ME-463

PETROLEUM ENGINEERING

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Contents

1 Lecture 01: Introduction

Date: 03/06/2023

Booklist

Introduction of Petroleum Geology & Drilling

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Basics

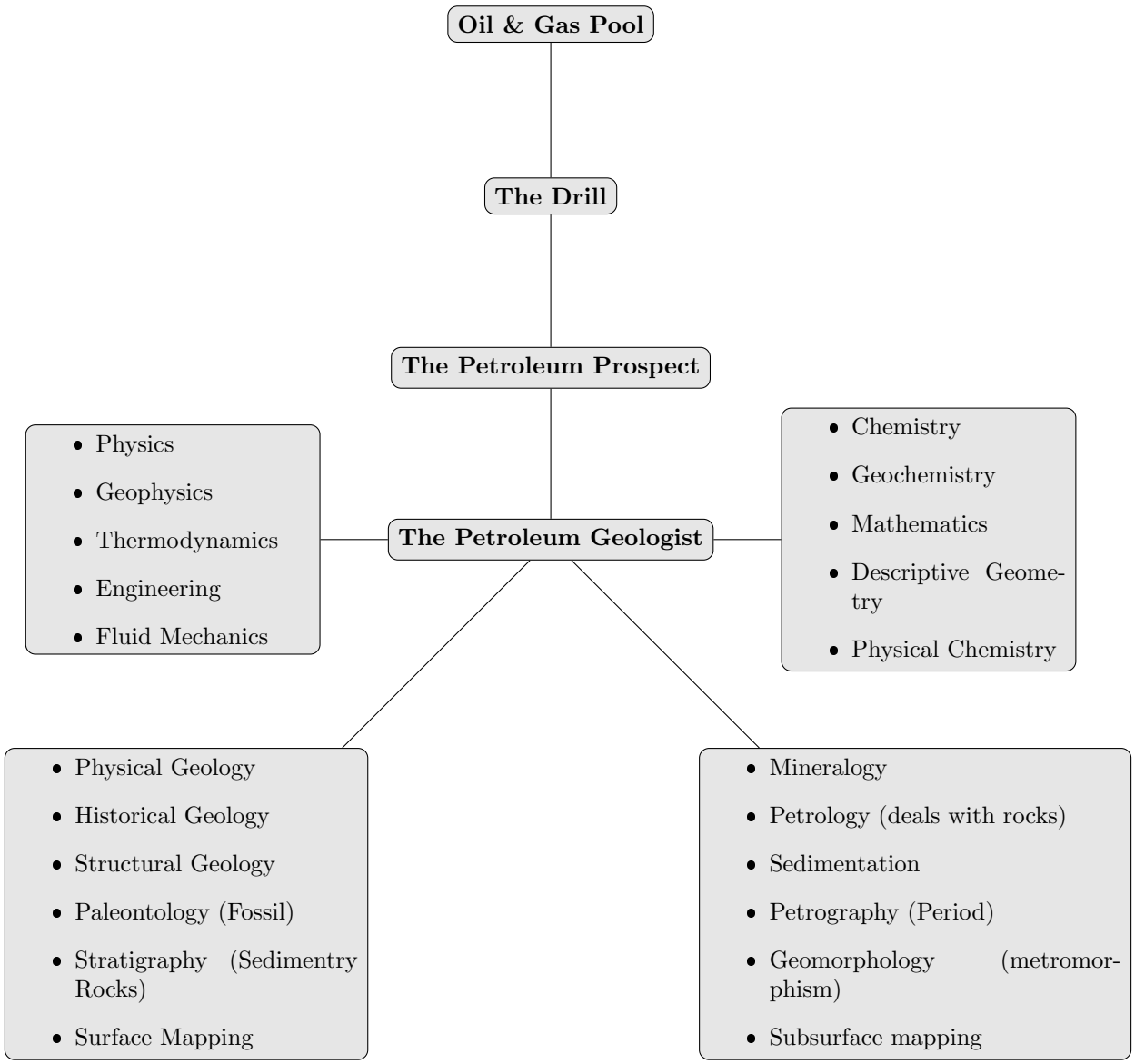
Latin: **Petra** → Rock or Stone
Latin: **Oleum** → Oil
So, Petroleum basically means "Rock Oil"

Petroleum occurs widely in the earth as gas, liquid, semi-solid or solid, or in more than one state in a single place.

