RAFFLES
UNIVERSITY

Couse Non-Conventional Energy Resources (Petroleum Engineering)
B.Tech Mechanical Engineering
Course Code:OEC - 401
Program Outline
Instructor: Dr. Jaspreet Hira

Brief Description

- History of Oil and Gas Applications, International Petroleum Reserve
- Fundamentals of Petroleum Geology: Rock Cycle, Oil and Gas and Water Deposits
- Major Exploration Techniques : Seismic methods, well testing, basics of reservoir engineering and modelling.
- Basics of Well drilling and production.
- Concept of Oil and Gas Production.
- Reservoir Engineering and modelling.
- Petroleum deposit drainage.
- Development Systems
- Well Operation techniques

Objectives of the Course

- The main objective of this course is to provide in depth knowledge of the technologies used in Petroleum Industries. Materials occupied worldwide and circulation to refining processes i.e. Technologies adapted for the material procurement.

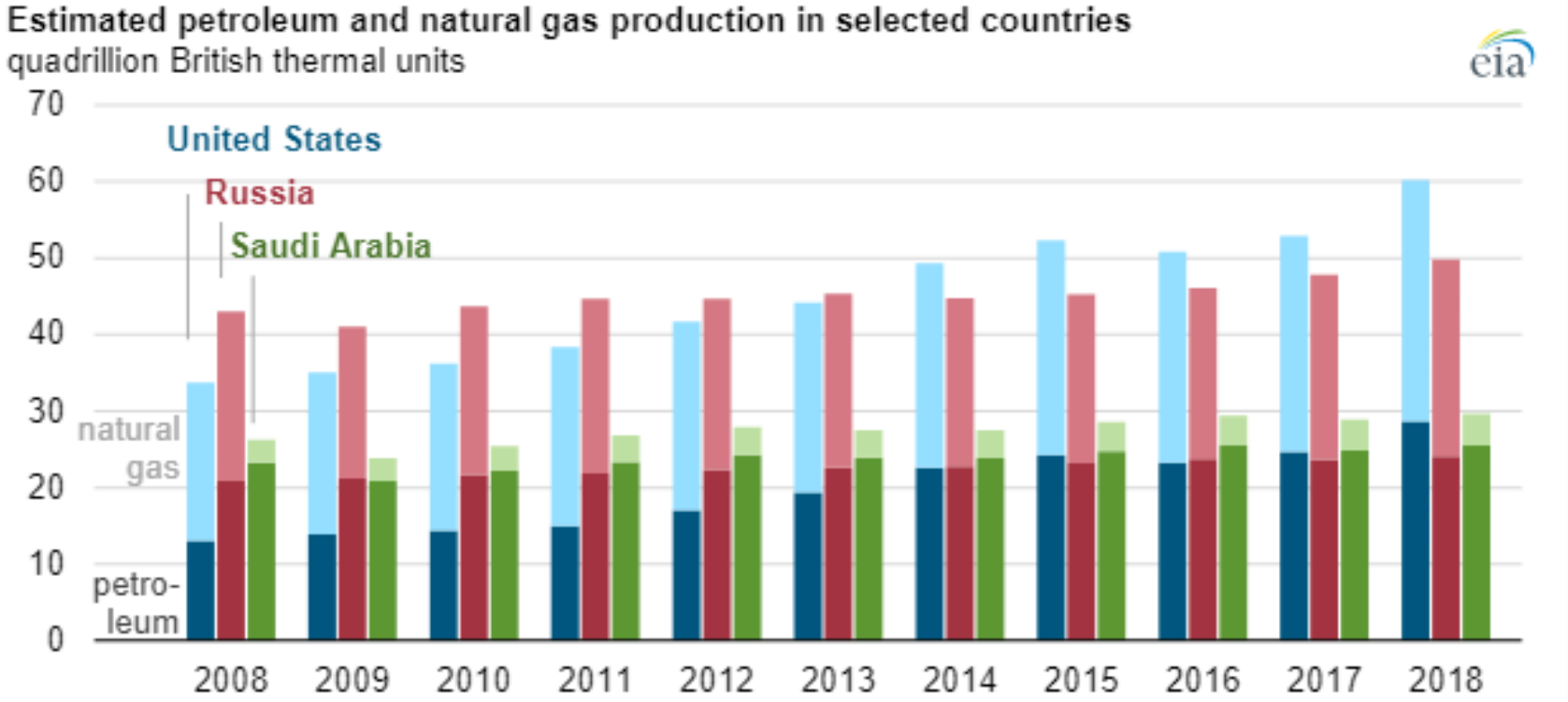
Day 1. Session Introduction to Petroleum Development

- What is Petroleum?
- Petroleum is a combination of Hydrocarbon and impurities that exist in solid, liquid, and gaseous phase. These hydrocarbon are being stored in the rocks.
- Engineers are required to explore these hydrocarbon from deep sea through the technology.
- Petrochemical engineers acquire the knowledge of behavior of oil, water, gas in porous rock to extract hydrocarbon.
- The hydrocarbon are stored in the reservoir, so the wells are needed to extract these hydrocarbons.
- Each well must be drilled and completed so that the fluid flow onto the surface.
- Surface equipment’s have been used to drill, complete and operate well.
- The Drilling rig can be moved by the ships, trucks and bags and mobile platforms.

Formation

- Petroleum is the foundation of the industrial civilization.
- Petroleum has been formed from the remains of plants and animals comprising mainly the (i) algae, (ii) fungi, (iii) diatoms, (iv) foraminifera that were used to float on the surface of sea.
- Mesozoic (about a million year back)
- Cainozoic (about 65 million year back)
- Shells and skeletons of dead plankton, sponges and jelly fish sublime on seabed and subsequently gets buried under the pilling sediments.
- Due to the formation of the complex chemical transformation takes place that is being facilitated by the overburden pressure and rise in temperature and the absence of oxidizing agent.
- The process continues through the various complicated stages and chemical reactions forming fats, amino acids, lipids and finally into oil and gases.

Global petroleum and natural gas production in selected countries



United States

Russia

Saudi Arabia

US are the maximum producers of both the natural gas and crude oil.

Figure 1. Data US Lead global Petroleum and natural gas production with record growth.

Crude Oil

- Naturally occurring mixture consisting predominantly of hydrocarbons and or of Sulphur, Nitrogen and Oxygen derivates of hydrocarbon which is being removed from the Earth in the liquid state or capable of being removed.
- API is a unique number that is being assigned to every oil and gas well where the specific gravity oil is the ratio of density of the oil to the density of water. Most Petroleum liquids falls between 10 and 70 degree and the crude oil has the API – 15 and 45 degrees
- $API = {}^{141.5}/_{\gamma o} - 131.5$

Elements composed of crude oil

Elements	Amount wt%
C Carbon	83.9 - 86.8
H Hydrogen	11.0 - 14.0
S Sulphur	0.06 - 8.00
N Nitrogen	0.02 - 1.70
O Oxygen	0.08 - 1.82
Metals	0.0 - 0.14

Classification of Hydrocarbons

- A large data base reveals that the organic compound list about 10 million substances which includes the compounds originating from living organism and those that have been synthesize of chemical engineers.
- The ability of the carbon atoms to form up to four strong bonds to the other carbon atoms, that results in the chain and rings of many sizes, shapes and convolutions.
- The simplest organic compound containing the elements of carbon and hydrogen so combining these are called the Hydrocarbons.

Classification of Hydrocarbon

Alkanes CnH2n+2	Cycloalkanes CnH2n+2-2n	Arenes or Aromatics CnH2n	Hybrids CnH2n -2 Unsaturated hydrocarbons
Methane **Ethane** **Propane** **Butane**	Cyclopentane Methylcyclopentane Cyclohexane Methylcyclohexane 1,1,3 - trimethlyecyclohexane	Benzene Ethlybenzene p-xylene	C8H16
Other elements	1. Sulphur compounds 2. Nitrogen		

Some latest Development in Petroleum Exploration

Enhanced Oil Recovery	5 G Network Data Transmission
Hydraulic Fracturing	Collaboration tools
Horizontal Drilling	
Deep Water Production	
Big Data and Analytics	
Iiot and Edge Computing	
Artificial Intelligence and Machine Learning	
Robotics and Drones	

The above table depects the most recent technologies created in the petroleum industry. The use of big data analysis adds to the understanding of the petroleum development. Artificial Intelligence and machine learning have made important contributions to the identification and exploration of petroleum products and poweful networking and has examined the most effective parameter for product discovery.

Session 2 History of Oil and Gas Applications

- It was in the middle century that the consumption of the crude oil exploded.
- It was 1846 the modern oil era when the oil exploration takes place.
- Europe and North America were the ones who rapidly increased their energy requirement and that were previously met by coal.
- From the Russian Empire to Europe to North America the first modern drilling operation sites.
- Also, in United states which causes a rush in the black gold. Therefor the US has been the largest oil producer in the world.
- With the development of the Automobile sector, the reconversion of the ship engines and the aviation boom during the world war I.
- The application includes the products such as LPG, motor spirit, Naphtha, Aviation Fuel, Diesel and Heavy oil are produced during the fraction distillation of the crude oil, bitumen used for the construction and roofing applications. Crude oil has been transported in barrels with the capacity of 42 US gallons. 159 litre, the barrel became the unit.
- More and more oil deposits are being made worldwide including Venezuela.

History of Oil and Gas Applications

- During the World War II the demand for the oil markets skyrocketed and the petroleum resources became major international matter of concern.
- Western countries dominating the oil market contributes to nationalist movement in producer countries.
- The overexploitation of oil and being cheap overtakes the coal becoming the primary source of energy on Globe.
- Also through the historical perspective the early use of oil and bitumen exist in the ancient history.
- The Eternal fires of Baku were the results of the ignition of oil and natural gas from seepage.
- The basket in which the baby Moses was hidden was made waterproof with bitumen. The tower of babel was constructed using the bitumen as mortar. In the far eat oil has been used as lightening.
- It has been rubbed into the coasts of camels to cure them of mange. The north Americans used petroleum as medicine.
- The Mexican Indian valued bitumen as chewing gum. Christopher Columbus used the bitumen to make his ships seaworthy.
- Marco polo observed that mineral oil burned well to give both the light and heat. Alexandra the great visited the Persia Inhabitants sprinkled the street with oil and set it light.

History of Oil and Gas Applications

- The history says that so long as some alternative sources of energy are not discovered in economically large scale, hydrocarbons will continue to have their enormous dominance and influence on the world's economy, politics and other social activities for many years to come.

Table showing the top ten rankers in consumption of oil and gas and their Revenue in Billions

Company	Industry	Revenue in Billions	Ranks
Wal mart store	Supermarkets	421849	1st
Royal Dutch Shell	Oil and Gas	378152	2nd
Exxon Mobil	Oil and Gas	354674	3rd
British Petroleum	Oil and Gas	308928	4th
Sinopect Group	Oil and Gas	273422	5th
China National Petroleum	Oil and Gas	240192	6th
State Grid	Power	226294	7th
Toyota Motors	Automobiles	221760	8th
Japan Post	Delivery	203958	9th

Session 3 Fundamentals of Petroleum Geology – Rock Cycle

- Geology has always been concerned with Earth facts.
- Geologists primarily engage in two types of work: describing current geology and interpreting that geology in terms of geographic location.
- The geologist's principal purpose is to create a model of the area under investigation as an oil and gas field.
- The team must operate in a synchronized manner to achieve this exploration strategy.
- Until drilling takes place on site, the region that must be examined must be determined.
- The Petroleum System consists of a mature source rock, migration pathway, reservoir rock, trap and seal.
- Appropriate relative timing of formation of these elements and the processes of generation, migration and accumulation are necessary for hydrocarbons to accumulate and be preserved.
- The components and critical timing relationships of a petroleum system can be displayed in a chart that shows geologic time along the horizontal axis and the petroleum system elements along the vertical axis.
- Exploration plays and prospects are typically developed in basins or regions in which a complete petroleum system has some likelihood of existing.

3.2 Source Rock Hydrocarbon Generation

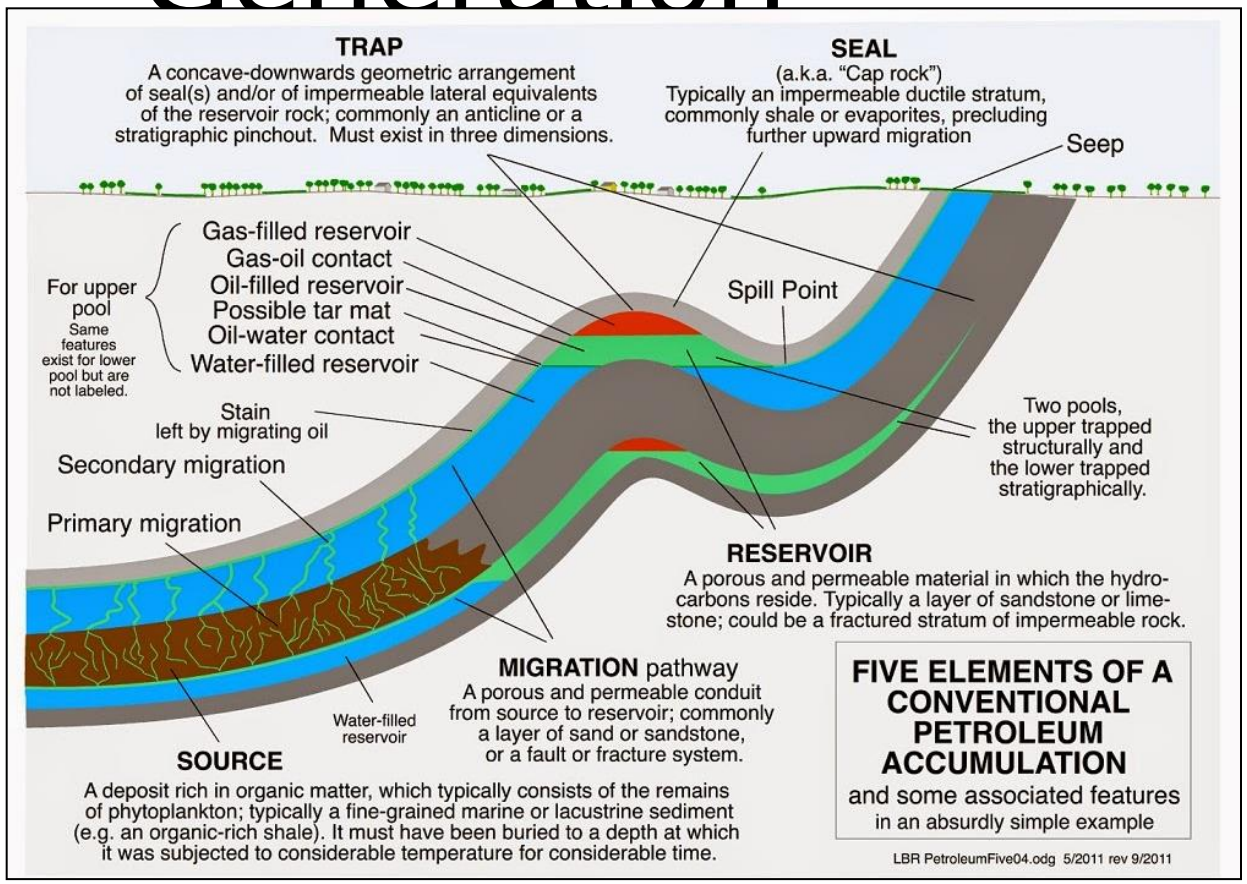


Figure 2. Five Elements of conventional Petroleum Accumulation

- The formation of hydrocarbon liquids from an organic rich source rock with kerogen and bitumen to accumulate as oil or gas. Generation of the Hydrocarbon depends on the following three main factors
- (a) Presence of Organic matter rich enough to yield hydrocarbon
- (b) Adequate Temperature
- (c) Sufficient time to bring the source rock to maturity.

3.2 (a) Migration

- The movement of hydrocarbons from their source into reservoir rocks.
- The movement of newly generated hydrocarbons out of there source rock is primary migration called expulsion.
- The further movement of the hydrocarbons into reservoir rock in a hydrocarbon trap or other area of accumulation is secondary migration.
- Migration typically occurs from a structural low area to a higher area in the subsurface because of the relative buoyancy of hydrocarbons in comparison to the surrounding rock.
- Migration can be local or can occur along distances of hundreds of kilometers in large sedimentary basins and is critical to the formation of viable petroleum system.

3.2 (b), (c) and (d)

Reservoir	**A subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and they form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum system.**
Seal Cap	An impermeable rock that acts as barrier to further migration of hydrocarbon liquids. Rocks that forms a barrier or cap above and around reservoir rock forming a trap such that fluids cannot migrate beyond the reservoir. The permeability of a seal capable of retaining fluid through geologic time i.e. 10-6 to 10-8 darcies. Commonly shale, mudstone anhydrite salt, A seal is critical component of a complete petroleum system.
Trap	A configuration of rocks suitable for containing hydrocarbons and sealed by a relatively impermeable formation through which hydrocarbons will not migrate. A trap is an essential component of a petroleum system. Traps are described as structural traps Hydrocarbon traps that form in geological structure such as folds and faults stratigraphic traps.

Session 4 Gas and Water Deposits

- A natural gas deposit is formed when the crude oil or natural gas on the way to the earth surface is encapsulated (Captured) by Impermeable layers of rock so it can be accumulated accordingly.
- The Gas and water deposits can be seen in the schematic layout as shown in the figure.
- How oil and Gas Deposits are being formed?
- Answer: Deep in the Earth, oil and natural gas are formed from organic matter from dead plants and animals. These hydrocarbons takes millions of years to form under specific pressure and temperature conditions. .
- When living organism dies, its generally recycle in two ways:
- Answer: Its been eaten by predators, scavengers or bacteria.
- Through exposure to air or oxygen rich water it oxidizes that means the hydrogen, carbon, nitrogen, sulphur, and phosphorous contained in the matter combined with oxygen atom present in the air. The organic matter breaks down into water and carbon dioxide, nitrates, sulphates and phosphates that nourish the new plant.

Slow formation of source rock

- Specific requirements

A Hot climate that is necessary/ conducive to the growth of large quantities of plankton.

A location near the month of a major river carrying a lot of plant debris.

No near by mountain that could limit the volume of inorganic sediments within the rocks.

How oil and gas are formed

- At a depth of 2000 meters when the temperature reaches 100oC the Kerogen starts to release (preservation hydrocarbon)
- At 2000-3000 meter the mixture turns into oil and this depth is known as Oil window. When the source rock sinks further to between 3800 to 5000 meters production of liquid hydrogen peaks.
- The liquid produced become increasingly lighter hydrocarbon.
- This depth interval is known as Gas Window.
- There are no hydrocarbon on below a depth of 8-10 kilometer that is decomposed by the high temperature conditions.

