**UNIT: II - MINERALOGY**

**Mineral:** The study of the characters of minerals ( eg: quartz, pyroxene, amphibole, mica, chlorite, garnet) is known as Mineralogy. A mineral is a naturally occurring homogeneous substance, inorganically formed with a definite chemical composition, with a certain physical properties and crystalline structures

Under favourable conditions, the internal atomic structure of minerals result in the development of a definite external geometrical shape i..e crystal form.

The stability of minerals depends on temperature, pressure and chemical composition of the environment. At present more than 3000 mineral species have been established.

The earth’s crust is mainly composed of feldspars and quartz and accounts 55% and 10% respectively. Pyroxenes, amphiboles, chlorites, micas, clay carbonates are widely spread too. Following a few rare minerals are also common:

Phenacite …Be2 (SiO4) Bertrandite … Be4 (Si2O7) (OH)4

Baddeleyite …Zr O2 Cordierite … Hg3 S2 Cl2

**Explanation**:

Homogeneous : all parts of the minerals should possess the same physical and chemical characters.

Crystalline: possess atomic structure in a mineral.

Crystal: A crystal may be defined as a natural solid body bounded by smooth and plain surfaces, arranged geometrically.

Crystals develop under favourable conditions depending on: (1) slow cooling (2) surroundings to facilitate the crystal growth in different directions. (3) non-interference by the adjacent growing minerals during solidification.

**Exceptions for Definition of Mineral:**

l. Precious gemstones like diamonds, rubies, sapphires and emeralds are *synthetically produced* under controlled laboratory conditions.

2. Coal, amber, petroleum, etc., are typical *organic substances* which can be considered as minerals.

3. Amethyst, smoky quartz, citrine, cat's eye, aventurine quartz are some varieties of quartz. Colour or appearance peculiarity in them is because they possess some impurities or inclusions or *in homogeneities.*

4. Asphalt ( a variety of bitumen, semi-solid in nature, black in color) , mercury and natural gas are semisolids, liquids or gases. Though these are called minerals, they are *not solid substances.*

5. A good number of minerals are now found to be members of isomorphic groups. Isomorphic minerals *do not have a definite chemical composition,* but have a definite range of composition.

6. Some minerals like flint, chert, jasper and agate are cryptocrystalline, i.e., they do not have a well-developed crystal structure. A few others like opal, bauxite, Psilomelane, pitchblende etc are typically amorphous, i.e., they *do not possess any regular internal atomic structure.*

The most widespread elements in minerals are: O, Si, Al, Fe, Ca, Na, Mg, K, Ti while S, Cl, C, Mn, H are moderately spread. B, Be, Pb, Sb, As, Bi, Se, U, etc are either rare earth elements or not spread at all.

Minerals are broadly grouped into

1. Rock forming minerals ( constitute a rock ) and
2. Ore–forming minerals (composition of an ore which is economically imp ).

The term ore mineral embraces minerals from which valuable metallic elements can be extracted. Eg; Cu, Ag, Fe, Al.

Minerals are extremely important economically, aesthetically, industrially and scientifically.

**Economically**, utilization of minerals is necessary to maintain anything for standard of living. Gold, silver, copper, iron, aluminum etc are economically important minerals for human beings.

**Aesthetically,** minerals of diamond, ruby, sapphire, emerald shine as gems and enrich our lives. Gems in jewellery, crown jewel collections attract the attention of millions of people.

All in all, approximately 10% of all mineral species are used at present for **industrial**  purposes.

**Scientifically**, minerals comprise the data bank from which we can learn about our physical earth and its constituent materials.

Chemistry has developed on the basis of the study of the chemical composition and the properties of various minerals and ores. Mineralogical methods are widely used in Petrology, Geochemistry, soil study, Paleontology (in the study of fossils), in medicine, in archeology.

**All the minerals are grouped into 8 classes**:

1. Native elements (Eg: Au, Ag, Cu, Arsenic, Bismuth, Platinum, Diamond)
2. Sulphides ( Eg: Galena, Pyrite, Cinnabar, Stibnite, Pyrrhotite)
3. Oxides (Magnetite, Haematite, Rutile, Brookite) and hydroxides (Eg: serpentine; amphiboles)
4. Halides (Eg: Fluorite, Halite)
5. Carbonates ( Eg: calcite, Magnesite), nitrates and borates
6. Sulphates ( Eg: Barytes, Gypsum), chromates (Eg: Uvarovite)
7. Phosphates ( Eg: Apatite, Monazite)
8. Silicates ( eg: Quartz, feldspars, Muscovite, Biotite, Hornblende, Tourmaline, Zerolite, Topaz ) .

