인하대학교 INHA UNIVERSITY

2018 인하대 **K-MOOC** 강의 교재

인류의 그림자, 에너지 바로알기

신 현돈 교수
(hyundon.shin@inha.ac.kr)

인하대학교 에너지자원공학과

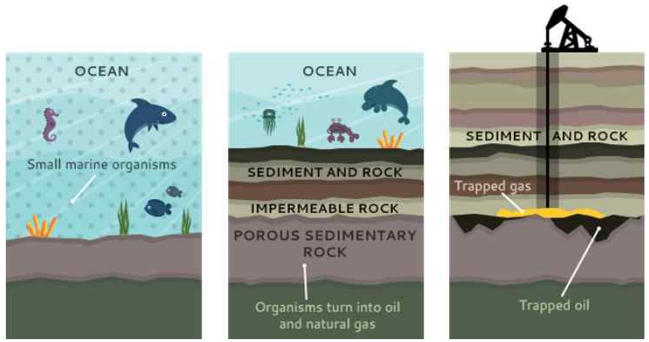
2018

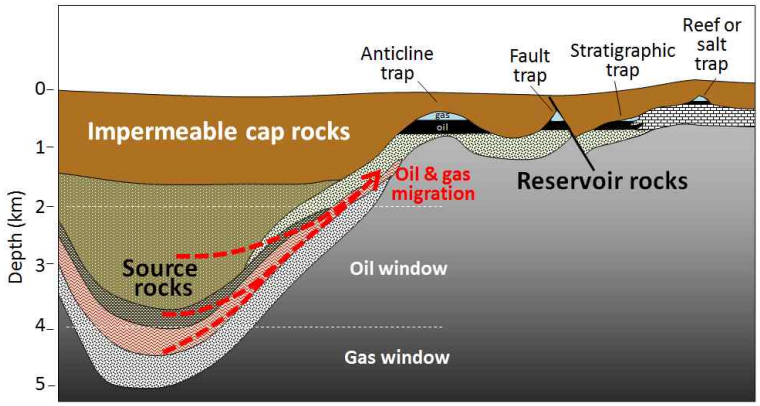
4: 석유의 탐사와 개발

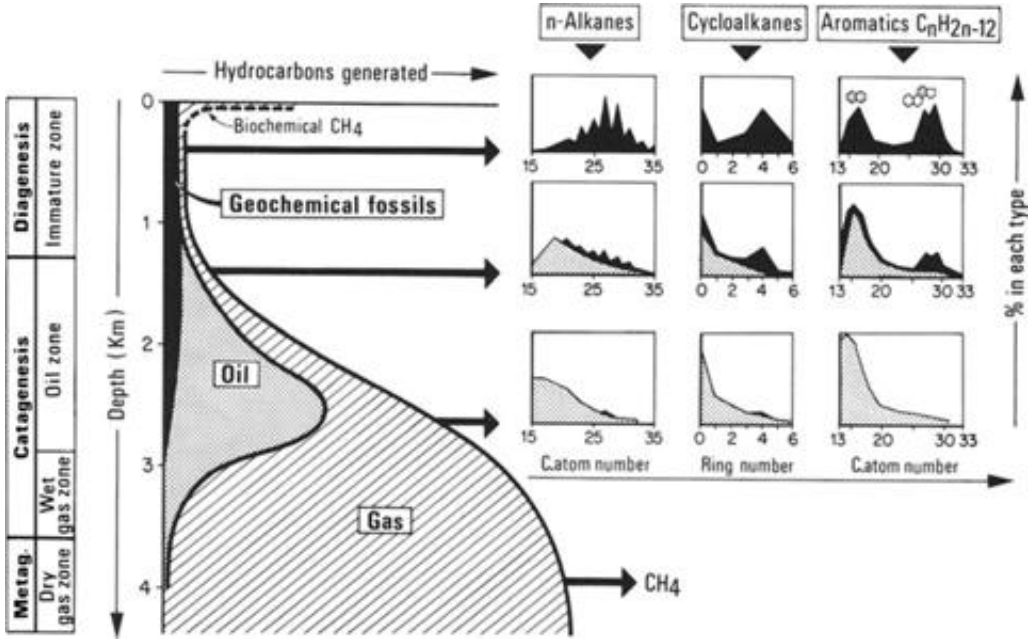
4-1: 땅속의 석유를 어떻게 찾을까?

석유의 생성과 이동

- 근원암에서 생성(Generation) – 저류암으로 이동 (Migration)



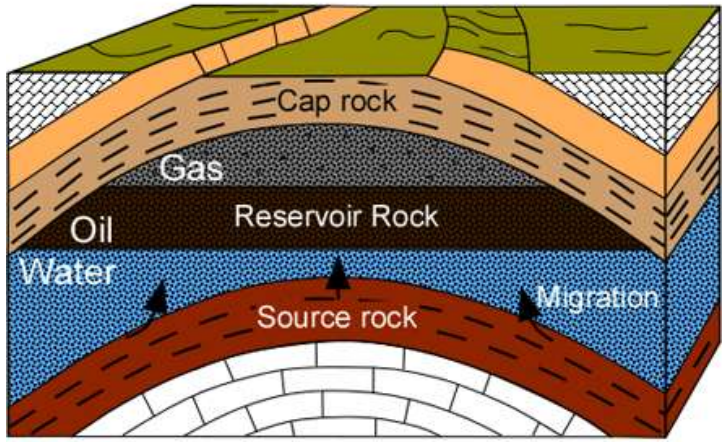




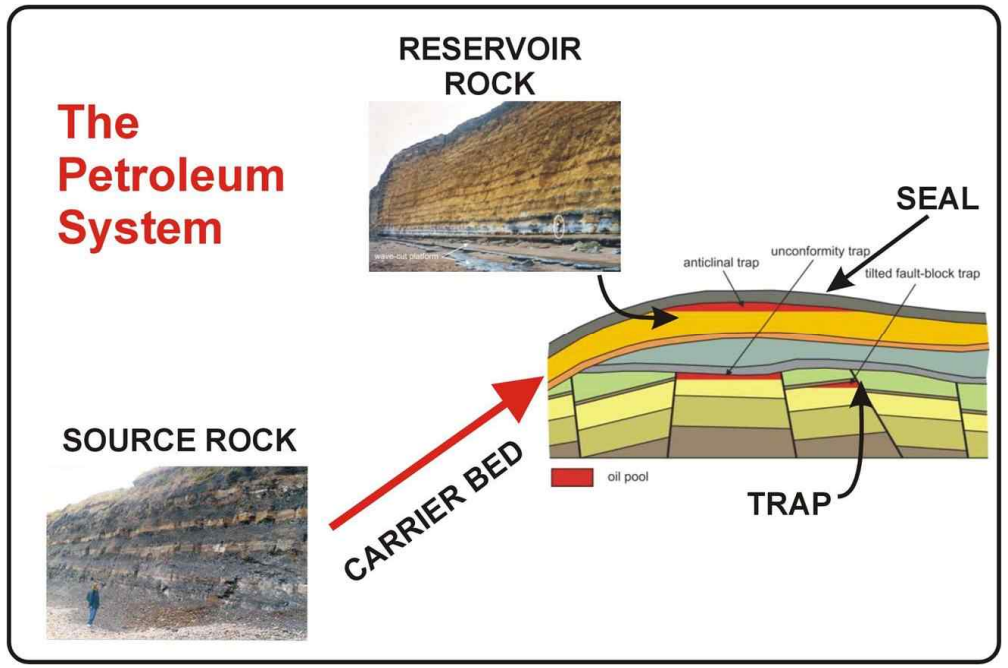
석유저류층 (Petroleum Reservoir)

Key requirements

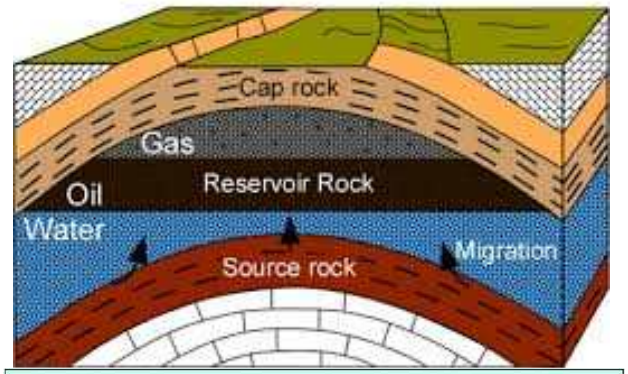
- Trap
- Cap rock
- Permeable media
  - Oil, gas, water



