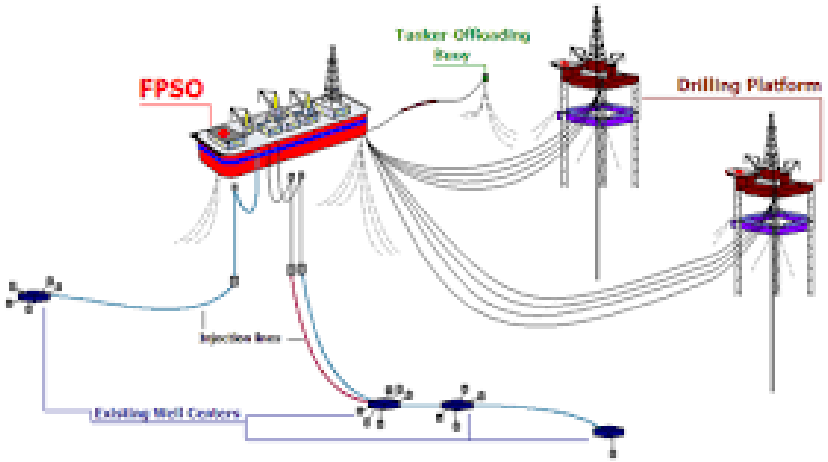




지상 처리 설비 (process facility)

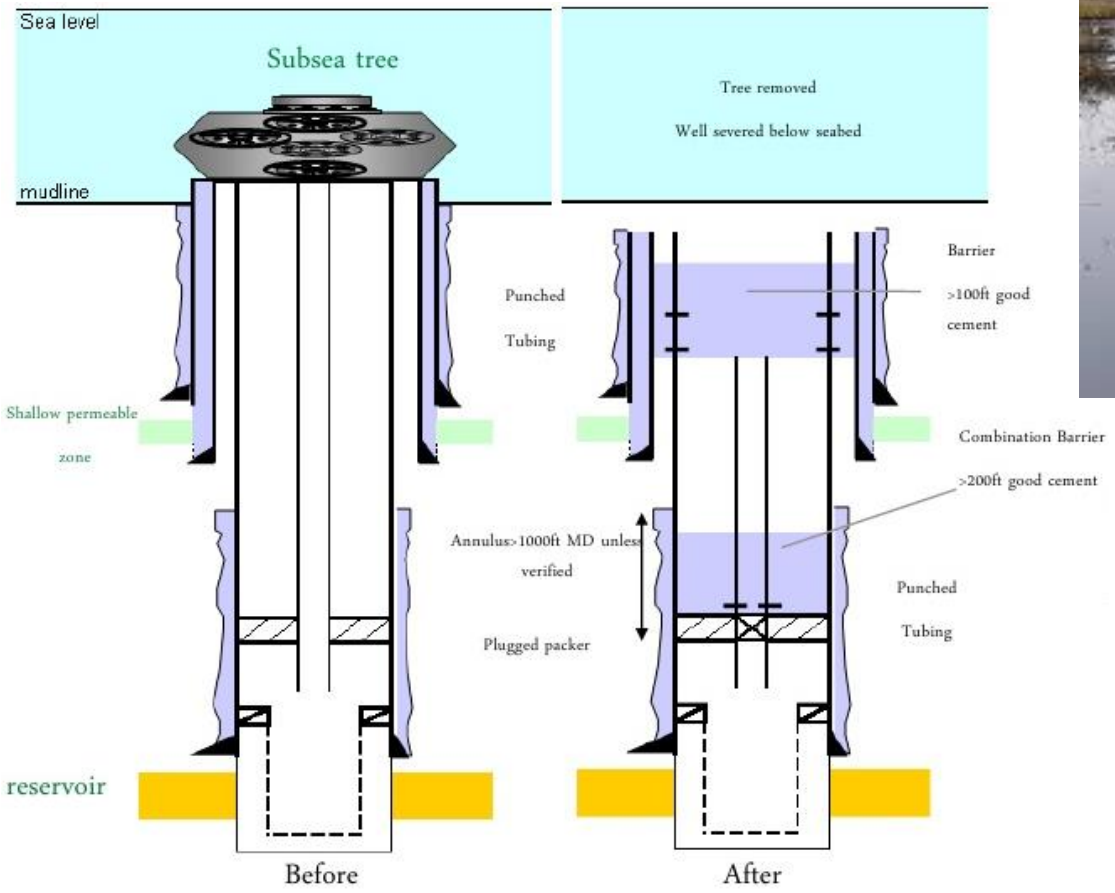
- 육상유전: 운영이 쉽다
- 해상유전: 복잡하고 운영이 어렵고 고비용
  - FPSO





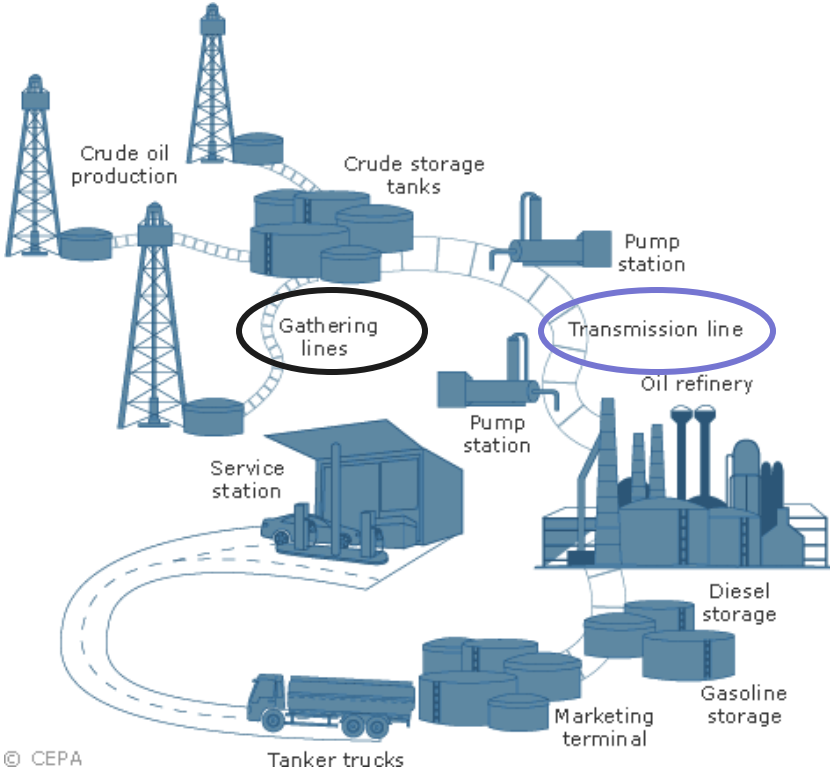
폐공(Plug & Abandonment)

