B. Tech - Petroleum Engineering
Year/sem - II / IV

PES402 - Fundamentals of Petroleum Geology.

Unit - I Part B & C Questions with Answer.

1. Classify and describe the types of rocks.

Rock: A rock is an aggregate of one or more minerals where as a rok may also include organic remains and minoraloids.

Rock composition: Some rocks are composed of just one minerals. Pyrite and quartz are two common rocks that fit this category. Most rocks are a solid mixture of several minerals like granite.

Rock classification: Rocks are classified by how they are formed. There are three basic groups.

1. Igneous Rocks
2. Sedimentary Rocks
3. Metamorphic Rocks

The Earth's crust is composed of these three basic rock types.

1. Igneous Rock: Igneous Rocks are formed from the crystallization of molten rock (magma or lava) from within the earth's mantle.

⇒ Formed when rocks melt and then cool.

⇒ Rocks are pushed under the earth crust where it melts and turn in to magma.

⇒ Magma comes out of a volcano and cools to from igneous rocks.

⇒ When magma comes out of the volcano, it is called LAVA.

⇒ Examples: Granite, Basalt, Gabbro

Scanned with CamScanner

Cool down quickly	Cooldown Slowly
⇒ It happens outside the Volcano. ⇒ Extrusive Ingneous Rock ⇒ It looks like a glass and having fine grains.	⇒ It happens inside the Volcano. ⇒ Intrusive igneous Rock. ⇒ It has large grains.

2. <u>Sedimentary Rocks</u>: Sedimentary rocks are formed as sediments, either from eroded fragments of older rocks or chemical precipitates.

⇒ Sediments lithify by both compaction, as the grains are squeezed together into a denser mass than the original.

⇒ By cementation, as minerals precipitate around the grains after deposition and bind the particles together.

⇒ Sediments are compacted and cemented after burial under additional layers of sediments.

⇒ Sand stone forms by the lithification of sand particles and limestone by the litification of shells and other particles of calcium carbonate.

⇒ These types of rocks are typically deposited in horizontal layers or strata, at the bottom of rivers, oceans and deltas.

⇒ Examples: Lime stone, Sandstone, clay, chalk

Weathering → wind & water Break the rocks into small pieces.
↓
Erosion → wind & water carries bits of rock and soil away.
↓
Sediments → Bits of rocks & soil settle into layers.
↓
Compression → After a long time, layers formed due to compression.

Scanned with CamScanner

3. Metamorphic Rock:

⇒ Metamorphic Rocks are formed from pre-existing rocks by mineralogical, chemical and/or structural changes in response to marked changes in temperature, pressure, shearing stress, and chemical environment.

⇒ These changes generally take place deep within the earth's crust.

⇒ Otherwise simply it forms when other rocks are changed under heat or pressure.

⇒ Example:

1) Marbles (Transformed lime stone)
2) Slate (Transformed clay)
3) Schist.

2. Give an account on a Sedimentary environments and Sedimentation.

Sedimentation:

⇒ Sedimentation, in the geological sciences, process of deposition of a solid material from a state of suspension or solution in a fluid (usually air or water).

⇒ Sediments are loose grains and chemical residues of earth materials, which include things such as rock fragments, minerals grains, part of plants or animals and rust (oxidized iron).

⇒ It also includes deposits from glacial ice and those materials collected under the impetus of gravity alone, as in talus deposits or accumulations of rock debris at the base of cliffs.

⇒ The term is commonly used as a synonyms for sedimentary petrology and sedimentology.

⇒ The geochemist also considers the sedimentation process in terms of the chemical end products.

Scanned with CamScanner

Sedimentary process:

1. River Process
2. Wind process
3. Glacier process.

Sedimentary Environment:

There are three major Sedimentary environments

1. Continental Environments
2. Transitional to Shallow Marine Environments
3. Deep Marine Environments.

1. Continental Environments:

⇒ Predominantly siliciclastic sediments (conglomerate, Sandstone, Siltstone etc.) characterized by Scarce fossils and no marine fossils.