**DIFFERENT METHODS OF STUDY OF MINERALS**

According to the mineral definition, every mineral has *its own chemical composition and atomic structure* and it *is unique for every mineral.* This fact facilitates the study of mineral in different ways. Common methods of study and identification of minerals based on their

(i) physical properties

(ii) chemical properties

(iii) optical properties and

(iv) x-ray analysis.

**(i) *Study of Physical properties***: Physical properties like **Color, Form, lustre,** **Hardness** (resistance to scratching), **Density** (Specific Gravity), **cleavage** etc., can be studied with simple observations. These properties are dependent on chemical composition and atomic structure i.e., if the atomic structure and chemical composition remains the same, the resulting properties should also be similar.. This principle is the basis for the study of minerals.

For example, any **galena** mineral irrespective of its place of occurrence, size, shape, association ,consistently exhibits lead grey colour, metallic shine, opaque character, high Sp gr (density = 7.4 – 7.6), tendency to break easily along three different directions and is scratched easily by knife. This set of physical properties is never exhibited by any other mineral .Therefore, if such properties are observed an unknown mineral it must be only galena.

**(ii) *Study of Chemical composition***: According to the definition, every mineral which is expected to have its own individual chemical composition, which is not to be found in any other mineral. Therefore, by chemical analysis if composition is known it should be possible to identify the mineral.

For example, if the composition of an unknown mineral is found to be **lead sulphide (PbS),** then that must be only **galena** because galena always has the composition lead sulphide and no other mineral has this composition.

**(iii) *Study of optical properties***: In this method of study, the minerals are made very fine (0.03 mm ) and fixed over glass slide by means canadabalsam such skillfully prepared slides are called thin sections. **They are studied under petrological microscope.** Different optical properties such as interference colours, their order, interference figures, optic sign, twinning, alteration etc., are studied under crossed nicols with help of some other accessories, if necessary.

The optical properties of every mineral are also distinctive and hence helpful in the identification of minerals. For example, quartz is characterized by:  **anhedral shape, clourless, no cleavage, transparent, low relief, non-pleochroic, grey or yellow, interference colours of first order, positive uniaxial interference figure, positive elongation, no alteration etc,**.

**(iv) *Study of X-ray analysis***: When a beam of x-rays falls on a crystal, it is diffracted by the layers of the atoms within the crystal. In making an x-ray analysis of atomic structure of the crystal, the diffracted x-rays are allowed to fall on the on photographic plate and resulting photograph shows a series of spots or lines which form more or less symmetrical pattern. From measurements made on the photograph, the arrangement of the atoms in the crystal can be deduced and also the distances between them. The results of x-ray analysis of minerals reveal their atomic structure, which is distinctive, for each mineral. This enables the accurate identification of minerals.

**STUDY OF PHYSICAL PROPERTIES OF MINERALS**

***Form*:** The form of mineral is defined as its shape. The external shape of mineral reflects the internal arrangement of atoms. When a mineral occurs as a well developed crystal, it is called **crystallized**. If the growth of the crystals is hampered due to interference of other crystal grains then the resulting form is called **crystalline**. When just traces of crystalline structures are present, it is called **cryptocrystalline**. Due to random network of ions or the total absence of crystalline structure, **amorphous (or) shape less** forms result. Some of important forms are listed below.