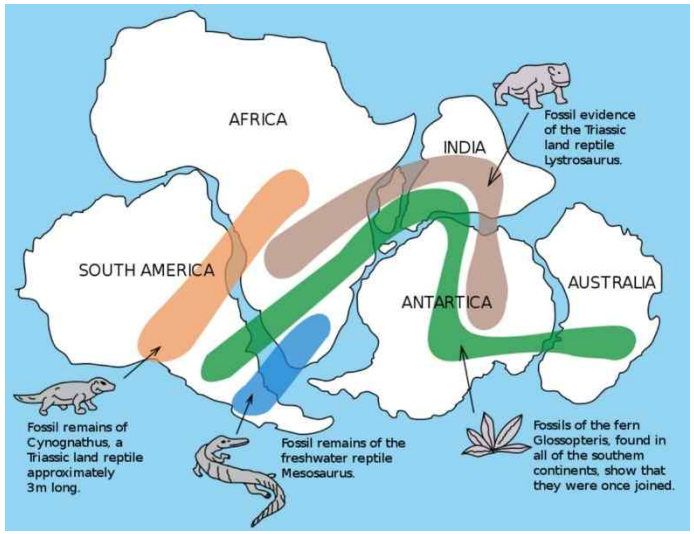
Anticline Trap

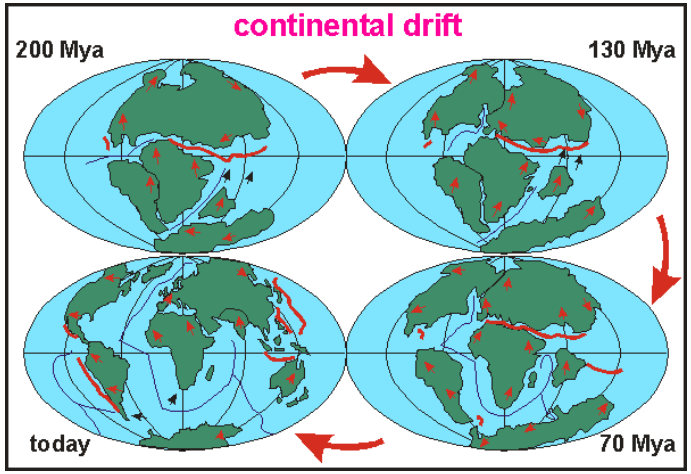


석유의 부존과 지구

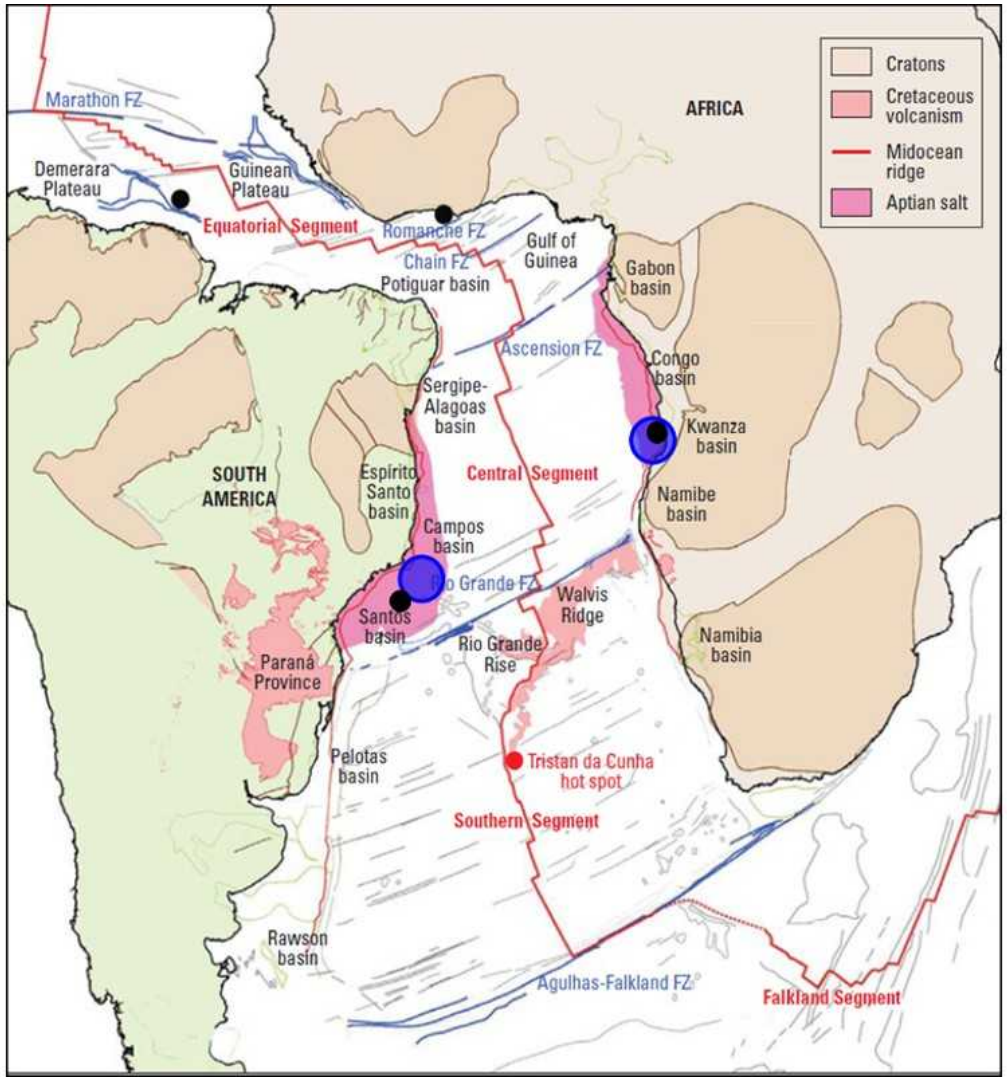


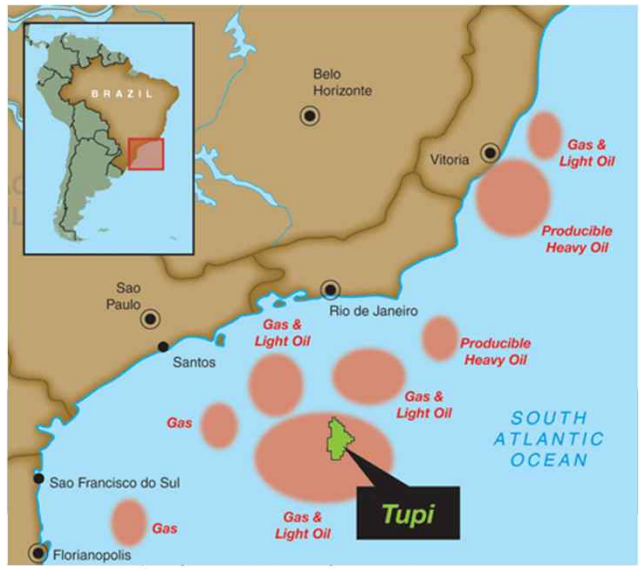
EON	ERA	PERIOD		EPOCH	MYA	
PHANEROZOIC	CENOZOIC	QUATERNARY		RECENT	0.01	← ICE AGE ENDS
				PLEISTOCENE	1.6	← ICE AGE BEGINS EARLIEST HUMANS
		TERTIARY	NEOGENE	PLIOCENE	5.3	
				MIOCENE	23.7	
			PALEOGENE	OLIGOCENE	36.6	
				EOCENE	57.8	← FORMATION OF HIMALAYAS
				PALEOCENE	66	← DINOSAUR EXTINCTION ROCKY MTS. FORMED
	MESOZOIC	CRETACEOUS			144	← FIRST MAMMALS PANGEA BREAK UP FIRST DINOSAURS
		JURASSIC			208	
		TRIASSIC			245	
	PALEOZOIC	PERMIAN			286	
		PENNSYLVANIAN			320	← FIRST REPTILES
		MISSISSIPPIAN			360	← FIRST ANPHIBIANS
		DEVONIAN			408	
		SILURIAN			438	← FIRST LAND PLANTS
		ORDOVICIAN			505	← FIRST FISH
		CAMBRIAN			570	
PRECAMBRIAN	PROTEZOIC EON				2500	← EARLIEST SHELLED ANIMALS
	ARCHEAN EON				3800	← EARLIEST FOSSIL RECORDED OF LIFE
					4600	

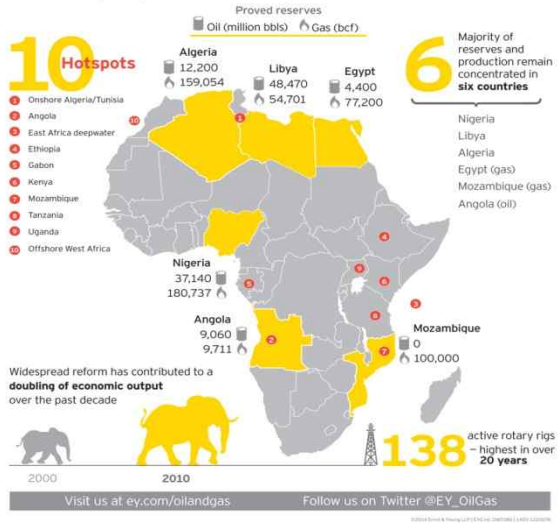




아프리카와 브라질


Cratons
Cretaceous volcanism
Midocean ridge
Aptian salt
AFRICA
SOUTH AMERICA
Marathon FZ
Demerara Plateau
Guinean Plateau
Equatorial Segment
Romanche FZ
Chain FZ
Potiguar basin
Gulf of Guinea
Gabon basin
Ascension FZ
Congo basin
Sergipe-Alagoas basin
Kwanza basin
Espírito Santo basin
Central Segment
Namibe basin
Campos basin
Rio Grande FZ
Walvis Ridge
Santos basin
Rio Grande Rise
Namibia basin
Parana Province
Pelotas basin
Tristan da Cunha hot spot
Southern Segment
Rawson basin
Agulhas-Falkland FZ
Falkland Segment


BRAZIL
Belo Horizonte
Vitoria
Gas & Light Oil
Producible Heavy Oil
Sao Paulo
Rio de Janeiro
Santos
Gas & Light Oil
Producible Heavy Oil
Gas & Light Oil
Gas
SOUTH ATLANTIC OCEAN
Sao Francisco do Sul
Tupi
Gas
Gas & Light Oil
Florianopolis


Proved reserves
Oil (million bbls) Gas (bcf)
10 Hotspots
Onshore Algeria/Tunisia
Angola
East Africa deepwater
Ethiopia
Gabon
Kenya
Mozambique
Tanzania
Uganda
Offshore West Africa
Algeria 12,200 159,054
Libya 48,470 54,701
Egypt 4,400 77,200
Nigeria 37,140 180,737
Angola 9,060 9,711
Mozambique 0 100,000
6 Majority of reserves and production remain concentrated in six countries
Nigeria
Libya
Algeria
Egypt (gas)
Mozambique (gas)
Angola (oil)
Widespread reform has contributed to a doubling of economic output over the past decade
2000
2010
138 active rotary rigs – highest in over 20 years
Visit us at ey.com/oilandgas
Follow us on Twitter @EY_OilGas

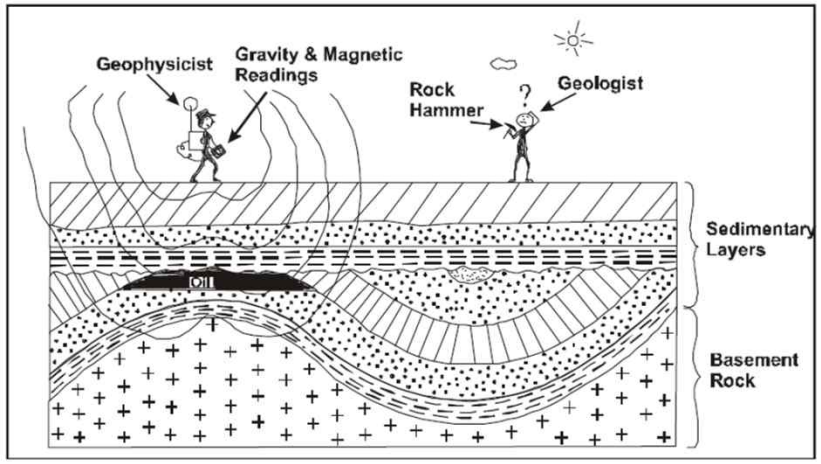
4-2: 석유가 숨어있는 집 찾기

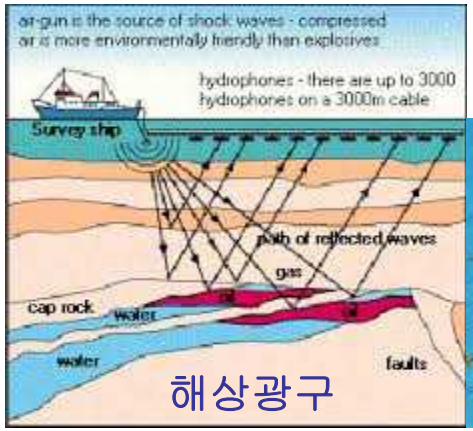
유전 개발 싸이클 (Oil field life cycle)

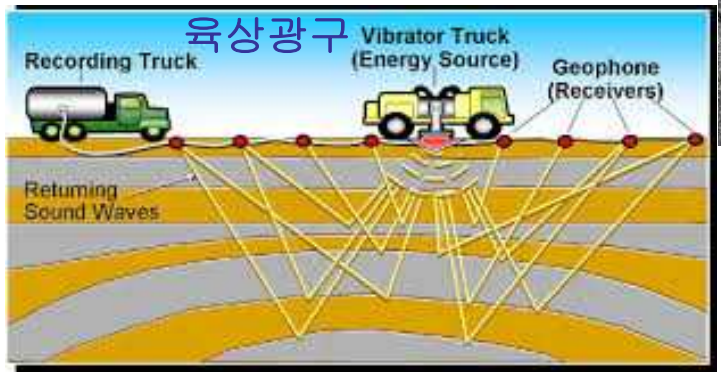
1. 저류층 구조 확인
2. 시추위치 결정
3. 탐사정 시추
4. 저류층 평가
5. 평가정 시추
6. 개발계획
7. 생산
8. 폐공

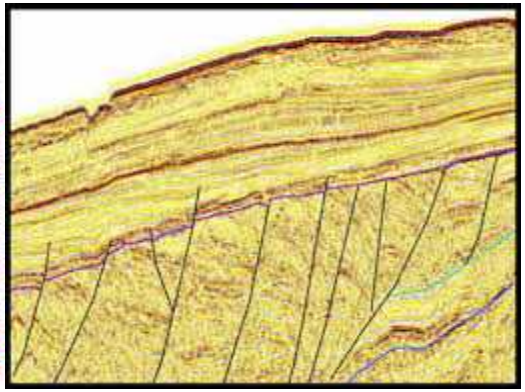
저류층 구조확인 (Trap)

- 탄성파탐사(Seismic survey) – 자료처리(processing) – 자료해석(interpretation)