A. Fluvial (Rivers)

⇒ Alluvial fans :- Deposits that form at the base of mountains where rapidly flowing streams suddenly emerge from a narrow valley.

⇒ Braided Rivers:- Characterized by many channels separated by bars or small islands.

* There are two main types of braided river facies.

1) rippled, cross-stratified gravels and coarse Sandstones (bars)

2) horizontally stratified, fine to coarse Sands (channels).

⇒ Meandering Rivers :- confined to one, highly sinuous channel, and contain finer sediment load than braided rivers. It also form bars, but they are formed on the inside bend of meander loops.

Scanned with CamScanner

* There are two main types of meandering river

1) Rippled, cross-bedded, fining-upward sequences of gravel and sand (bars)

2) Fine-grained sediments, such as silt and clay, containing in burrows and plant debris (overbank or flood deposits).

B. Lacustrine (lakes) - difficult to characterize.

* They may contain numerous sedimentary structures, include cross-bedding, ripples, graded beds, footprints, mudcracks and raindrop impressions.

* Fossils may be common, plant fossils and freshwater bivalves and gastropods are particularly abundant.

C. Paludal (swamps and marshes)

* Organic-rich shale and sandstone or coal deposits with thin stringers of siltstone and shale.

* plant fossils are common in all stages of preservation.

D. Eolian (Deserts and near beaches - wind)

* Recognized by dune deposits, although the dominant sedimentary layering that is preserved is horizontal.

E. Glacial

* Range in size from small bodies deposits by valley glacier (alpine glacier) to large sheets dumped from continental glaciers.

* Characterized by a variety of facies, but the most unique is pebbly mudstone.

2. Transitional to Shallow Marine Environments:

A. Deltas:

* Form where the rivers enters a standing body of water,

Scanned with CamScanner

slow down and deposit more sediment than can be removed by waves and currents.

* Although deltas also from in lakes, the largest deltas occur in the oceans.

B. Beaches and Barrier Islands:

* Long, narrow accumulations of sand parallel to the shoreline. Barrier islands are separated from land by a shallow lagoon or marsh.

* Beach facies are composed primarily of fine-to medium grained, well-sorted sand that displays subhorizontal parallel laminations and low-angle, seaward, landward, and alongshore dipping crossbeds.

* The variously dipping crossbeds are a result of the back-and-forth action of tides and longshore currents.

* Burrows are common in sediments of the transition zone between the beach and open shelf.

C. clastic shelf:

* Bounded by coastal environments on the landward side and by the continental slope on the seaward side.

* Sediments consist mainly of sand and mud, and nearshore sands commonly grade seaward through a transition zone of mixed sand and mud to deeper-water muds.

* Cross bedding is common in the sands and bioturbation is common in the muds.

D. Carbonate shelves and platforms

* Located primarily at low latitudes in clear, shallow, tropical seas where little continental clastic sediment is introduced.

3. Deep Marine:

A. Pelagic: Fine-grained sediments deposited far from land influence by slowly settling particles suspended

Scanned with CamScanner

in the water column.

1. Carbonate ooze - carbonate shells of tiny planktonic organisms (foraminifera, coccolithoforids)

2. Silica ooze - Silica shells of tiny planktonic organisms (radiolarian, diatoms)

3. Red clay - clay sized particles of continental origin (mostly transported by wind). Very high Fe and Mn contents produce the coloration, and frequently Mn pavements, crusts and nodules are found in this environment.

B. Turbidites:

* Fining-upward deposits that were transported seaward in deep-sea channels and canyons by high-density, sediment laden currents.

* In map view, turbidites form fans that spread outward on the sea floor from the mouths of the canyons.

3. Explain in detail about nature and properties of Minerals.

Minerals: minerals are naturally-occurring, homogeneous solid with a definite, but generally not fixed, chemical composition and an ordered atomic arrangements.
It is usually formed by inorganic processes.

Mineral Occurrences and its Environments:

* Learning to recognize different types of geological environments can be thus be very helpful in recognizing the common minerals.