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| --- | --- | --- | --- |
| S.No | Name of the form | Description | Mineral Examples |
| 1. | Lamellar Form | Mineral appears as **thin separable layers** | Muscovite, Biotite |
| 2. | Tabular Form | Minerals appears as **slabs of uniform thickness** | Feldspars, Gypsum |
| 3. | Fibrous Form | Mineral appears as **fine threads** | Asbestos |
| 4. | Pisolitic Form | Mineral appears as sphericals | Bauxite |
| 5. | Rhombic Form | Rhombic shape | Calcite, garnet |
| 6. | Bladed Form | Minerals appear as independent blade or lath-shaped grains | Kyanite |
| 7. | Granular Form | innumerable equidimensional grains of coarse/medium/fine size | Chromite, graphite, Magnetite |
| 8. | Reni Form | Kidney-shaped | Hematite |
| 9. | Prismatic Form | Elongated crystals | Olivine, Augite |
| 10. | Spongy Form | Porous | Pyrolusite, Bauxite |
| 11. | Cubic Form | Geometrical Shapes | Garnet, Pyrite, Galena |
| 12. | Massive Form | No definite shape | Graphite, Olivine, Quartz, haematite, Magnesite, Jasper, Pyrolusite |
| 13. | Nodular Form | Irregularly shaped compact bodies with curved surfaces | Flint |

***Color*:** Minerals show great variety of colors and can be identified by their color. Color wise the minerals are of two types (i) Dark colored minerals and (ii) Light colored minerals. Mineral colors are generally related to the spatial arrangement of the constituent atoms or the impurities present in the minerals or all of these.

For example: (i)The color related to atomic structure. Diamond is colorless and transparent where as Graphite is black and opaque even though both contain carbon. (ii) The color related to impurities: Generally pure quartz colorless and transparent. But commonly due to impurities it shows colors such as pink, purple etc.

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| **Mineral** | **Color** | **Mineral** | **Color** |
| **Calcite** | Colorless / white / red / grey / yellow | | |
| **Feldspar** | White / grey / red / green / dirty white | | |
| **Quartz** | Colorless / white / green / violet / grey / yellow / pink | | |
|  |  |  |  |
| **hornblende** | Dark green | **Augite** | Greenish black |
| ruby | Red | **biotite** | Black, greenish black |
| Pyrite | Brass yellow | Chalcopyrite | Golden yellow |
| Emerald | Green | **Chlorite** | Grassy green |
| graphite | Shining black | Coal | Black |
| **barytes** | White / pale grey | gypsum | Colorless / white |
| **galena** | Dark lead grey | **Haematite** | Dark steel grey |
| **Microcline** | White/pink/green | **kyanite** | Blue |
| Chromite | Black | **magnetite** | Black |
| Sapphire | Blue | **Muscovite** | Silver white |
| Malachite | Dark green | **Olivine** | Olivine green |
| orthoclase | White / red | **plagioclase** | Grey / white |
| **Garnet** | red | **talc** | White/yellow |
| **opal** | Milky white | Tourmaline | Jet black |

***Streak*:** The streak of mineral is color of its powder. Many minerals exhibit a different color in the powder form compared to form of mass. The powder of the mineral is obtained either by scratching the mineral with a pen knife or rubbing it across piece of unglazed porcelain plate called streak plate. **Most transparent minerals show a white streak**.  **colored minerals show a dark color streak of the mineral.** Sometimes the streak is altogether different in color from the color of the mineral.

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| ***S.No*** | ***Streak*** | ***minerals*** |
| 1 | Dark brown, black | Pyrite, magnetite, chromite, Pyrolusite, biotite, graphite. |
| 2 | Bluish black | Pyrolusite., |
| 3 | Cherry red | haematite |
| 4 | Dark grey | galena |
| 5 | white | Calcite, jasper, olivine, muscovite, asbestos, Kyanite, garnet, talc, calcite, Magnesite, |
| 6 | colorless | quartz |
| 7 | White to grey | Augite, biotite, |
| 8 | Grey to greenish grey | Hornblende, |
| 9 | Silver white | Muscovite |
| 10 | Greenish black | Biotite, pyrite, |
| 11 | Red or reddish brown | Haematite, |

***Lustre*:** Lustre is the nature of shining on the surface of the mineral under reflected light. It varies considerably depending upon the amount and type of light reflected.