Theory

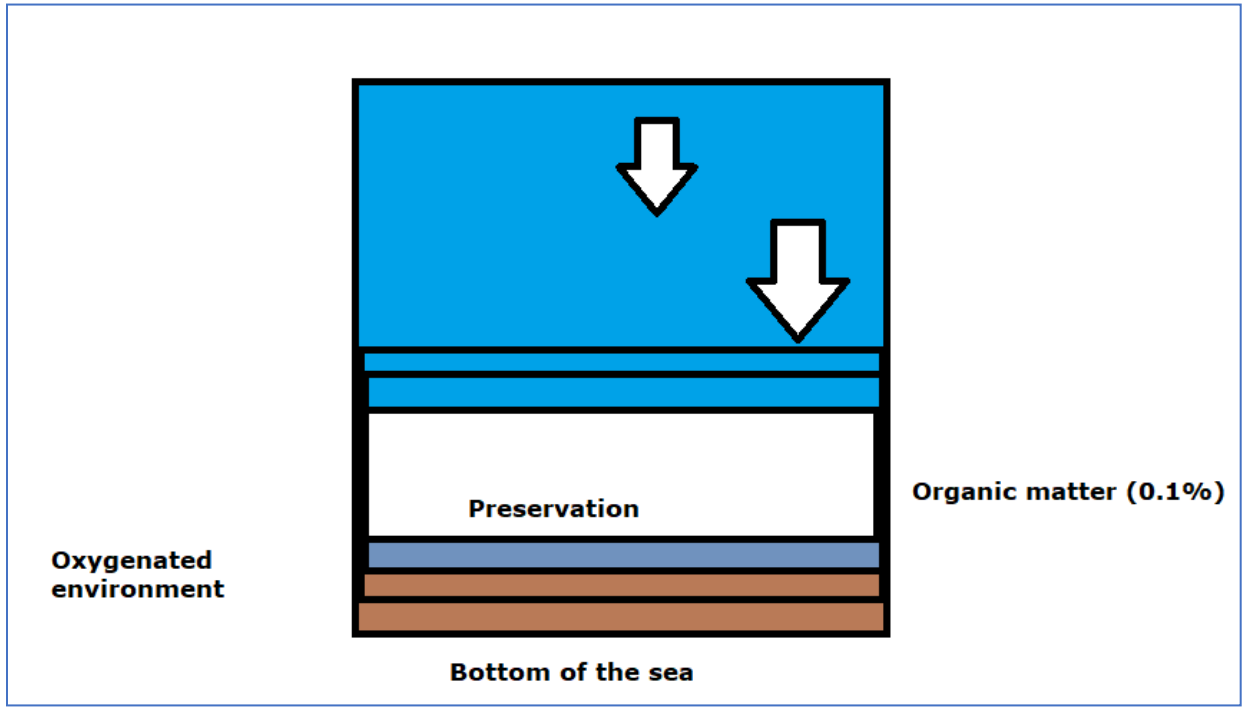


Figure 3. Organic Matter sinks to the bottom

- ✓ The figure shows the sea where the organic matter sinks to the bottom.
- ✓ Its partially preserved in these oxygenated environment well away from the tidal current.
- ✓ It then mixes with the inorganic matter such as clay particles and very fine sand and with dead marine plakton i.e. microscopic organism.
- ✓ This mixture is then transformed into dark, foul-smelling mud by anaerobic bacteria.

Session 5 Gas Composition

- Hydrocarbon gases are the most common in the marine sediments.
- Such gases originated from the decomposition of the organic matter by the biochemical and chemical routes.
- The staged of natural gas formation
- 1. Biological C1 Formation: Occurring almost at the lowest temperature under certain environmental conditions where the temperature is less than 50^{o}C.
- 2. Thermogenic Stage: Gas formation in which the whole series of the gaseous and liquid hydrocarbons are being formed at the rates that becomes geologically significant when the burial temperature are in the range of 80 -120 ^{o}C.
- 3.Late stage: This is the thermogenic stage C1 rich gas formation at which the gas formed are at higher temperature more than about 150oC at which the previously formed heavier hydrocarbon are converted to C1.

The natural gas has a characteristic chemical and isotropic composition, Also based on the methane content there are two types of hydrocarbon gases:

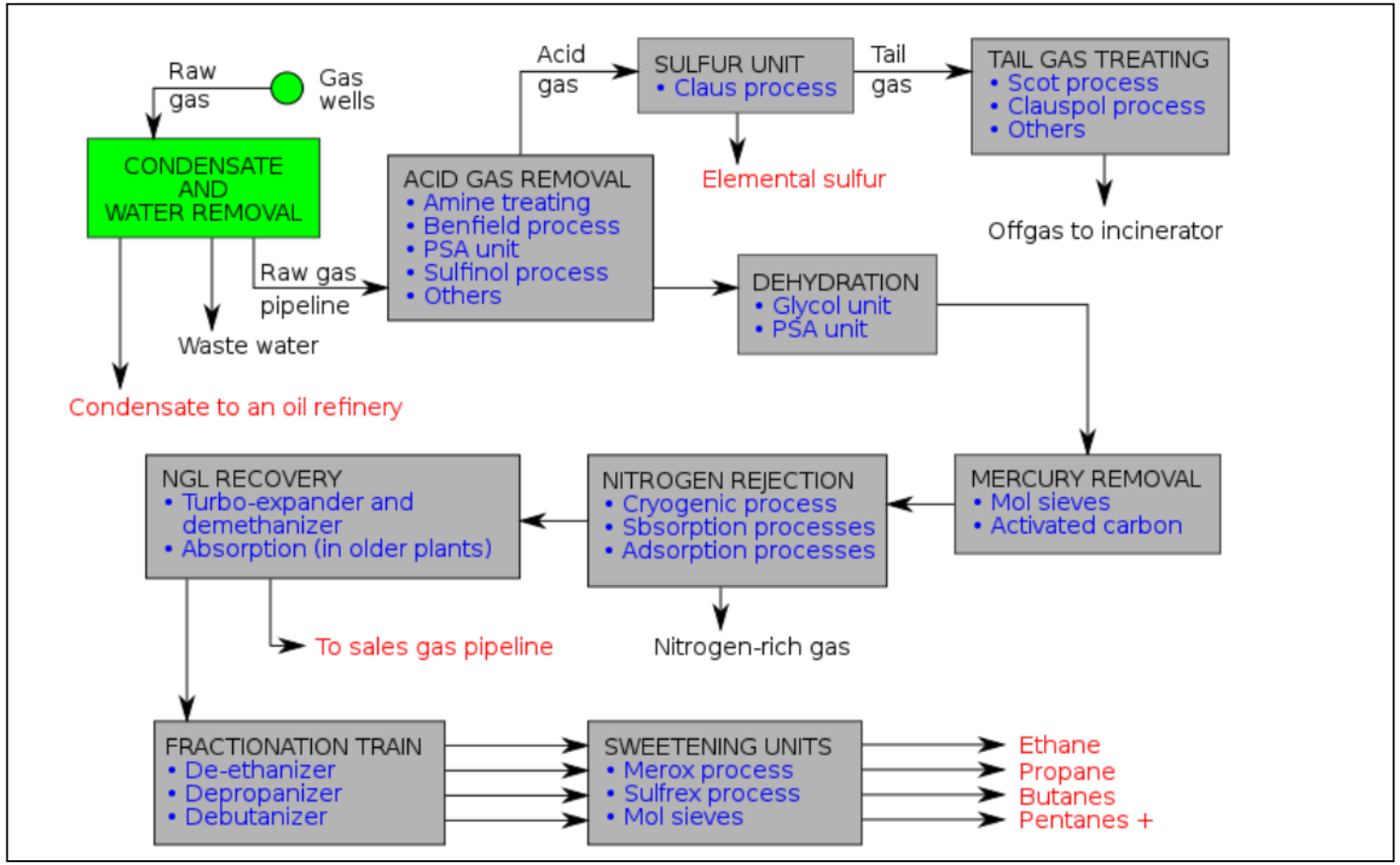
1. Biogenic gas/dry gas : Formation at shallow depth.
2. Thermogenic Gas: Lower quality gas formed at high temperature.

Wet gas on the other hand contains the compounds such as Ethane and Butane in addition to methane.

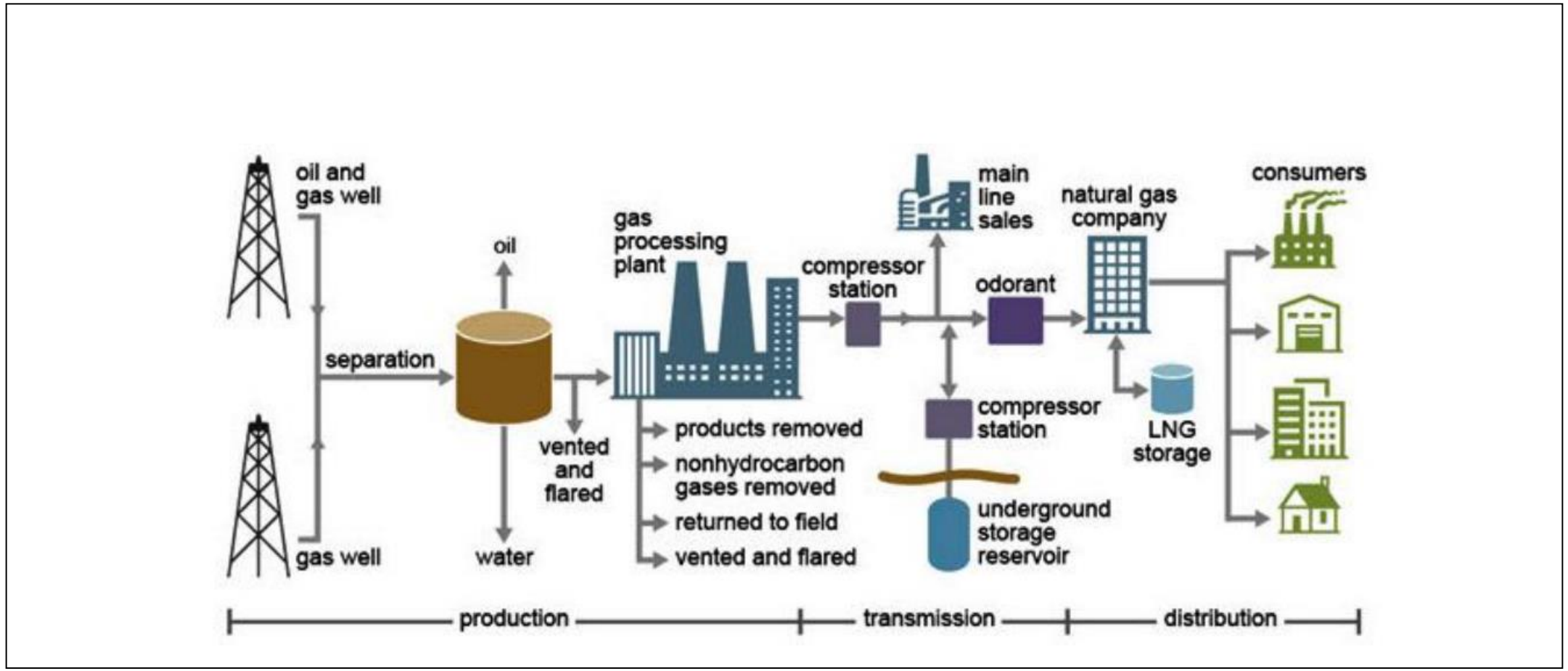
Classification of Gases

Inorganic sources	Natural Gas	Mixed Sources
Nitrogen	Organic sources	Carbon Dioxide
Inert Gases	Hydrogen	Hydrogen Sulfide H2S
Helium	Hydrocarbons	
Argon	Dry methane CH4	
Krypton	Wet gas ethane C2H6	
Radon	Propane C3H8	
	Butane C4H10	

Flow Diagram of a typical natural gas processing plant



Flow Path of Natural Gas Production and Delivery



Gas Reservoir Classification

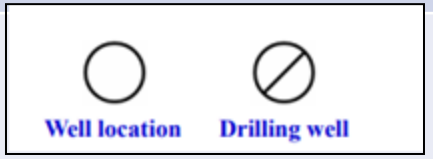
Proved Reserves	Probable Reserves	Possible Reserved
Developed Reserves	Probable Reserves	Possible Reserves
Through analysis of geological and engineering data can be estimated with reasonable certainty	A 50 % probability that the quantity actually recovered.	Equal or exceed sum of estimated proved plus probable plus possible reserves.

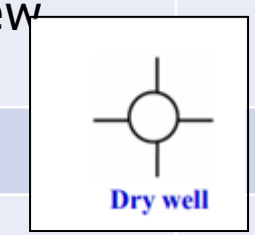
Session 6 Oil Generation

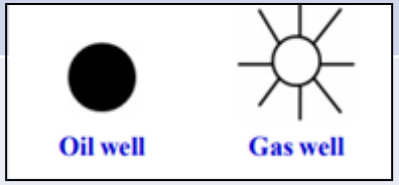
- ***What is oil generation?***
- Oil generation is the boring technique done under the earth surface layers to bring the Petroleum oil hydrocarbon to the surface and thus uses for the various engineering applications.
- The Oil well produces the oil, and the gas well produces gases.
- Also, some natural gas is being produced with the oil exploration.

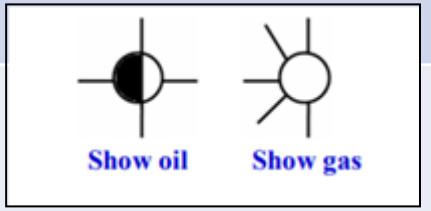
Types of Well

Wildcat well	Well Location
The first test petroleum well in a new field	
Discovery Well First successful petroleum well in a new field	Drilling Well
Dry Well	
Unsuccessful well that produces no petroleum	
Show Well	
Well found to be incapable of producing either oil or gas in sufficient quantitates to justify completion as an oil or gas well	



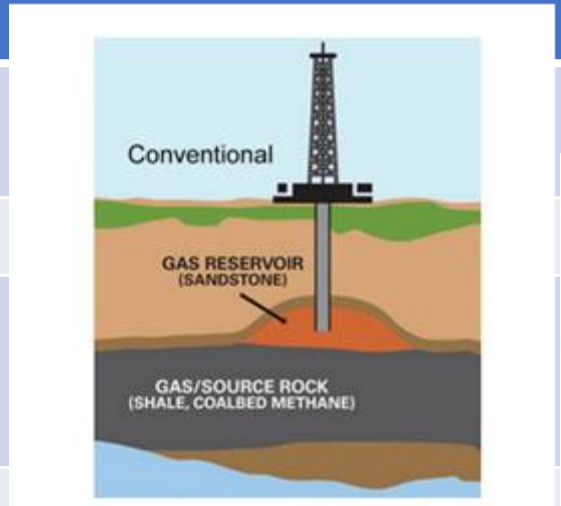


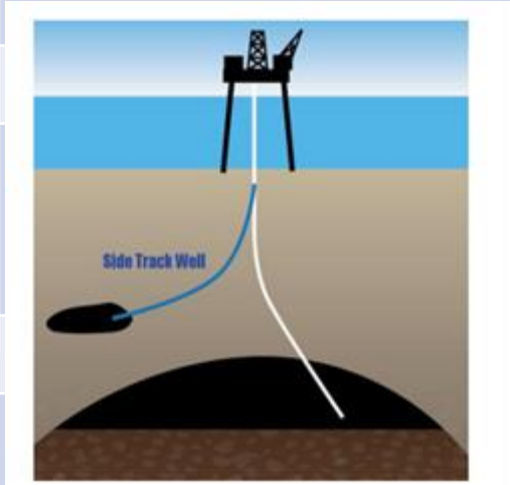




Types of Well

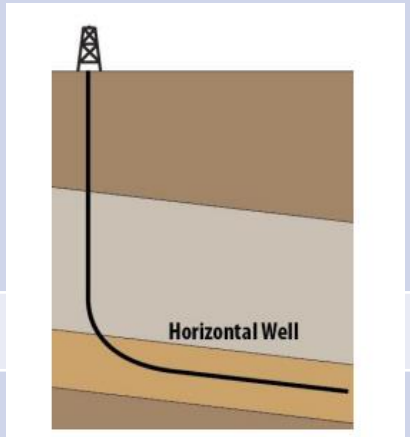
Development well
A well driven in a proven producing areas for the production of oil and gas
Conventional well
A Well location is chosen at the top of the reservoir and therefore the well is being drilled vertically to the target
Side track well
A Side track may be required if an object stuck in the original hole, which cannot be fished out

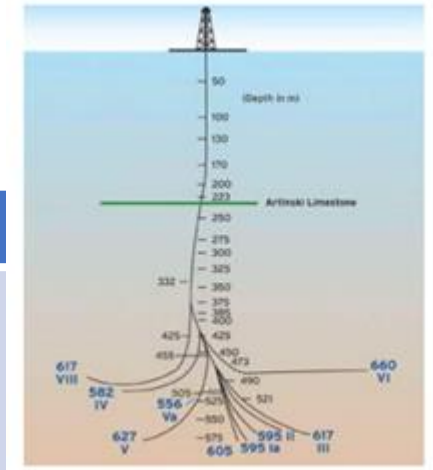


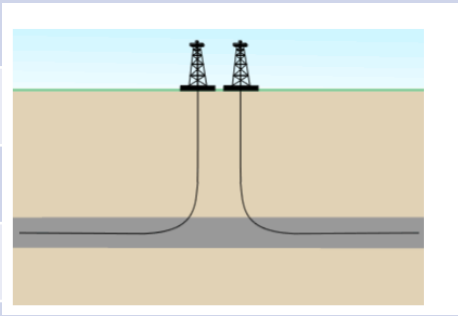


Types of Well

Horizontal Well
Horizontal well are the wells where the reservoir section is being drilled at a high angle. These wells are rarely perfectly horizontal mostly generally at an angle greater than 80o Vertically.
Designer Well
They have more than one intended target
Multilateral Well
Multilateral well are well that have more than one branch radiating from the main borehole



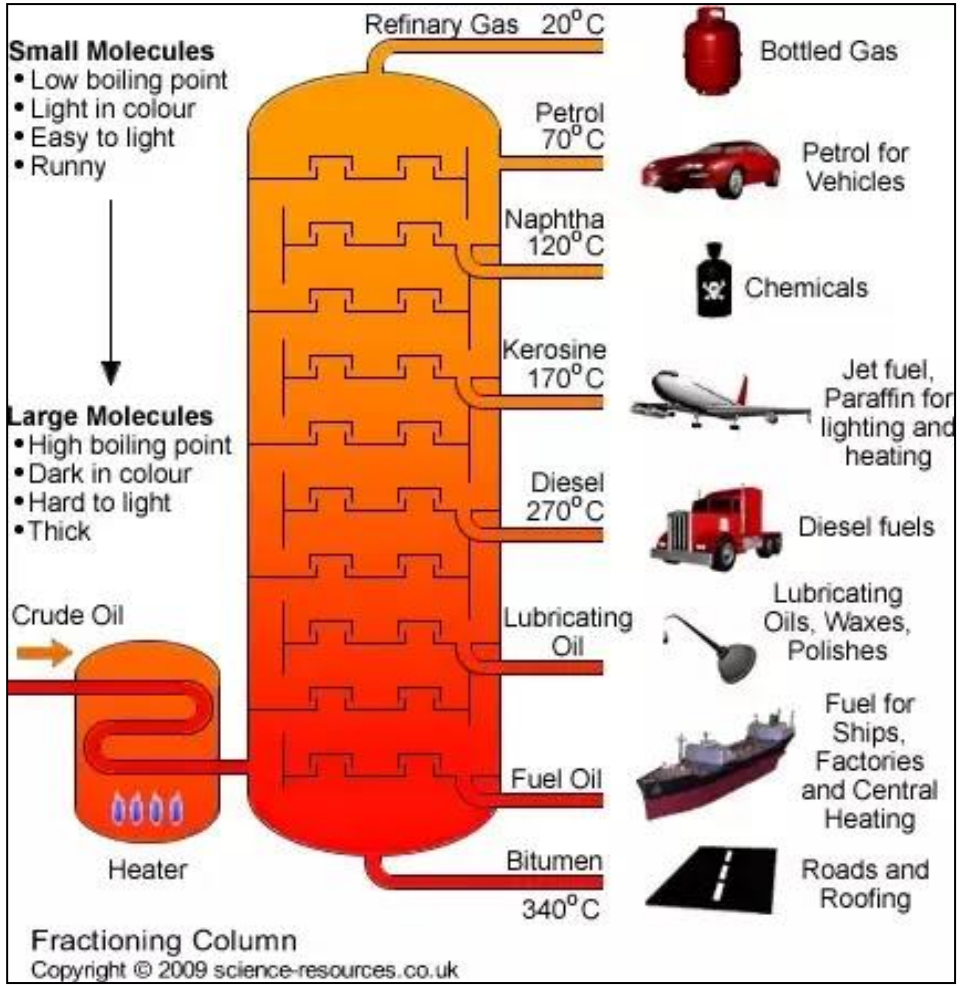




Session 7- Application for Oil and Gas

- Petrochemical, fuel gas, refinery, exploration and production, LNG (Liquid Natural Gas), Pipeline and Gas Storages are the major producers of oil and gas industry.
- These applications focuses on the upstream, midstream and downstream.
- Focus of Upstream : (i) Extract, (ii) Refine, (iii) Produce Crude oil and (iv) Natural Gas.
- Focus of Midstream : Transport
- Focus of Downstream : Chemical and Petrochemical Industry.