Definition

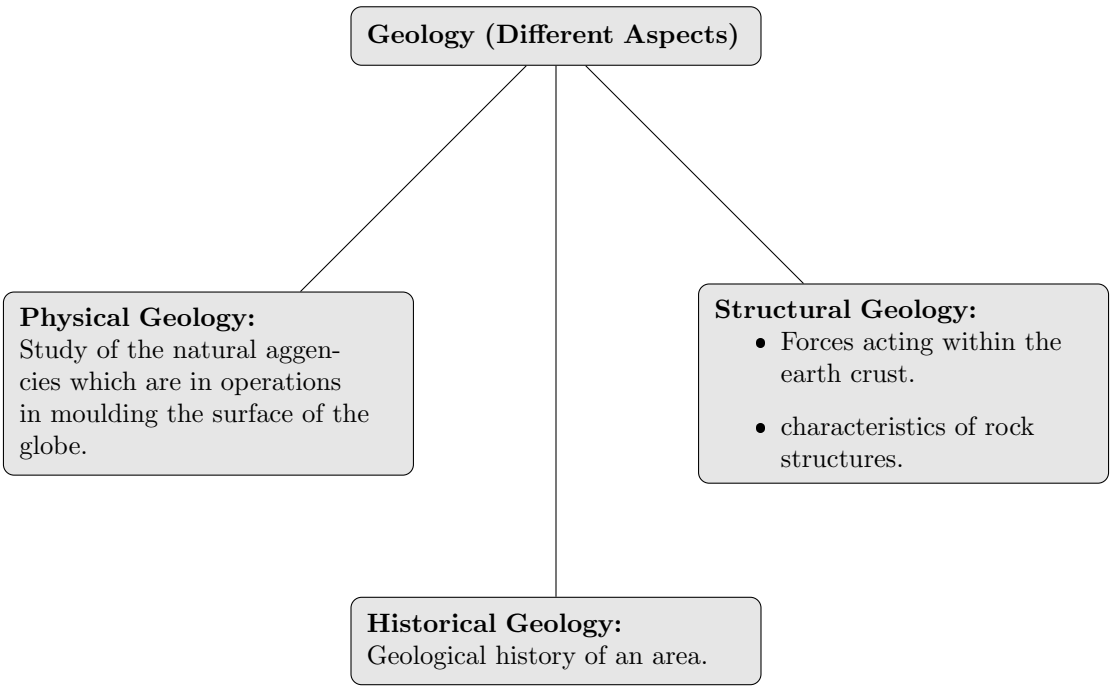
Chemically, any petroleum is an extremely complex mixture of hydrocarbon (hydrogen and carbon) compounds with minor amounts of nitrogen, oxygen, and sulfur as impurities. The weight percentage of petroleum is as follows:

Elements	**Amount**
Carbon	85%-90%
Hydrogen	10%-15%
Sulfur	0.2%-5%
N_2	0.1%-2%
O_2	0.6%-2%



Petroleum Geology

Geology is the sciecne that deals with the history and structure of the earth and its life forms. It is used to credit where oil accumulation might occur. Geology is based on observation and the knowledge derived from mant others sources.



Petroleum Geologiest (activities)

- Observes the rock and rock formations.
- Reconstructs the geological history of an area
- Determines whether the formations contains petroleum in the reservoirs.

2 Lecture 2: Petroleum Classification

Date: 17/06/2023

A petroleum deposit must be commercially valuable. it depends on some factors:

1. Amount recoverable
2. Expected production rate
3. Cost of drilling and producing well

✓ if there is fire in well, then another well should be dug nearly to reach there.