* For the purpose of aiding minerals identification, we have developed a very rough classification of geological environments, most of which can be visited locally.

Scanned with CamScanner

A. Igneous Minerals:

* Minerals in igneous rocks must have high melting points and be able to co-exist with, or crystallize from, silicate melts at temperatures above 800°C.

* Igneous rocks can be generally classed according to their silica content with low-silica (<<50% SiO_2) igneous rocks being termed basic or mafic, and high-silica igneous rocks being termed silicic or acidic.

* There are two types

1) Basic Igneous rock (BIR)

2) Silicic Igneous rock (SIR)

B. Metamorphic Minerals:

* Minerals in metamorphic rocks have crystallized from other minerals rather than from melts and need not be stable to such high temperatures as igneous minerals.

* In a very general way, metamorphic environments may be classified as

1) Low-grade metamorphic (LGM) (temperatures of 60° to 400°C pressures << 0.5 GPa (=15 km depth)

2) High-grade metamorphic (HGM) (temperatures > 400° and pressures > 0.5 GPa).

C. Sedimentary minerals:

* Minerals in Sedimentary rocks are either stable in low-temperatures hydrous environments (e.g. clays) or high temperature minerals that are extremely resistant to chemical weathering (e.g. quartz).

* There are two types

1. Detrital Sedimentary Minerals (gold, quartz, diamond)
2. Evaporative Sedimentary Minerals (phosphates, Calcite)

Scanned with CamScanner

D. Hydrothermal Minerals:

* The fourth major minerals environment is hydrothermal, minerals precipitated from hot aqueous solutions associated with emplacement of intrusive igneous rocks.

* This environment is commonly grouped with metamorphic environments, but the minerals that form by this process and the elements that they contain are so distinct from contact or regional metamorphic rocks that it useful to consider them as a separate group.

* These may be sub-classified as

1. High Temperature Hydrothermal (HTH)
2. Low Temperature Hydrothermal (LTH)
3. Oxydized Hydrothermal (OXH)

Chemical Properties of Minerals

Native elements:

* The first group of minerals is the native elements, and as pure elements, these minerals contains no anion or polyanion.

* Native elements such as gold (Au), Silver (Ag), Copper (Cu), and platinum (Pt) are metals, graphite is a semi-metal, and diamond (C) is an insulator.

Sulfides:

* The sulfides contain sulfur (S) as the major "anion". Although should not be considered ionic, the sulfide minerals rarely contain oxygen, so these minerals form a chemically distinct group.

* Examples are pyrite (FeS_2) Sphalerite (ZnS) and galena (PbS).

* Minerals Containing the elements As, Se, and Te as "anions" are also included in this group.

Scanned with CamScanner

Halides:

* The halides contain the halogen elements (F, Cl, Br, and I) as the dominant anion.
* These minerals are ionically bonded and typically contain cations of alkali and alkaline earth elements (Na, K, and Ca).
* Examples: Rock salt (NaCl), fluorite (CaF_2).

Oxides:

* The oxide minerals contain various cations (not associated with a polyanion) and oxygen.
* Examples: Hematite (Fe_2O_3), Magnetite (Fe_3O_4)

Hydroxides:

* These minerals contain the polyanion OH– as the dominant anionic species.
* Examples: Brucite ($Mg(OH)_2$) Gibbsite ($Al(OH)_3$).

Carbonates:

* The carbonate contain $CO_{3^{2-}}$ as the dominant polyanion in which C^{4+} is surrounded by three O^{2-} anions in a planar triangular arrangement.
* A familiar examples: Calcite ($CaCO_3$)

Sulfates:

* These minerals contain SO^{42-} as the major polyanion in which S^{6+} is surrounded by four oxygen atoms in a tetrahedron.
* Example: gypsum [$CaSO_4 2H_2O$]

phosphates:

* It contains tetrahedral PO^{43-} groups as the dominant polyanion.
* Examples: Apatite [$Ca_5(PO_4)_3(OH)$] a principal component of bones and teeth.