Fractional Distillation of crude oil



Final Products are	Products from single barrel of crude oil
Gasoline	7 % fuel Oil
Naptha	8 % Naptha
Paraffin	9 % Kerosene
Diesel	10 % other products
Fuel Oil	15 % LPG
Lubricating Oil	27 % Gasoline
Bitumen and Petroleum Gas	32 % Diesel Fuel

Fractions of crude oil and their properties

Name	Number of carbon atoms	Boiling Point (oC)	Application
Refinery Gas	3-4	Below 30	Bottled gas
Gasoline	7-9	100-150	Fuel for car engine
Naptha	6-11	70-200	Solvent and used in gasoline
Kerosene (paraffin)	11-18	200-300	Fuel for aircraft and stoves
Diesel Oil	11-18	200-300	Fuels for road vehicles and trains
Lubricating oil	18-25	300-400	Lubricant for engine and machines
Fuel Oil	20-27	350-450	Fuels for ships and heating
Grease and Wax	25-30	400-500	Lubricants and candles
Bitumen	Above 35	Above 500	Road Surface and Roofing.

The upstream segment of the oil and gas industry contains exploration activities (i) Geological Survey , (ii) Obtaining land rights and production activities including onshore and offshore drilling.

Natural Gas can be found in both association formations, meaning it is formed and produced with oil and nonessential reservoirs.

Gas can either be dry methane or wet exists with other hydrocarbons like butane.

The advent of shale gas in the United states country is the biggest breakthrough in the history of energy industry. Using horizontal drilling and hydraulic fracture.

Products of Petroleum and its Applications

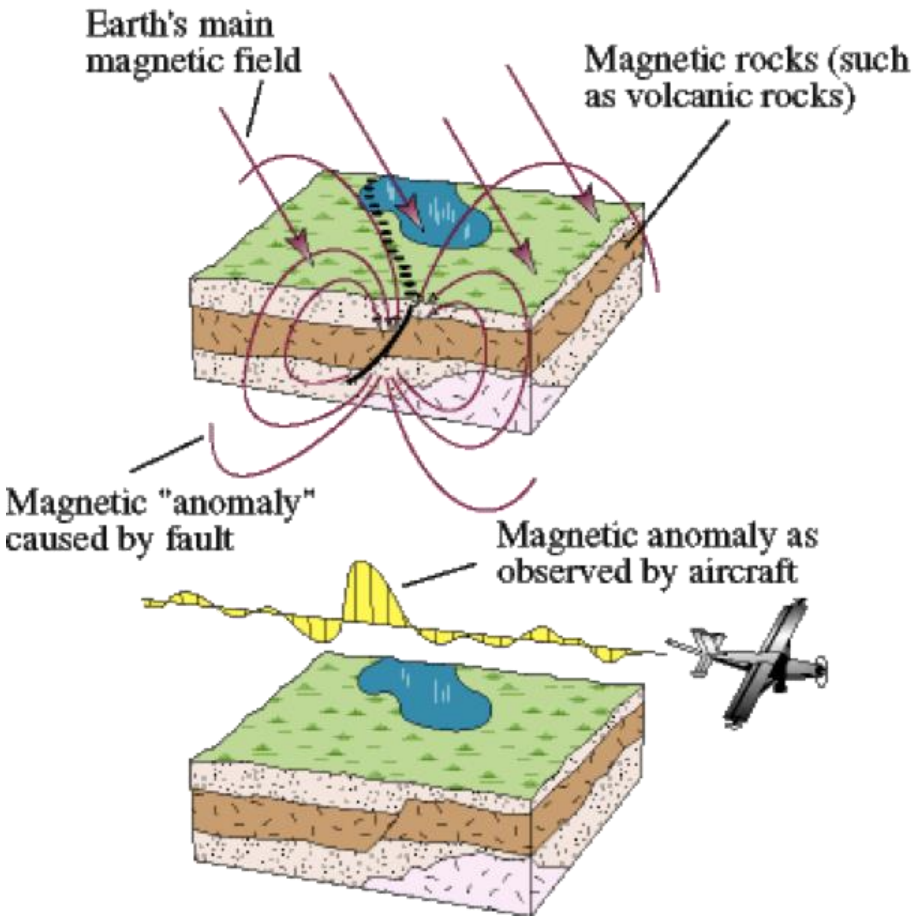
Petroleum Products	
LPG	A mixture of certain light hydrocarbon derived from petroleum which are gaseous at normal ambient temperature and atmospheric pressure but condense to the liquid state at ambient temperature. Commercial butane , butane propane mixture
Napthas	Fertilizer and petrochemical industries
Motor spirit	Internal combustion engines
Motor Spirit Additives	Enhances the fuel properties
Kerosine	Carbon number varies from 10-14 Compounds (i) Paraffins (ii) Napthenes (iii) Aromatics (iv) non hydrocarbon compounds sulphur, nitrogen, oxygen and metals
Aviation turbine fuel	Aircraft engine, fuel contains high thermal stability.
Diesel fuels	Automotive purposes, buses, lorries, diesel locomotives,
Lubricating oils	Automotive engine oils, Automotive gear oil, Hydraulic oils, Turbine oils, Cylinder Oils, Axle oils, Low Viscosity Index, High Viscosity Index oil.
Metal working oils	Cutting and forming of metals, rolling oils.
Petroleum wax	

Session 8 – Major Exploration Technique

- There are three primary methodologies used for finding hydrocarbons in the subsurface:
- 1. Geophysical.
- 2. Remote sensing.
- 3. Wildcating.

Deciding where to drill may be as much of an art as it is a science. The primary search for hydrocarbon frequently begins with observation of surface terrain.
Location of the faults at the surface are very important because they indicate where the potential structural trap may lie beneath the surface in reservoir rocks.

Major Exploration Techniques



- Direct Indications
  - Surface Data
  - Field Geology
- Airborne Imagery
- Gravimetric Methods
- Magnetic methods
- Seismic Methods

Geophysical Techniques

- Geophysical Techniques used for petroleum exploration utilizes equipment to measure : (i) Electrical current, (ii) Gravitational and magnetic anomalies, (iii) Heat Flow, (iv) Geochemical Relationship and (v) Density variations all these within the Earth.
- Each of these techniques records different set of characteristics for location of hydrocarbons beneath the surface of the earth.

Remote sensing

- Remote Sensing (RS) is the use of aerial photographs to locate and map surface features. Increasing use of satellite imagery is being made because it shows large areas on the surface of the earth.
- Even though the photographs are taken form several hundred miles up in space, they are able to show features only a few feet in size. And satellite imagery not only indicates what the human eye can see, but they can also reveal subtle variations in soil moisture, mineral and vegetation distribution, and soil type, all of which are import pieces to the exploration puzzle.
- Once an area is selected and the satellite imagery obtained, the exploration geologist utilizes mapping techniques to produce a geologic map (a map that indicates geological structures by using conventional symbols) for the area. The series of lines and arrows indicate the type of structure that exists at the surface. For example, , taken in November 1972 by a NASA satellite orbiting over 500 miles out in space, shows the surface topography very clearly for an area in Southeastern Oklahoma known as the Ouachita Mountains.
- These mountains are comprised of folded and faulted Paleozoic strata which are buried beneath younger sediments toward the south. These mountains are made of a combination of structures called anticlines, synclines, and faults, all of which form various types of hydrocarbon traps.
- Another type of RS technique uses imagery that was created from a radar looking at the ground called Side Looking Airborne Radar (SLAR). Some of this imagery is flown with an aircraft while some of it is onboard satellites or the US Space Shuttle. It produces an image much like a photograph that also shows earth structure at the surface.
- Until this SLAR image was made, there were no accurate maps of the region because the area is usually covered by clouds. But now, there are new opportunities based on this image.

Wildcat

- A wildcat well is one that is drilled in a new area where no other wells exist and generally with scant information. It is drilled in an effort to locate undiscovered accumulation of hydrocarbons. About 1 in 10 wildcat wells strike oil or gas, but only one in perhaps 50 locate economically significant amounts. Many wildcat wells are drilled on a hunch, intuition, or a small amount of geology. Many times they are based on photography and experience in a particular area. Wildcat wells are generally drilled at a smaller diameter than normal because this saves money (the average onshore well at present costs about 10 MM dollars to drill).

- One of the earliest exploration tools was referred to as Creekology, discussed earlier. But recent technological advances have lead to computer-enhanced capabilities using laptops that has had a major affect on the petroleum industry. New seismic techniques, for example, have created more mobile, less expensive, and easier to operate exploration tools that has created a wealth of information designed specifically for hydrocarbon exploration. Field equipment is smaller, lighter, more accurate and reliable and provides far greater detailed data.

- But the basic tool needed for the search for hydrocarbons still remains a knowledge of the Earth and earth processes of formation, lithology, and structure. But even with all of this, wildcat wells are still drilled, but their success rate is substantially lower than a well spudded in (to begin a new well) using all of the geological tools available.

Session 9 Seismic Survey

- Uses vibrations (induced by an explosion charge or sound generating equipment) to provide a picture of subterranean rock formation at depth, often as deep as 30,000 feet below the ground level.
- This is accompanied by generating sound waves downward into the earth crust which reflects off various boundaries between different rock strata.
- On land the sound waves are generated by vibrator truck, sometimes referred to as thumper which shake the ground with hydraulic driven metal pads.
- The human ear can barely hear the thump, but the frequency generated penetrates the earths crust.
- The echoes are detected by the electronic devices called geophones which receive the reflected sound waves and the data are being recorded on magnetic tape which is printed to produce a two dimensional graphic illustrating the subsurface geology.

Seismic Survey

- Offshore surveys are conducted in a slightly different manner.
- Boats tow cables containing hydrophones in the water, which is similar to geophones on land.
- Sound waves use to be created by dynamite, but this method killed a variety of sea life.
- The most acceptable method today is to generate sound waves using pulses of compressed air which creates large bubbles that burst beneath the water surface creating sound.
- The sound waves travel down to the sea floor, penetrate the rocks beneath, and return to the surface where they are intercepted by the hydrophones.
- Processing and illustration is the same as the dry land method.

Seismic Survey

- The most sophisticated seismic surveys are three-dimensional (3-D).
- The recorded data is processed by computer and the results are a detailed, 3-D picture of the formations and structures below the surface.
- The process is expensive, on the order of $30,000 per mile (Satterwhite, pers comm).
- But drilling a well can cost multiple millions of dollars, so time and money spent on accurate seismic surveys can be a good investment since it helps locate prospects and minimize dry holes.
- In general, seismic surveys can be carried out without disturbing people or damaging the environment, whether they are being conducted on land or water.
- It is a primary tool used by exploration geologists to locate [hydrocarbon] prospects.

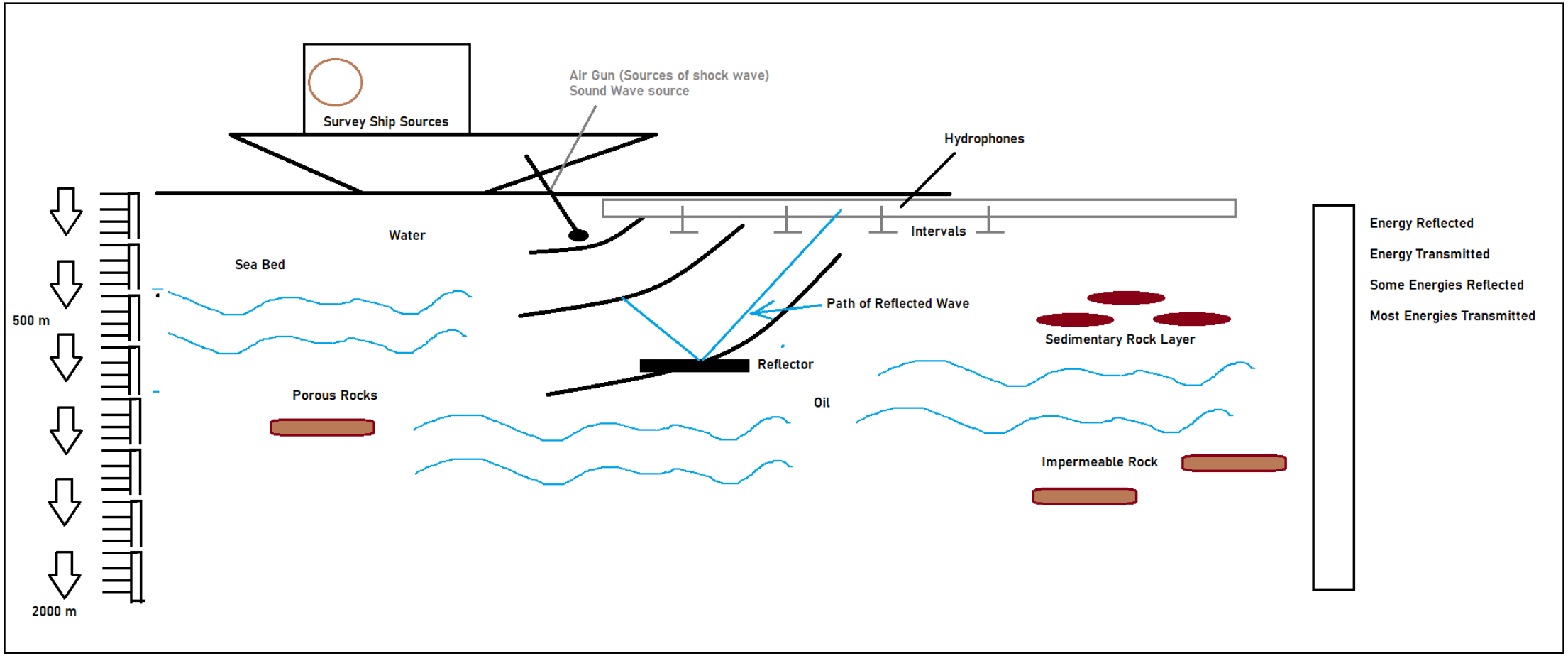
Seismic Survey

- There are a number of other geophysical techniques such as magnetometers and gravimeters, and geochemical prospecting, a relatively new technique.
- A magnetometer is a device that is pulled behind an airplane on a long cable that detects variations in the earth's magnetic field.
- Sedimentary rocks generally have low magnetic properties compared to other rock types.
- A gravimeter measures minute differences in the pull of gravity at the earth's surface.
- Mapping these differences reveals large masses of dense subsurface rock which allows geologists to have a better idea of the structures below ground.
- Geochemical prospecting uses sensitive instruments to detect minute quantities of gases that seep upward from petroleum deposits.
- This is a relatively new technique but is one that is gaining wider acceptance.

Seismic Method

- Involves measuring the propagation of seismic wave through the earth material.
- In this survey, seismic waves radiates outward from the sound source at the surface, which can be explosive charge or a mechanical impact.
- During the exploration- waves are being sent deep into the Earth and allowed to bounce back.
- Two Vibro sources working in Unison to form a seismic source array across a CO_2 sequestration site.
- The Reflected refracted seismic waves are being recorded by the receiver (Geophones or Hydrophones) in water.
- They give the first image of the sub surface.
- Acquisition system: They involve the generation of short pulse of seismic energy
- Seismometer: Energy is being detected
- They are being operating with electronic amplifier and a suitable recorder
- Reflection seismology, seismic refraction, seismic topography 2D, 3D seismic to survey for deposits from.

Seismic Method



Types of seismic survey

- 2D: In a 2D survey, one source of energy and one set of receiving provides a 2D image of the rock layer below the surface 2D survey shows one single cross section slice through the surface.
- 3D: A 3D survey is used in which a 2D survey reveals a geographical structure or elements that are suspected to contain oil or gas. It yield a more detailed picture by providing the information about a smaller area in 3 dimension.
- 4D: A 4D survey is a 3D survey repeated multiple times in order to observe change in the amount and the location of oil and gas in a particular field over a period of time.
- Marine seismic survey: During a marine survey vessel travels about five knot in a predetermined pattern and tows one or two sound source to generate a sound wave and one or several long cables or streames, contains hundreds of evenly spaced hydrophones. The position of the vessel and equipment must be controlled carefully using advanced navigation and acoustic systems, to ensure geological features are pin pointed accurately.
- Each streamer can be upto 12 kilometer long and is towed six to fifteen meter below the water surface to reduce the effects of oceans waves on the data. In the most technically advanced seismic surveys upto 12 streamers are towed at the same time, each about 50 to 150 meter apart.
- A seismic acoustic source array emits a sound that last less than 0.1 second. It is typically repeated every ten to fifteen seconds as the seismic vessel moves along a straight data acquisition line at a speed of about 5 knots for many kilometers. After which the vessel will move to another acuquistion line and may return to the area many hours later.

Some features of Seismic Methodology

- Involves measuring the propagation of seismic wave through the earth material.
- In this survey, seismic waves radiates outward from the sound source at the surface, which can be explosive charge or a mechanical impact.
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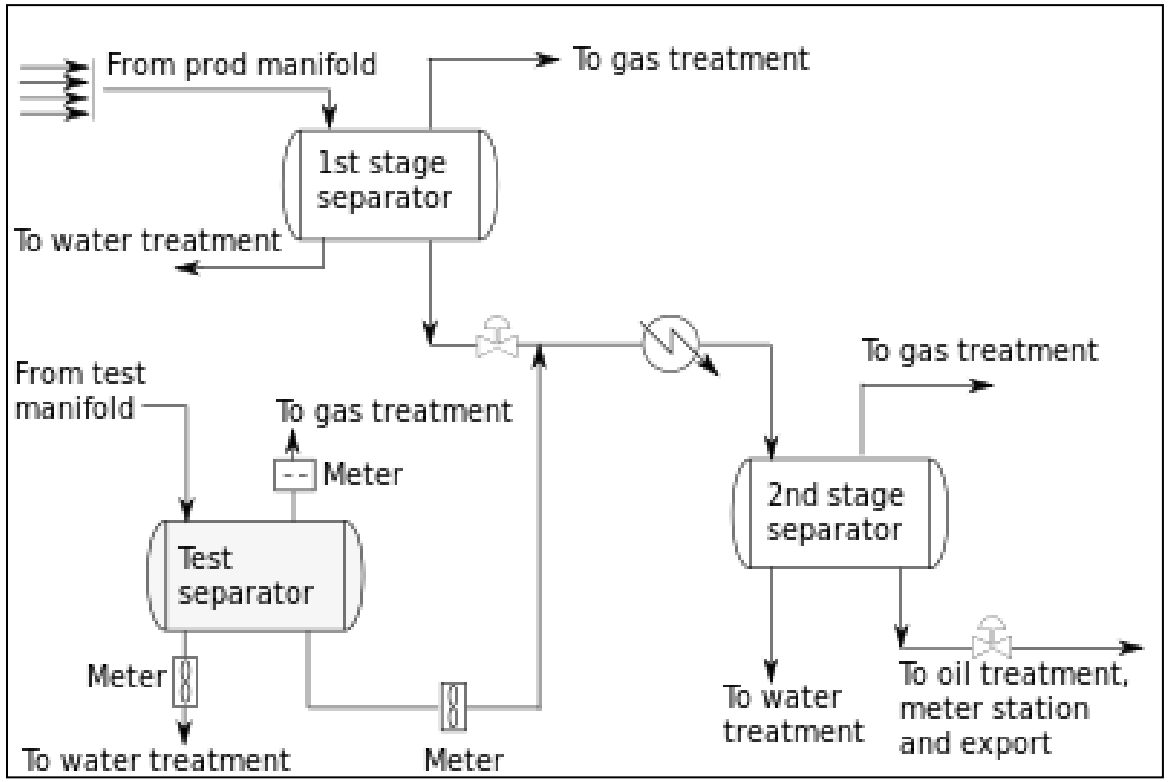
Session 10 - Well Testing

- Time period in which the production of the well is being measured with the portable devices such as well test equipment or in the construction capacity. For successful well testing certain parameters are very important such as:
- (i) Measure of time
- (ii) Rate
- (iii) Pressure
- (iv) Control Rate
- There are other parameters such as the Flow conductance, Skin Factor, Storativity, Drainage devices. The purpose of well testing to find out the fluid or gas at below the earth conditions including the chemical properties and physical properties. The Thermodynamics properties plays significant role for flow characteristics in the well testing.