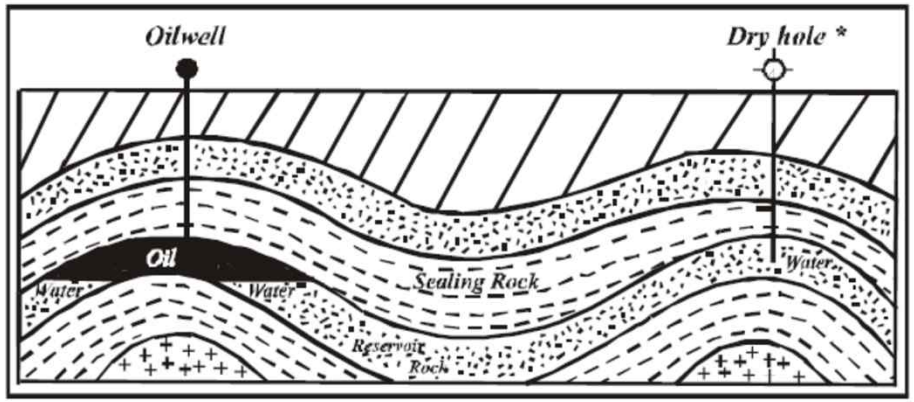


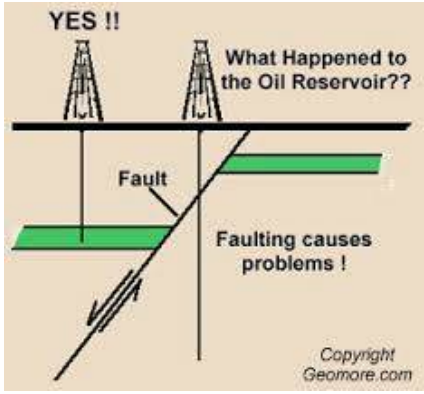




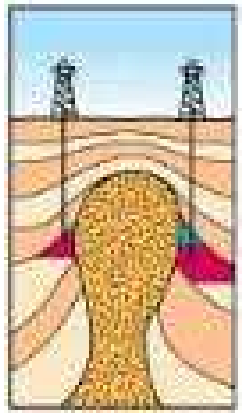
시추위치 (Drilling location)

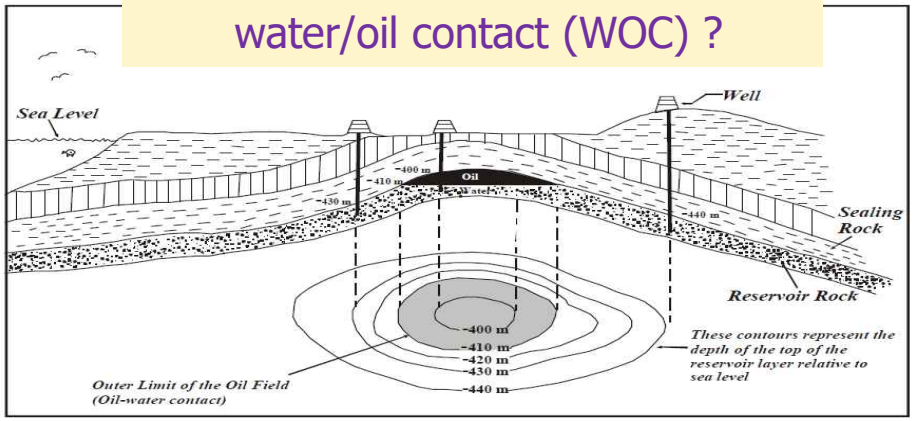
Luck does play a role !
Same trap, but…Oil or Dry

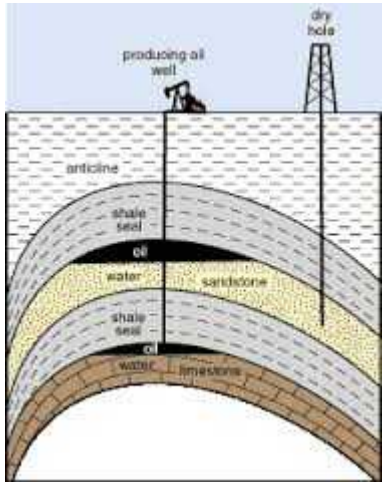




Drill at center or
water/oil contact (WOC) ?

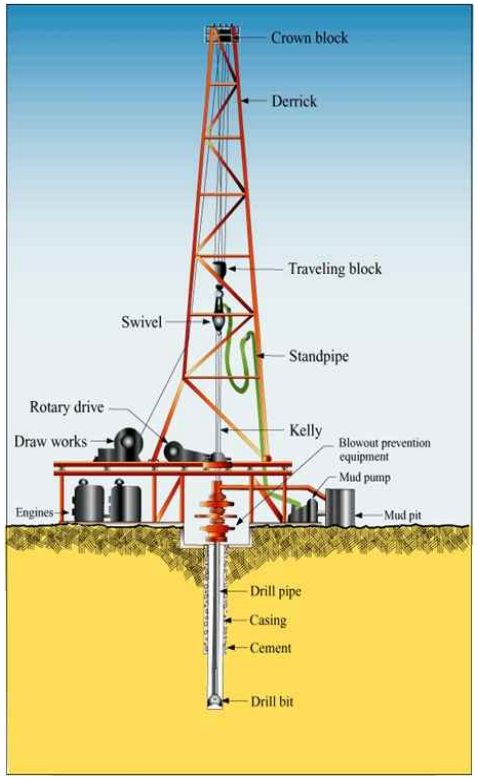


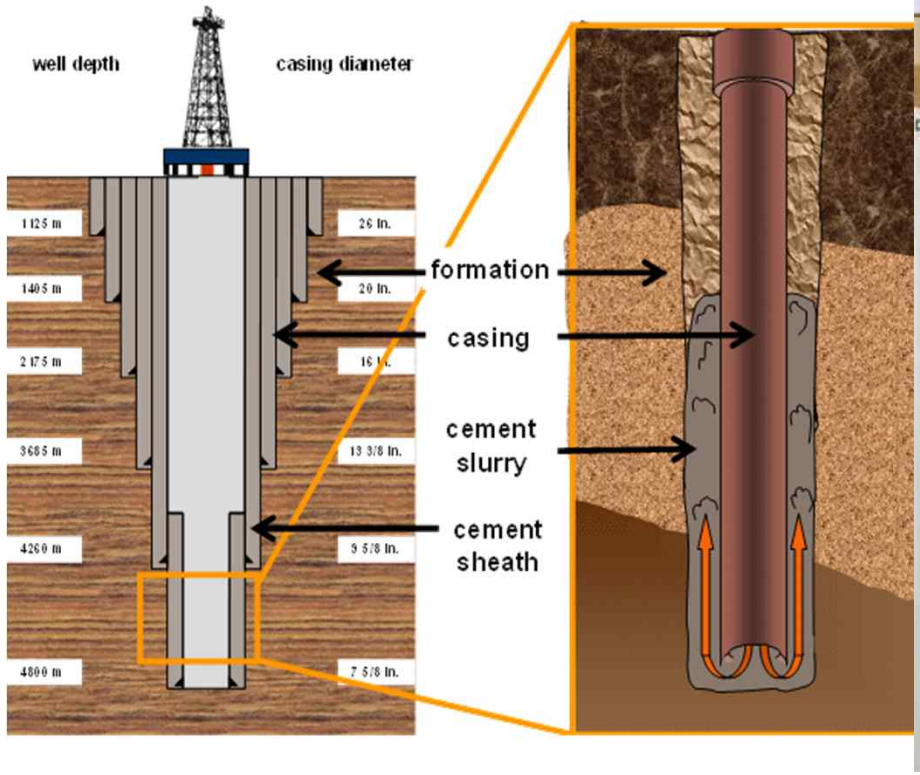


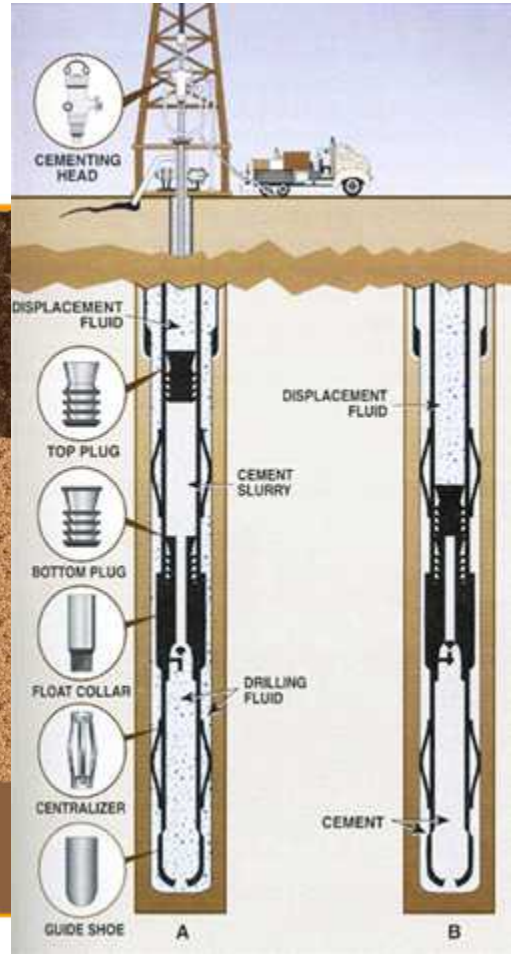


탐사시추

- 시추(Drilling) –케이싱(Casing) – 시멘팅(Cementing)