Petroleum Reservoir characteristics

A good reservoir must have:

- Right shape or configuration to hold the oil and some kind of seal or trap to keep it from escaping
- it must be large enough usually 10 ft thick or more.
- About 10% porosity or pore space in needed.
- It must be permeable, that is, pores must be connected so that, oil, gas and water can flow through it from one pore to another.

✓ Sandstone → Porous

Petroleum Classification

The petroleum and petroleum like substance may be classified as follows:

1. **Petroleum** : An almost infinitely complex mixure of saturated hydrocarbon with relatively small amounts of S, N_2, O_2 and many other lesser constituents in combination. Petroleum occurs in solid, liquid and gaseous forms as follows :
   (a) Asphalt or tar, paraffin waxes, brittle bitumen etc.
   (b) Crude oils (liquids)
   (c) Natural Gas
2. **Tar Sands**: Semi-solid petroleum bearing sands
3. **Oild Shales**: These are fine grained sediments sometimes known as kerogen shales.
4. Torbanites, boghead and cannel coal etc all are rich in bitumen

✓ Fishing → If drill bit is broken inside well
✓ Catwalk → pipe movement through crane

Age of the earth (Structure of the earth)

it is very difficult to ascertain the actual and exact of the earth.

- Darwin fixed the age of the earth at 57 billion years on the basis of the concept of separation of the moon from the body of the earth.
- Through the study of the history of cooling of the earth, calvin estimated that our planet should be as old as 20 to 40 million years
- Study of radioactive naterials in meteorites indicate that the members of the solar system must be as old as about 4500 million years
- Modern theory is that the earth is thought to have formed about 4.6 billion years ago out of a cosmic dust. As the planet was pulled together due to its own gravity, the heat of compression and of it's radioactive elements caused it to become molten. The heaviest components form the core. Lighter minerals form the thick mantle. The lighter elements form the thin rocking crust.

3 Lecture 3: Internal Structure of the earth crust

Date: 08/07/2023

Internal structure of the earth consists of the followings:

1. Earth crust
2. Mantle
3. Core

Earth Crust (Lithosphere)

Outer envelope of shell of the earth is known as earth crust. This crust consists of solid rocks. The thickness of earth crust ranges from 5 to 70 km.

Two part of earth's crust:
i) Outer crust
ii) Lower crust

The earth's outer crust mainly consists of sedimentary rocks.
Outer crust:
i) Continental crust (30 km thick, average specific gravity 2.8, high over 0.2 to 0.3 km above sea)
ii) Oceanic crust (5km thick, average specific gravity 2.9, 4 to 5 km sea level)

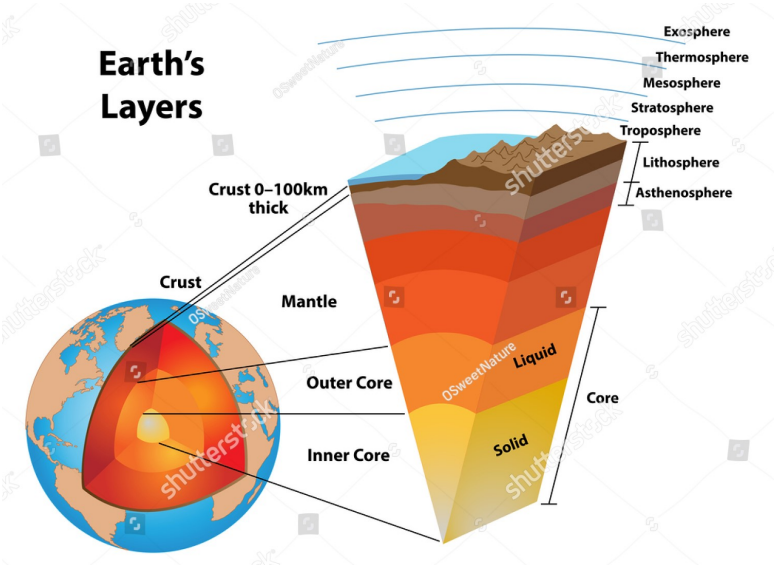


Figure 1: Cross section of Earth

The lower part of earth crust has two envelopes.
Lower crust:
i) Granite Layer
ii) Basalt Layer

The average thickness of each of this layer ranges from 15 to 20 km.