Types of Well Testing Methodology

Flow Test	**Providing an indication of the potential productivity of the reservoir to be explored, Measurement or estimate of initial or average reservoir pressure.**
RFT	Repeat formation tester designed to measure formation pressure, Also the measure the formation pressure downhole via wireline.
Drill stem test	Drilling rig onsite and the string through which the well is produced is manipulated by the drilling rig.
Draw down test	Rate is held constant.
Multi Rate test	Rate variation, kh product, boundary configurations, skin, FE, PI
Production test	Run for longer period of time
Buildup test	Well designed, shut down pressure recorded
Banker test	Adequate rates can be obtained
Interference test	Large scale reservoir, directional permeability and reservoir storativity.

Schematic Layout of Well Testing

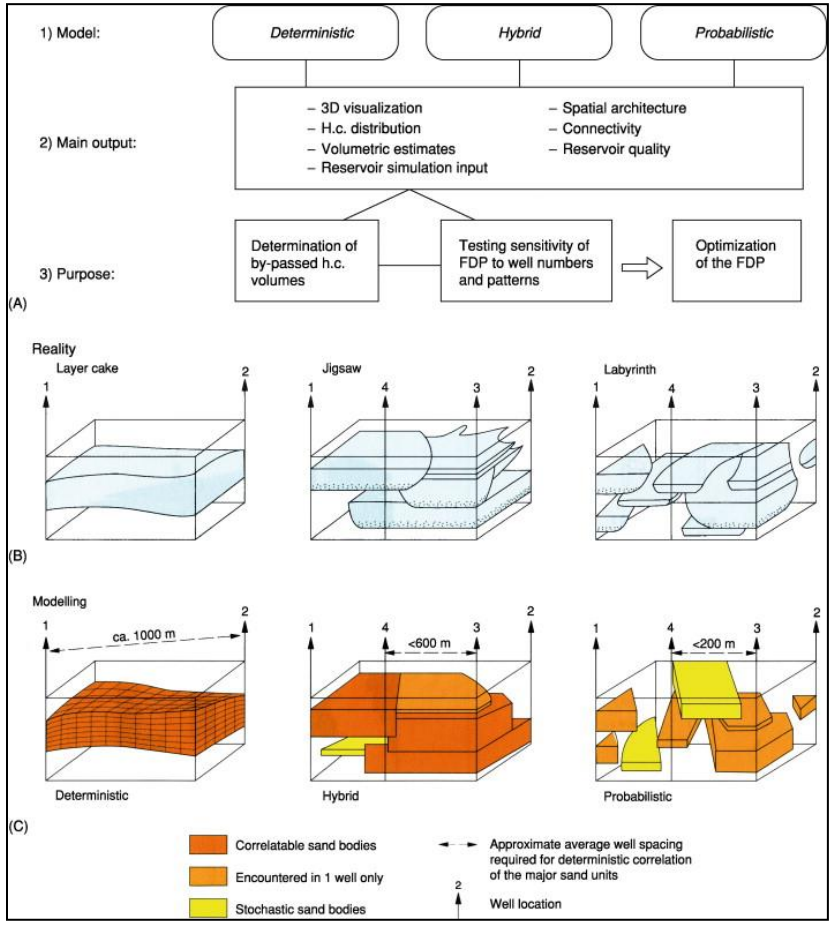


- ✓ A plant is receiving a multi phased flow of oil and gas from many wells via a manifold.
- ✓ Flow from one well only may be taken to the test separator (shaded).
- ✓ The test separator has the feature to separate gas and water from the oil, and to have each component measured, under different conditions.

Session 11 – Basics of Reservoir Engineering and Modelling

- For 3D reservoir the modelling depends on the reservoir types. For the layer cake reservoir, the deterministic model can be made from well to well relations and also the rock properties has to be determined. The Computer systems have been developed to generate a series of equally probable 3D model throuht the probabilistic modelling techniques.
- The working of the reservoir engineering and the modelling can be worked based on the three techniques such as:
- 1. The correlatable reservoir bodies are determined and incorporated in the model.
- 2. Characteristics variograms for the thickness distribution of genetic sand body types in different orientations related to their expected trend.
- 3.When the well spacing is large there are smaller or narrow reservoir bodies not penetrated by wells.
- The Jigsaw type reservoir are also difficult to correlate in the appraisal stage and probabilistic modelling is being required.

Three-dimensional reservoir modelling techniques illustrated through the layout



The designed architectural model can be compared with the seismic model and comparison can be developed.

The prediction in the model can be time effective and the designed principle on which the model is being suited is architected and developed.

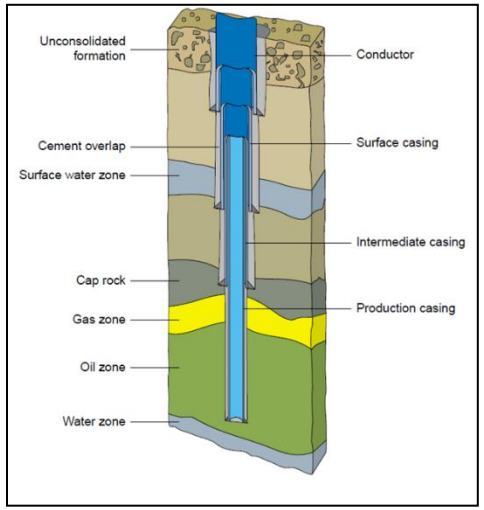
With respect to the geographical and geological anomalies the model can be predicted.

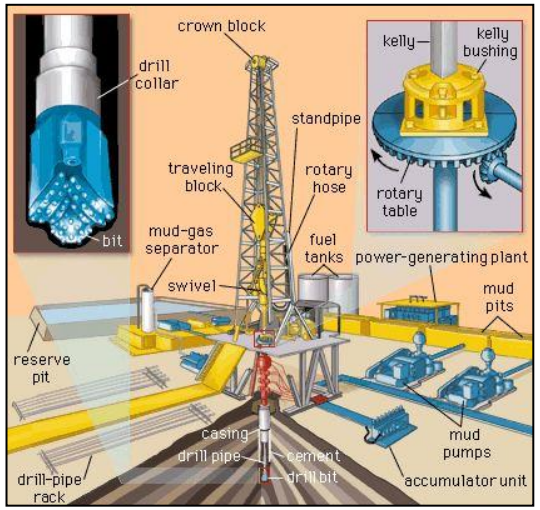
Therefore these 3 D models can be selected ranging the variation in the reservoir and with respect to the number of hydrocarbon volume, connectivity, architecture and permeability distribution.

Session 12- Well Drilling and Production

- The reserves are safely developed and maximizing the potential of its existing producing assets in gulf countries including Gulf of Mexico, Brazil and Venezuela. Drilling a safe deep water well takes years of planning and preparation.
- After Identifying the potential of oil and natural gas reservoirs beneath the seafloor using seismic technology (i) A drill site is been selected. In an exploratory path the seafloor location is generally direct above the reservoir.
- A drilling rig is required to drill a well, in deep water the rig may be on one of the three vessels (i) A drill ship , (ii) a semisubmersible vessel (iii) a part of a floating production platform. All the rigs have an hoisting system to raise and lower the drill pipe and tools needed to drill the pipe.
- A BOP Blow out Preventer or BOP stack and a pumping system to circulates the fluids in and out of the well while drilling. A hole is being drilled using drill bit, this initial step is called **spudding** in the well.
- Material : The shallow sediments just below the seafloor are often very soft and loose to kkep the well from caving in and carry the weight of the well head, a large diameter base pipe or casing is drilled or jetted into place. The base pipe is being assembles at this rig floor and a drill bit connected to a drill pipe is run thru the inside to the bottom of the casing.
- The entire assemble is lowered to the seafloor by the rig hoist. At the sea floor the driller spuds the assembly into the seafloor sediments then it turns on the pump. Water or drill fluid is being used to Jet the pipe into place until the well head is just above the seafloor.

Wellbore systems description mechanism





With the base pipe and the well head at the right depth the driller will release the bit and drill string from the jet pipe and drill ahead. While the well bore is being drilled mud is pumped from the surface down through the inside of the drill pipe, the mud passes through the jets in the drill bit, and then travels back to the seafloor through the space between the drill bit and the walls of the hole.

Purpose of Drilling Mud

- (i) Lift rock cutting from well bore.
- (ii) Keep the drill bit cool and lubricated
- (iii) Fill the bore with fluid to equalize pressure and prevent water and other fluids from flowing into the well bore. (The mud is a friendly water based mixture of clay for thickness or fine ground rock or barite for weight.
- At the planned depth the driller will stop the drilling and pull the bit out of the hole, a smaller pipe or casing string is then screwed together connected to the drill pipe and run down to the seafloor and into the well. To permanently secure the casing in its place, cement followed by the pumped down the inside of the drill pipe. To separate the cement from the mud a cementing plug is being used.

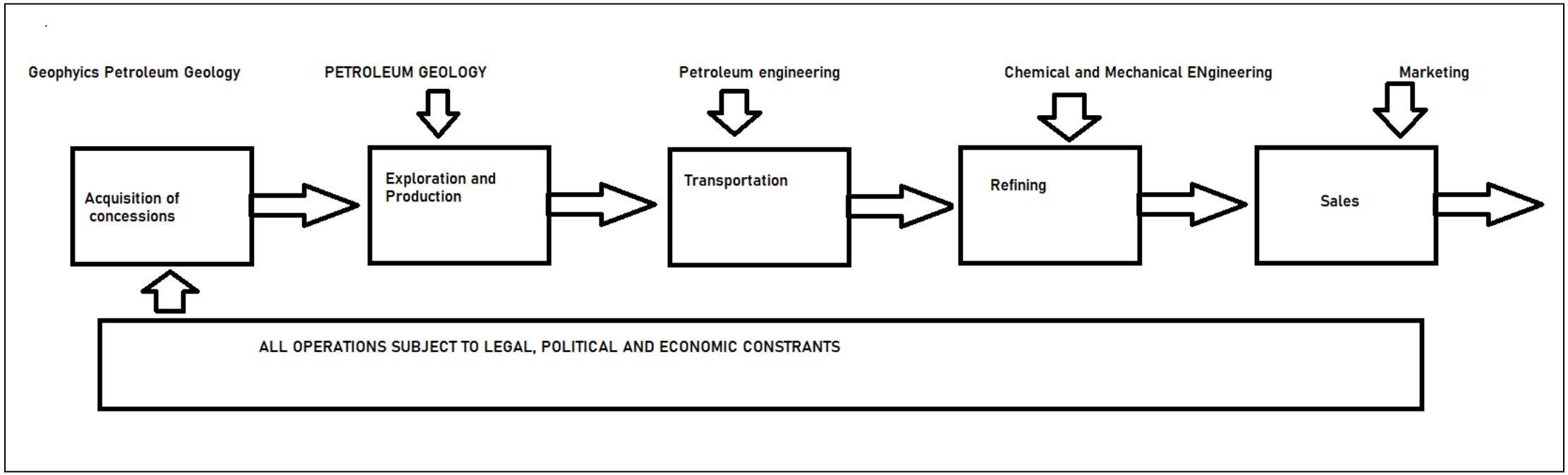
Purpose of Drilling Mud

- The plug is pushed by the mud to ensure the cement is placed outside the casing filling the annular space between the casing and the open hole wall. On some locations a second surface casing is needed, thus the well is drilling even deeper, the same procedure used in the last hole section. At this part of the well the pressure may be too high to continue with simple water-based clay mud or there may be the potential to encounter oil or gas. Below this point a blowout preventer with a riser will be installed at the seafloor. The BOP stack is a massive system of valves and rams that protects the rig and environment from oil and gas flows should the weight of the mud be low. The BOP stack is connected to a pipe called a riser. The riser connects the rig with the well and allows us to circulate the drilling fluid and rock cuttings all the way back to the rig on the surface.
- The BOP stack is fully tested before we drill further. Drilling now resume with the drill bit and drill pipe always operating through the BOP stack.
- When the geologist gives green signal to the foundation of oil or gas then a final casing may be installed if the seafloor location is favorable for future development. This final casing givens sustainable technology for the oil and natural gas.

Day 3 –Session 13- Petroleum Geology

- Petroleum geology is the application of geology i.e. the study of rocks to the exploration for and production of oil and gas.
- Geology is based on the chemistry, physics and biology, involving the application of essentially abstract concept to the observed data.
- The preceding discussion shows how the petroleum exploration has advanced over the years as various geological techniques were been developed.
- Its now appropriate to consider more details the role of chemistry, physics and biology in petroleum engineering.

Layout of Petroleum Geology



The flowchart how petroleum geology is the only one aspect of petroleum exploration and production and how these enterprises themselves are part of a continuum of events subjects to various constraints and expedited by many disciplines.

Chemistry and Petroleum geology

- ✓ The application of chemistry to the study of rocks i.e. geochemistry has many uses in petroleum geology.
- ✓ Detailed knowledge of the mineralogical composition of rocks is important at many levels. In the early stage of exploration, certain general conclusions as to the distribution and quality of potential reservoirs could be made from their gross lithology. For examples the porosity of the sandstones tends to be facies related.
- ✓ Detailed knowledge of minerology of reservoir enables estimates to be made of the rate at which they may lose porosity during burial and this detailed minerology information is essential for the accurate interpretation of geophysical well logs through reservoirs.
- ✓ Knowledge of the chemistry of pore fluids and their effects on the stability of minerals can be used to predict where porosity may be destroyed by cementation, prescribed in its original form, or enhances by the solution of minerals by formation waters.
- ✓ Organic chemistry involved both in the analysis of oil and gas and in the study of the digenesis of plants and animals in sediments and the way in which the resultant organic compound, kerogen, generate petroleum.

Physics and Petroleum Geology

- ✓ The application of physics to the study of rocks i.e. geophysics is very important in the petroleum geology.
- ✓ In its broadcast application geophysics makes a major contribution to understanding the earths crust and especially through the application of modern plate tectonic theory, to the genesis and petroleum potential of sedimentary basins.
- ✓ More specifically, physical concepts are required to understand the fold, faults and diapirs, and hence the roles in petroleum entrapment.
- ✓ Modern petroleum exploration is unthinkable without the aid of magnetic gravity and seismic surveys in finding the potential traps.
- ✓ Nor could any find be evaluated effectively without geophysical wireline well logs to measure the lithology, porosity and petroleum content of a reservoir.

Biology and Petroleum Geology

- ✓ Biology is applied to geology in several ways notably through the study of fossils paleontology and is especially significant in establishing biostratigraphy zones for regional stratigraphical correlations.
- ✓ The way in which oil exploration shifted the emphasis from the use of macrofossils to microfossils for zonation has already been noted.
- ✓ Ecology the study of living organism is also important in petroleum geology.
- ✓ Carbonate sediments in general and reefs in particular can only be studied profitably with the aid of detailed knowledge of the ecology of modern fauna and flora.
- ✓ Biology and espacillay biochemistry is important in studying the transformation of plants and animal tissue into kerogen during burial and the generation of oil or gas that may be caused by this transformation.

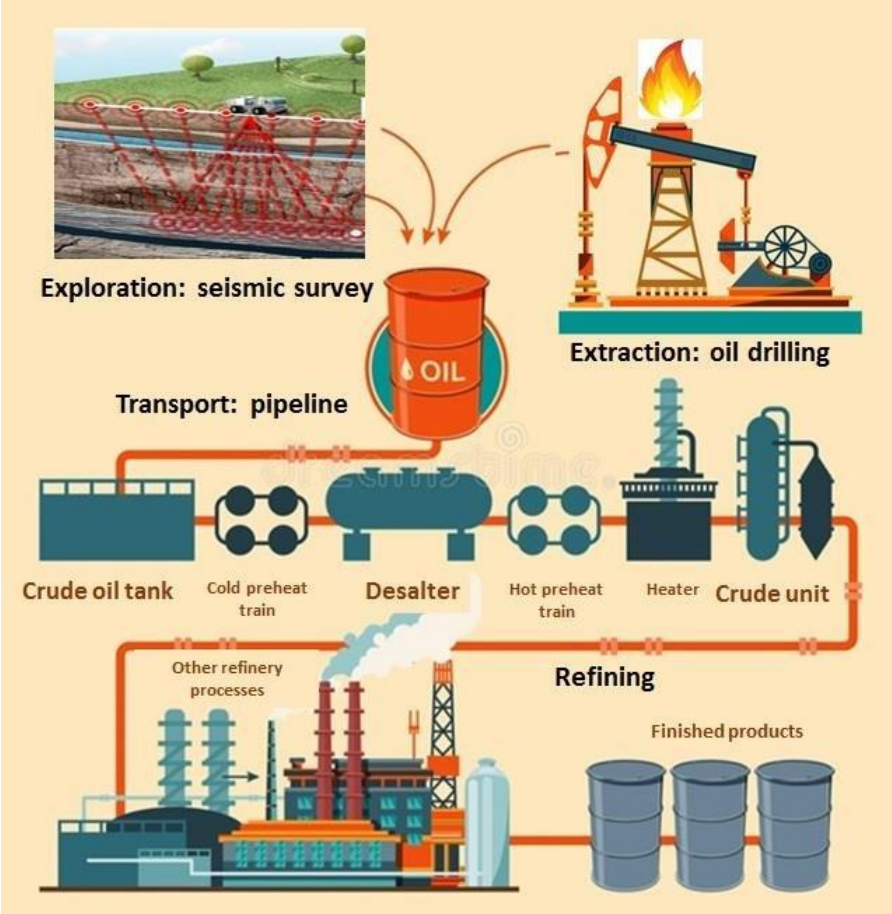
Relationship of Petroleum Geology to Petroleum Exploration and Production

- Petroleum geology is only one aspect of petroleum exploration and production.
- Petroleum exploration now involves integrated teams of people possessing a wide range of professional skills. Geophysical surveying is involved in preparing the initial data on which leasing and later drilling recommendations are being based. Geology concepts are applied to the interpretation od the geophysical data once they have acquired and processed. As soon as oil well has been drilled, the engineering aspects of the discovery needs appraisal.
- Petroleum engineering is being concerned with establishing the reserves of a field, the distribution of the petroleum with in the reservoir and the most effective way of producing it.
- Thus petroleum geology lies with a continuum of discpliles, beginning with geophysics and ending with petroleum engineering, but overlapping both in time and matter.
- Underlying this sequence of events it's the fundamental control of economics. Oil companies exista not only on the oil and gas but also business enterprise to make money. Thus every step of the journey from leasing to drilling and to production and finally to enhance the recovery, its monitored by accountants and economists.
- Activity in the petroleum exploration and production accelerates when the world price of the petroleum increases and its deceases when the prices drops. With an endless supply of taxpayers money to sustain them, the politically expediency of searching for indigenous petroleum reserves may outweigh any economic consideration.