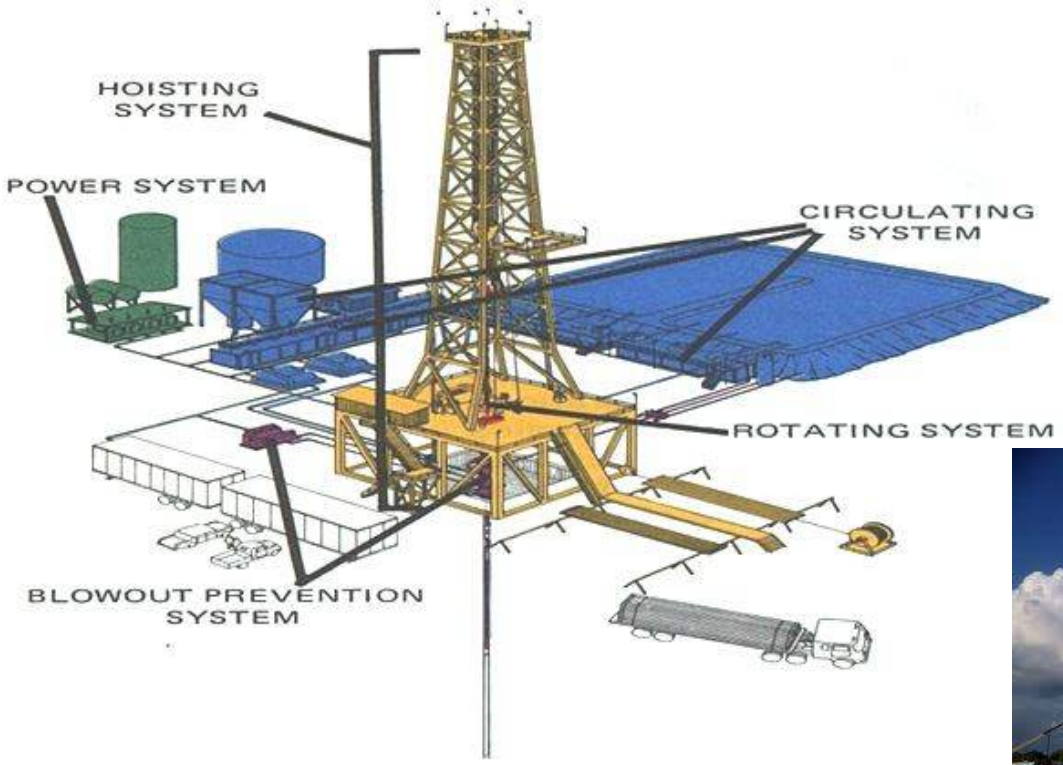




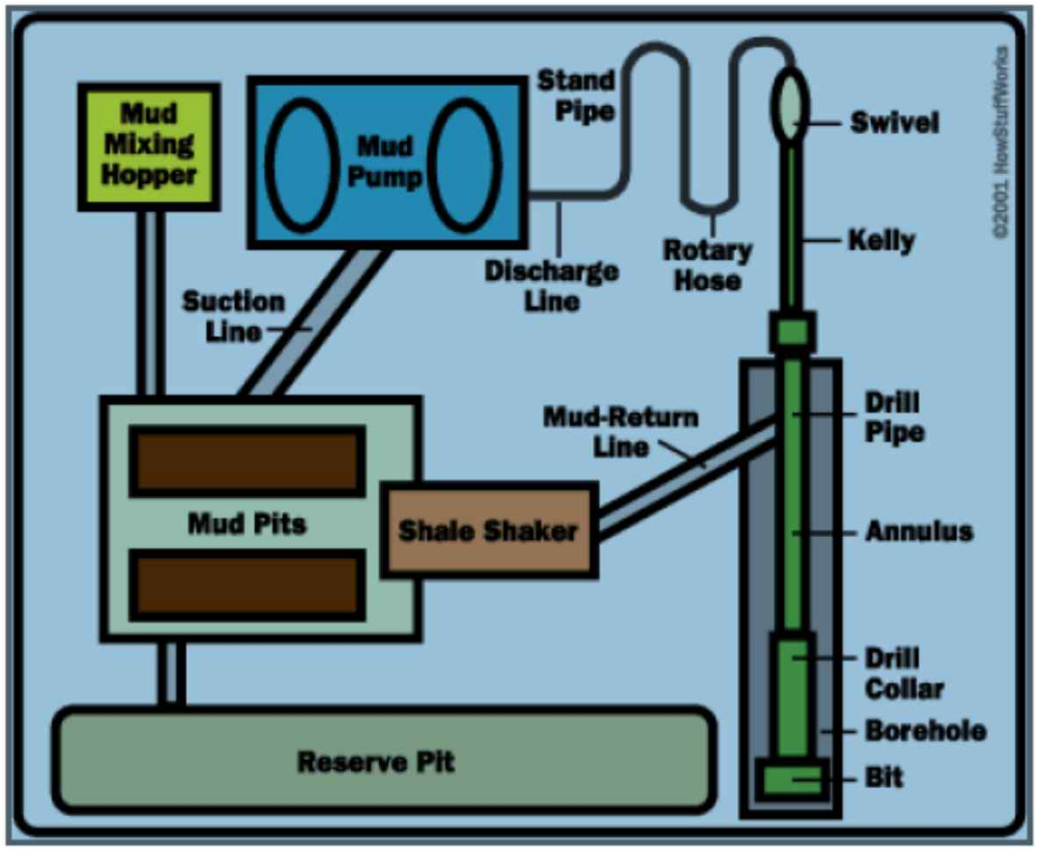


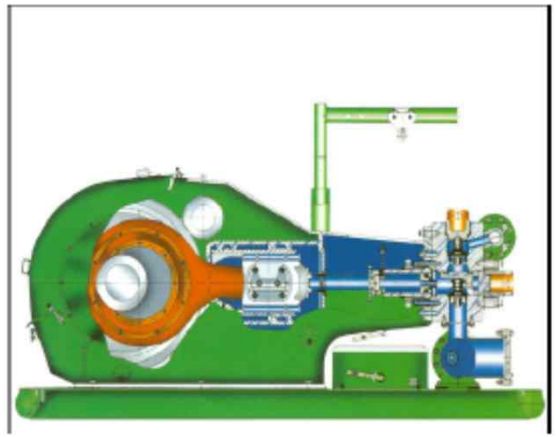
시추 시스템

- Power system, Hoisting system, Rotating system, BOP system, Circulation system



시추액 순환 시스템


Mud Mixing Hopper
Mud Pump
Stand Pipe
Swivel
Kelly
Rotary Hose
Discharge Line
Suction Line
Mud-Return Line
Drill Pipe
Mud Pits
Shale Shaker
Annulus
Drill Collar
Borehole
Reserve Pit
Bit
©2001 HowStuffWorks



다양한 시추방법

- Vertical, Horizontal, Directional Drilling

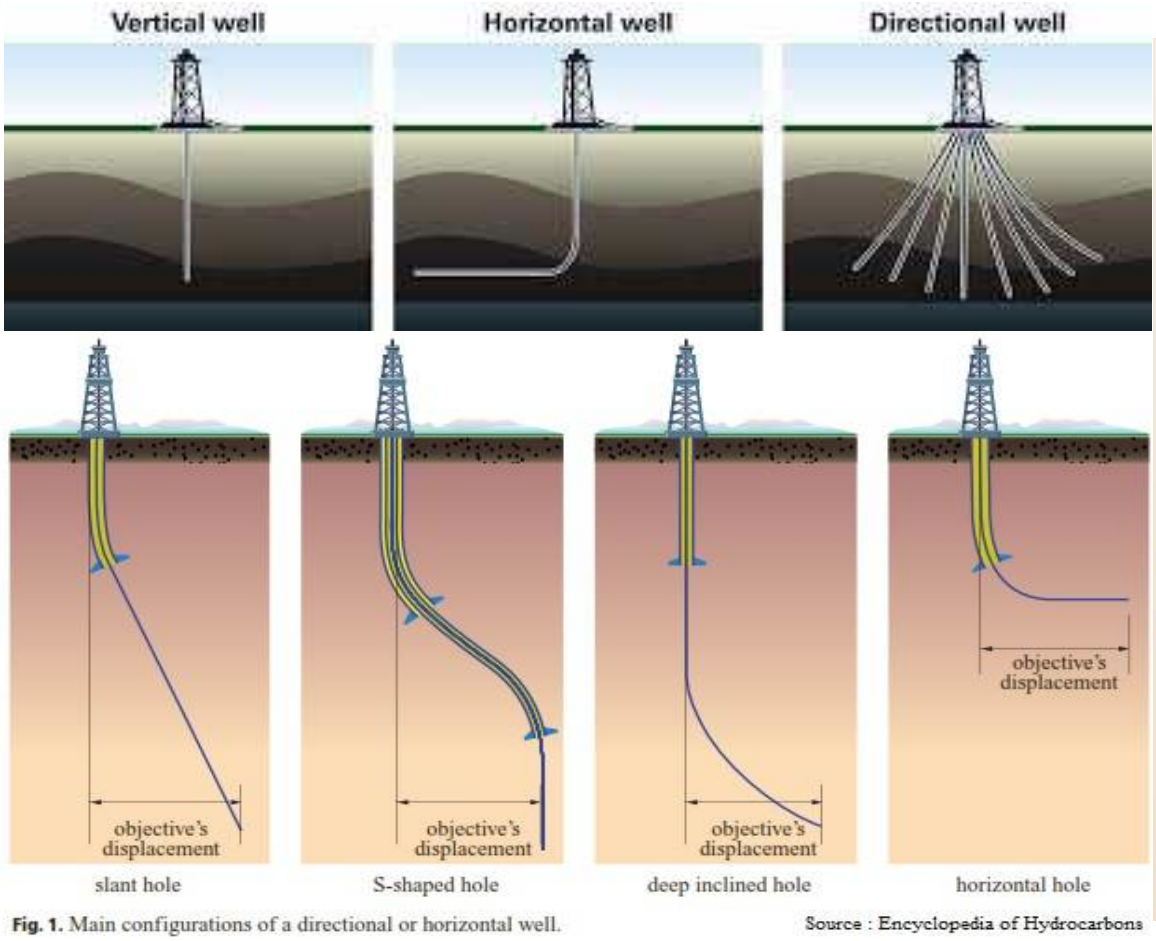
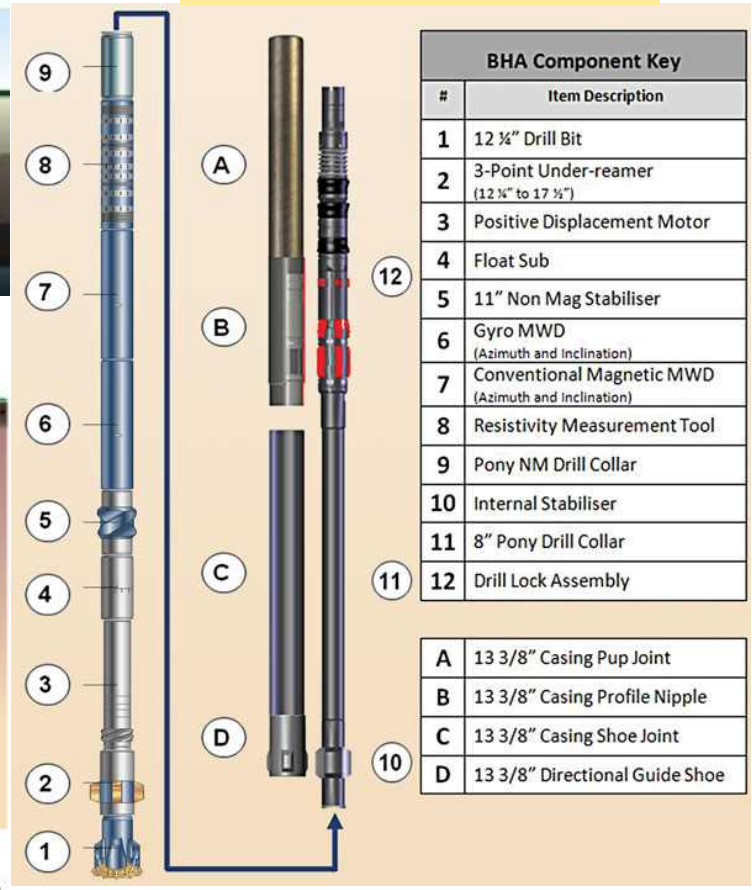


Fig. 1. Main configurations of a directional or horizontal well.

Source : Encyclopedia of Hydrocarbons

Bottom Hole Assembly

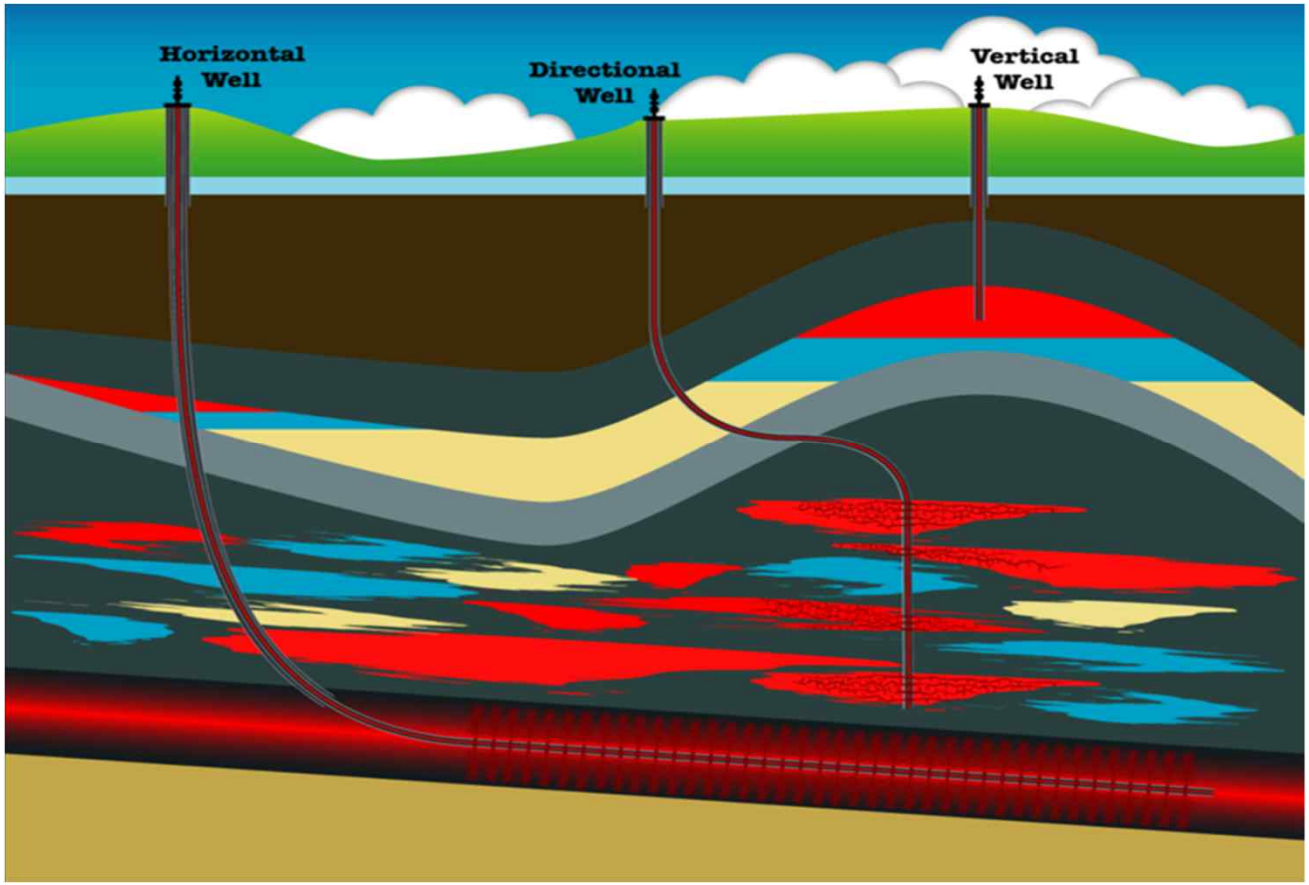


BHA Component Key	
#	Item Description
1	12 ¼" Drill Bit
2	3-Point Under-reamer (12 ¼" to 17 ½")
3	Positive Displacement Motor
4	Float Sub
5	11" Non Mag Stabiliser
6	Gyro MWD (Azimuth and Inclination)
7	Conventional Magnetic MWD (Azimuth and Inclination)
8	Resistivity Measurement Tool
9	Pony NM Drill Collar
10	Internal Stabiliser
11	8" Pony Drill Collar
12	Drill Lock Assembly