Tectonic Plates and Plate Boundaries

Lithosphere consists of spherical caps or plates. These plates are in relative motion to each other on the non-rigid asthenosphere.
There may be a -

- Collision

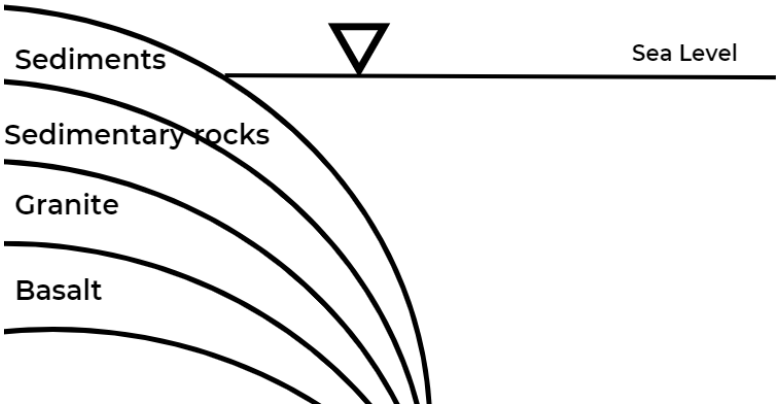


Figure 2: Outer crust & inner crust

- Pulling away
- Slide Past one another

The theory that explains this processes is called plate tectonic theory.

Plates may be -

- Continental (Eurasian Plate)
  - Thick and relatively light.
- Oceanic (Pacific Plate)
  - Thin and made up of wavy igneous rocks.

Mountain ranges, ocean basins, major features of earth etc are found due to the movement of plate boundaries.

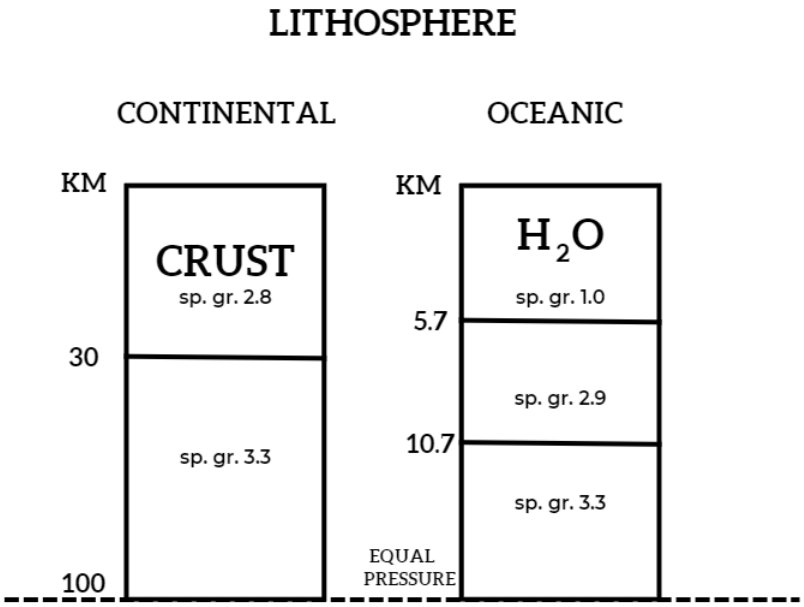


Figure 3: Plastic Higher Temperature Layer
(Asthenosphere 100 to 200 km)
Lower part of earth's crust

Classification of Plate Boundaries

Three types of plate boundaries exist:

1. Divergent Boundaries
2. Convergent Boundaries
3. Transcurrent Boundaries

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4 Lecture 4: Internal Structure of the earth

Date: 08/07/2023

ii) Mantle

characteristics:

- Next to earth's crust
- Rich in Al, Si, Mg
- 2900 km thick

It has three sections:

1. Upper mantle: 40 to 200 km below the earth's surface
2. Middle mantle: At a depth of 200 to 1000 km
3. Lower mantle: 1000 to 2900 km below the surface of the earth

Maximum temperature of these section in 2200°C.

iii) Core

charateristics:

- Next to mantle
- About 3400 km radius
- two parts: Outer core & Inner core

Outer Core:

- Temperature 2200°C to 5000°C
- Consists of hot molten nickel, cast iron etc.