Session 14 – Production Technology

- Crude oil is extracted through the wells and further processed for production of various products, there are various stages through which the crude oil functions
- **Crude Oil Desalting and Distillation:**
- Crude oil before the separation in various products are first treated to remove the corrosive salts. The desalting process also removes some of the metals and suspended solids which causes catalyst deactivation. The process of desalting involves the mixing of the heated crude oil with water (about 3-10% of the crude oil volume) so that the salts may be dissolved in water. The water may be separated from the crude oil in a separating vessel by adding demulsifier chemicals to assist natha from the FCC and cooking units.
- The by product of steam cracking of naptha or light hydrocarbon during the production of ethylene and propylene, catalytic dehydrogenation of isobutane and conversion of tertiary butyl alcohol recovered as a by product in the manufacturing of propylene oxides. Several different processes are currently is use to produce MTBE and TAME from isobutylene and methanol. Most processes use a two stage acidic ion exchange resin catalyst. The reaction is exothermic and cooing to the proper reaction temperature is critical in obtaining the optimal conversion efficiency. The process usually produces an MTBE and TAME stream and a relatively small stream of unreacted hydrocarbon and methanol. The methanol is extracted in a water wash and the resulting methanol water mixture is distilled to recover the methanol for recycling.

Petroleum Production Technology



- The study of Petroleum Production Includes: Geology, the science of Rock cycle, Oil, gas and water deposits.
- The study of oil and gas composition and oil generation methods and techniques.
- Major Exploration techniques include seismic methods, well testing, basics of reservoir engineering and modelling and simulations.
- The technology includes supercomputers for the analysis of exploration data and simulation behavior.
- The Technology includes maximization in oil production and gas production in very cost-effective manner.

Production Technology- Blending

- Blending is a final operation in petroleum refining process.
- It consist of mixing the products in various proportions to meet requirement usually produces an MTBE and TAME stream and a relatively small stream of unreacted hydrocarbon and methanol.
- The methanol is extracted in a water wash and the resulting methanol water mixture is distilled to recover the methanol for recycling.

Blowdown systems

- Most refinery process units and equipment's are manifold into a collection unit called the blowdown system. The Blowdown system provides for the safe handling and disposal of liquids and gases that are either automatically vented from the process units through pressure relief valves or that are manually drawn from units. Recirculated process streams and cooling water streams are often manually purged to prevent the continued build up of contaminants in the stream. Part or all of the contents of equipment can also be purged to the blowdown system prior to shutdown before normal or emergency shutdowns.

- The Blowdown system uses a series of flash drums and condensers to separate the blowdown into its vapors and liquid components. The liquid is typically composed of the mixtures of water and hydrocarbons containing sulphides, ammonia, and other contaminants which are sent to the wastewater treatment plants. The gaseous components typically contains hydrocarbons, hydrogen, sulfide, ammonia, mercaptans, solvents and other constituents and is either discharged directly to the atmosphere or is combusted in a flare. The major air emission from the blow down systems are hydrocarbon in case of direct discharge to the separator which may contain disulfides.

Dewaxing of Lubricating Oil

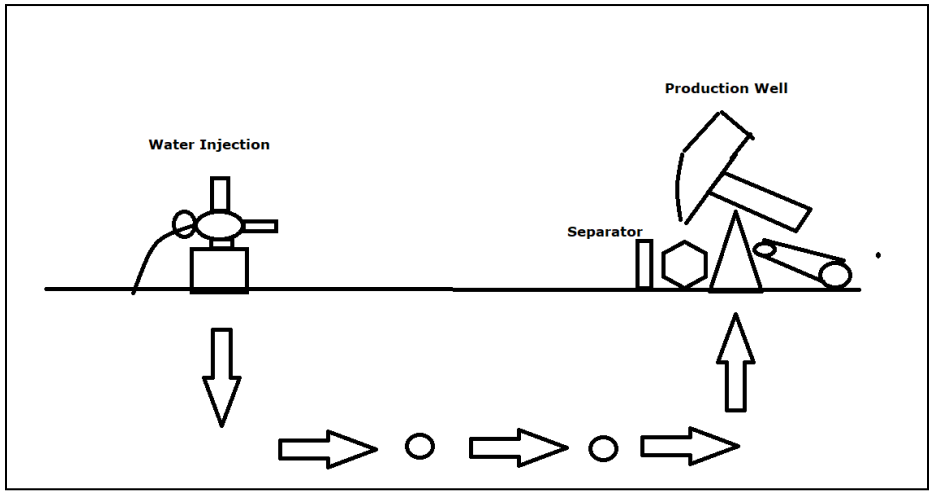
- Dewaxing of the lubricating oil is necessary to ensure that the oil will have proper viscosity at lower ambient temperature.
- Two types of dewaxing processes are used: selective hydrocracking and solvent dewaxing.
- In selective hydrocracking one or two zeolite catalyst are used to selectively crack the wax paraffins.
- Solvent dewaxing is more prevalent. Insolvent dewaxing the oil feed is diluted with solvent to lower the viscosity, chilled until the wax is crystallized and then filtered to remove the wax.
- Solvents used for the process includes propane and mixture of methyl ethyl ketone (MEK) with methyl isobutyl ketone (MIBK) and MEK with toluene. Solvent is recovered from the oil and wax through the heating and two stage falsing followed by steam stripping.
- The solvent recovery stage results in solvent contaminated water typically is send to the wastewater treatment plant.
- The wax is either used as feed to the catalystic cracker or is deoiled and sols as industrial wax.
- Air emission may arise from fugitive emissions of the solvents

Various other Production Techniques

1. Propane DE asphalting
2. Supporting Operations
3. Wastewater treatment
4. Gas Treatment and Sulphur Recovery
5. Blending
6. Storage Tanks

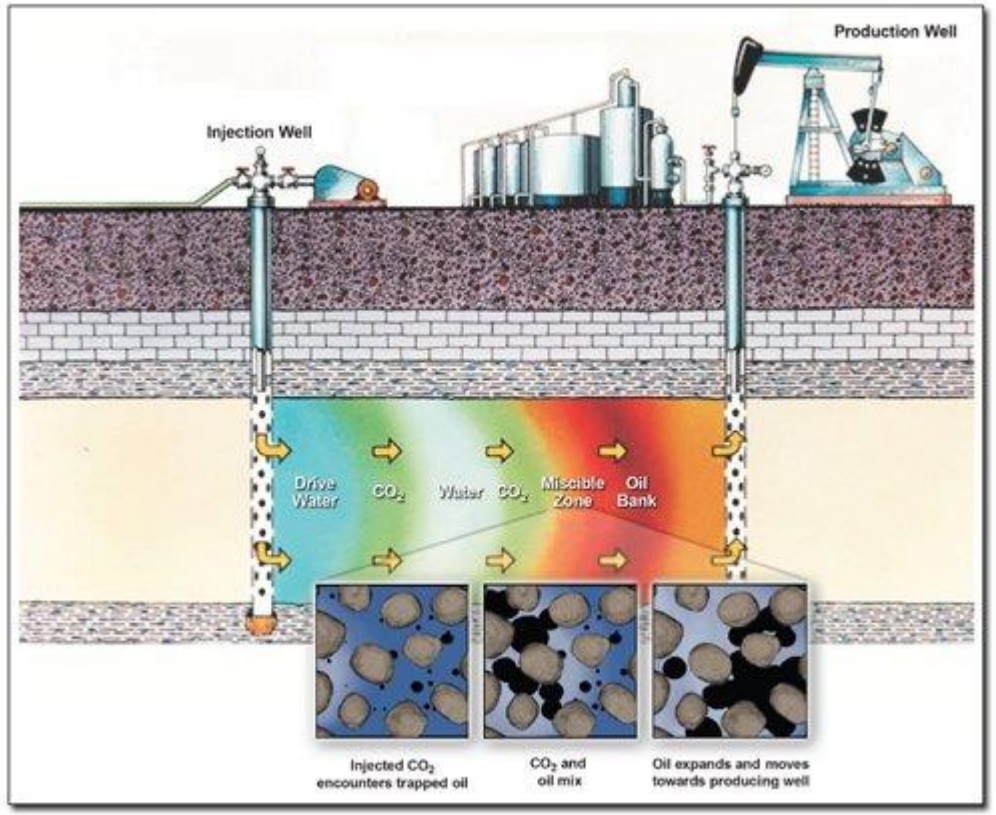
Session 15- Enhanced Recovery Techniques

- The process of extracting oil that has not already been retrieved through the primary or secondary oil recovery techniques.
- There are mainly three primary techniques such as (i) Gas Injection, (ii) Thermal Injection and (iii) Chemical Injection. The Gas injection which basically uses gases such as natural gas, nitrogen and carbon dioxide, it accounts to almost 60 % of major energy consumption countries.
- The Thermal recovery works by heating the oil to reduce its viscosity and allowing the easier gas flow to the surface.



Explanation 3 D

Enhanced Recovery Techniques



- Thermal Recovery (Injecting heat to lower Viscosity)
- Gas Injection (Injection of gases pushing the addition oil to the production wellbore)
- Chemical Injection (Injecting long chain molecules to increase the effectiveness of waterfloods
- In the U.S., there are about 114 active commercial CO2 injection projects that together inject over 2 billion cubic feet of CO2 and produce over 280,000 BOPD (April 19, 2010, Oil and Gas Journal)

Enhanced Recovery Techniques

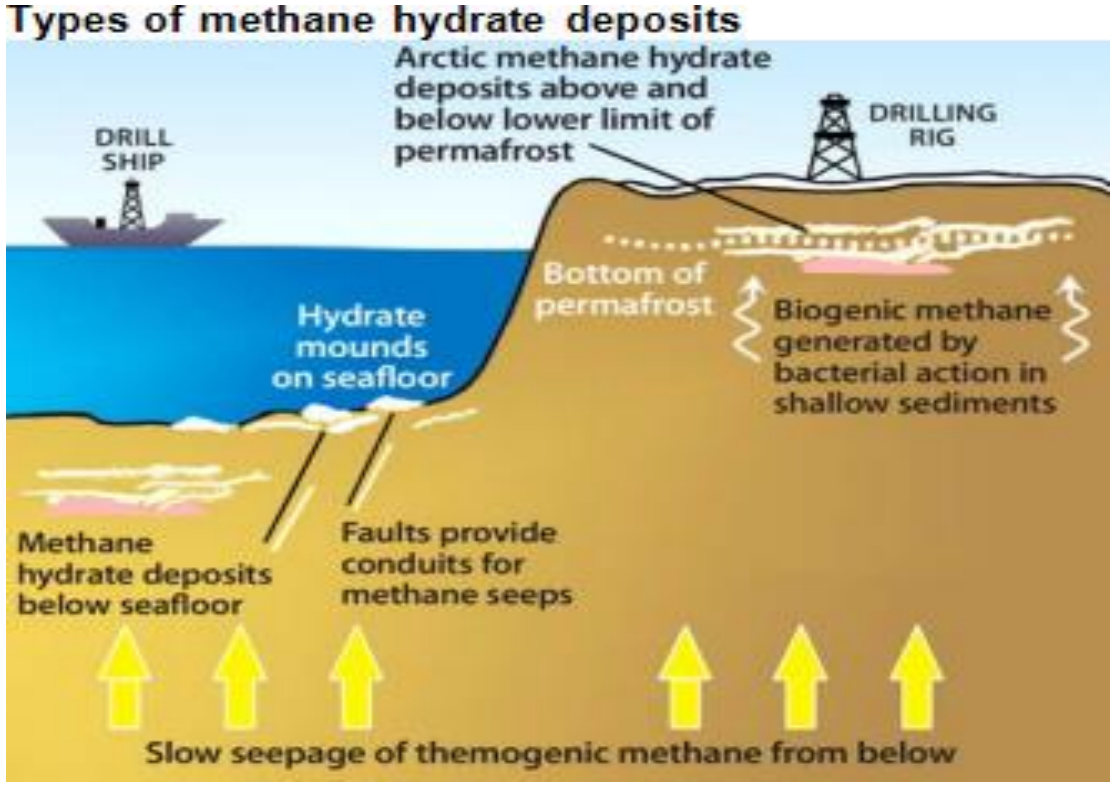
- the layout of the enhanced recovery process technology, the passage clearly indicates the flow of the fluid in a particular direction and dimension and equally occupying the area and volume of the oil and other petroleum products. The Petroleum companies are looking for a prolong method of life of wells in proven or portable oil fields. Proven reservoir is those with a greater than 90 % chances that oil will be recovered, and the probable reservoirs have capacity of 50 % chances of recovering the Petroleum products.
- Those some take concern of the effect such as harmful chemicals leak into the ground water. There is a advanced technique that might be helpful these environmental risk is called the plasma pulsing. This technology is developed in Russia, and it involves the radiating oil fields with low energy emissions thereby lowering their viscosity much as these conventional methods.
- The reason may be due to plasma pulse does not require any injection of gases or chemical or heating the ground it proves less environmentally harmful than other methods.
- Other major effect is the pumping of the water produced onto the surface and this water brings brine and other toxic heavy metals and radioactive substances to the surface. Also, this can be a danger to the plants and animals drinking the same water and it adds into the nutrient matter.
- Countries have mandated certain laws and regulations. According to the environmental protection agencies the enhanced oil recovery has been regulated as class II wells. The regulations require the well operator to inject the brine used for the recovery deep underground in class II disposal wells.

Session 16 – Gas Hydrates

- Gas Hydrates are the compounds of frozen water that contains the gas molecules. These are *Clathrates*
- Gas Hydrates consists of molecules of natural gas enclosed with in a solid lattice of water molecules.
- When brought to the earths surface, one cubic meter of gas hydrates release about *164 cubic meter of natural gas.*
- Gas hydrates deposits are found wherever methane occurs in the presence of water under elevated pressure and at relatively low temperature. Beneath Permafrost or in shallow sediments along deepwater continental margins.
- Methane that forms the hydrates can be both biogenic, created by biological activity in sediments and thermogenic created by geological processes deeper with in the earth.

Gas Hydrates

- Once assumed to be rare, gas hydrates are now thought to occur in vast volumes and to include 250,000-700,000 trillion cubic feet of methane.
- The formation can be several hundred meter thick.

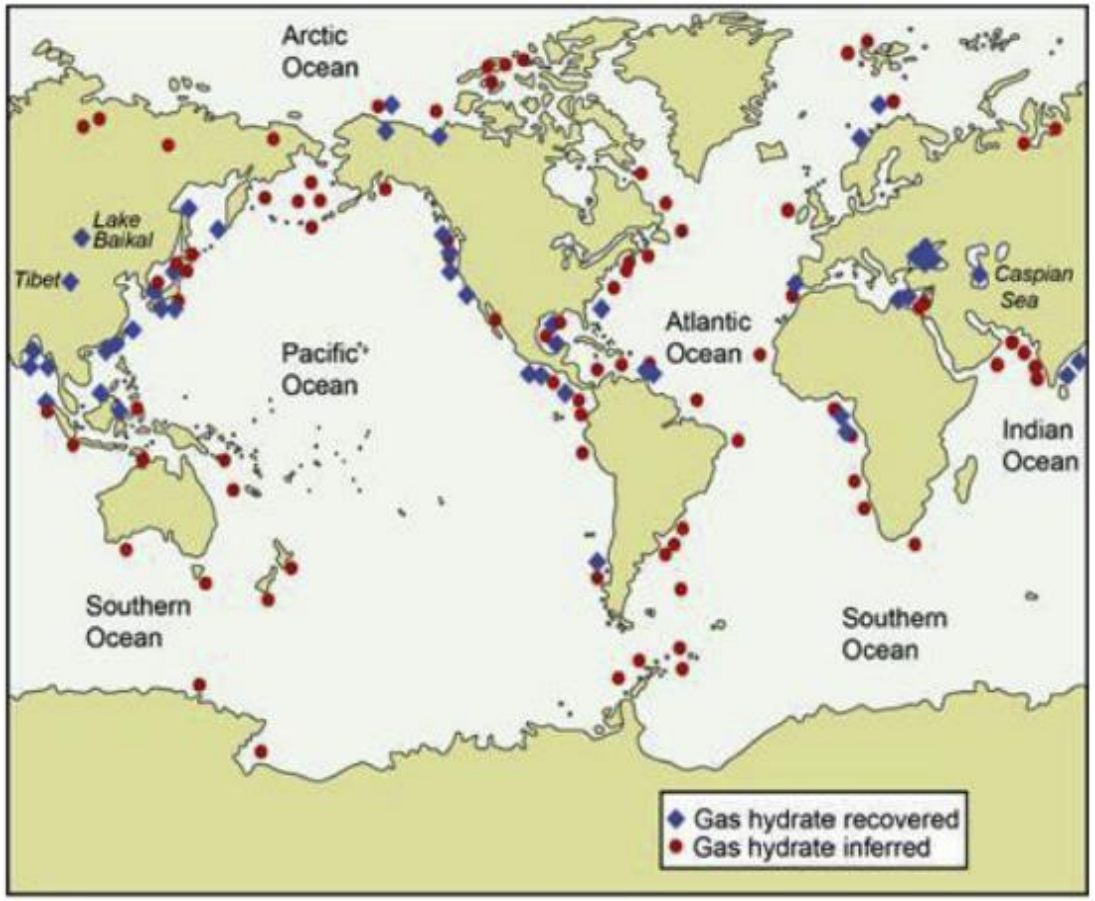


- ✓ The appearance of physical structure looks similar to the white powdery snow and contains two types of unit structure.
- ✓ The smaller structure holds up to eight methane molecules within 46 water molecules.
- ✓ This clathrate not only contains the methane but they also contain ethane, hydrogen sulphide, and carbon dioxide.
- ✓ There are also larges structures holding higher molecules of pentane and n butane. The occurrence of gas hydrates is in specific conditions of temperature and pressure.
- ✓ They are stable at high pressure and low temperature. The Gas hydrates occur in shallow artic sediments and deep oceans deposits.
- ✓ The occurrence of these gas hydrates are at the depth of about 750 and 3500 m.

Gas Hydrates

- The hydrates have been formed in the sediments of many of the oceans around the world. They have been recovered in the deep sea drilling projects and the presence have been inferred in the seismic data.
- During the discussion of the formation origin the gas hydrates have been attributed to a shallow biogenic origin.
- Methane comes from these sources (i) Mantle , (ii) thermogenic (iii) thermal maturation of kerogens (iv) bacterial degradation of the organic matter at shallow burial depth.
- The sedimentary gas hydrates exists in large quantities beneath permafrost and offshore.