- 생산후 생산정 폐쇄 처리



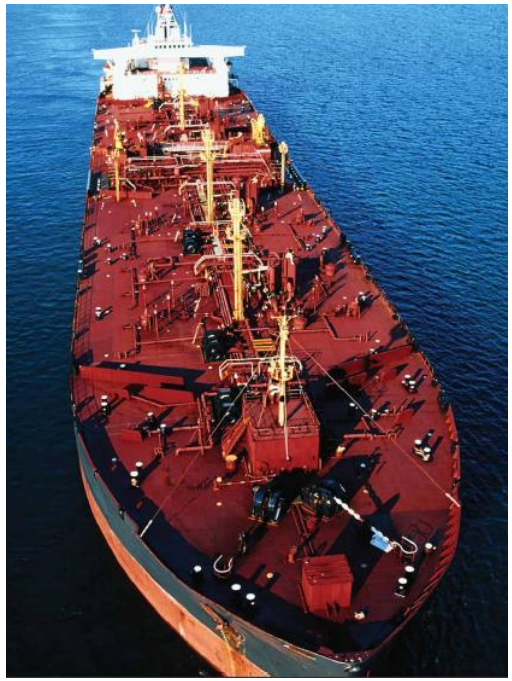
파이프라인

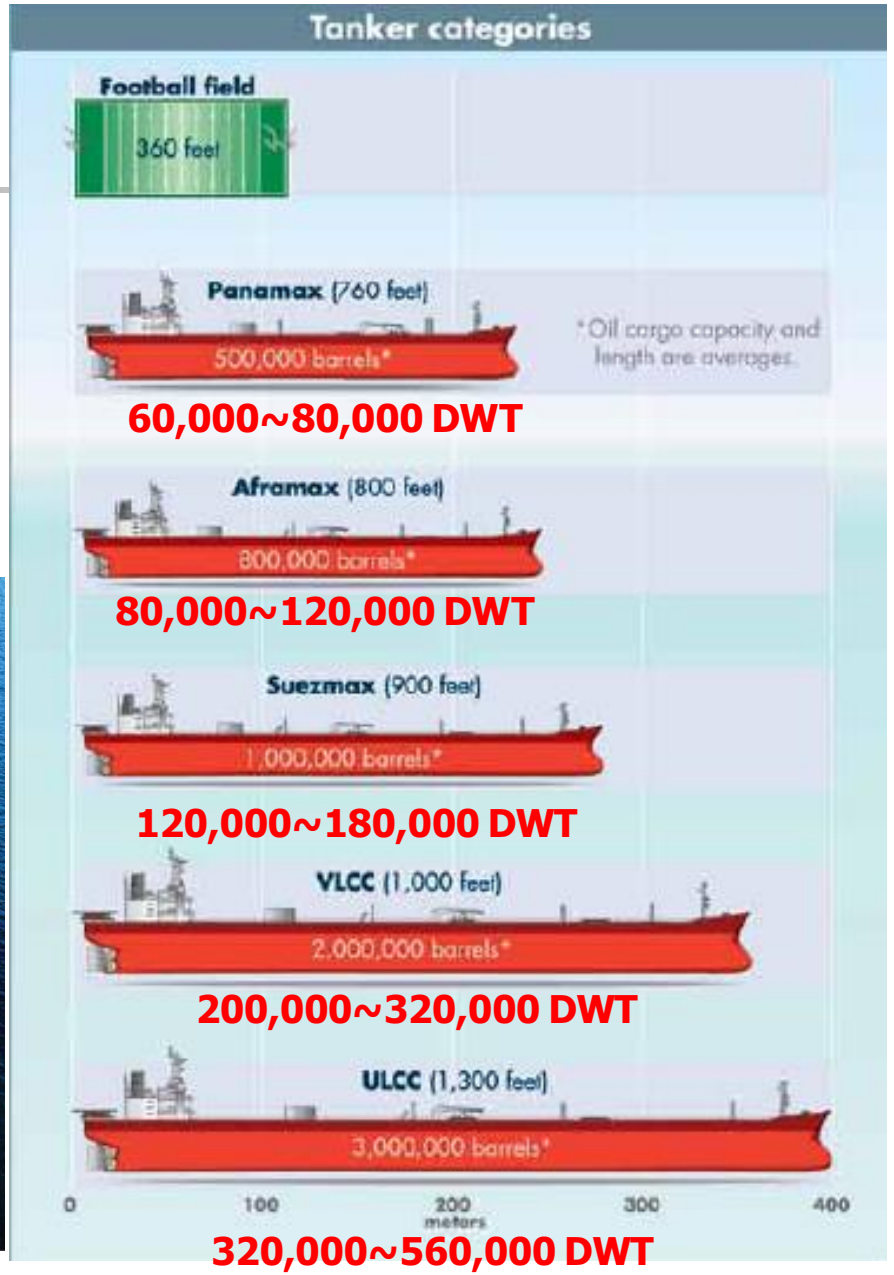
- World Total : 3.5 MM km (USA 65%, Russia 8%)
- Gathering – Transportation – Distribution
- Pipeline: 4~48”dia (Buried 3~6 ft), 40ft long
  Speed: 5km/hr(oil), 40km/hr(gas)



탱커(Tanker)

- Very Large Crude Carrier (VLCC)
- Ultra Large Crude Carrier (ULCC)

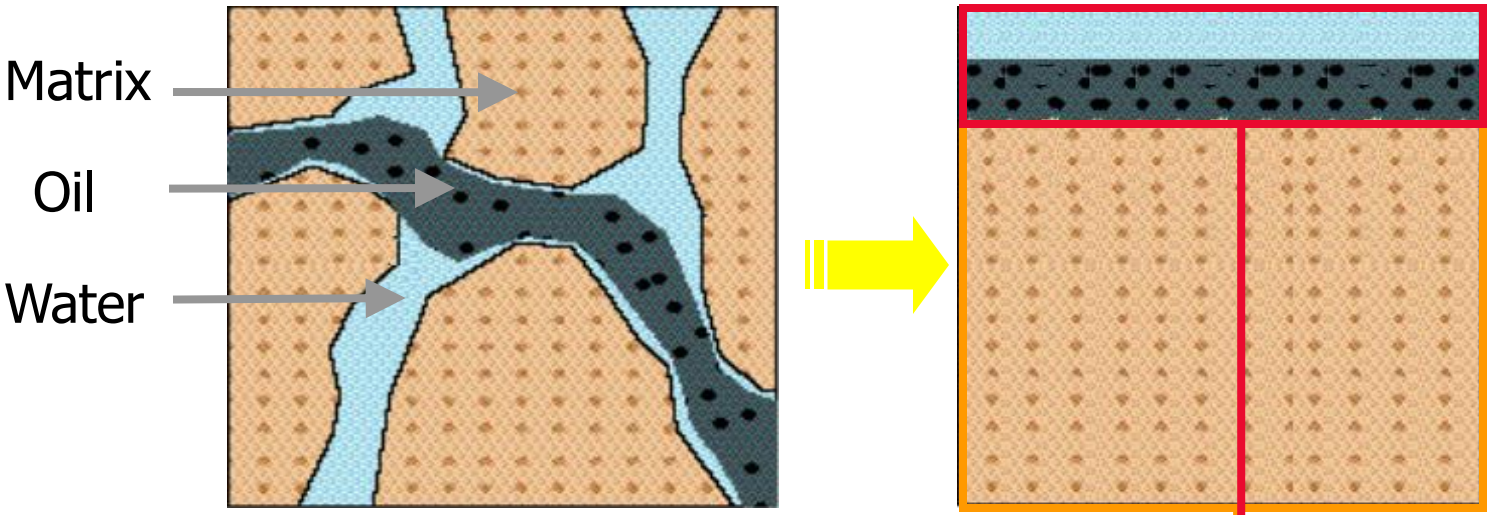




5-2: 석유만 생산될까?

공극율

- 유체(석유와 물)가 존재할 수 있는 공극의 부피



Porosity (Ø) : $\phi = \frac{V_{bulk} - V_{matrix}}{V_{bulk}} = \frac{V_{pore}}{V_{bulk}}$

암석의 공극율

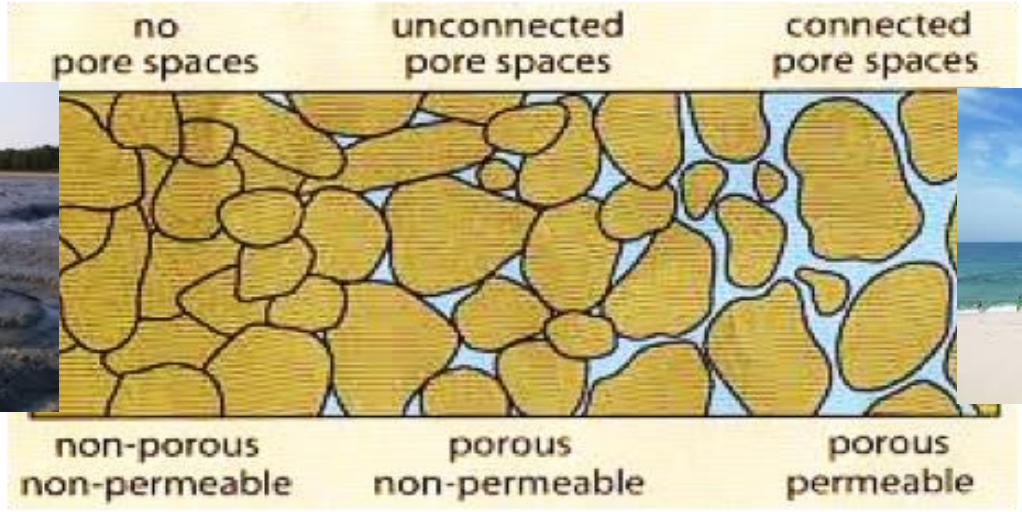
- 공극율의 크기

  30% : 분급이 잘된 미고결사암층

  20% : 분급이 잘된 고결사암층

  8% : 저 투수율 저류층

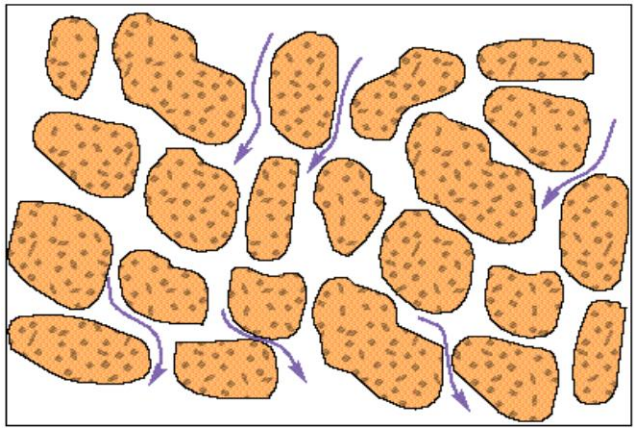
갯벌

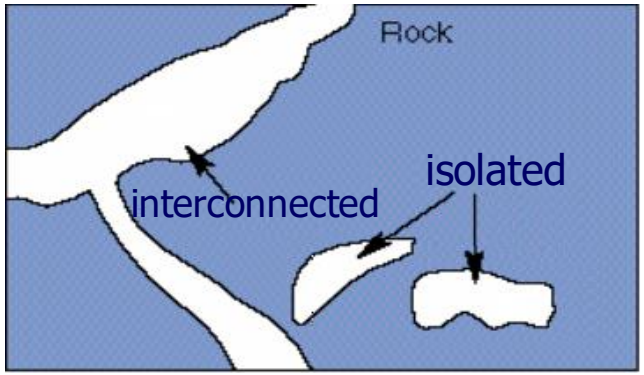


모래해변

투과도(Permeability)