Inner Core:

- The temperature is 5000°C
- Consists of solid balls of iron and nickel.
- The atoms of the metal are pressed together so tightly by gravity that melting is impossible.

Tectonic Plates and Plate Boundaries

(a) Divergent Boundaries:

It is a tensile regime, as the two plates of the continent diverges or separates, magma rises from mantle after solidification forms mid-ocean ridge.

Example: About 200 million years ago, the atlantic ocean was born in this process.

(b) Convergent Boundaries:

It is a compressional regime and several things can happen.

- Ocean-ocean convergent boundaries
- Ocean-continent convergent boundaries
- Continental-continental convergent boundaries

Ocean-Ocean convergent boundaries:

One plate slips beneath the edge of the other. The lower plate is melted as it moves into the hot mantle. The melting minerals rises through the crust forming granite and other igneous rocks.

Example: South sandwich trench of atlantic ocean formed in this way.

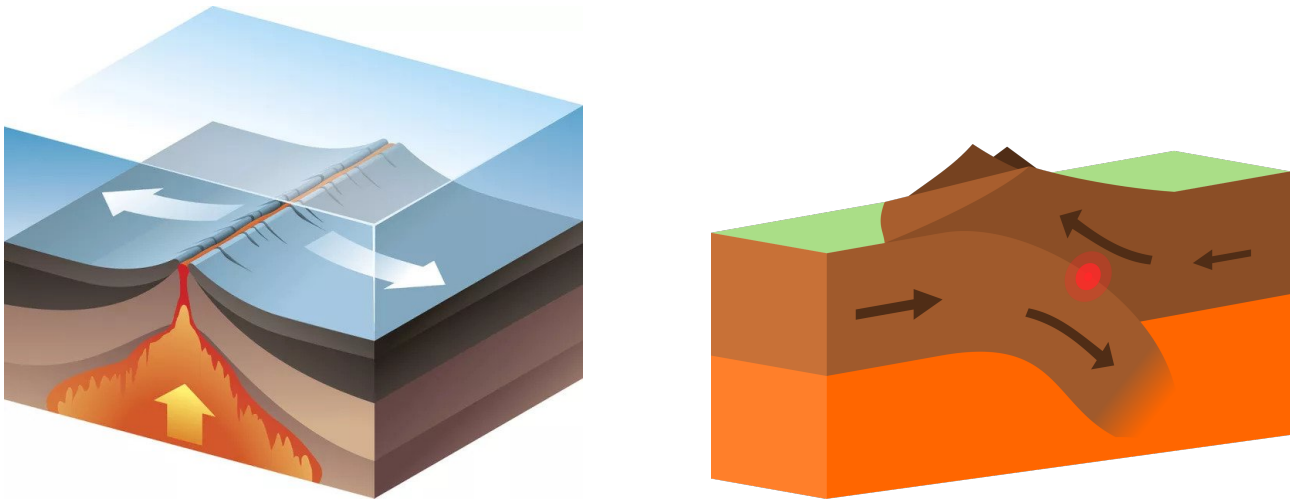
Ocean-Continent Convergent Boundaries:

Thinner and heavier oceanic plate plunges beneath continental crust, forming a deep sea trench. Magma rises from descending pipe.

Example: Mount saint helens volcanos formed in this way.

Continent-continent Convergent Boundaries:

The collision buckles and folds the rocks.