A	13 3/8" Casing Pup Joint
B	13 3/8" Casing Profile Nipple
C	13 3/8" Casing Shoe Joint
D	13 3/8" Directional Guide Shoe

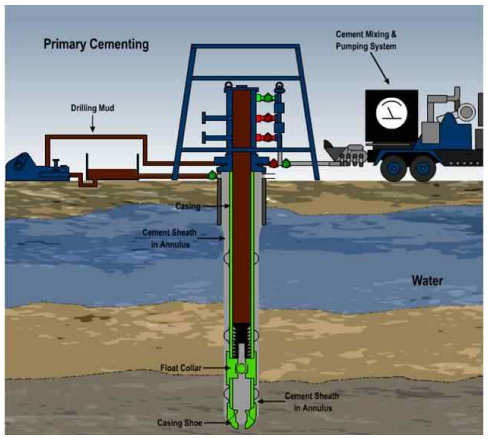
시추 유형 결정

- 저류층 형태와 경제성에 따라 결정



다양한 시추 장비

- 드릴비트(Drill bit), 시추파이프(Drill string), 케이싱(Casing), 방폭장치(BOP)



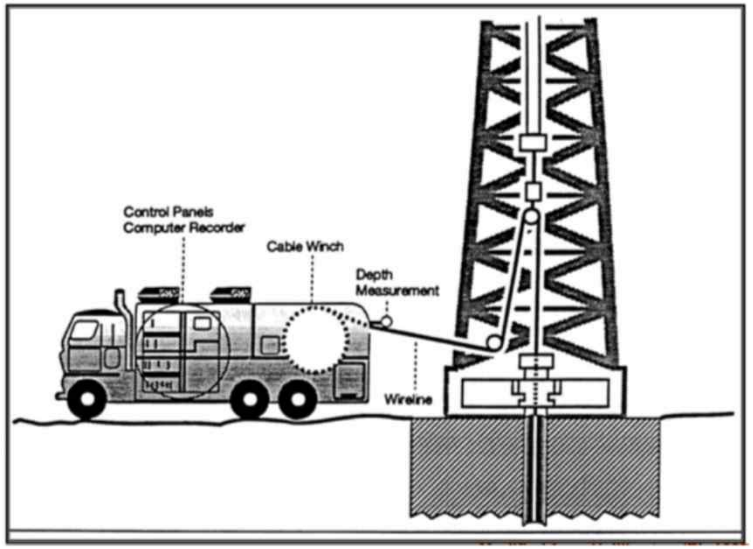
4-3: 석유가 집에 있는지 확인하기

물리 검층 (Well logging)

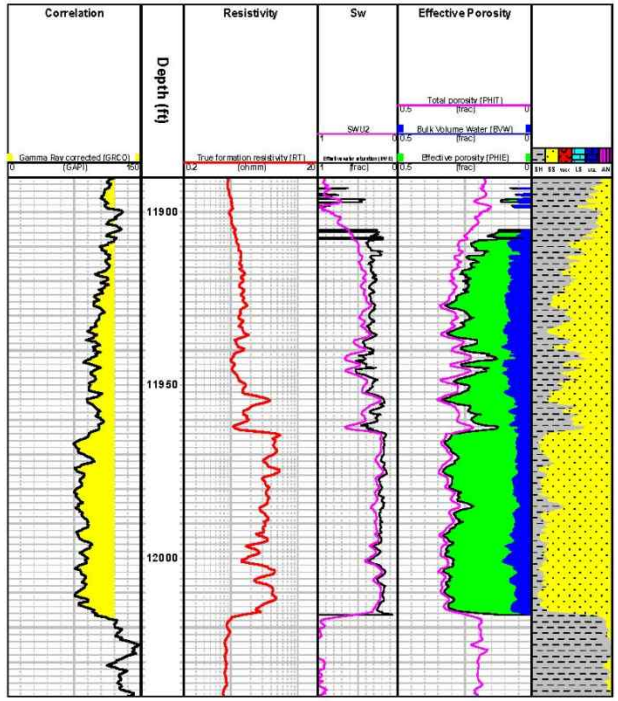
- To get reservoir parameters: pay thickness, porosity, oil saturation for OIIP calculation

  $OIIP = GRV*(N/G)*\phi*S_{oil}*(1/B_{oil})$

- Logging during/after the drilling job

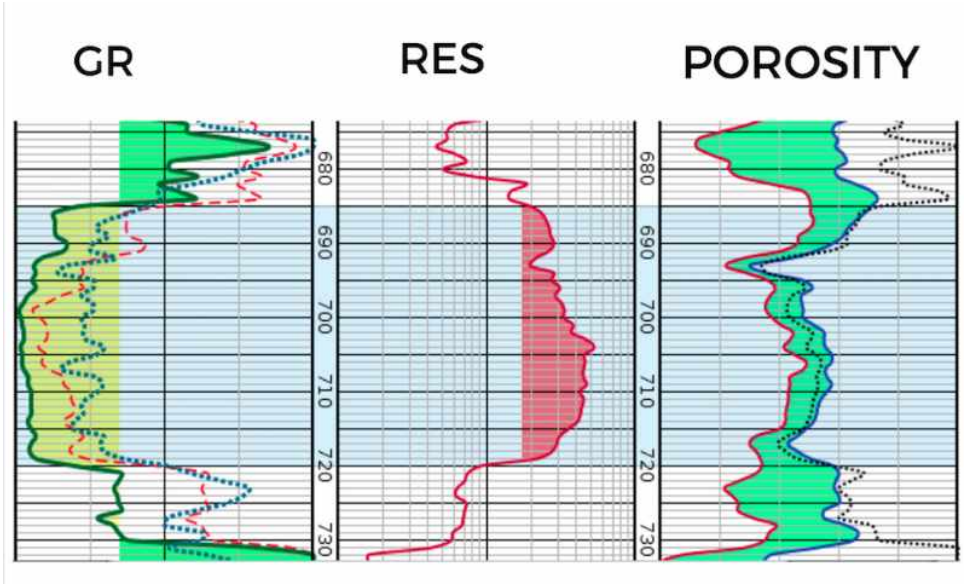


The Logging Truck is a High-Tech Computer Lab on Wheels (Courtesy Schlumberger)

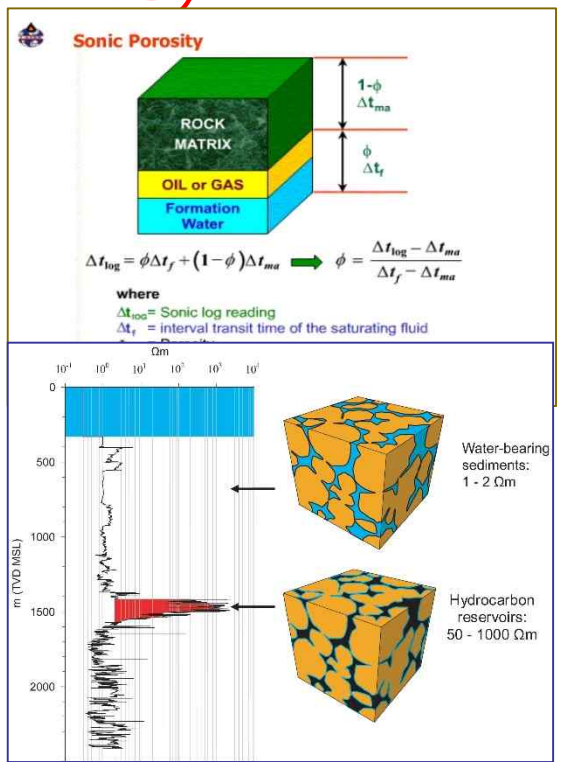


물리 검층 (Well logging) 원리

- OIIP = A*h*(N/G)*ϕ*S_{oil}*(1/B_{oil})
  - h: 암상(사암층 구별)
  - ϕ : 공극률 계산 (암석의 밀도차 이용)
  - S_{oil}: 오일포화도 (오일과 물의 전기 비저항차 이용)



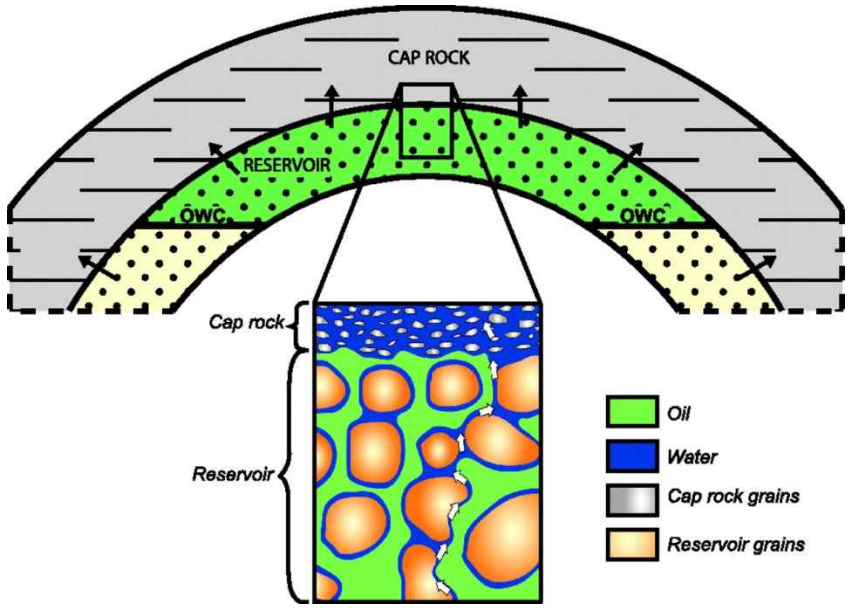
두께(h)



4-4: 얼마나 큰 규모로 존재하는지 계산하기

자원량(Oil Initial In-Place, OIIP)

- 자원량: 지하 저류층의 공극에 존재하는 탄화수소의 총량
- OIIP = GRV*(N/G)*ϕ*S_{oil}*(1/B_{oil})
- 회수가능 OIIP = OIIP * RF
  - GRV (Gross Rock Volume) =Area * Thickness
  - N/G: Net to Gross of pay thickness
  - Φ = 공극율(porosity)
  - S_{oil}= 오일포화도(oil saturation)
  - B_{oil}=오일체적계수
  - RF = 회수율 (Recovery Factor)
    - ✓ Oil : 20~60% (ave. 35%)
    - ✓ Gas: 40~ 90%