Scanned with CamScanner

Borates:

* The borates contain triangular BO^{3-}_{3} or tetrahedral BO^{5-}_{4}, and commonly both coordinations may occur in the same mineral.
* Example: Borax

Silicate:

* This group of minerals contains SiO^{4-}_{4} as the dominant polyanion.
* Types: ⇒ orthosilicates eg: Forsterite; Pyrope
  ⇒ sorosilicates eg: epidote;
  ⇒ cyclosilicates eg: Tourmaline
  ⇒ Chain silicates eg: Pyroxene; Pyroxenoid
  ⇒ sheet silicates eg: Micas

Physical properties of Minerals

Color: Color in mineral is caused not only by the chemical composition, but also by atomic arrangement, impurities and structural defects.

* Many minerals exhibit a range of colors caused by impurities.
* Some minerals are classified by their color.
  ⇒ orange-red – Realgar
  ⇒ pale brass yellow – pyrite
  ⇒ Copper red – Copper.
* changes in color may result in variations in chemical composition.

Luster:

* Luster represents the appearance of the mineral surfaces in reflected light
* Two major categories – Metallic and Non-metallic
* Native metals and most sulfides have metallic luster.
* Non metallic luster can be described by these terms:
  1. Glassy ; 2. Brilliant ; 3. Resinous ; 4. silky
  5. waxy ; 6. Greasy ; 7. pearly ; 8. Dull or earthy

Scanned with CamScanner

Streak

* It represents the color of the powdered mineral.
* Rub mineral across an unglazed porcelain plate (Streak plate)
* Hardness of the Streak plate surface is 6 ½ so some minerals won't show streak.
* Notably some dark metallic minerals have streaks that vary from the mineral color.
* Hematite - black mineral with red brown streak.

Hardness:

* Hardness is the extent to which the mineral resists abrasion.
* Time honored scale is the Moh's Hardness Scale based on 10 minerals.

Moh's Minerals		Equivalent
1. Talc		
2. Gypsum	-	2 ½ Fingernail
3. Calcite	-	3 copper coin
4. Fluorite		
5. Apatite	-	5 ½ Knife blade
6. Orthoclase	-	6 Glass 6 ½ steel file
7. Quartz		
8. Topaz		
9. Corundum		
10. Diamond		

Tenacity

* This describes the way a mineral breaks or deforms under stress

⇒ Brittle - Breaks or powders. Quartz, diamond

⇒ Maleable - can be hammered into sheets. Gold, Silver

Scanned with CamScanner

⇒ Ductile - can be drawn into a wire. Gold, Silver, Copper.
⇒ Sectile - can be cut with a knife like wax. Gypsum.
⇒ Flexible - Can be bent but doesn't return to original shape. Talc, molybdenite
⇒ Elastic - returns to original shape. Micas.

Cleavage:

* Tendency of a mineral to break along planes parallel to crystal faces.
* cleavage is described as perfect, good, fair or poor along with the number and direction of cleavage planes.

* ⇒ Fluorite - perfect to good - octahedral cleavage in 4 planes.
⇒ Galena - Perfect to good - Cubic, 3 planes at right.

Fracture:

* Breakage along other than cleavage planes.

Specific gravity

* Weight of the mineral with respect to an equal Volume of pure water.
* i.e., SG of 3 is 3X heavier than water.
* SG. of Non-metallics:
  ⇒ Low (<2.2) Sulfur, Halite, opal
  ⇒ Avg. (2.6 - 3.0) Quartz, feldspar, calcite
  ⇒ High (> 3.5) topaz, Barite & cinnabar.
* SG of Metallics:
  ⇒ Low (209 - 223) Graphite
  ⇒ Avg (~5) Marcasite, Pyrite
  ⇒ High (>7) Galena, copper, Silver

Magnetism: Self evident - magnetite is the example.

4. Explain in detail about Nature and properties of rock.

Nature : Ref. Qn.(1)

Physical properties of rock.

* There are 5 physical properties of rocks.
  1. Luster
  2. Texture
  3. Density
  4. Stress and Strain
  5. Color.