- 유체가 다공질 매체를 잘 흐르는 정도
- 단위: 다르시(Darcy, D),





SI unit: 0.987 $(\mu m)^2$

$$q = \frac{kA}{\mu}\frac{\Delta P}{L},$$

q	volumetric flow rate (cm^3/sec)
A	cross-sectional area of the sample (cm^2)
L	length of the sample in the flow direction (cm)
ΔP	hydrostatic pressure drop (atm)
μ	viscosity of the fluid (cP)

저류암의 투과도 범위

- 저류층 품질과 관련(reservoir quality)

k < 1 md	나쁨 (**poor**)
1 < k < 10 md	양호 (**fair**)
10 < k < 50 md	중간 (**moderate**)
50 < k < 250 md	좋음 (**good**)
250 md < k	아주 좋음 (**very good**)

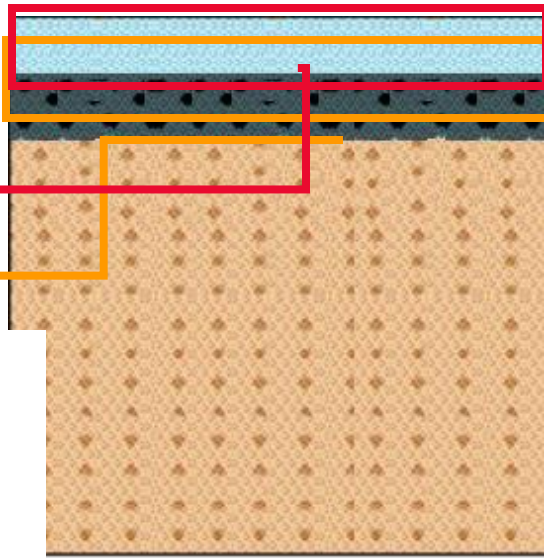
k < 0.1 md : 치밀암층(Tight formation)

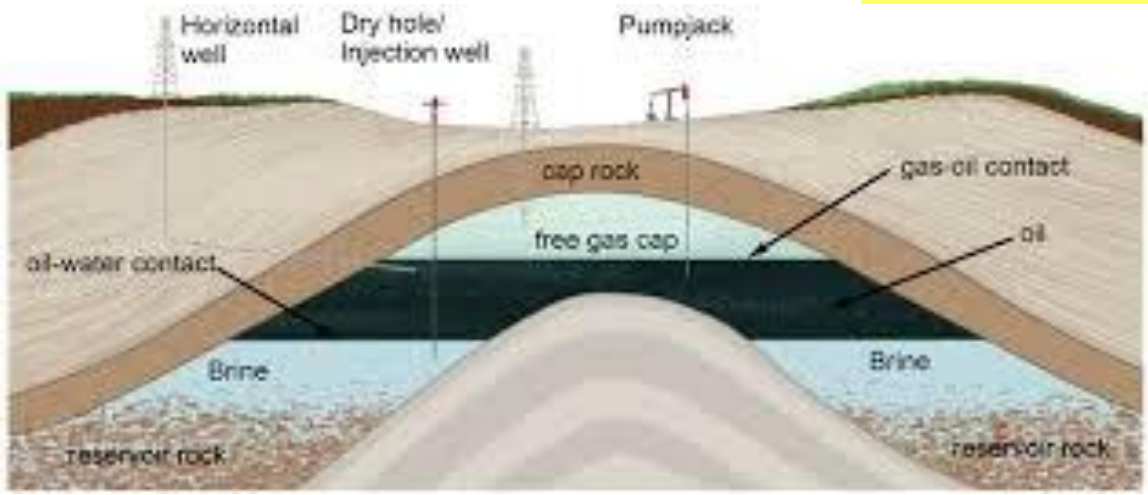
포화도

- 포화도 (S): $S_o+S_w=1$

  공극을 채우고 있는 유체의 비율

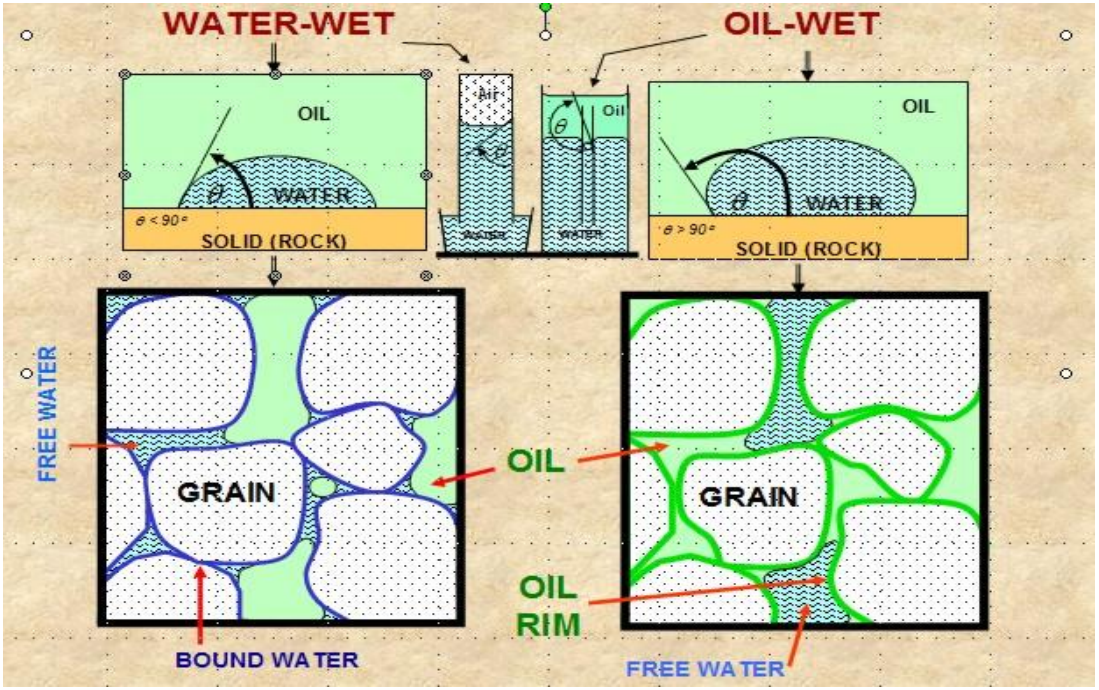
  - Water Saturation: $S_w = \frac{V_{water}}{V_{pore}}$





습윤도

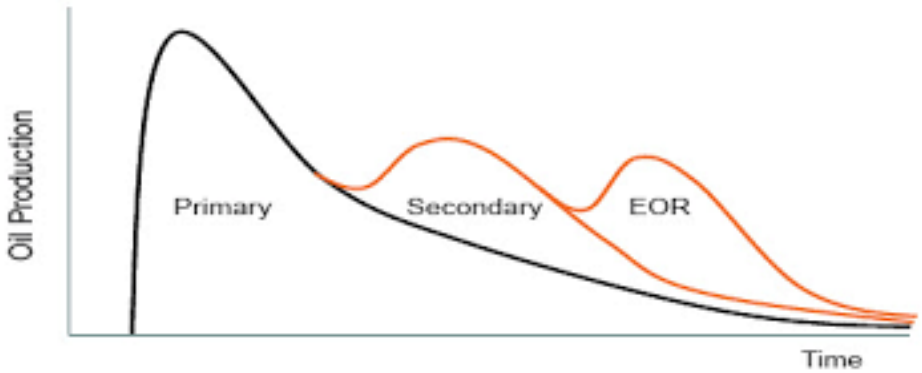
- 유체가 고체 표면에 달라붙거나 떨어 지려는 정도
  : 유체와 암석과의 관계
- 친수성(Water wet) vs. 친유성(Oil-wet)

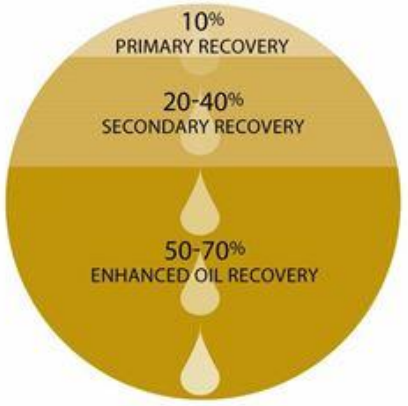


5-3: 석유를 생산할 때 필요한 에너지

석유회수 단계

- 석유 생산은 오일을 생산정으로 이동시켜 최종적으로 지상으로 이동시키는 일
  - 1차 회수 (Primary recovery): 저류층내 에너지 활용
  - 2차 회수 (Secondary recovery): 외부에서 에너지 제공
  - 석유회수증진 (Enhanced oil recovery, EOR): 암석과 유체의 성질 변경





저류층 에너지

- 1차 회수 : 석유 생산이 저류층의 자연압력을 이용하여 이루어 짐

- 자연 저류층 에너지의 형태는 ?