Gas Hydrates

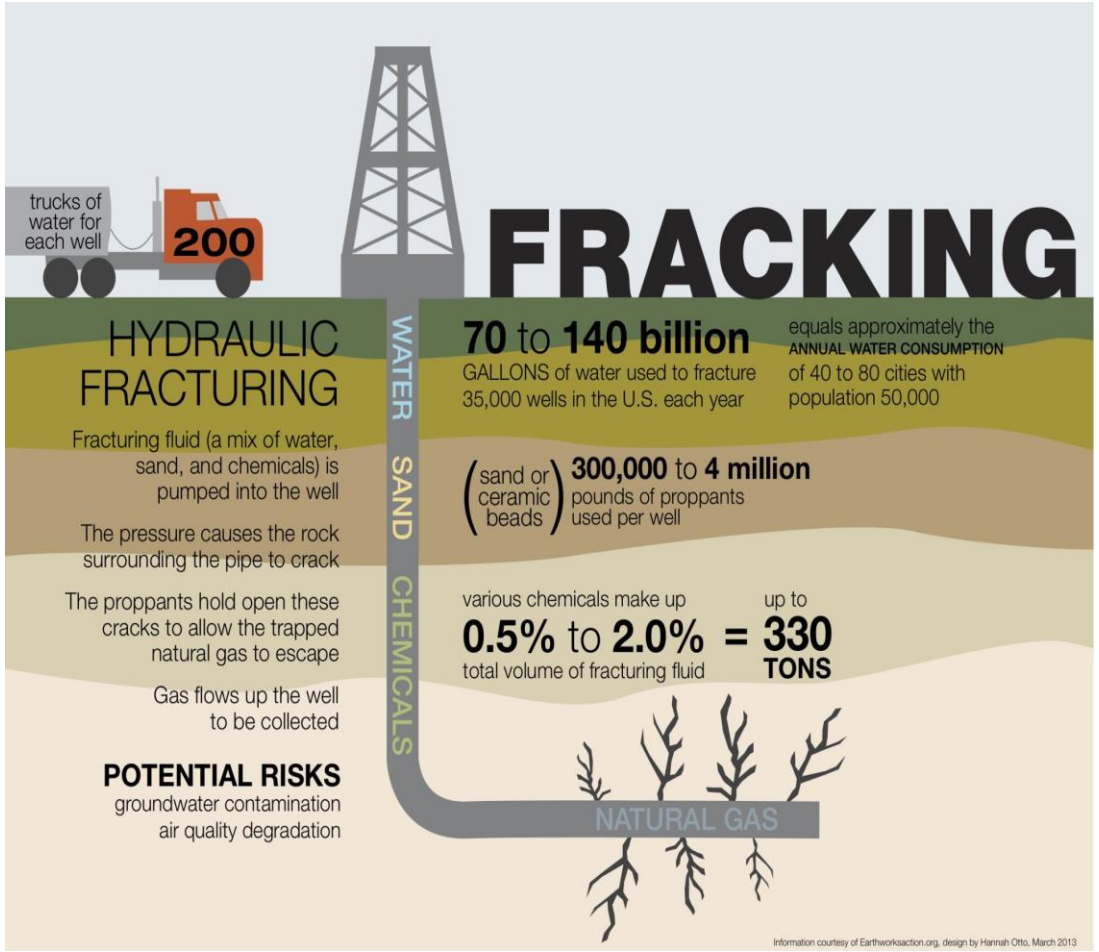


- Countries such as Japan, Canada, US, Korea and India have gas hydrates occur in shallow sediments in the outer continental shelves and Artic Regions.
- Gas hydrates have high resistivity, and acoustic velocity, coupled with low density.

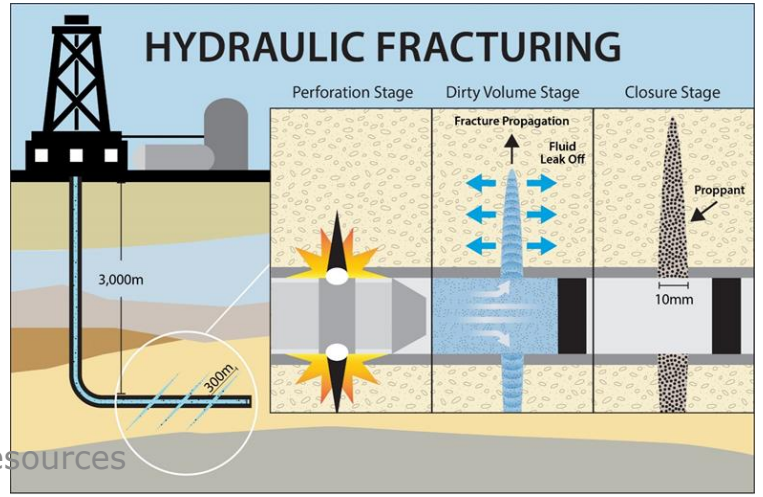
Gas Hydrates – Production methods

- Thermal Stimulation: injection of heated fluids into the formation or directly heating the formation.
- It introduces heat into gas hydrates bearing sediment, changes the gas hydrates stability zone and dissociates gas hydrates.
- Depressurization causes the gas hydrates to dissolve so extra safety in procuring the gas through the hydrates in of concern.
- Climatic temperature rise destabilize the hydrates and also huge amount of methane gas will be released.
- Also, the gas hydrates release of methane gas in the atmosphere results in the GHG rise in the Global temperature which is a cause of concern looking at current world scenario.

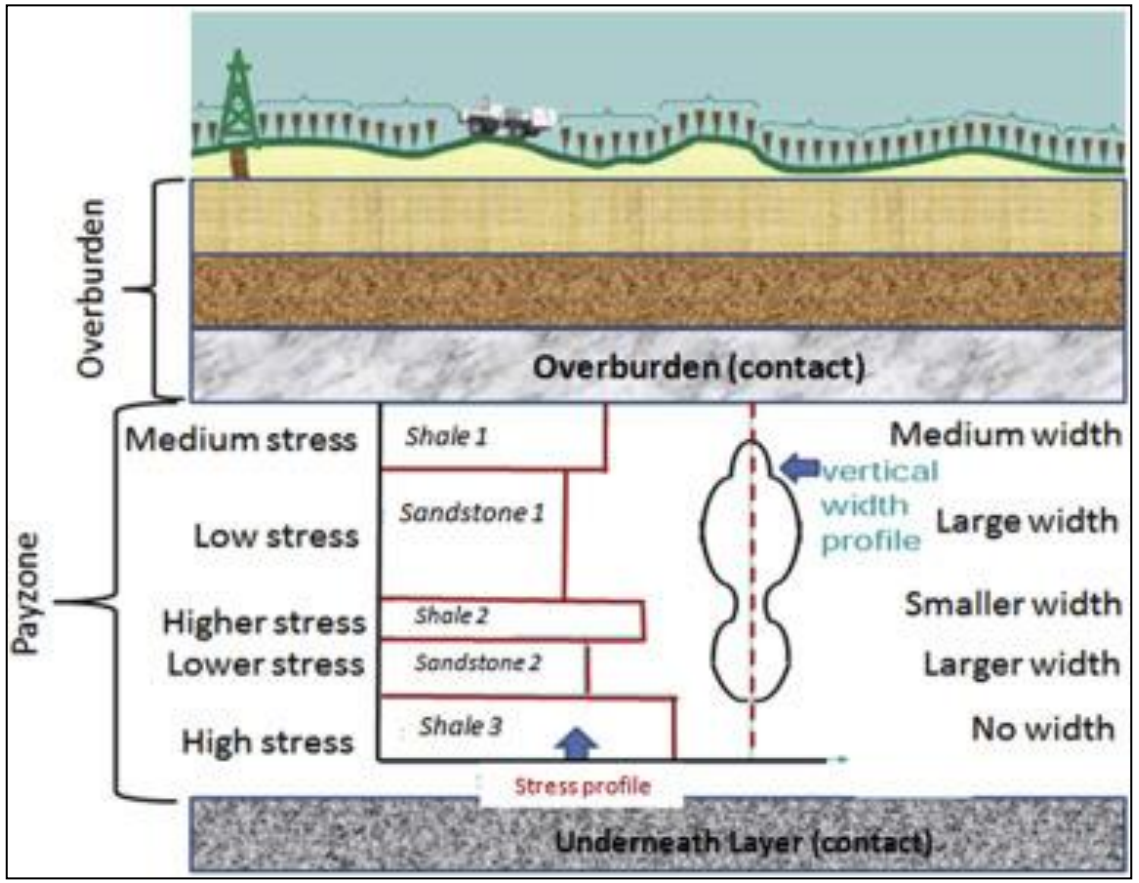
Session 17 Hydraulic Fracturing Fluid Design



- Hydraulic fracturing is widely accepted technology to unlock unconventional reservoirs and produce the hydrocarbon fluids at feasible rates, but reaching these rates requires an optimal designing of the hydraulic fracturing treatment.
- An optimized hydraulic fracture, resulting in high hydrocarbon production rates, and reduce the overall cost by selecting the compatible fracturing fluids and adequate amounts of proppants.



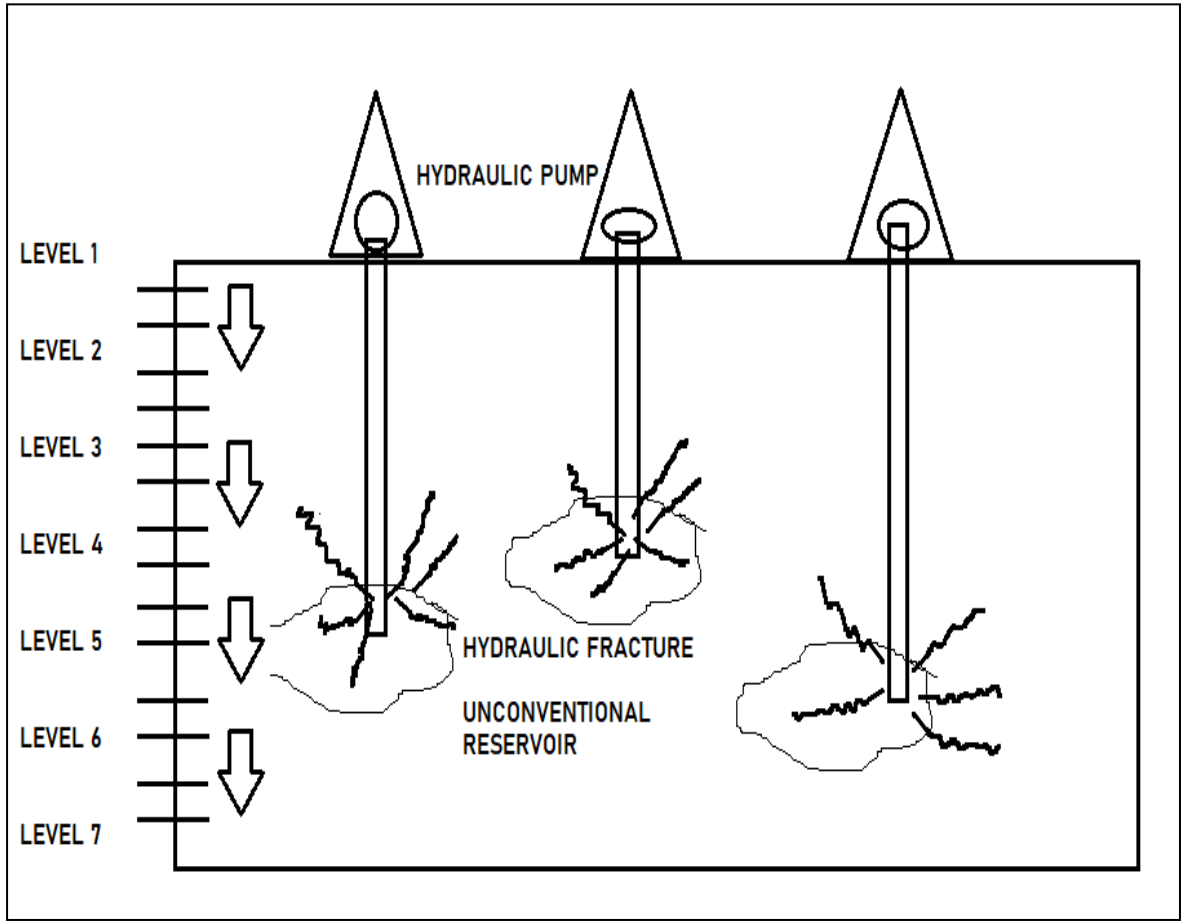
Hydraulic Fracturing Fluid Design



- ✓ Smaller fracture width due to higher in situ stress in shale layers and greater fracture width due to lower in situ stress in sandstone layers from a hydraulics stimulation.

Explanation

Layout showing the Hydraulic Fractures



- The figure depicts the schematic arrangement of the hydraulic fracture mechanism, where drilling can be done horizontally or vertically.
- The pipe is placed into the path's hole, followed by the hole mechanism's transportation via which the section containing the gas and raw material is present.
- Following the insertion of the holes, the machines are removed from the installation mount and new mechanism machines are installed.
- The fluid and gases are then returned, and the product collection is completed.

Session 18 Heavy Crude Oil in Water Emulsion

- The stability of the oil in water emulsions was increased verses surfactant concentration due a decrease in the crude oil-water interfacial tension. The natural surfactant has been responsible for the very low values of interfacial tensions observed and for the stabilization of the viscous crude oil in water emulsions. By increasing the surfactant concentration in the aqueous phase, as well as the speed and duration of homogenization, the emulsion stability was increased.
- Oil in water emulsions can be efficiently stabilized by colloidal particles after in situ modification of the particle surface with short amphiphilic molecules. The surface modification with short amphiphiles rendered the particles partially hydrophobic, favoring their adsorption at the oil water interface.

Treatment method for oil emulsion

- For treating and separation of an emulsion there should be a method to weaken the film surrounding the water droplets. There are four methods through which the production wells use to break the emulsion i.e. (i) Heat, (ii) Retention Time, (iii) Agitation and (iv) Chemical demulsifies
- Also, separation can be done due to the gravity separation, the elements in the well stream such as oil and water have different gravities. These density differences allow the water to separate by gravity, well with enough time in a non-turbulent state, the different specific gravities will naturally separate.

Retention Time

- the amount of time the fluid stays in a steady or non-agitated state inside a separator unit and longer retention time means more separation.
- The larger diameter and taller vessel increase the retention time and allow more water to settle out by gravity.
- **Coalescing:** During this process the water droplets comes together to form larger droplets.
- Vane type mist elevators droplets are being removed from the vapor stream through inertial impaction.
- Also chemical demulsifies separate oil and water emulsion, treating the fluids with demulsifies aids the separation process.
- The chemical move to the oil and water interface and therefore weakening the surface tension and enhances the coalescence.
- This can be an alternative methods amids the heat treatment and retention time method.

Day 4 Session-19 Multiphase flow and Transport Process in Porous Media

- What is a Porous Media?

- The material which contains pores in their skeleton structure that is usually a frame. This skeleton structure is solid and the analysis in this study contains the porous media. Porosity and other properties such as permeability, tensile strength, electrical conductivity.
- The concept of the porous media implies to many engineering application of Petroleum studies including the rock mechanism, hydrogeology, petroleum geology etc.
- The fluid that is flowing in this porous media is of great significance and under research.
- At microscopic level the porous media grows indefinitely.
- The main experiment method for the investigation in the porous media are the confocal microscope and x ray tomography.

Multiphase flow and transport process in porous media

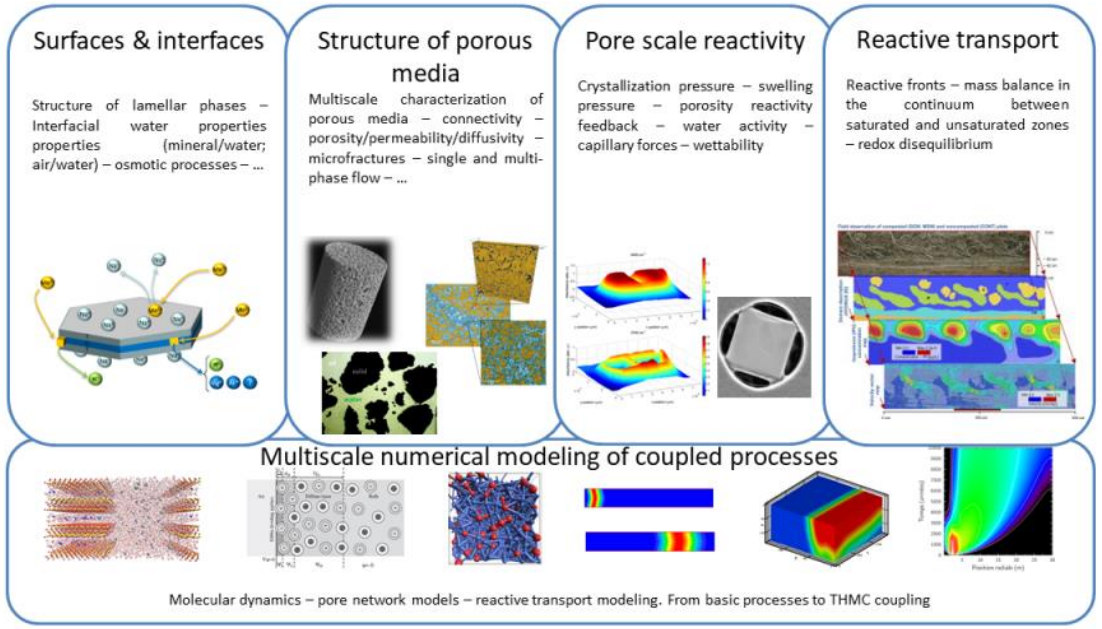


Fig 15.

A number of complex and interacting transport phenomena may take place in a multiphase, multicomponent system. In general, multiphase flows in porous media are driven by gravitational, capillary and viscous forces. Gravity causes phase migration in the direction of the gravitational field.

What is the concept of the Transportation process in porous media?

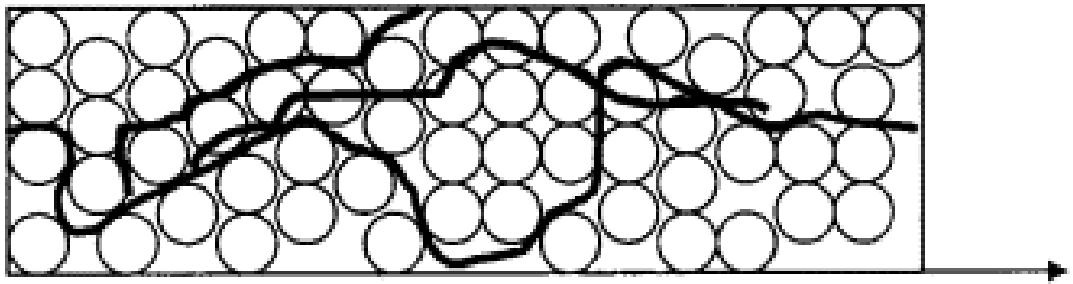
- There are various types of solution underground and the main are the aqueous phase, or aqueous miscible, the contaminants that have been controlled by the physical, chemical and other biological process in the laboratories. The main primary physical processes governing the aqueous miscible contaminants transport are the adhesion, dispersion and diffusion.

- This porous media often known as the filtration combustion separates the liquid phase and the gaseous phase making the right material for the separation of the matter. This is totally a heterogenous interaction of the two different media

Importance of Multiphase flow and Transport Process in Porous Media

- The topic is subjected to the fluid dynamics in the porous media and its affects on the fluid properties and material flow properties.
- The mathematical and statistical methods in conjunction with the computer experiments of the models predicted gives the significance in the material extraction and collection.
- This study is very helpful to the engineers who are working in the field of petroleum engineering.
- The overall fluid flow in porous media is described by Darcy law which states that the flow rate is proportional to the pressure gradient. The most obvious property of the porous media is that it partially occupies the volume that it would be otherwise by for the fluid.
- This volume occupation is very important to extract the gas or the oil from the petroleum reservoirs.

Flow Analysis



Explanation

Hydrodynamic dispersion is the macroscopic outcome of a large number of particles that are moving in the porous media.

- In the absences of the porous media the particle will travel with decrease in pressure gradient along x direction without the turbulent but with small Brownian transverse movement.