1. Luster

* Luster is a property that describes how light is reflected on the surface of a rock. It is one of the properties mineralogists look at when trying to determine the Identity of a mineral present in the rock.

2. Texture

* The texture of a rock is the size, shape and arrangement of the grains (for Sedimentary rocks) or crystals (for igneous and metamorphic rocks).

3. Density

* Density varies significantly among different rock type because of differences in mineralogy and porosity.
* Knowledge of the distribution of underground rock densities can assist in interpreting subsurface geologic structure and rock type.
* The bulk density of a rock is $\rho B = WG/VB$

* where

  WG - weight of grains

  VB - total volume of grains.

Scanned with CamScanner

4. Stress and Strain

* When a stress σ (force per unit area) is applied to a material such as rock, the material experiences a change in dimension, volume or shape.

* This change or deformation is called strain (ε)

5. Colour:

*Rocks are made up of things called minerals which give them their colours and patterns.

Chemical properties of rocks

* Each individual rock has a distinct chemical composition which can be written as chemical formula.

* Except for native elements, minerals are salts composed of positively charged cations (eg. K^+, Na^+, Ca^{++}, Fe^{+++}) and negatively charged anionic groups. (eg CO_3, PO_4).

* **Silicates**:– are the largest group. 86% of the earth's volume is silicate.

* The silicate group has been subdivided into a number of smaller groups using their minerals structures as a basis.

* These include:

⇒ 1. Tectosilicates – quartz, feldspars, zeolites
⇒ 2. phyllosilicates – micas, serpentines, clays, chlorites
⇒ 3. Inosilicates – pyroxenes, pyroxenoids
⇒ 4. cyclosilicates – tourmalines, beryl
⇒ 5. Sorosilicates – epidote, vesuvianite
⇒ 6. Nesosilicates – garnets, olivine, alumino-silicates.

Scanned with CamScanner

- Arsenites and vanadates AsO_4 and VO_4

(Adamite, Erythrite, Mimetite, Olivenite, Carnotite, Vanadinite)

- Carbonates CO_3

(Calcite, Cerussite, Dolomite, Siderite, Smitosonite)

- Halides : Cl; Cl_2; F; F_2

(Atacamite, Carnallite, Cryolite, Fluorite, Halite)

- Native elements Au; Ag

(Nitratine, Chambersite, Inderite, Borax)

- Oxides and hydroxides O, O_2 and OH $(OH)_2$

(Baddeleyite, Corundum, Chrysoberyl, Rutile, Goethite, Manganite)

- Molybdates and tungstates MoO_4 and WO_4

(Ferrimolybdite, Wulfenite, Wolframite)

- Phosphates : PO_4

(Anapaite, Apatite, Brazilianite, Chalcosiderite, Fluorapatite, Herderite, Lazulite)

- Silicates SiO_4 Si_2O_4
- Sulphides S, S_2

(Chalcosite, Cinnabar, Galena, Jamesonite, pyrite, Sphalerite, Stibnite)

- Sulphates and chromates SO_4 and CrO_4

(Anhydrite, Barite, Celestite, Sulphohalite)

Scanned with CamScanner

5. Describe in detail about the identification of rocks in the field and techniques adopted.

Rock Identification:

* A rock is any naturally occuring solid mass of aggregate of minerals or mineraloid matters.

* It is a composition of chemical and the way in which it formed.

* It is categorized by the minerals.

* To classify a rock, there are three things must be considered.

  * Origin
  * Composition
  * Texture

Rock origin:

* The first step to identify a rock is to try to categorize the rock in to one of the three main types or groups of rocks.

* They are
  * Igneous rock
  * Sedimentary rock
  * Metamorphic rock.

Recognition of origin

* It include the common presence of bedding or layering in sedimentary rocks.

* presence of minerals.

Scanned with CamScanner

* Limitations in metamorphic rocks.
* It also include geological environment where the rock is found.
* Where origin is not always obvious, when it is not obvious then composition and texture is the test guess).