저류층 에너지의 유형

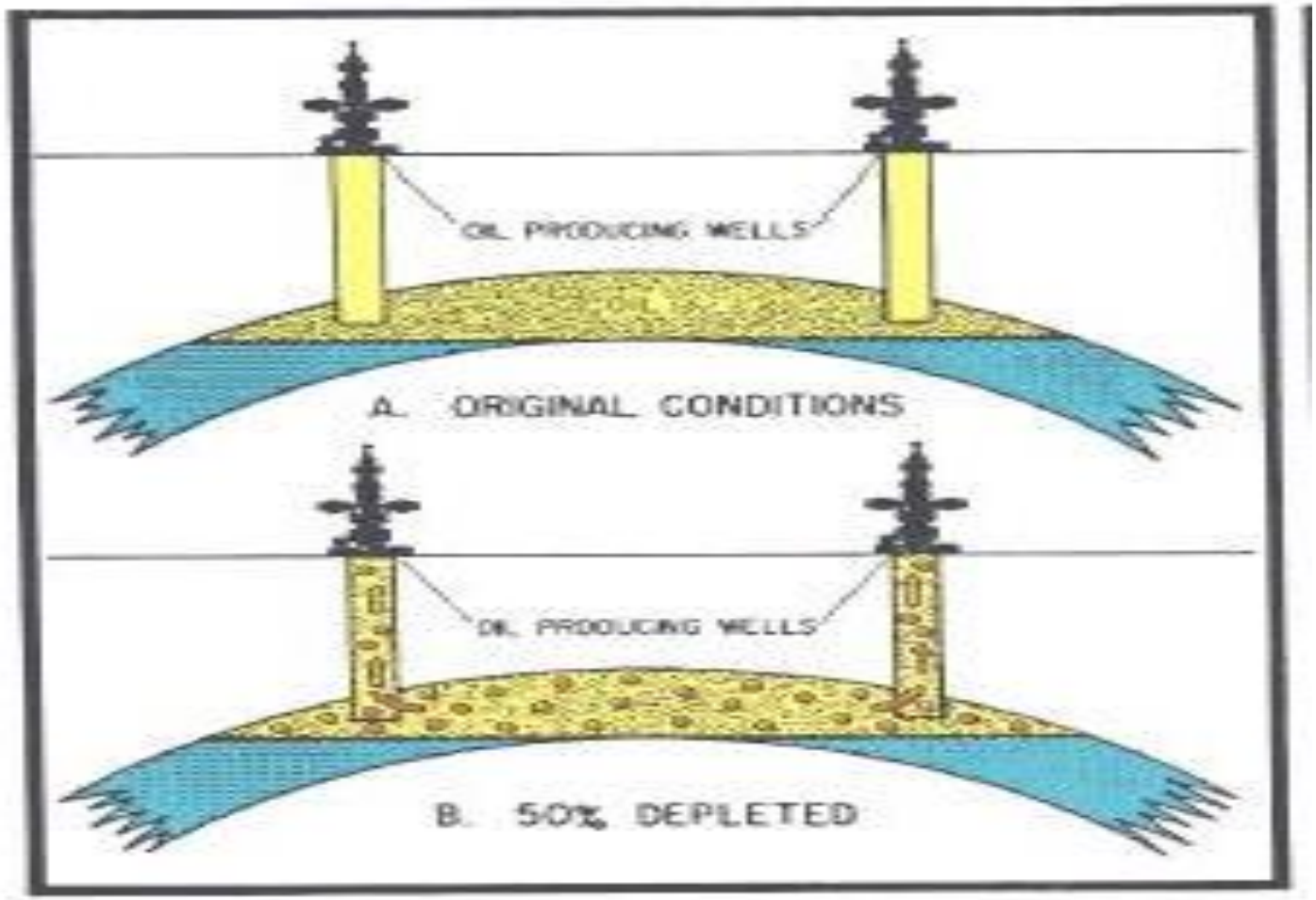
- 저류층의 압축: 오일, 가스 압축률
- 물의 압축: 하부 및 인근 대수층
- 중력: 저류층내 물과 오일의 분리
- 저류암 자체 에너지: 공극 내 삼투압

저류층의 생산 에너지

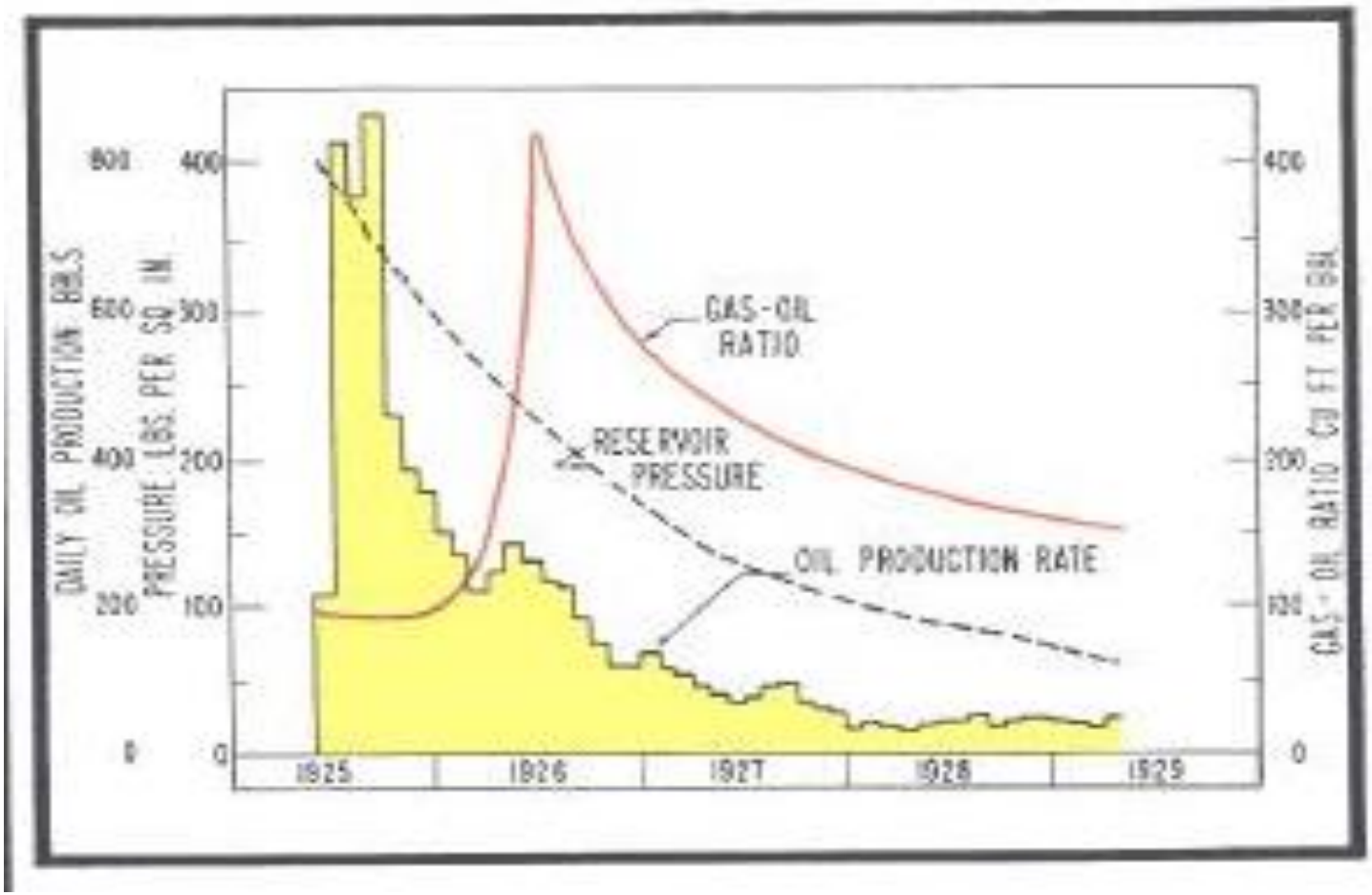
- 저류층구성 물질의 압축률 (Craft, Hawkins and Terry)