Based on the type of shining, lustres are grouped as metallic and non-metallic. Metallic lustre is the type of shining that appears on the surface of the metal. Non-metallic lustres are named considering the type of shining that appears in some common materials. Some important non-metallic lustres that are observed mainly in rock-forming minerals are:

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| **S.No** | **Non-metallic Lustre** | **Description** | **Minerals** |
| 1. | Vitreous lustre | Shining like a glass | Quartz, Calcite, Feldspar |
| 2. | Subvitreous lustre | Subvitreous lustre is similar to vitreous lustre but with less shining | Pyroxenes (augite) |
| 3. | Pearly lustre | Shining like pearl | Talc, Muscovite(mica) |
| 4. | Silky lustre | Shining like silk | Asbestos |
| 5. | Resinous lustre | Shining like resin | Opal, Agate |
| 6. | Greasy lustre | Shining like grease | Graphite, Serpentine |
| 7. | Adamantine lustre | Shining like diamond | Garnet, Diamond |
| 8. | Earthy or Dull lustre | No shining like earth or chalk | Magnesite, Bauxite |

***Cleavage*:**  **The definite direction or plane along which a mineral tends to break easily is called the cleavage of that mineral**. Crystallized and crystalline minerals can have cleavage. **Amorphous minerals do not show cleavage**. Cleavage, if present , occurs as innumerable planes along which mineral is equally weak. Hence all such parallel planes of weakness are referred to as a **set.**

Depending upon their atomic structure, crystalline minerals will have 1 set of cleavage (or) 2 sets (or) 3 sets (or) 4 sets (or) 6 sets of cleavages (or) no cleavage.

**Since atomic structure of a mineral is definite, the cleavage character of the mineral will also be definite**. Depending upon the degree of perfection, cleavage may be described as perfect or eminent or excellent (mica) , good (calcite) , imperfect or poor or indistinct (apatite).

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| S.No | cleavage | Sets | Minerals |
| 1 | None |  | Quartz, Flint, Jasper, Olivine, garnet, haematite, |
| 2 | Indistinct |  | Pyrolusite, Graphite, apatite |
| 5 | Present | 1 | mica, chlorite, talc, Asbestos |
| 6 | perfect | 3 | Calcite, Magnesite, galena |
| 7 | perfect | 2 | Feldspars, hornblende, Kyanite, augite |

***Fracture*:**  Fracture is the nature of randomly broken surface of mineral. Based on the nature of a broken surface, fractures are described as even fracture, uneven fracture, hackly fracture, and conchoidal fracture.

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| **S.No** | **Name of fracture** | **Description** | **Minerals example** |
| 1. | Even Fracture | If the **broken surface of a mineral is plain and smooth**, it is called even fracture | Magnesite, Chalk |
| 2. | Uneven Fracture | If the **broken surface is rough and irregular** | Augite, hornblende, mica, chlorite, talc, pyrite, haematite, magnetite, Pyrolusite, graphite, bauxite. |
| 3. | Hackly Fracture | If the broken surface is very irregular like **the end of a broken stick** | Asbestos, Kyanite, chlorite, |
| 4 | Conchoidal Fracture | If the **broken surface is smooth and curved** | Agate, Flint, Jasper, galena, bauxite. |
| 5 | Even to uneven |  | Olivine, Magnesite |
| 6 | Conchoidal to sub-conchoidal |  | Garnet, |

***Tenacity***: The tenacity is a measure of the cohesiveness of minerals as shown by its resistance to breaking, crushing or other deformation methods. The different kinds of tenacity are classified as follows

1. *Brittle*: Theminerals breaks into **powder**
2. *Malleable*: The minerals be beaten into **sheets**
3. *Ductile*: The mineral can be drawn into **thin wires**
4. *Sectile*: The mineral can be cut into **thin sheets**
5. *Elastic*: The minerals **bend** on the application of pressure **but regains** the original shape when the pressure is released.

***Hardness*:** Hardness may be defined as the **resistance offered by the mineral to abrasion or scratching.**

For example, if mineral specimen is muscovite (mica), when it is tested on the mohs’ scale of hardness, it should not scratched by gypsum but by calcite. The composition of the mineral appears to have less influence over hardness.

For example, graphite and diamond which possess the same composition, but different atomic structures, represent nearly two extremes of the hardness in the mineral kingdom i.e. graphite is extremely soft and diamond is extremely hard.

***Mohs’ Scale of Hardness***: In 1882 an Australian mineralogist, Mohs proposed a relative scale for hardness of minerals. The standard set of ten reference minerals used to determine the hardness of any unknown mineral is called Mohs’ scale of hardness. The actual minerals of the set and their hardness are as follows:

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| Talc = 1;  Gypsum = 2;  Calcite = 3;  Fluorite = 4;  Apatite = 5; | Feldspar = 6;  Quartz = 7;  Topaz = 8;  Corundum = 9;  Diamond = 10; |

Thus Talc is the least hard mineral and Diamond is the most hard mineral. The relative hardness of an unknown mineral is determined by scratching it with the Mohs’ scale of hardness starting with Talc and followed by minerals of increasing hardness. Common minerals like finger nail (H = 2.5) , a copper coin (H=3.5), a broken glass piece (H=5.5) and pen knife (H=6.5) may be used to fix the lower limit.