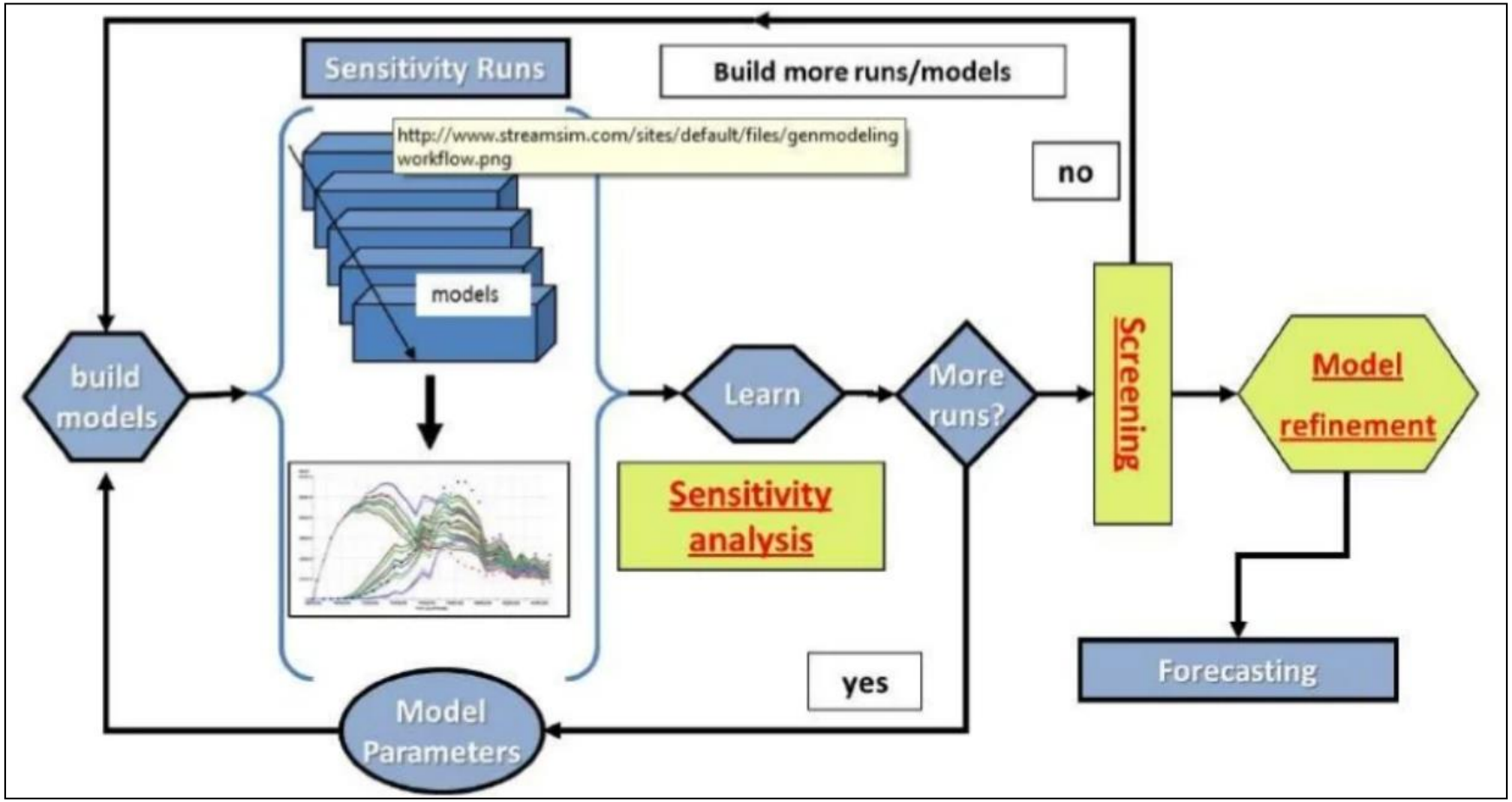
Session 20 – Reservoir Simulation

- What so you mean by a reservoir simulation?
- Simulation means the combination of mathematical equation and physical modelling of the setup or equipment that can be solve the purpose of reservoir engineering, the prediction and management of the systems and subsystems.
- Solving the real time problems through the simulator.

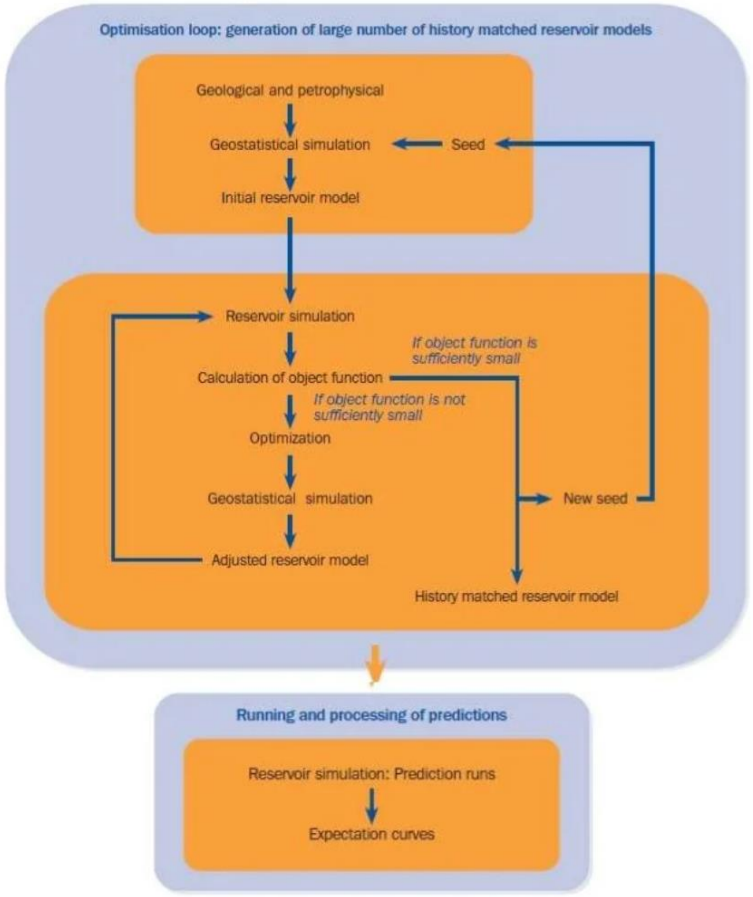
There are various types of simulators

- Black Oil Model
- Compositional Model
- Thermal model
- Chemical
- Miscible
- Dual Porosity
- Dual Permeability

Flow Chart analysis done by the model and flow channels



Flow Channel



Session 21. Computational Geomechanics

- What do you mean by computational geomechanics?

- The use of computer systems especially for the research work and the utilization of mathematical modelling and calculations are all the term computation. The computational geomechanics is a disciple of computational mechanics that models and simulates the static and dynamics behavior of structures and solids that are made of geomaterials. Geomaterials are pressure dependent, dilative/comprehensive, porous material and it consists of porous matrix/ skeleton and fluid in pores.

- The porous matrix/skeleton of geomaterial is usually modeled as continuum material, using the incremental theory of elasto-plasticity and several elastic-plastic material model of various complexity. Mechanical behaviour of geomaterial is intrinsically connected to the full interaction, coupling between porous matrix and the pore fluid. Full coupling is modelled through the application of effective stress principle.

Computational Geomechanics

- Computational geomechanics deals with numerical analysis of response and instability of porous media and related structural systems.
- One can argue that in the case of soils, apart from the elemental level constitutive behavior, interaction of soil layers with structures built around them brings an additional source of complexity due to nonlinear response aspects.
- There are many sub-fields of geomechanics where such aspects should be handled with care.
- Geotechnical earthquake engineering and geotechnical coastal engineering are two of those most commonly encountered sub-fields.
- In the case of geotechnical earthquake engineering, the actual response of soils and soil-structure systems under earthquake shaking is frequency-dependent and elemental soil behaviors determine how much of induced energy will be absorbed by soils and how much of it will be transferred to the upper structures.
- In this short opinion, the aim is to focus on topics where accurate modeling of soil behavior is indispensable.
- It is important that one has the necessary understanding of cyclic soil plasticity and incorporates related theoretical models into their numerical algorithms to provide accurate solutions to the earthquake-related problems.

- The field of computational mechanics where geo-engineering systems are analyzed using the principles of mechanics through numerical methods. In those systems lie porous media with a variety of multi-phase materials such as soils, rock, composites or living tissues.

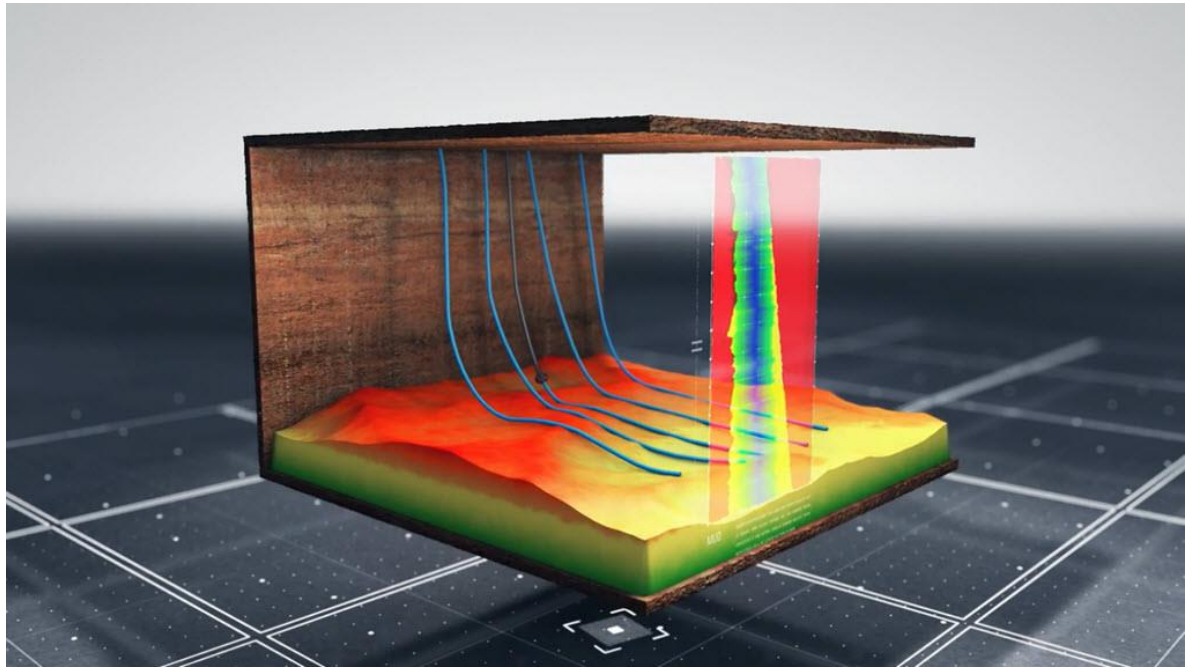


Fig 17.

Computational Geomechanics

- Computational geomechanics uses computation models to simulate the state of a geomechanics system upon application of generalized loads. Computational simulations can in general be used for verification, validation, and predictions. The confidence in prediction relies heavily on proper ventilation and validation process. Is a mathematical issue and it provides evidence that the model is solved correctly? Validation is the process of determining the degree to which a model is accurate representation of the real world from the perspective of the intended use of the model. Verification and the validation procedures are the primary means of accessing accuracy in modelling and computational simulations are essential tool in building confidence and credibility in computational predictions.
- Consider the dynamic equilibrium (equation of motion) for a general three dimensional solid made of any geomaterial. The external forces such as surface tension, body and inertia forces) are in equilibrium with internal and inertial forces.
- $\int \delta UPdV = \int \delta \rho UbdV - \int \delta U\, PtdS$ (2)
- Where P is the first Piola Kirchhoff stress tensor, initial material density, body forces, surface traction, U is generalized displacements. The above equations and other parameters can be solved to determine the displacement of soil or structure loaded with general time varying forces.

Computation geomechanics can be further classified:

Explanation

- Finite element formation
- Elasto-Plasticity
- Verification and Validation
- Software and hardware platform

Application to Practical problems

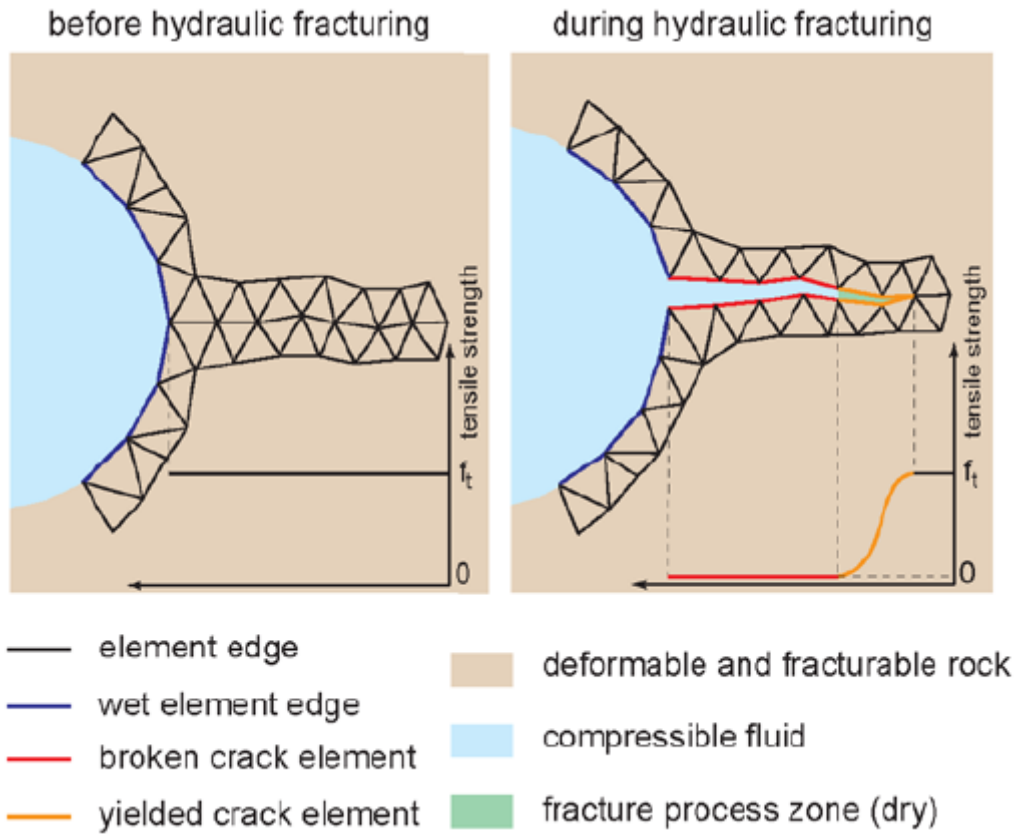
- Dynamics of Earthquake soil structure systems
- Dynamics of Saturated soils
- Probalilistic Geomaterial Response

Session 22- Hydraulic Fracture Propagation Modelling and Mesh Free Methods

Explanation

Hand Written Explanation

Hydraulic Fracture Propagation modelling and Meshfree methods

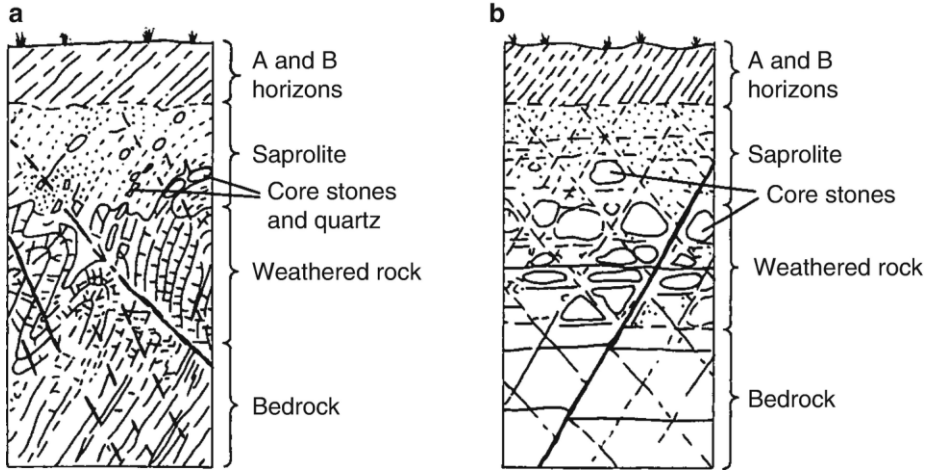


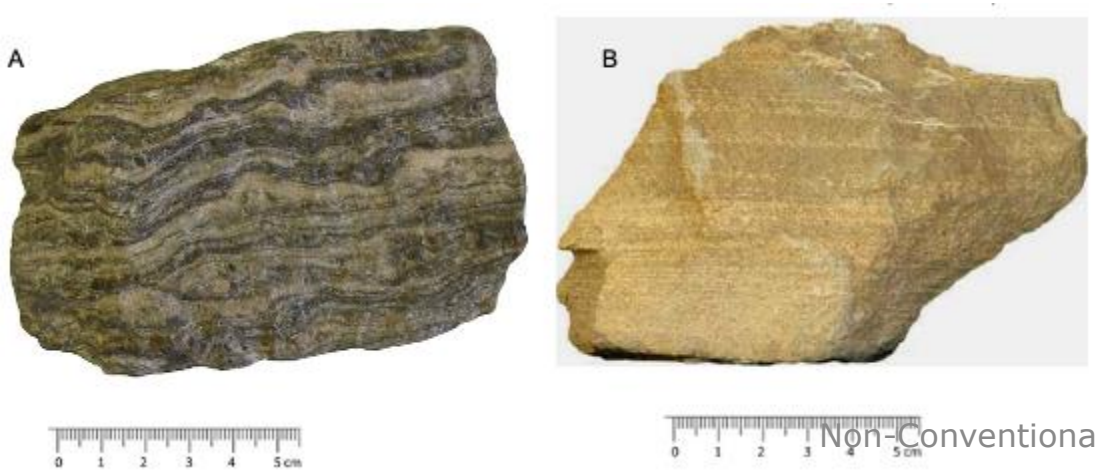
- A fully coupled poro-viscoelasticity fracture propagation model was adopted for hydraulic fracturing in creep formation. Fractures propagating in creep formation tend to be wider and longer with low propagation pressure. Fluid diffusion from crack to the matrix is more efficient due to modulus decay in creep formation.

Session 23. Engineering Properties of Rock and Soil, Rock Mass Characterization

- Properties of Rock and Soil, Rock Mass Characterization
- Sieve Analysis of Topsoil
- Hydrometer
- Moisture Content
- Atterberg limits
- Plastic Limit of the soil
- Liquid limit
- Plasticity Index
- Activity
- Organic Content

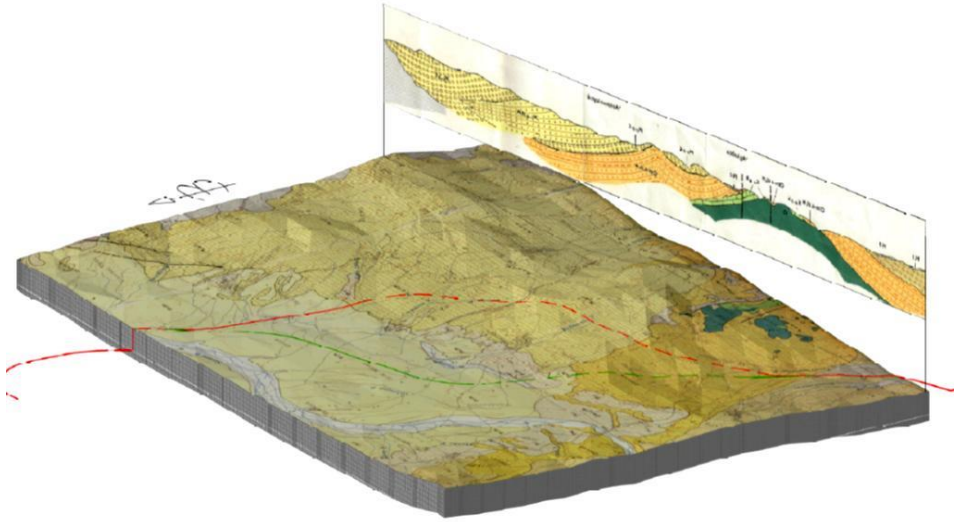
Engineering Properties of rock and soil

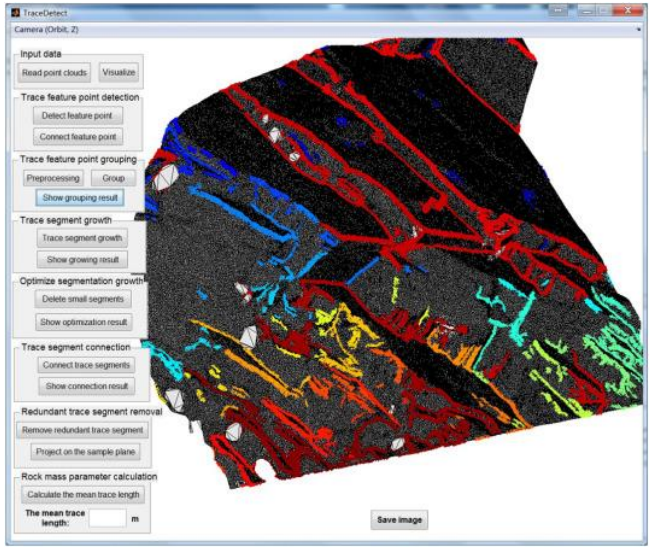




- Rock properties can be divided into two categories: intact rock properties and rock mass properties. ... Common engineering properties typically obtained from laboratory tests include specific gravity, point load strength, compressive strength, tensile strength, shear strength, modulus, and durability.