저류층암	3-10 x10^{-6}, psi^{-1}
물	2-4 x10^{-6}, psi^{-1}
오일포화 저류층	5-100 x10^{-6}, psi^{-1}
가스 at 1000 psi	900-1300 x10^{-6}, psi^{-1}
가스 at 5000 psi	50-200 x10^{-6}, psi^{-1}

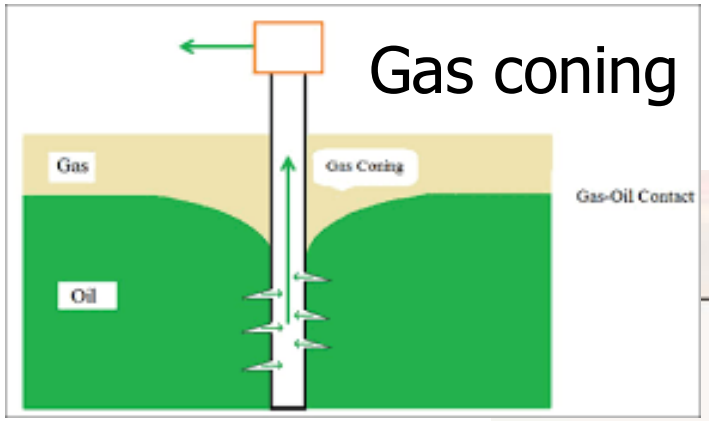
자연 감퇴 생산에너지 (Depletion Drive)

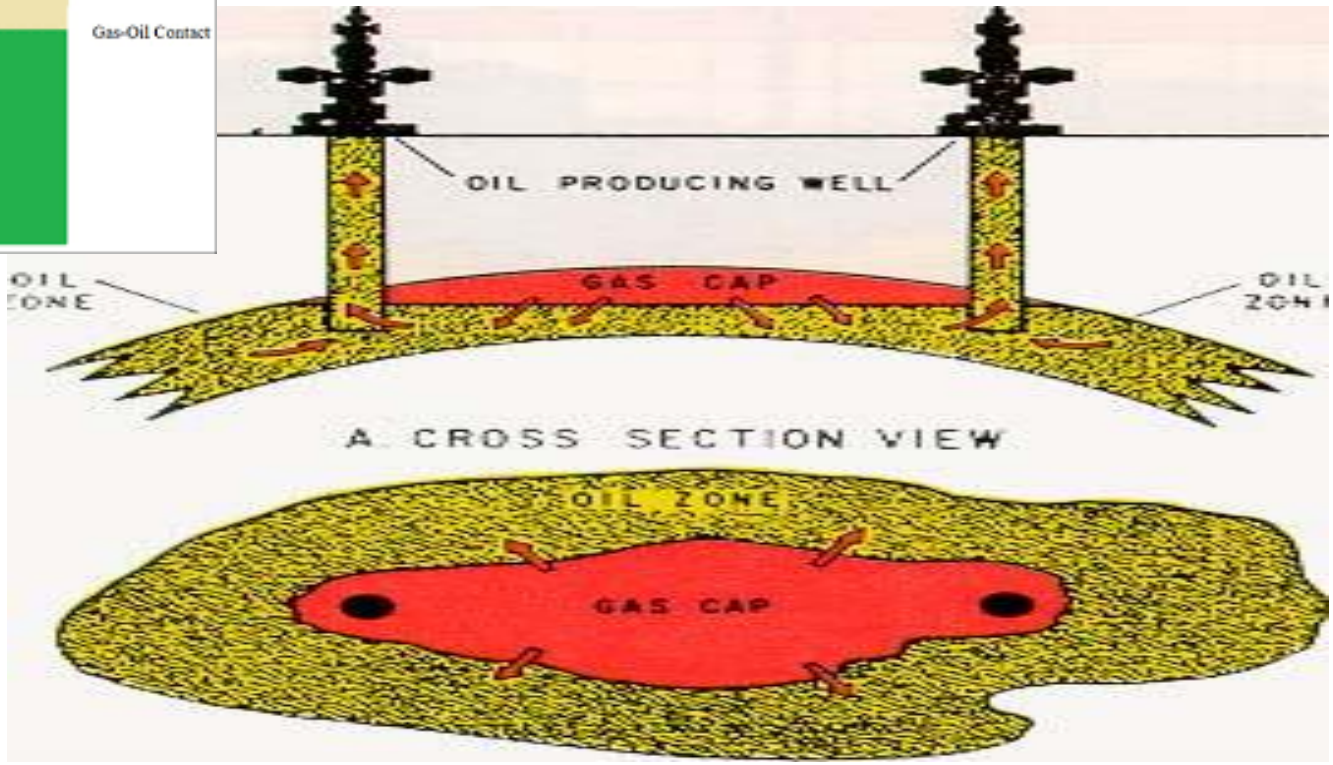


자연감퇴 생산에너지 생산 특성

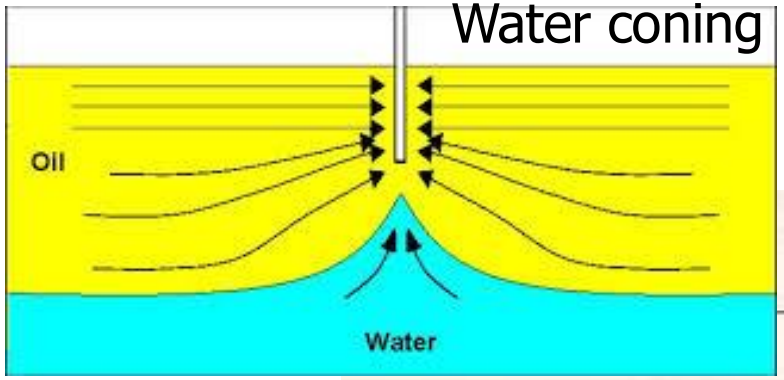


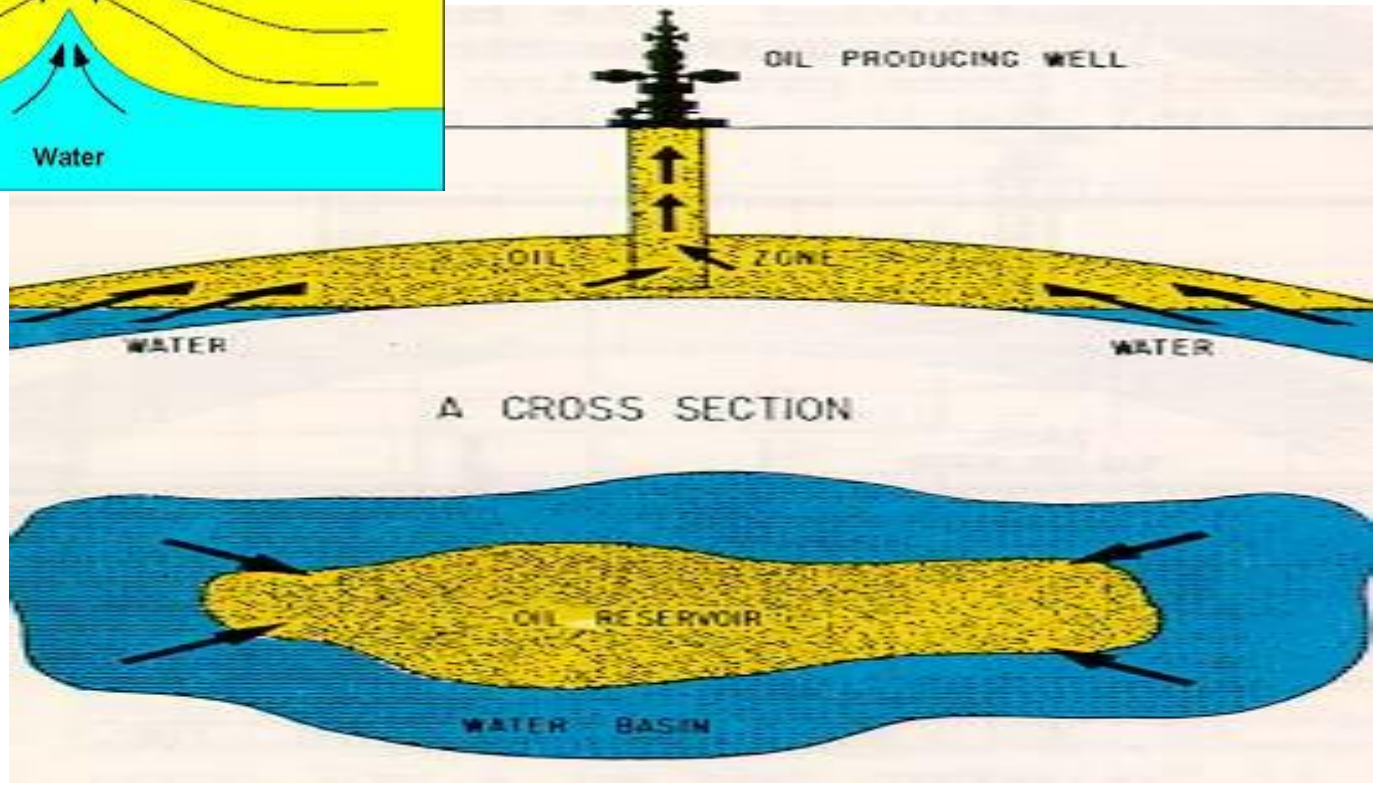
상부 가스 생산에너지 (Gas cap Drive)