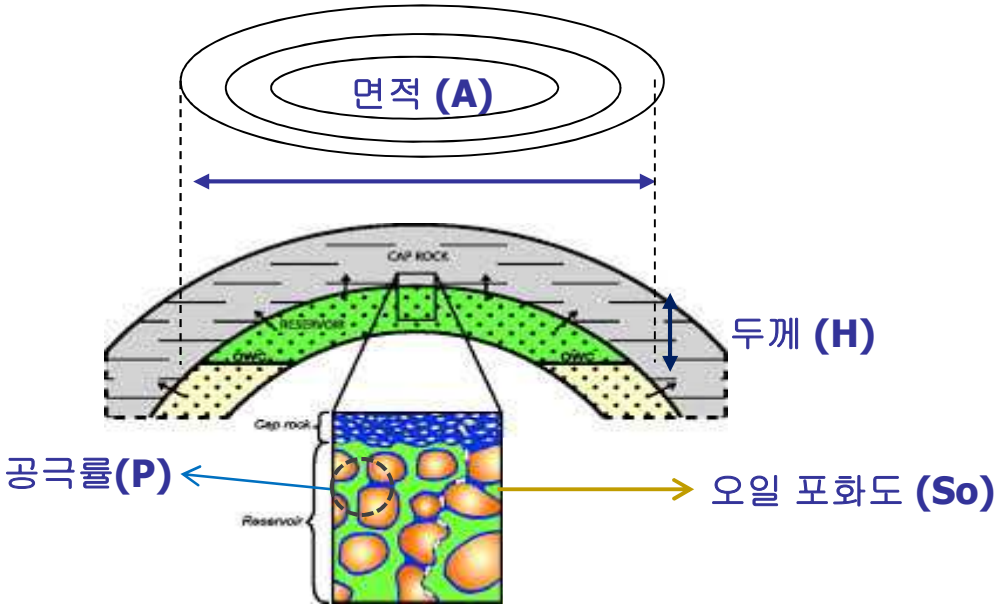


자원량 및 매장량 계산

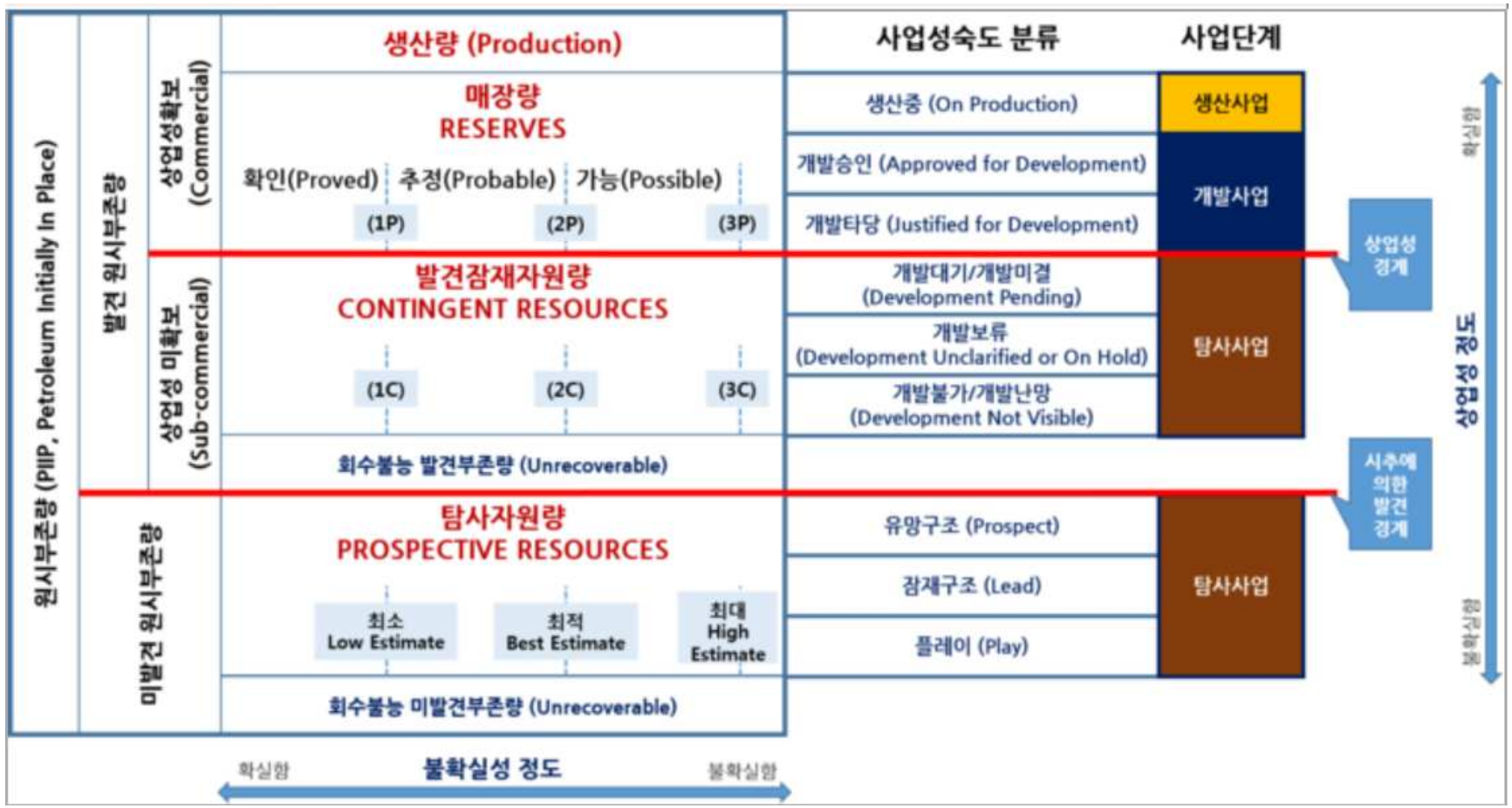
총 암석부피
(Gross Rock Volume)

매장량 = 면적 **x** 두께 **x** 공극률 **x** 오일포화도 **x** 회수율

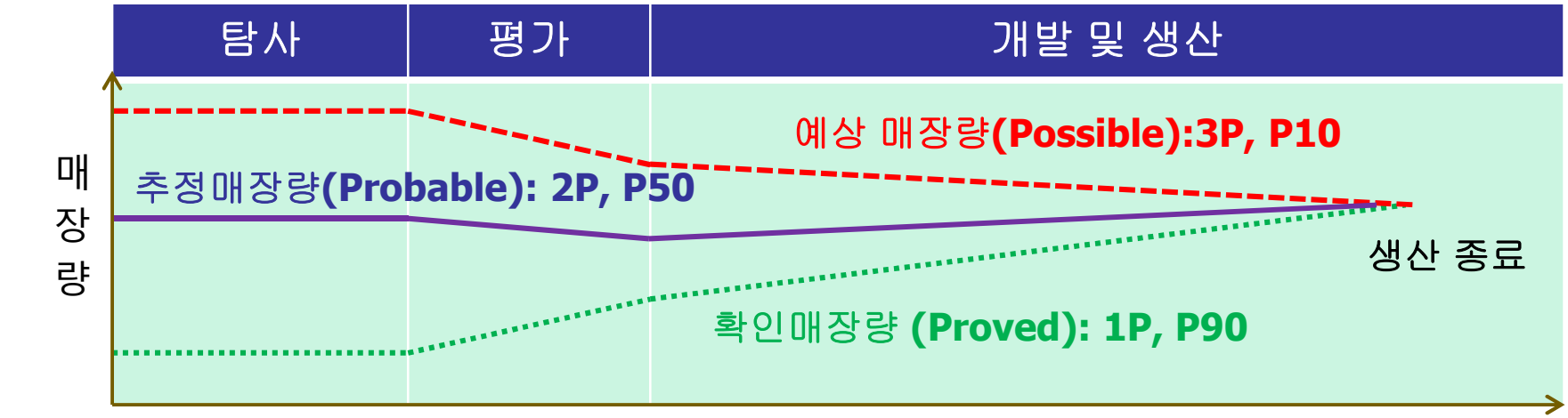
총 탄화수소 부피 **(Gross Hydrocarbon Pore Volume)**



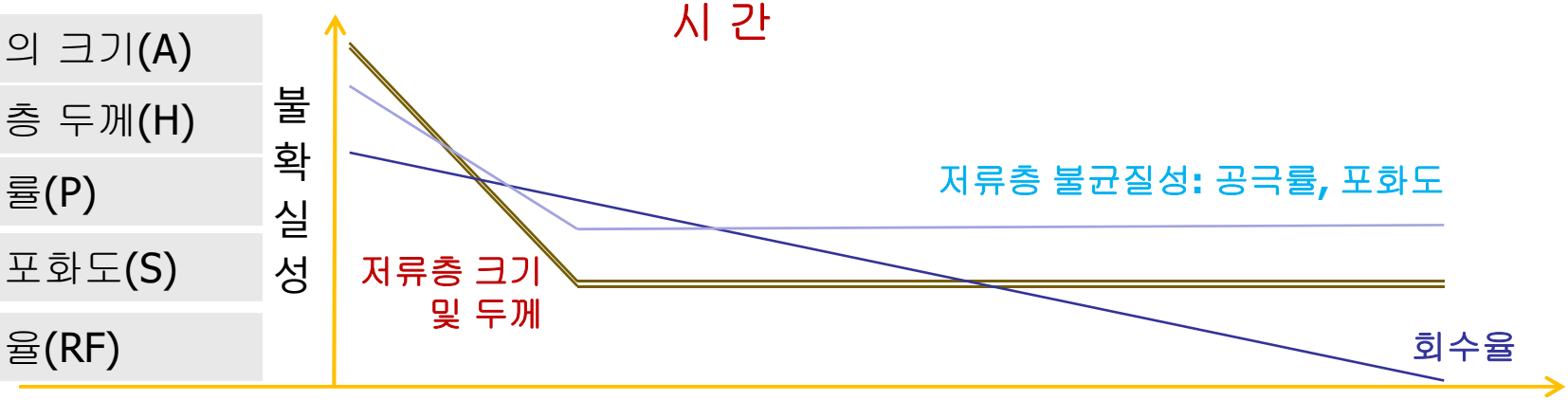
석유 매장량 분류


원시부존량 (PIIP, Petroleum Initially In Place)
발견 원시부존량
미발견 원시부존량
상업성확보 (Commercial)
상업성 미확보 (Sub-commercial)
생산량 (Production)
매장량
RESERVES
확인(Proved)
추정(Probable)
가능(Possible)
(1P)
(2P)
(3P)
발견잠재자원량
CONTINGENT RESOURCES
(1C)
(2C)
(3C)
회수불능 발견부존량 (Unrecoverable)
탐사자원량
PROSPECTIVE RESOURCES
최소
Low Estimate
최적
Best Estimate
최대
High
Estimate
회수불능 미발견부존량 (Unrecoverable)
사업성숙도 분류
사업단계
생산중 (On Production)
생산사업
개발승인 (Approved for Development)
개발타당 (Justified for Development)
개발사업
개발대기/개발미결
(Development Pending)
개발보류
(Development Unclarified or On Hold)
개발불가/개발난망
(Development Not Visible)
탐사사업
유망구조 (Prospect)
잠재구조 (Lead)
플레이 (Play)
탐사사업
상업성 경계
시추에 의한 발견 경계
상업성 정도
확실함
불확실함
확실함
불확실성 정도
불확실함

매장량 변화 경향



- 구조의 크기(A)
- 저류층 두께(H)
- 공극률(P)
- 오일포화도(S)
- 회수율(RF)