(a) Divergent Boundaries

(b) Convergent Boundaries

Figure 4: Tectonic Plates and plate boundaries

5 Lecture 5: Transcurrent Boundaries

Date: 22/07/2023

This is a shear of wrench fault regimes and may have shear, torsional (divergent) or compressional (convergent) components depending on relative movement between the plate boundaries

Example - San Andreas fault in carrizo plain of california.

Rocks

Rocks are natural mineral formation making up earth crust consisting of either dissimilar and similar rock forming materials.

Rocks Classification

1. Magmatic or igneous: Latin Ignis means fire.

   Formed by solidification of molten minerals matter with originated within the earth.

2. Sedimentary : Latin sedimentation means settling.
   Are made up of particles derived from the breakdown of older rocks.

3. Metamorphic: Greek meta means change and morphe means transformation of previously formed igneous or sedimentary rocks.

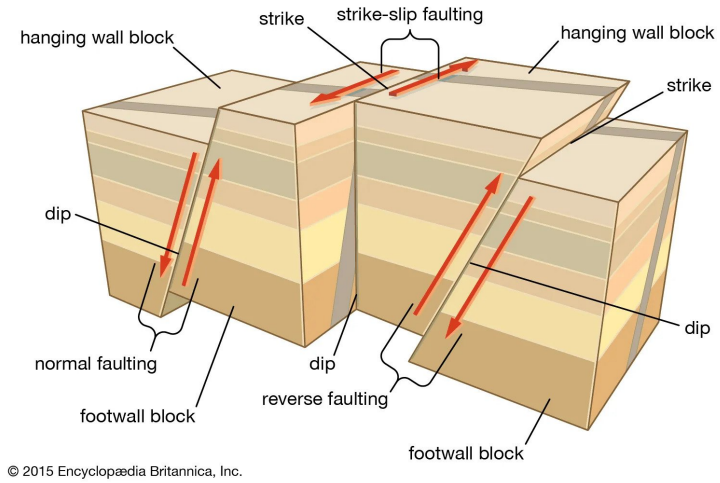


Figure 5: Transcurrent Boundary

6 Lecture 6: Properties of Rocks

Date: 05/08/2023

The various properties of rocks are determine by their origin and by the geological processes that have been occured over the long period of time the rocks have been in existance.

Properties

1. Physical Properties
2. Mechanical Properties

Physical Properties of Rocks

Characterized by physical condition. From a great variety of physical properties, we discuss those properties that directly or indirectly affect the drilling process.

Physical properties of rocks are: cohesion, porosity, density, specific gravity, texture, structure and granularity.

Mechanical Properties of Rocks

Strength, toughness, dynamic strength, hardness, elasticity, brittleness, plasticity, abrasiveness etc.

Physical and mechanical properties of rocks are essential for the following reasons:

- Selecting the method of drilling
- Selecting the most effective type rocks breaking tools
- Designing optimal drilling and easing programs
- Securing geological information

Special attention is given in studying the physical and mechanical properties of cores, recovered from Stratigraphic test holes. This information is necessary for planning new holes in the same medium. The physical and mechanical properties of rocks depends on their:

- texture
- Structure

Texture

The term texture covers the internal structure of a rock that is the sum of total features determine by-

1. Grain shape
2. Grain size
3. Relationship between the rock forming minerals and volcanic glass of cement.

The texture of rocks determine by conditions in which they were formed. The principal textures are-

1. Crystalline granular
2. Inequigranular
3. Glassy
4. Clastic

Structure

The term structure is sum of total features determine by the spatial arrangement and orientation of the rock components. The principal rock structures are mentioned as follows:

- Massive or Compact structure: Such a structure in typical of magnetic rocks
- Bedded of Stratified Structure: This is the characteristics of sedimentary rocks.
- Schistose Structure: which is found in metamorphic rocks. (flat surface of minerals)

Other Properties of Rocks

1. Porosity, P : The porosity of rocks is the total volume of voids (pores, microcracks etc) it contains.
$$P = \frac{V_p}{V} \times 100$$
where, V_p = pore volume, V = total volume of rock, ρ = Density / mass per unit volume, γ = weight per unit volume.