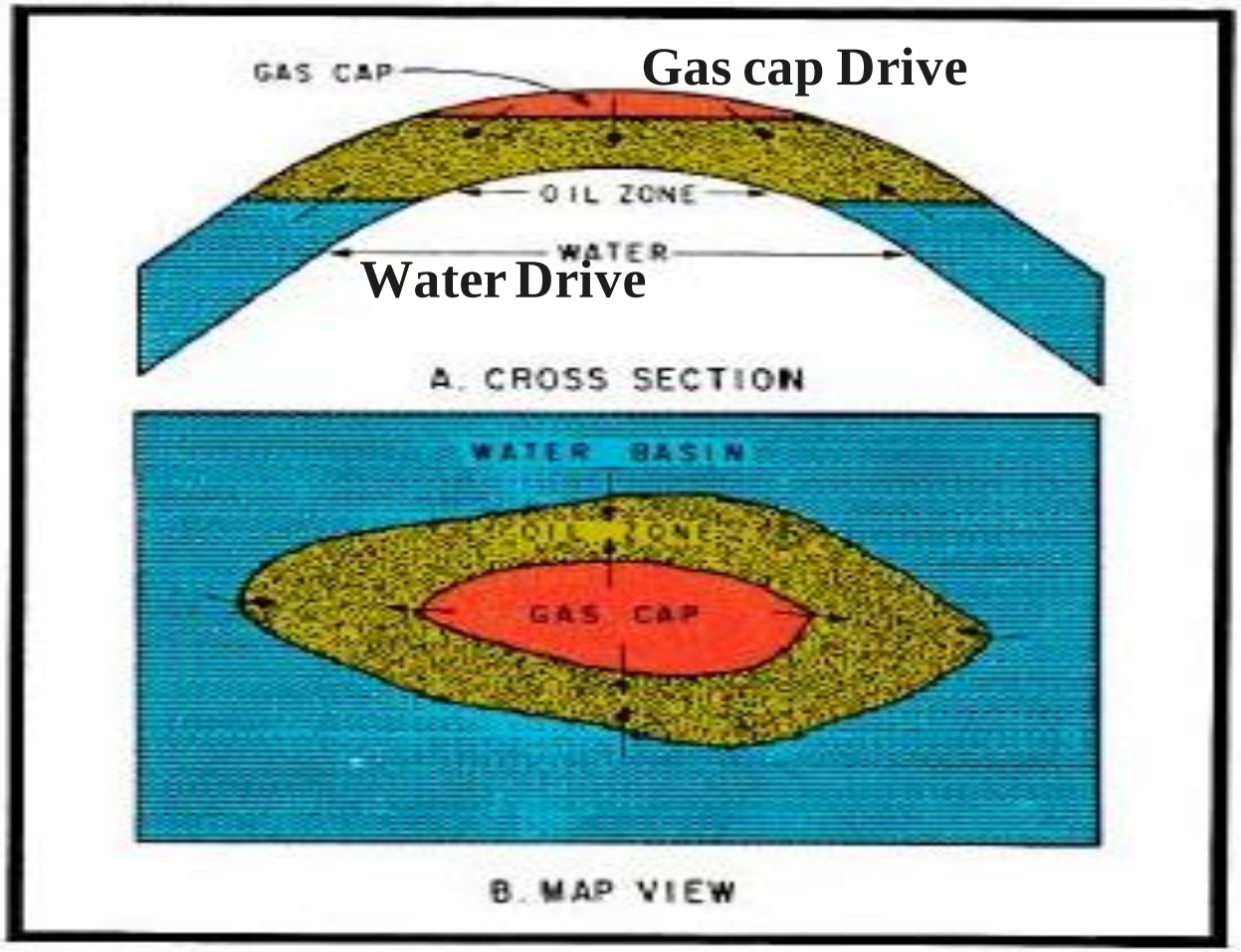


물 생산에너지(water drive)





복합 석유 생산 에너지


GAS CAP
Gas cap Drive
OIL ZONE
WATER
Water Drive
A. CROSS SECTION
WATER BASIN
OIL ZONE
GAS CAP
B. MAP VIEW

5-4: 석유를 많이 생산하려면?

탄화수소 유체 저류층 유형

- 오일 저류층 : 주로 오일과 가스를 생산하는 저류층
  - 전통오일
    - 블랙오일(Black oil)
    - 휘발성 오일(Volatile oil)
  - 중질유
- 가스 저류층: 주로 가스를 생산하는 저류층
  - 건가스(Dry gas)
  - 습가스(Wet gas)
- 가스 컨덴세이트: 액체 탄화수소를 포함한 가스를 생산하는 저류층

저류층의 압력과 유형분류

- 비 포화오일 저류층 (Under-Saturated Oil Reservoirs)

  : 초기 저류층 압력이 기포점 압력 보다 높다

- 포화 오일 저류층(Saturated Oil Reservoirs)

  : 초기 저류층 압력이 기포점 압력 보다 낮다

EOR 개념

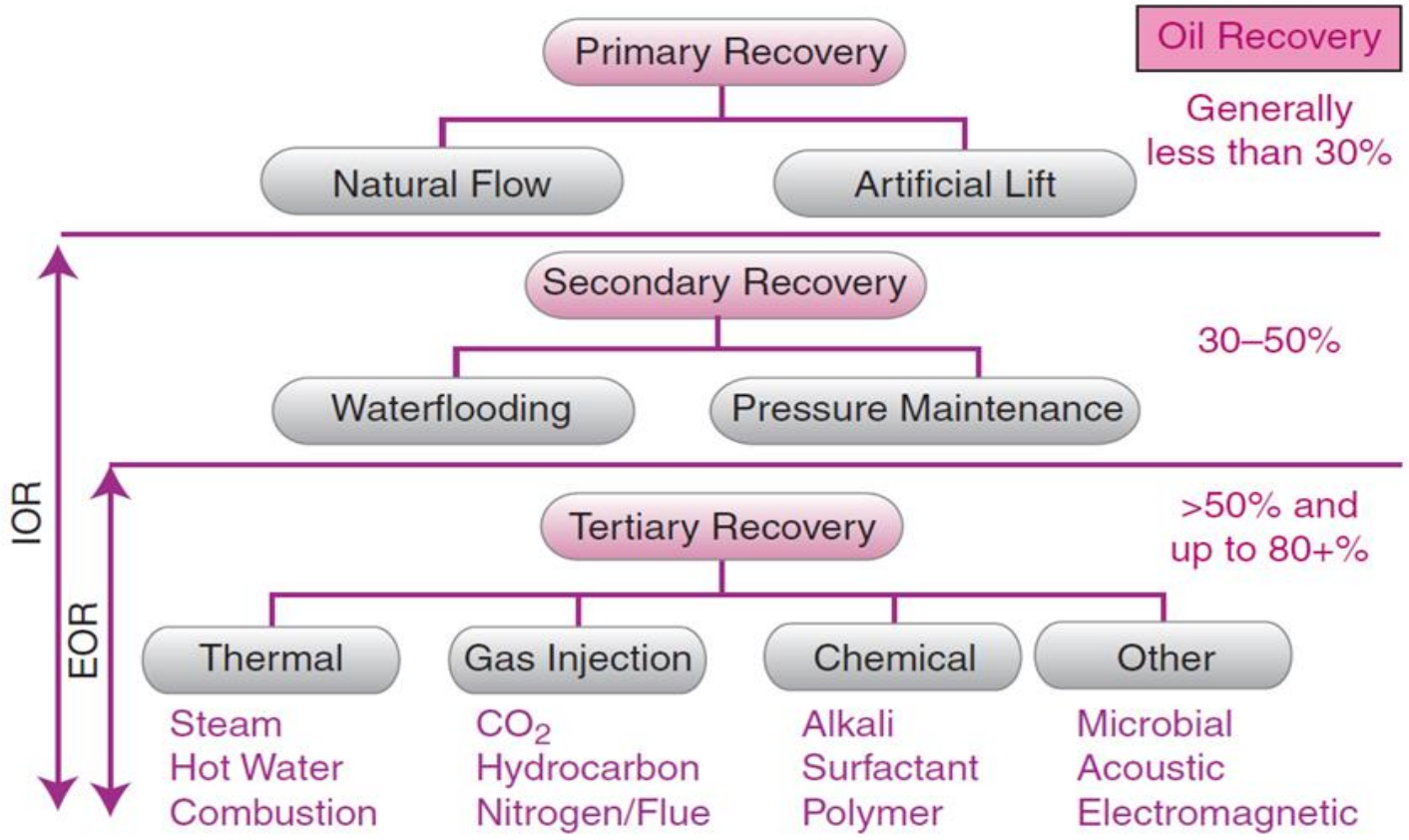
- 이동도 비 제어 "Mobility ratio, M"

$$M = \frac{\lambda_D}{\lambda_d} = \frac{(k/\mu)_w}{(k/\mu)_o} = \frac{Mobility\_Displacing}{Mobility\_displaced}$$