E&P 사업의 투자회수 특징

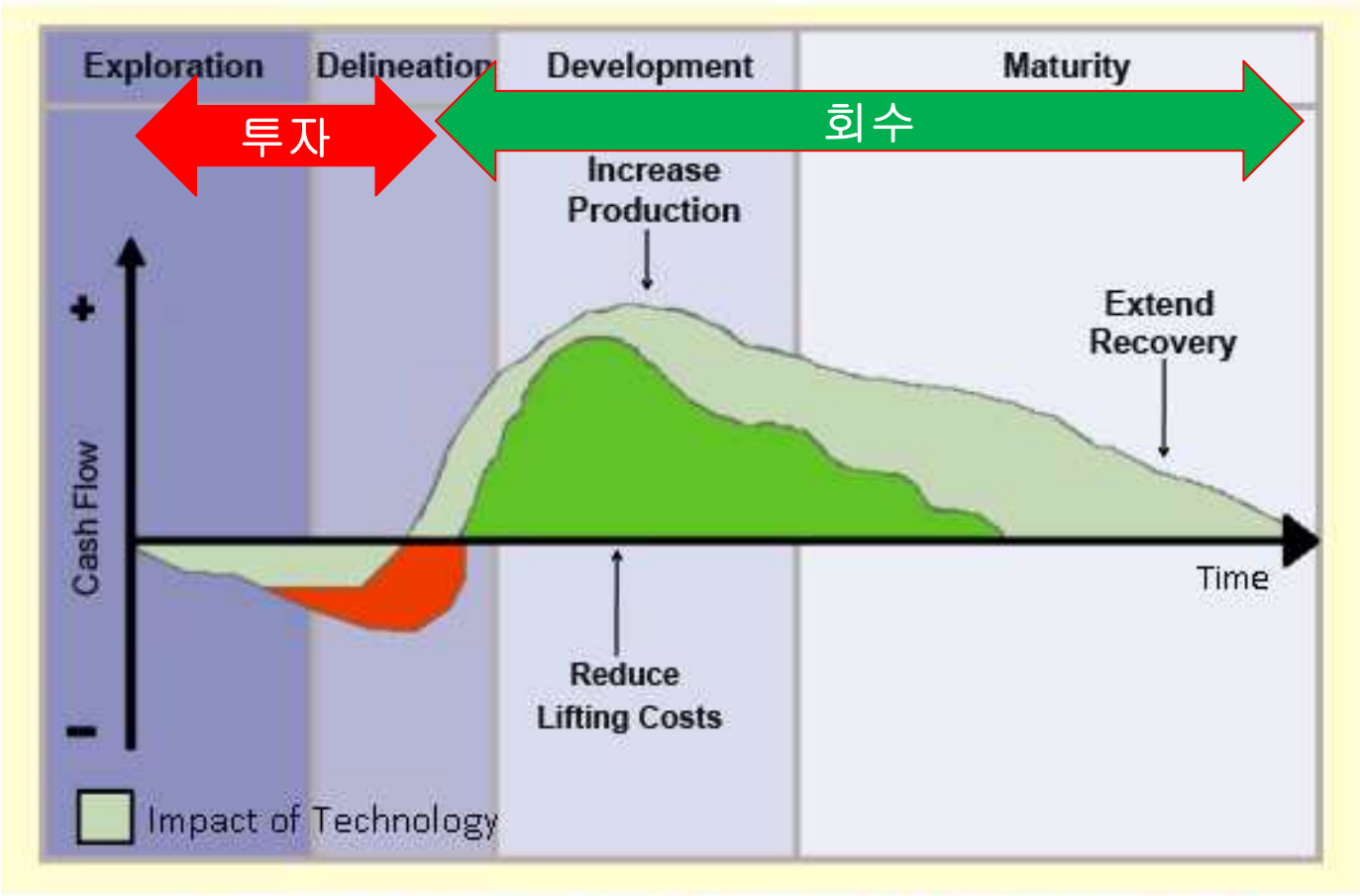


Figure: Impact of information technology on E&P life cycle cash flow.

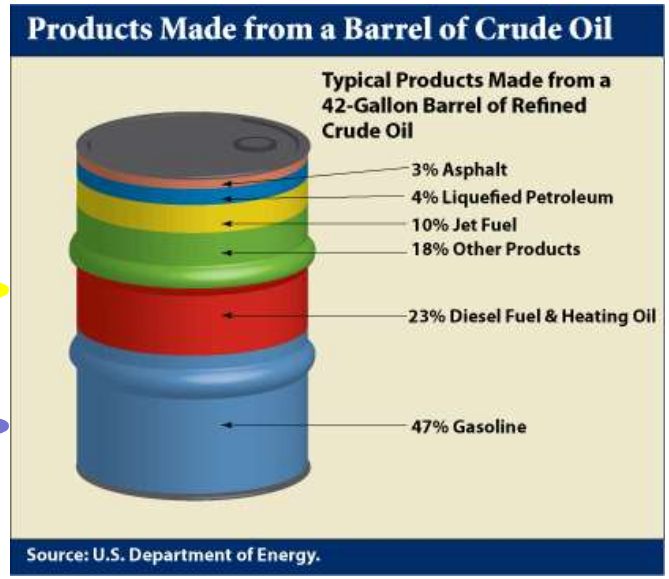
Source: The Digital Oil Field - Oil & Gas Investor, Apr 2004

4-5: 얼마나 지상으로 끌어올릴 수 있을까?

석유 유체의 특성

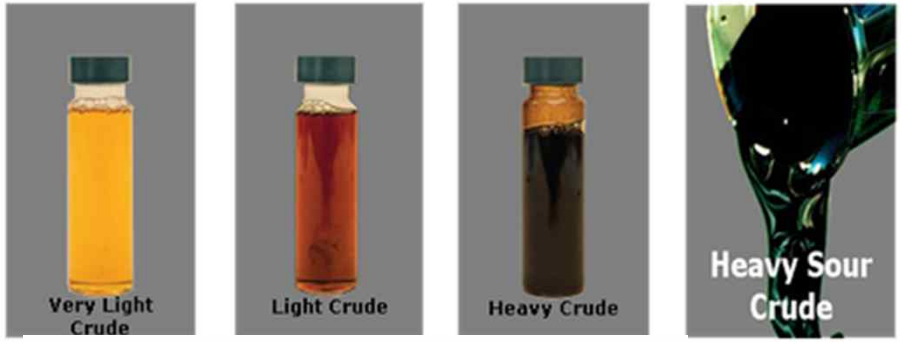
- 다양한 종류의 원유
- 연료 (>70%)와 석유 화학(<20%)

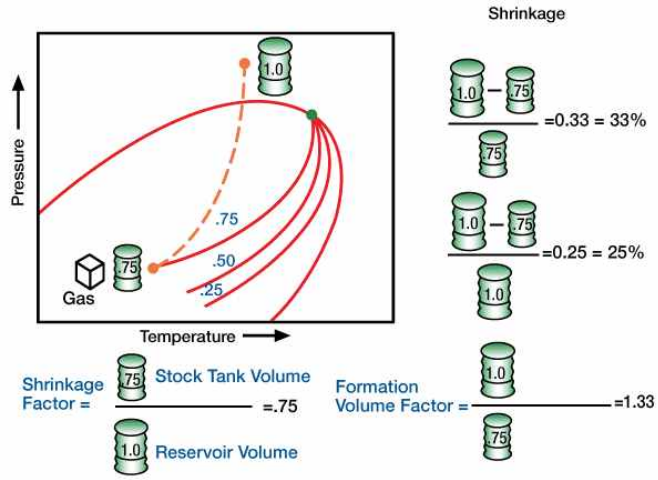
	Gullfaks (Norway)	Alaska N.S. (US)	E. Tex. Med. (US)	Maya (Mexico)	Athabasca (Canada)
Density:	Lighter				Heavier
Sulfur:	Less Sour				More Sour
Gravity, °API	37	31	27	22	8
lbs/bbl	295	305	312	322	355
Specific gravity	0.84	0.87	0.89	0.92	1.01
Sulfur, wt%	0.3	1.0	2.2	3.5	>4
Nitrogen, ppmu	716	1,600	1,015	3,600	>4,000
Total acid number (TAN)	0.1	0.1	0.1	0.3	>2.5
Cut ranges, vol%					
Naphtha, <330°F	23	23	13	17	1
Kerosine, 330–480°F	17	12	13	12	1
Diesel, 480–650°F	18	16	17	9	8
VGO, 650–975°F	28	28	31	27	34
Residue, 975°F plus	12	19	26	33	56
Other quality measures					
Jet range smoke pt, mm	20	21	23	22	N/A
Diesel range cetane no.	48	42	50	49	<30
Gasoil aniline pt., °F	194	169	178	168	122

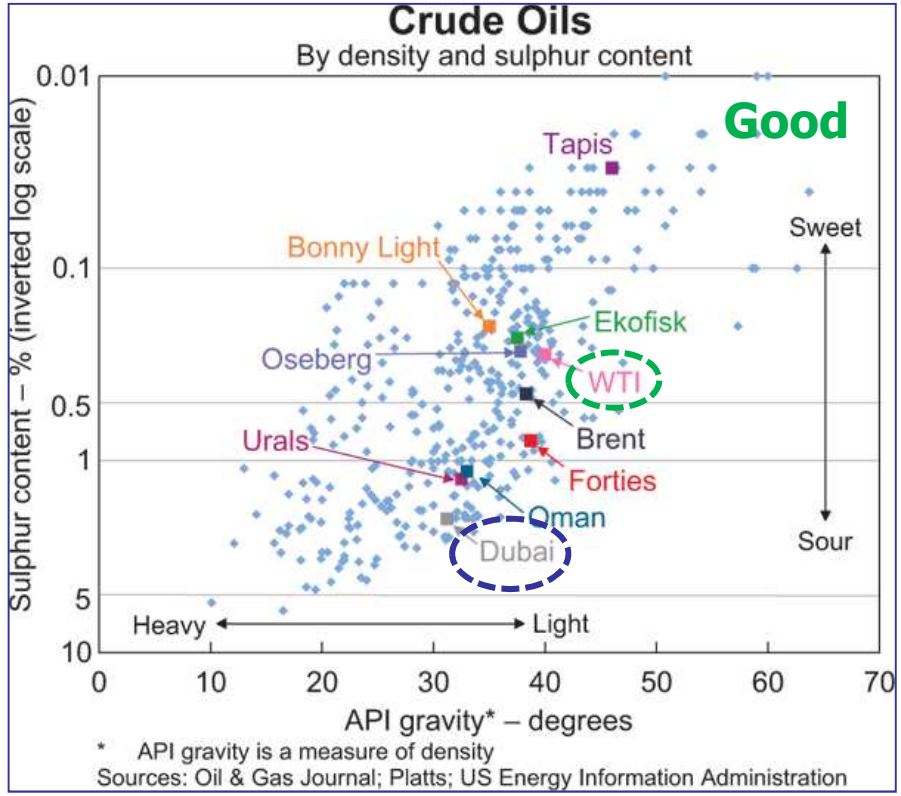


좋은 원유란 ?

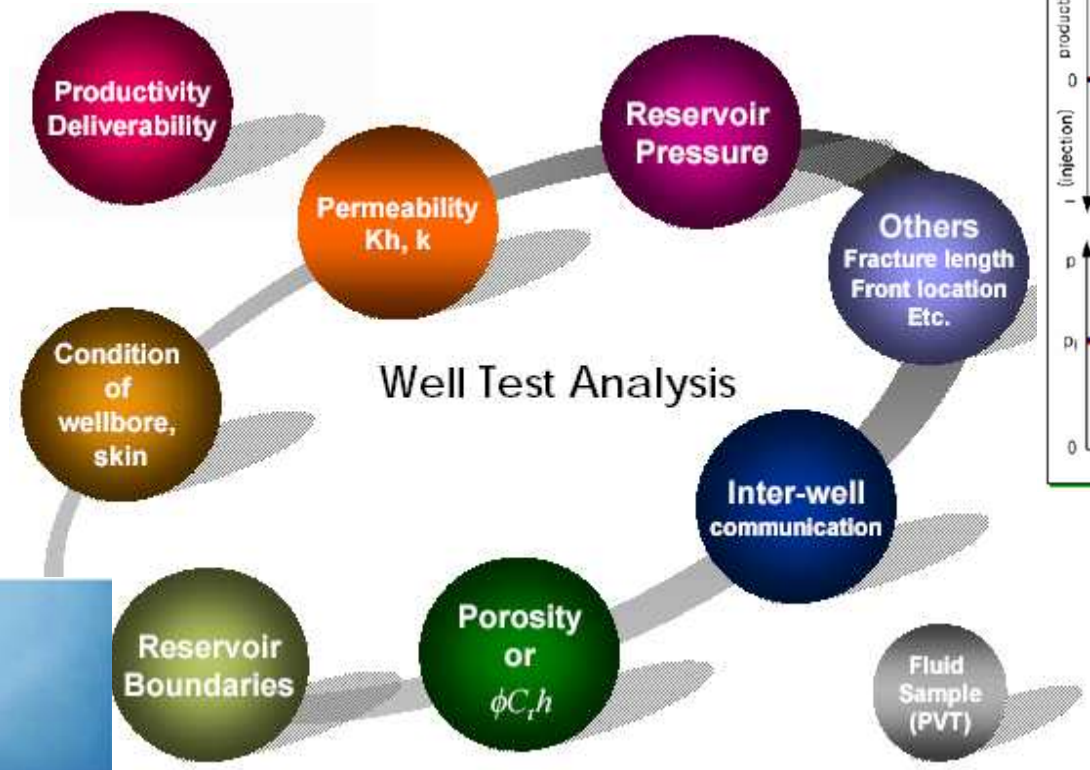
- 휘발유 성분이 많음: 경질유
- 분순물이 적음: Sweet (vs. Sour)