2. Strength of Rocks: It is the property of the solid to resist destructions under the action of external loads, either static or dynamic (compression, tension, bending, shear etc).

3. Toughness: The toughness of rocks implies its capacity to resist external stresses comprising a combination of elementary compressive, tensile, shear stresses. The character of combination depending on breaking the rock.

   The difference between the strength and toughness of rock is that, the strength determines the ability of the rock to resist breakage in a different type of deformation (uniaxial compression, tension, shear), whereas toughness is a measure of rocks resistance to breakage under the action of a combination of several types of deforming stresses.

7 Lecture 7: Properties of Rocks

Date: 12/08/2023

Hardness of Rocks

The hardness of the rock is the resistance of the surface layer to penetrate of a harder body. Therefore the hardness of a rock is its local indentations surfaces. Rock hardness is an aggregate hardness which depends on the hardness and composition mineral grains making up the rocks, the hardness and amount of cement holding the grains together, the porosity of the rock, its moisture content and temperature, and the rock pressure due to the weight of the overlying rock masses.

Rock harrdness is the main strength factor that the rock breaking tool in rotary drilling has to overcome when punching in the rock. It is more difficult to make the tool punch in the rock than to chip off the rock after punching in. Therefore rock hardness is the main factor governing the drilling process.

Elasticity of Rocks, E

The elasticity of rocks is the property of changing form and volume under the action of external forces. And then completely resuming original form and volume when the forces acting upon then are removed. The value of the E for rocks ranges from 10^5 to 10^7 N/cm^2.

$$\text{Elastic or young modulus} = \frac{\text{Normal Stress}}{\text{longitudinal Strain}}$$

$$E = \frac{\sigma}{\epsilon}$$

(add figure here!)

Plasticity of Rocks

The plasticity of rocks is the property of deforming irreversibility under the action of external forces. The plastic deformation do not disappear when the loads acting on the rocks are removed. And therefore are referred to as permanent or residual.

Stiffness

(add figure here)

It is the ratio between the load (F) on the indenter being pressed in the rock and rock deformation (δ) produced by this load.

$$\text{Stiffness, G} = \frac{F}{\delta} = \tan\alpha$$

Where, α is the deformation angle.

Brittleness of Rocks

The brittleness of a rock is its property of breaking without suffering any noticable plastic deformation under the action of external forces. The coefficient of brittleness of a rock is the ratio between the elastic work of a rock and the total work in deforming and breaking the rock under the indenter.

Abrasiveness

Latin abrasio means scrapping off.
Abrasiveness is the property of rocks of wearing away the surface of a harder body (a cutter, cutter tooth, cutting blade etc.). They are in contact with in the process of friction during relative movement. In drilling the higher abrasiveness of the rock, the more rapid wear of the drill bit. The smaller the footage per bit and slower the drilling rate.

Factors affecting abrasive action are:

- Hardness of rock grains
- Cohesive strength of rocks
- Grain shape
- Grain size
- Porosity of rocks
- Homogeneity of rocks
- Water content of rocks

Classfication of abrasiveness

i) **Primary Abrasive wear:** (due to rock being drilled) depends on -

1. abrasive properties of rocks
2. wear resistance of drill bit
3. bit load and speed, fluid circulation etc.

ii) **Secondary Abrasive wear:** Depends on -

1. Hardness and abrasive properties of cutting.
2. Drill speed and circulation rate.

Drillability

The drillability of rock is its resistance to the penetration of drilling tool. Drillability depends on mechanical and abrasive properties of rocks under down hole conditions. Drilling technologies and techniques that is the type and diameter of the drilling tool and the drilling method.