  - 물의 점성도를 증가: 검, 폴리머 주입
  - 오일의 점성도를 감소: 열, 솔벤트 주입
  - 상대 투과도

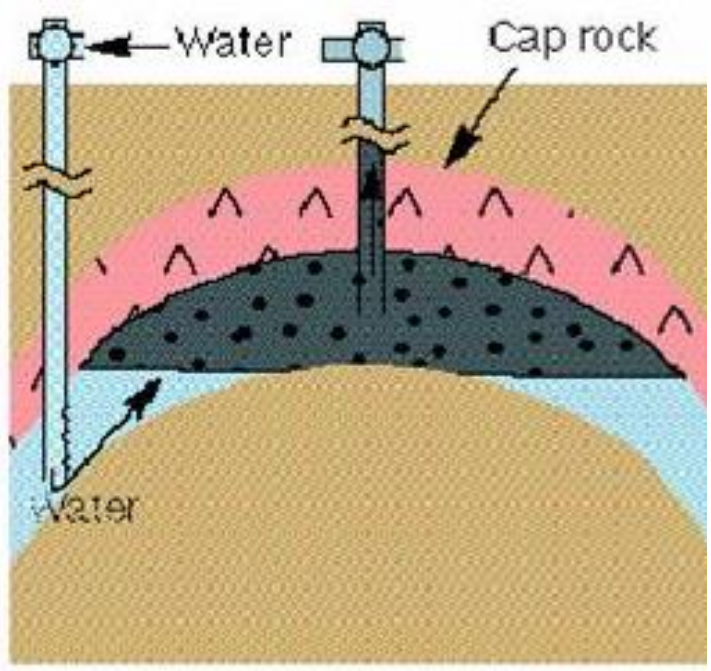
석유회수증진기술 (EOR)

- Thermal EOR is widely used: Steam injection

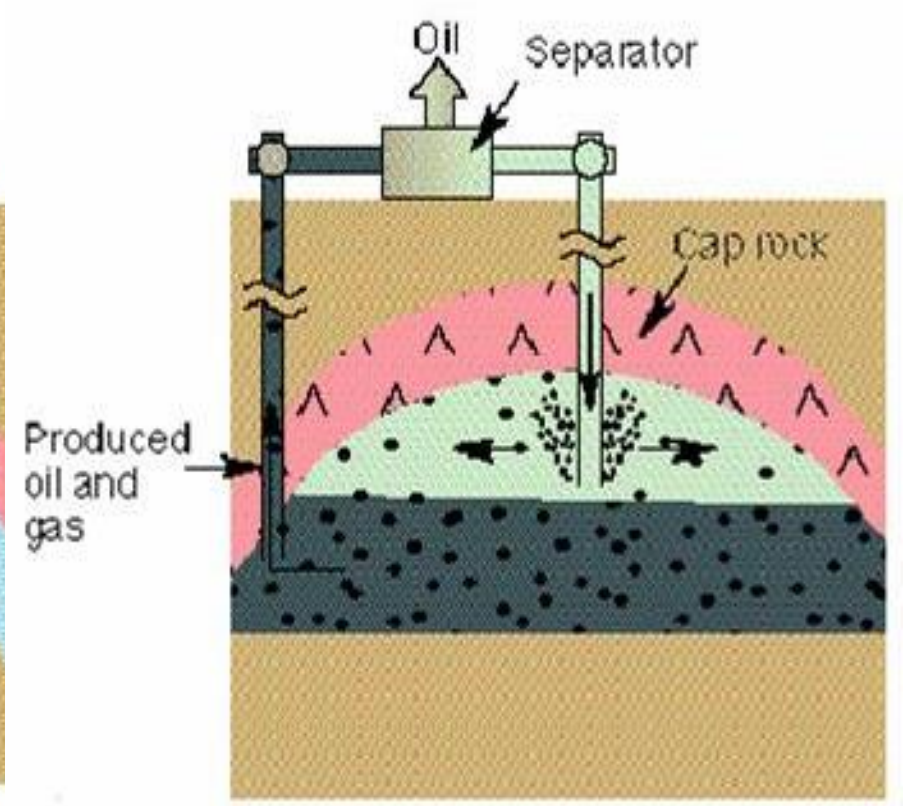


2차 회수 (Secondary recovery)