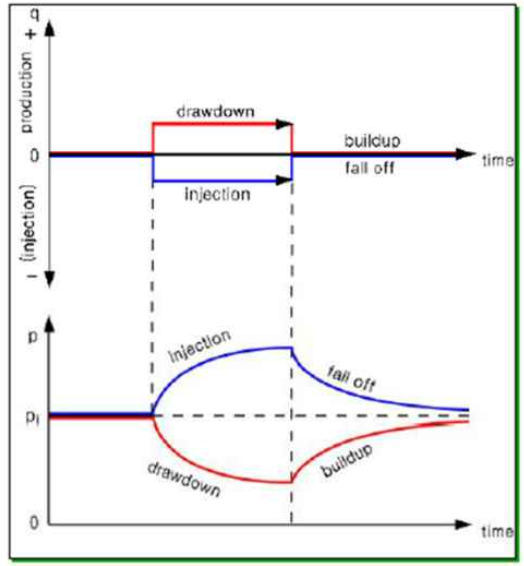






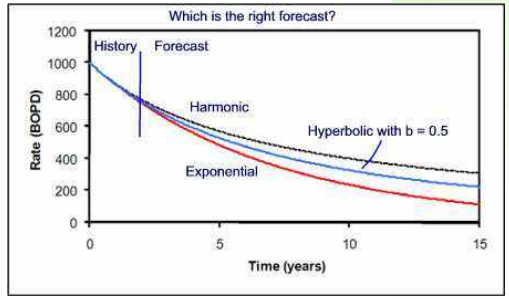
생산성 분석 (Well Test Analysis)

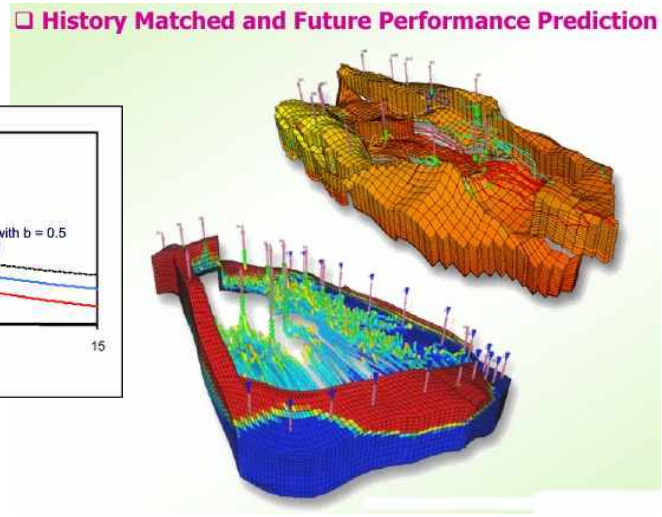


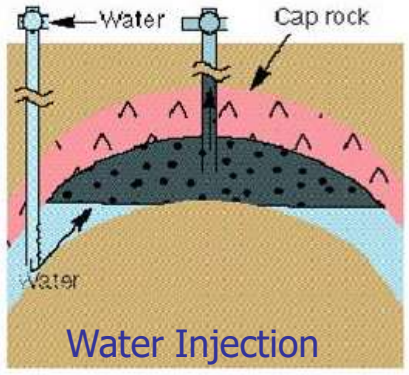


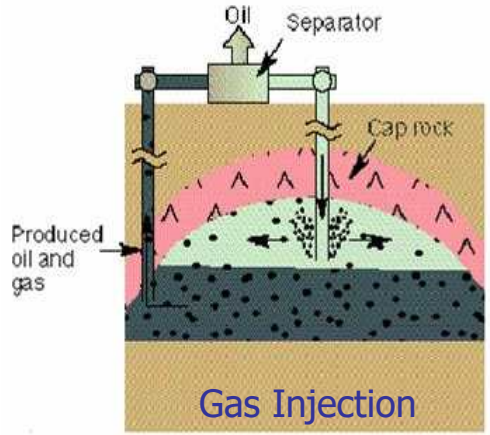
생산 예측

- Reserve estimation
  - Analogue
  - Volumetric
  - Material balance
  - Decline curve analysis
  - Numerical simulation
  - Monte Carlo simulation
- Production schedule
  - Infill drilling
  - Secondary recovery
  - Enhanced oil recovery



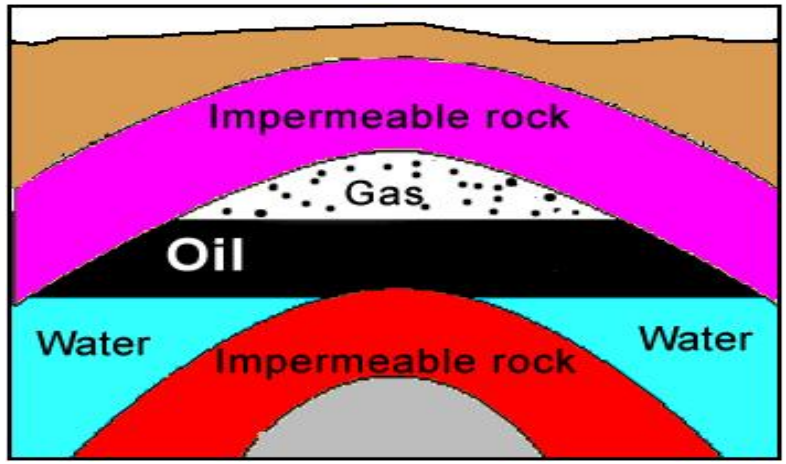




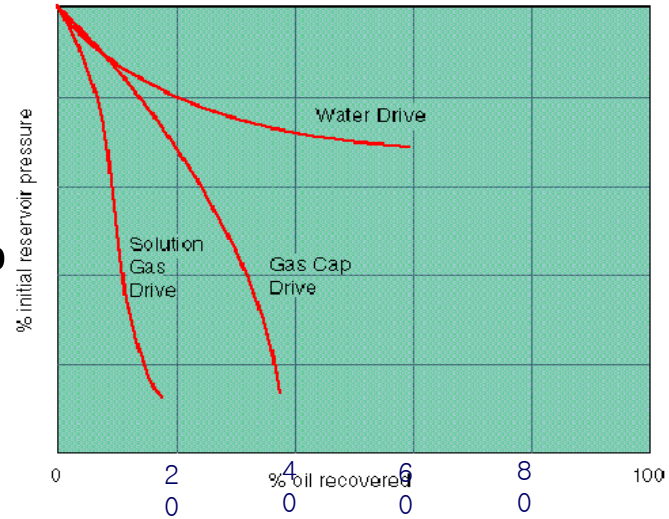


회수율 (Recovery Factor)

- 오일 생산정
  - Solution gas: 10-20%
  - Gas-cap: 20-40%
  - Water drive: 40-60%

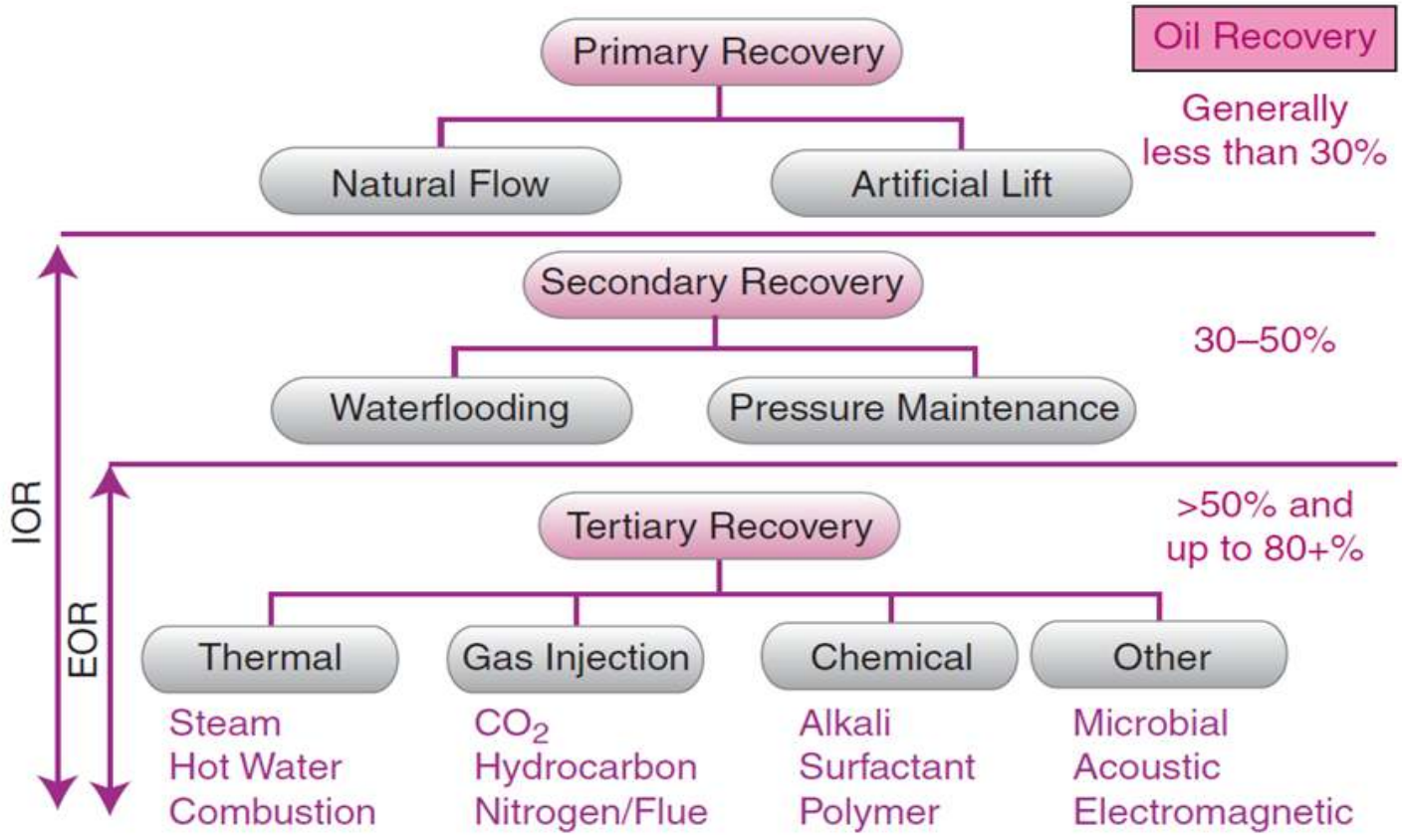


- 가스생산정
  - Pressure Depletion : 70-90%
  - Natural Water Drive : 40-60%
  - Pressure Depletion-Condensate : 20-40%
  - Gas Cycling-Condensate : 30-60%



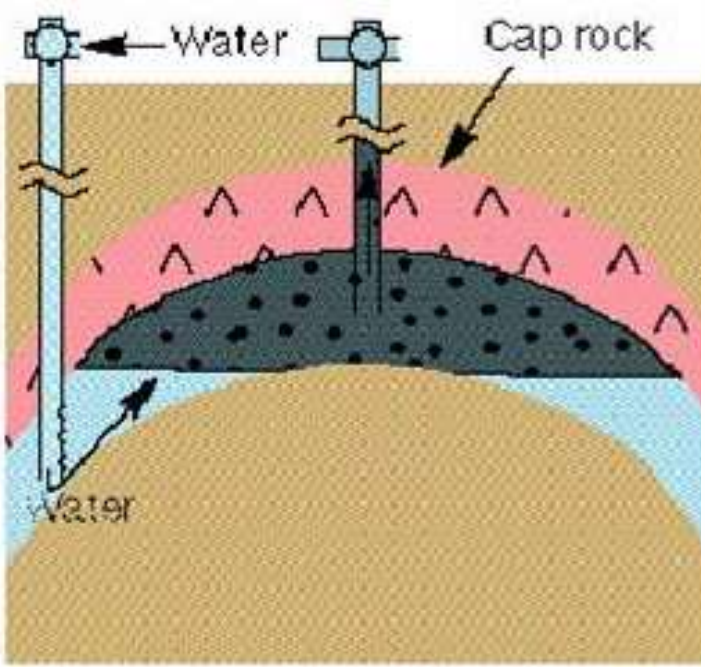
석유회수증진기술 (EOR)

- Thermal EOR is widely used: Steam injection



2차 회수 (Secondary recovery)

Water Injection



Gas Injection