8 Lecture 8: Drilling

Date: 19/08/2023

Definition: Drilling of holes implies a whole complex operation involve in making circular excavation of rocks. These operations are carried out by means of special equipment (drilling rigs and tools) without man's access to the excavation being made. Drilling of holes in earth crust is the most effective means of prospecting for and exploration of mineral deposits of all types.

characteristics of drill holes

- A drill hole (or a bore hole, a well) is a cylindrical mine opening having its diameter much less than the depth.
- Diameter of the drill holes ranges from 16 to 1500 mm. In some cases shafts as large as 1.5 to 8 m in diameter are sunk by drilling.
- Drill hole vary in depth from a few meters to a few thousand meters. In drilling for oil and gas well depth reached about 10000 m.
- Holes may be drilled from the earth surface, from underground mine openings, from the surface of water bodies (rivers, lakes, seas and ocean), from the surface of the moon and the future from the surface of other planet.

Classification of drill holes

Depending on their purpose, drill holes are classified into three main categories.

- **Exploratory Holes:** These are drilled for the purpose of exploration of mineral deposits or for investigation of geological features of a certain region.
  Example: Mapping holes, reconnassance holes, exploration holes, sesimic shooting holes, structure test holes.
- **Exploitation Holes:** These holes are drilled for extracting liquid (fresh water, mineral water, oil) and gaseous (natural gas) minerals.
  Example: Water wells, oil and gas wells, undergrouund gasification holes, brine wells (various salts, bromine, iodine etc.), geotechnical holes (water jet breaking of rocks) etc.
- **Technical Holes:** These holes are intended for various technical purposes.
  Example: Blast hole (for accomodating explosive charge), freezing holes (to freeze water bearing formation), injection oils, observation oils, auxiliary holes (ventilation of mine workings)

Classification of drilling methods

Regarding the rock breaking principle, holes may be drilled by one of the following methods, which differ fundamentally in their physical nature:

i) Mechanical drilling or drilling with rock breaking tools.

Two types:

1. Cable tool drilling
2. Rotary drilling

Advantages of Mechanical Drilling

- It's possible to collect natural samples of rocks through examination and substitute geological sections.
- Provide favorable condition for opening up and studying water, oil and gas bearing formation.
- It enables to drill holes in the specified direction.

9 Lecture 9: Drilling

Date: 26/08/2023

Disadvantage of Mechanical Drilling

- Wear of drill bits necessitating their replacement.
- Low efficiency with increasing depth of the hole if the drilling engine is on the ground surface. This advantage is led to the development of the down hole type (rotary drills, turbodrills, electrodrills) in which motor is located inside the hole immediately above the drill bit.

Hydrodynamic (jet) Drilling

It was high pressure fluid jet to break down or desolve the reck to making up the flow of the hole. There are two varieties of this method.

1. The jet completely breaks down the rocks and

forms the hole. For the jet to break the rock, the pressure must range from 20 to 200 MPa depending on the rock strength. The ability of the jet to break the rock improved if it is charged with abrasive material (steel shot, quartz sand) in a concentration of 5-15% by volume.

2. The jet only partially breaks from the rocks and softens them when the hole is formed by a bit equipped with jet nozzles that increase the ejection velocity. This method has found application in full hole drilling in soft and incoherent (barely bonded) rocks.

Thermal Drilling or Fusion (jet) Piercing

In this method, the rock is broken down by applying intense (about 2300°C) heat to flow of the hole. The high temperature required is produced by burning a jet of Kerosine in a jet of Oxygen. The jet's issue from the nozzles of a blow pipe run through the hole on a string of tubing. The blow pipe is filled with water. The free expansion of the rock in the heated areas of the hole bottom is restricted by the reaction of the rock in the unheated areas. As a result, thermal stress developed in the rock causing it to flake. The rocks flakes are blown up the holes by the waste gases and steam which are sucked from the hole by exhaust blower. The jet Piercing is used for drilling blast holes (technical holes). Jet pierce drills are capable of drilling holes from 160 to 250 mm in diameter and from 8 to 50 mm in depth. Thermal drilling methods are inapplicable to geological exploration works.

Thermo-mechanical drilling

This method envolves wickening of the rocks to be penetrated by their local heating with subsequent breaking with ordinary rotary heat.