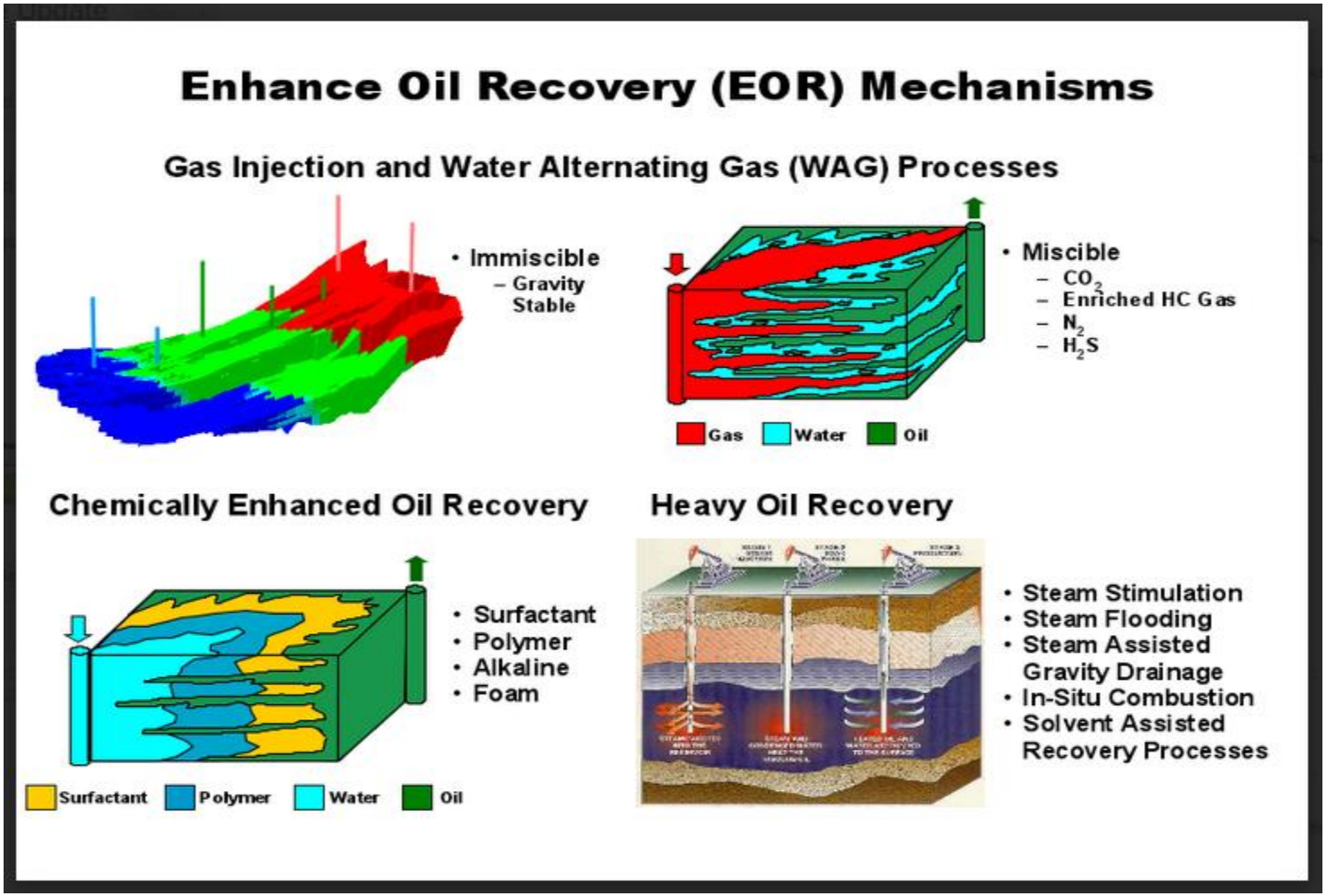
Water Injection



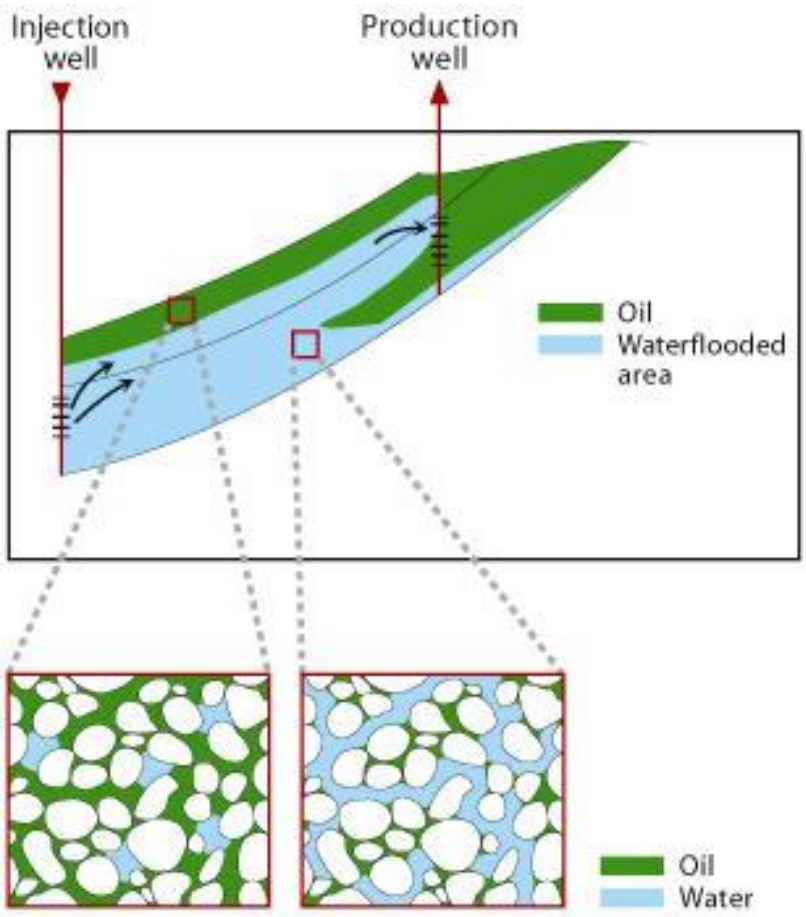
Gas Injection

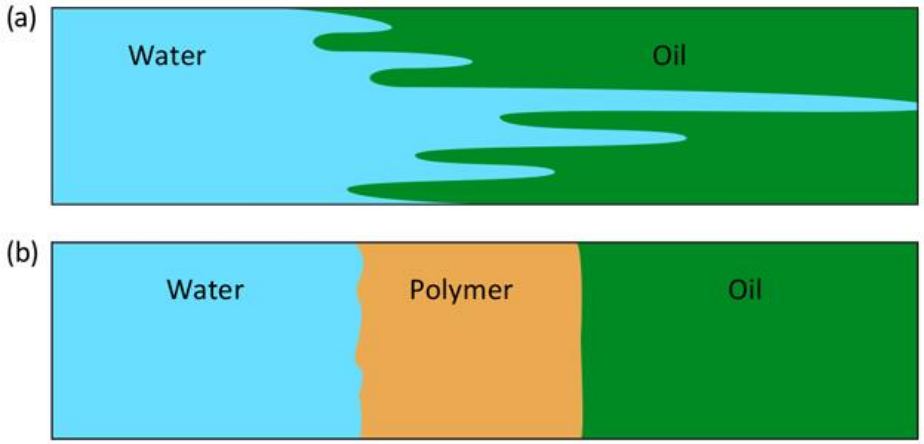


3차 회수 (Tertiary recovery)

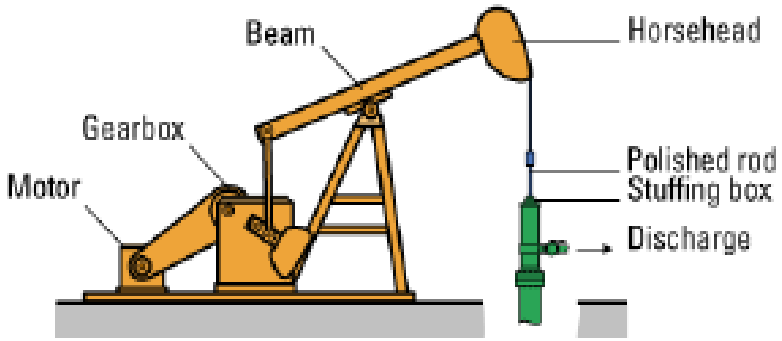


물 주입법과 포화도분포

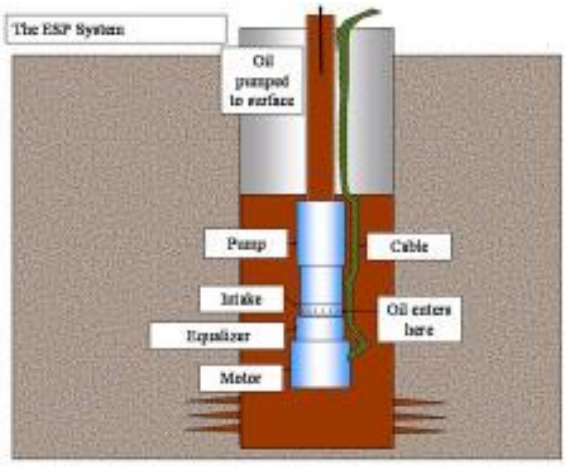

Injection well
Production well
Oil
Waterflooded area
Oil
Water


(a)
Water
Oil
(b)
Water
Polymer
Oil

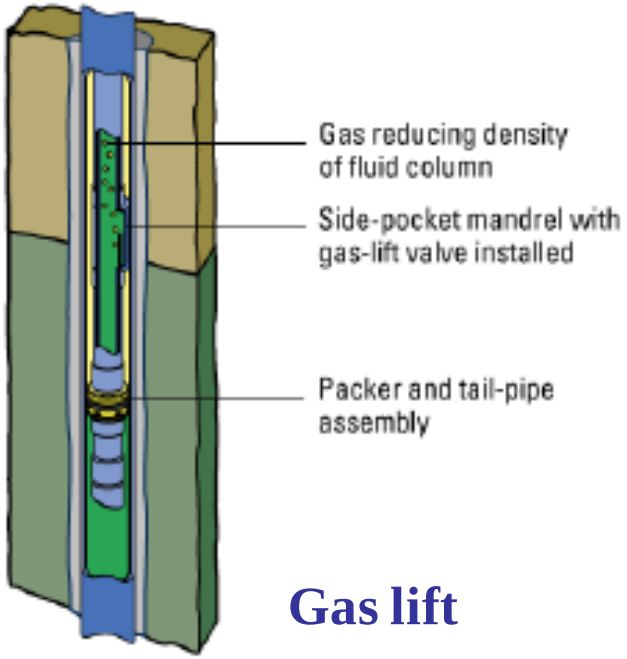
생산 펌프(Production pumps)



Rod pump



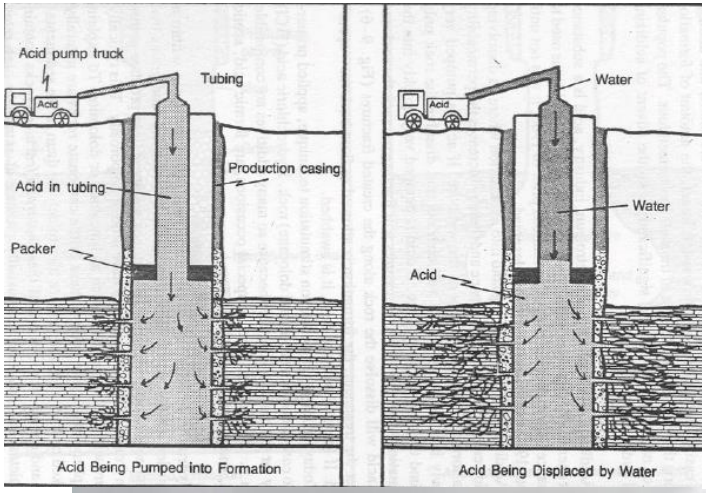
Downhole pump



Gas lift

유정 자극법 (Stimulation)

- Acidizing (산처리법)



- Hydraulic fracturing (수압파쇄)