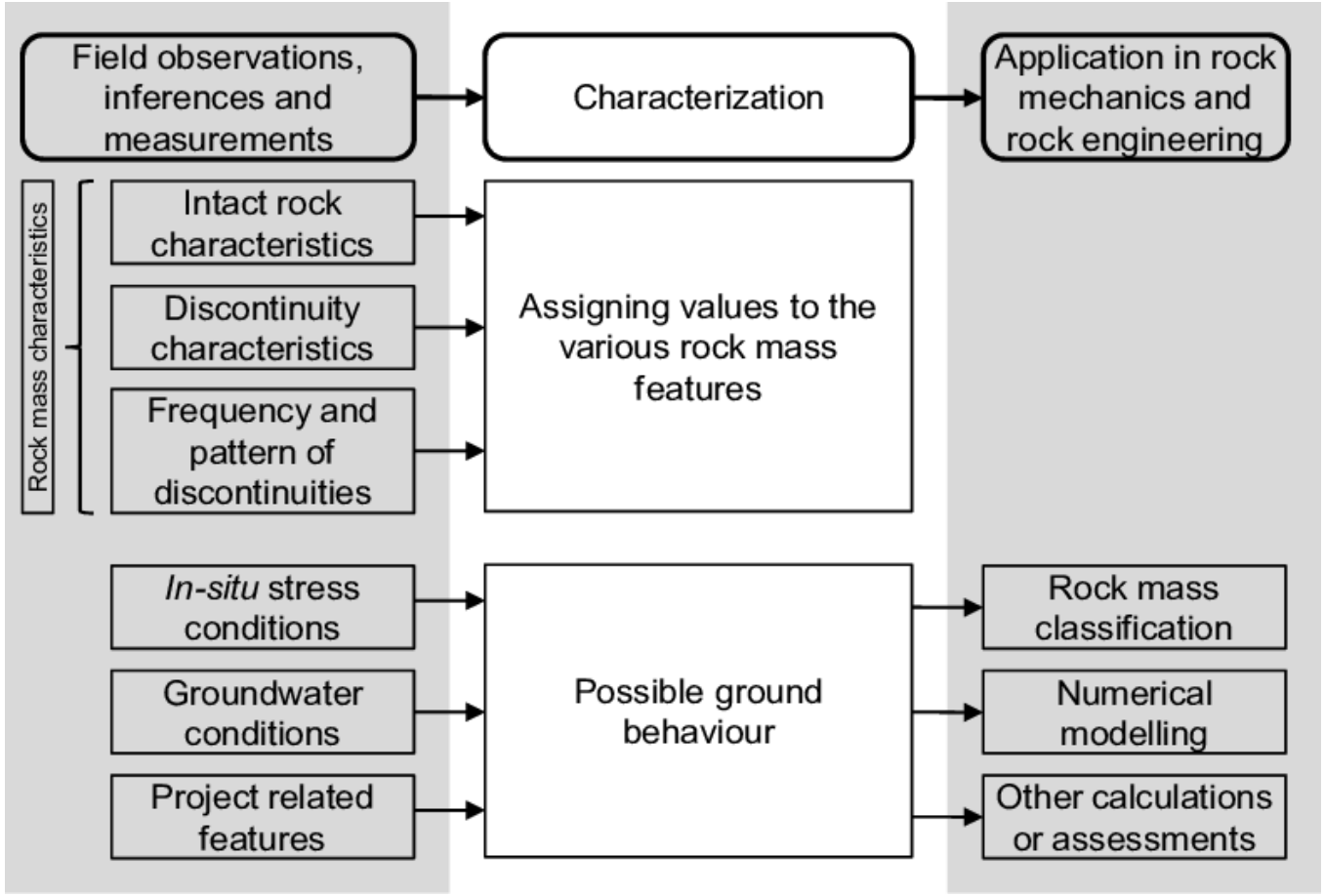
Rock Mass Characterization





- Rock mass is a matrix consisting of rock material and rock discontinuities. Its characterization and classification aim to determine the rock mass characteristics by assigning values to a set of rock parameters.
- The results of geotechnical explorations, engineering geological investigation (including laboratory and in situ tests) and field observations have been used, along with borehole logging charts, to obtain the rock mass geotechnical data.

Flow chart illustrating the role of mass characterization



Rock Soil Property Parameters

For Determining of Rock Properties	For Determining Soil Performance
Punch Penetration Index testing	Strength Tests
Cerchar Abrasivity Index Test	Unconfirmed compression test
Thin Section Petrographic Analysis	Triaxial compression test
	Unconsolidated undrained or Q test
	Consolidated Undrained or R test
	Consolidated Drained or S test
	Direct shear
	Consolidation test
	Shrinkage and swell
	Flexible wall permeability
	Particle Analysis
	Specific surface analysis

Explanation

Classification systems are briefly explained in the following section

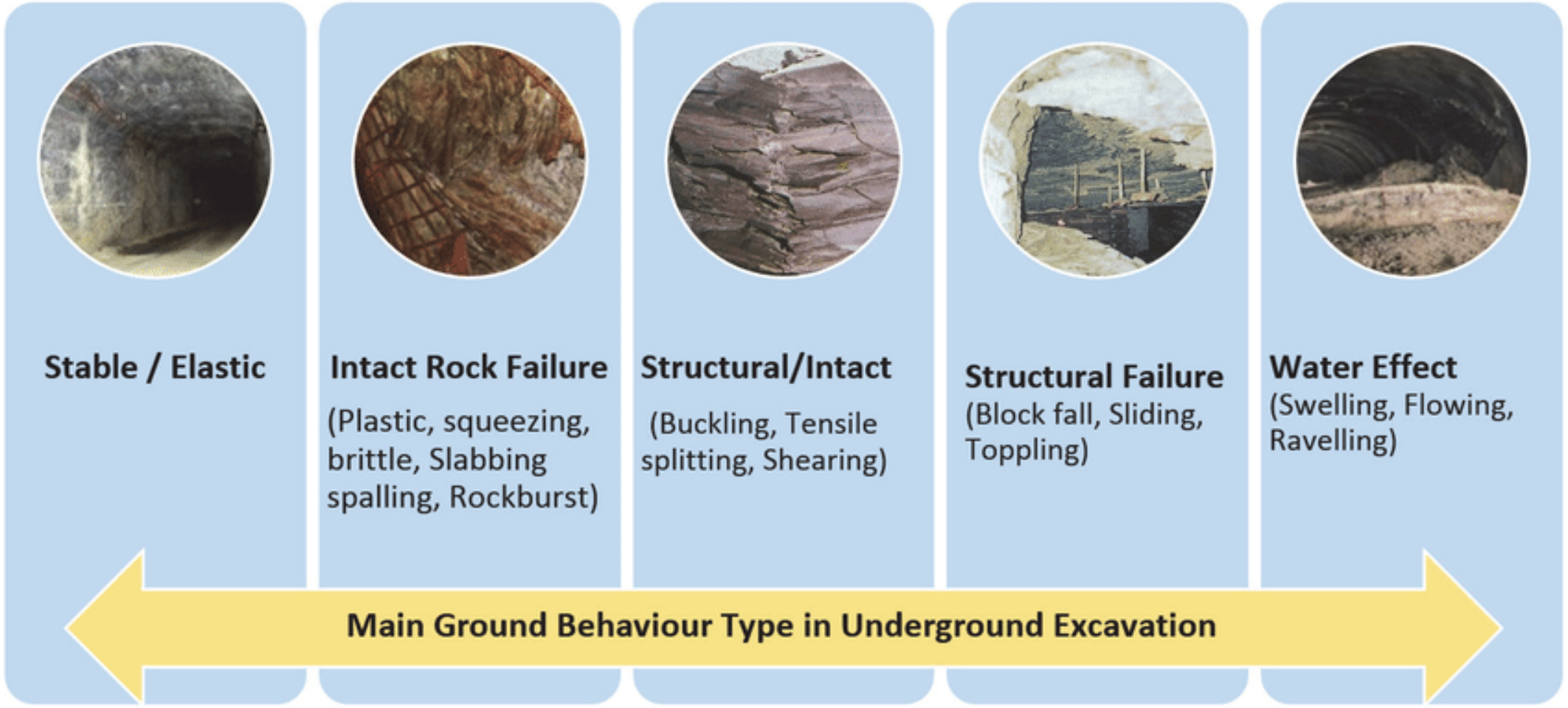
- (i) The RMR System : Geomechanical classification system (RMR) – The systems calculates an index bu summing the rating for main six factors, the uniaxial compressive strength of the rock material, the RQD value, spacing, condition and orientation of discontinuities, and ground water conditions.
- (ii) The Q system: The system is widely applied to various underground opening. The index of the system ranges from 0.001 to 1000 on a logarithmic scale.
- (iii) The GSI system: Geological strength index was fuether developed and modified, particularly in poor and heterogeneous rock masses for designing projects such as tunnels, slopes and foundation in rocks.

Session 24 - Rock Failure Mechanism, Geothermal Energy and Well Logging

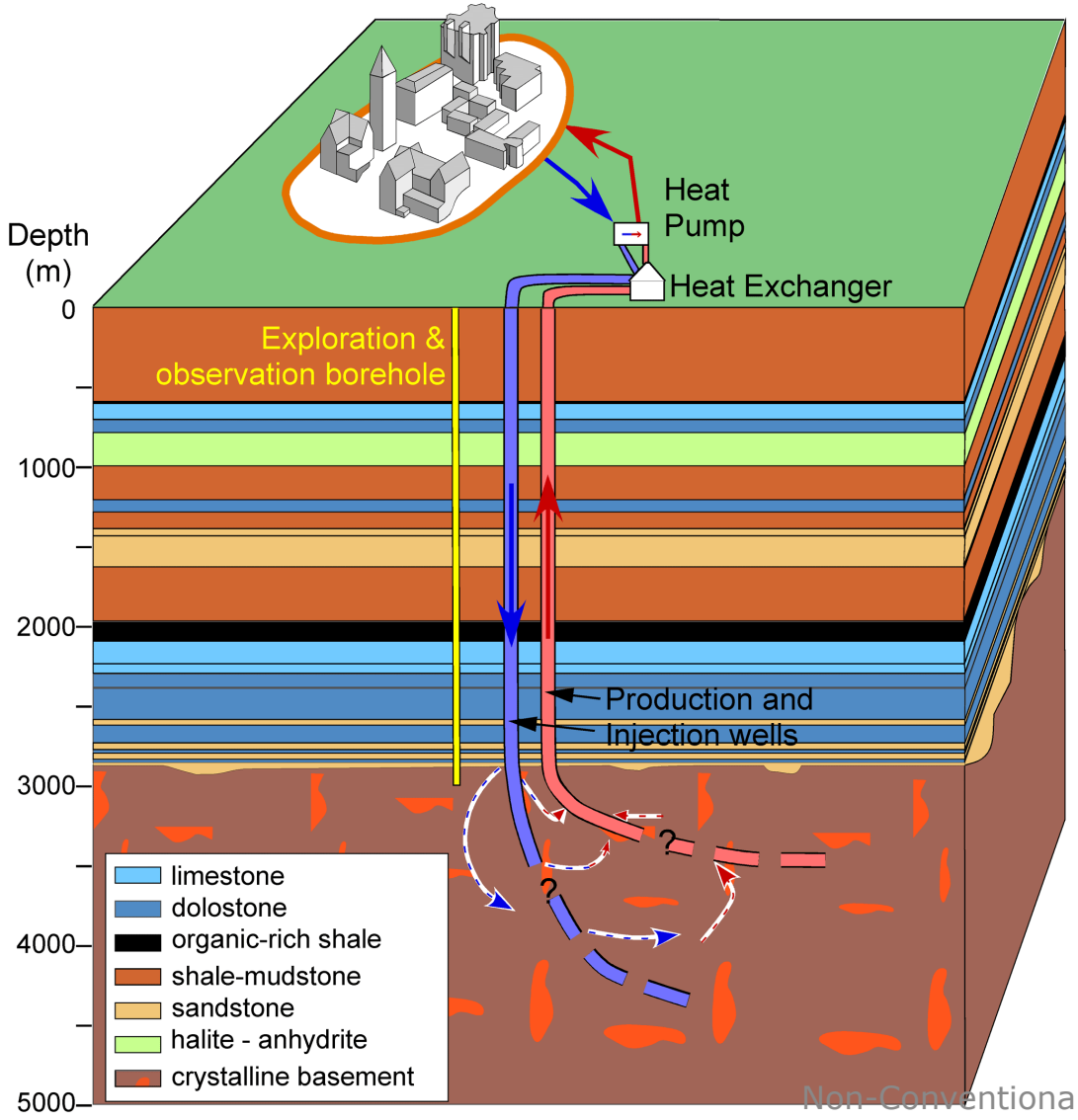
- What do you understand by Rock Failure Mechanism?

- When we are dealing with the rocks in any engineering disciples such as civil engineering, petroleum engineering, mining engineering we come across process during which loading in done on the Rock. If the loading on the structure fails then the infrastructure cannot be built on the site therefore new site has to decide by the engineers where the loading does not fails. Generally there are three types of failure being observed on the rocks (i) Shear, (ii) Mixed and (iii) Split. Other failures such as the corrosion, erosion, fatigue, and overload are also to considered.

Rock Failure Mechanism



Geothermal Energy and Well logging



- The geothermal power plant companies drill two separate wells to the extremely hot water reservoir under the earth's surface; the production well and injection well.
- Geothermal well means a well used to draw water from the earth or to return water to the earth for purposes of heating and cooling. Geothermal well means a well that is part of a system used to generate energy powered by geothermal resources (including steam and other gasses, hot water, and hot brines).
- Geothermal energy can heat, cool, and generate electricity: Geothermal energy can be used in different ways depending on the resource and technology chosen—heating and cooling buildings through geothermal heat pumps, generating electricity through geothermal power plants, and heating structures through direct-use

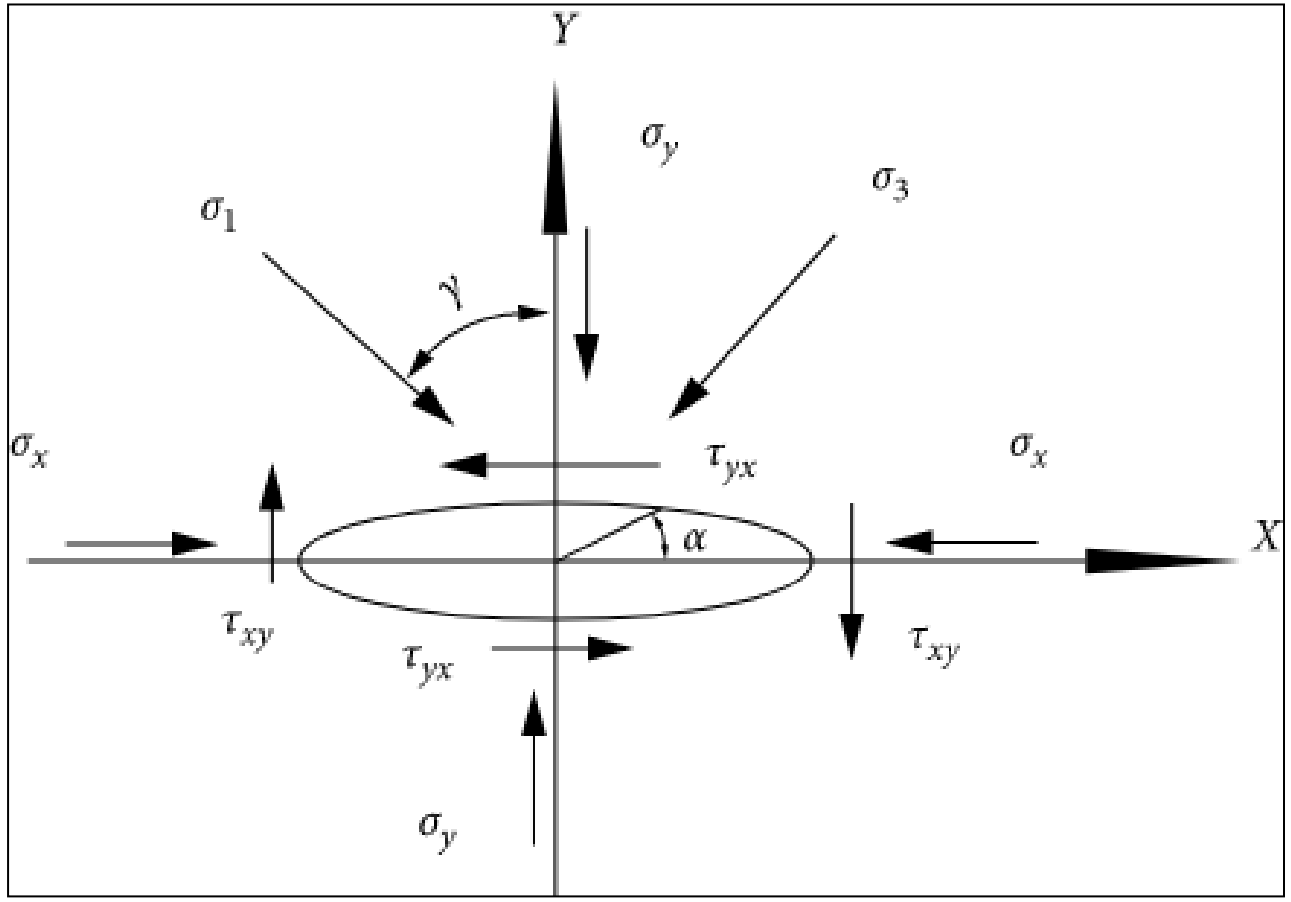
Testing on the Rocks

- There is a uniaxial compression tests to simulate the effects of preexisting joints and fissures of rock.
- It's been concluded through various research that the cracks easily initiated at the tip of discontinuity when the angles of the inclination are 0o, 30o, and 60o under the series of uniaxial compression tests.
- Also, the cracks are being extended vertically at low confining pressure and traced a horizontal trend at high confining pressure.
- The tensile cracks initiation and propagation plays a dominant role at small joints dip angle.
- More rock cracks are being initiated when the joint dip angle is small.

Failure mode during test analysis

Failure modes	Shear Failure Splitting Failure Mixed failure (tension and shear)	Slide along the joint plane Does not slide along the joint plane	Completely Partly

Stress being implied onto the rock sample simple stresses and shear stresses



Explanation