Rock composition

* Rock composition is found by determining which minerals makeup the rocks.
* Common field testing methods for individual minerals.
* The texture can be sufficiently distinguished with the naked eye or hand lens.
* The petrographic methods can be used for reliable identification in many cases.
* This method involve to examine the optical properties of minerals by the microscopic lens.
* The properties includes behaviour of refracted reflected and transmitted light.
* X ray deffraction techniques is one of the advanced method to identify small minerals, grains and it also measures the energy level of the photons.
* So that the mineral composition can be identified.

Scanned with CamScanner

Rock Texture :

* Texture can also identified by the nackedeye and handlens.

* Then the texture of a rock is defined by the observation of two criteria.

  * Grain Size (average size of mineral grains)
  * Grain Shape (general shape of minerals grains)

principles and some of the techniques to identifies the rock.

- Geological principles
  ⇒ (Relationship of different rocks)
- Law of cross cutting relationships
  ⇒ (It is to employ in igneous rocks)
- Law of superposition
  ⇒ (It is to employ in sedimentary rocks)
- Principle of Uniformities
  ⇒ (Results of natural forces)
- Geologic time
  ⇒ (Age of the rock ; Absolute age & Relative age)

Scanned with CamScanner

6. Write a short note on (i) Earth Science (ii) Origen of Earth.

(i) Earth Science :

* Earth Science is a study of earth and the universe around it.

* It helps us to understand our place in universe.

Branches of earth Science :

1. Geology :

* It is a study of the origen, history, processes, and Structure of the solid Earth.

⇒ Search for coal, oil and gas.

⇒ Study earthquakes & Volcanoes.

⇒ Study fossils to learn about past.

2. Oceanography :

* It is a study of Earth's Oceans

⇒ Study waves, tides, currents

⇒ Study Ocean floor for clues of Earth's history.

3. Meteorology :

* It is a study of Earth's atmosphere.

* Make weather observations using Satelite images and computer models.

Scanned with CamScanner

4. Astronomy:
* It is a study of the universe beyond Earth.
* One of the oldest branches.
* Babylonians charted planets and stars 4000 years ago.

5. Environmental Science:
* It is a study of way humans interact with their environment.
* Newest branch of earth science
* Study natural resources, pollution and health of plants and animals on earth.

(ii) Origin of Earth
* Earth is one of the 9 planets (8 excluding pluto) orbiting the Sun in the Solar system. The universe is composed of several Galaxies,
* Our Solar system is part of Milky Way galaxy which is disk shaped with about 1,00,000 million stars of varying sizes.
* Our Solar system consists of 9 planets and 31 Satellites, a belt of asteroids.
* Earth, along with the other planets, is believed to have been born 4.5 billion years ago as a solidified cloud of dust and gases left over from the creation of the sun.

Scanned with CamScanner

* For perhaps 500 million years, the interior of earth stayed solid and relatively cool perhaps 2000°F.

* The main ingredients, according to the best available evidence, where iron and silicates, with small amounts of other elements, some of them radioactive.

* As millions of years passed, energy released by radioactive decay - mostly of uranium, thorium, and pottassium gradually heated Earth, melting some of its constituents.

* The iron melted before the silicates and being heavier, sank toward the center. This forced up the silicates that it found there.

* After many years, the iron reached the center, almost 4,000 mi deep, and began to accumulate.

* No eyes were around at that time to view the turmoil that must have taken place on the face of earth — gigantic heaves and bubblings on the surface, exploding volcanoes, and flowing lava covering everything in sight.

* Finally the iron in the center accumulated as the core. Around it, a thin but fairly stable crust of solid rock formed as earth cooled.

* Depressions in the crust were natural basins, in which water, rising from the interior of the planet through volcanoes and fissures, collected to form the oceans.

* Slowly, Earth acquired its present appearance.

Scanned with CamScanner

* There are various Scientific theories of origin and evolution of the earth.

* 1. Nebular Hypothesis
* 2. Planetesimal Hypothesis
* 3. Gaseous Tidal Hypothesis
* 4. Binary Star Hypothesis
* 5. Gas Dust Cloud Hypothesis.

Scanned with CamScanner