***Specific Gravity ( density )*** : Specific gravity of mineral depends on their chemical composition. and atomic structure. **The specific gravity of a mineral is the weight of it to the weight of an equal volume of water**. In the laboratory, specific gravity of minerals is determined using either Walker’s steel yard or Jolly’s spring balance. In determining specific gravity care should be taken to select only fresh (ie un weathered ) minerals free from inclusions, impurities etc,.

For routine identification of minerals based on physical properties, **determination of actual specific gravity is tedious and unnecessary** because most of the rock-forming minerals have specific gravity range of 2.5 to 3.5, while common ore minerals like magnetite, hematite, ilmenite, galena, pyrite, Pyrolusite and Psilomelane, have specific gravity over 3.5. Only few minerals have a specific gravity less than 2.5. Thus based on this range of specific gravity of minerals, the density character of minerals may be described as **high, medium or low.**

The medium density refers to the common rock-forming minerals and higher density refers to the common ore minerals.

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|  | Sp. Gravity | Minerals |
| Low Density | < 2.5 | Talc, graphite, |
| Medium Density | 2.5 to 3.5 | Feldspars, quartz, flint, jasper, olivine, augite, hornblende, mica, chlorite, asbestos, calcite, Magnesite, bauxite |
| High Density | > 3.5 | Kyanite, garnet, pyrite, haematite, magnetite, chromite, galena, Pyrolusite, |

**Transparency –translucency:**

A mineral is transparent when the outlines of objects seen through it appear sharp and distinct. Eg: quartz … transparent

Selenite … transparent

Fluorite ; Topaz … sub-transparent

A mineral which, though capable of transmitting light, cannot be seen through is translucent.

When no light is transmitted the mineral is opaque.

**Phosphorescence – Fluorescence:**

Phosphorescence is the property possessed by some substances of emitting light after having been subjected to certain conditions such as heating, rubbing or exposure to electric or UV light.

Eg: pieces of quartz when rubbed together in a dark room emit a phosphorescent light. Diamond, ruby etc when exposure to x-rays show phosphorescent property.

Some minerals such as fluorspar emit light when exposed to certain electrical radiations ( means giving off a certain kind of light ) is called as Fluorescence.

**Depending upon certain senses …… taste; odour, feel etc**

**TASTE:**

When the minerals are soluble in water, generally possess a characteristic taste which may be designated as follows:

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| Taste | Result |
| Saline | The taste of common salt , eg: halite |
| Alkaline | That of potash & soda |
| Acidic / sour | The sour taste of H2SO4 |
| Cool | The taste of potassium chlorite |
| Sweetish astringent | That of alum |
| Bitter | That of Epsom salt |

**ODOUR:** Some minerals have characteristic odours when struck, rubbed, breathed, heated etc… terms used are::

|  |  |
| --- | --- |
| Odour | Result on smell |
| Alliaceous | Garlic odour when arsenic compounds are heated . eg: arsenopyrite, orpiment, realgar |
| Horse-radish odour | The odour of decaying horse radish when selenium compounds are heated |
| Sulphurous | The odour of burning sulphur when sulphides heated |
| Foetid | The odour of rotten eggs given by heating |
| Clayey | The odour of clay. Eg: kaolin |
|  |  |

**FEEL:** Rough feeling of touch………. Eg chalk

**Depending upon the state of aggregation**……. Gases & liquids

Form

Hardness

Tenacity

Fracture

Cleavage

**Gases & liquids**

O2; N2; CO2 are examples for natural gases

H2O ; Hg ; HYDRO-CARBONS are examples for natural liquids.

**MODE OF FORMATION OF MINERALS**

Minerals are the products of natural physic – chemical processes and the conditions in which they originate are various. The conditions include the temperature, pressure and the interaction of minerals with country rocks.

Since, minerals are hard crystalline substances, their origin is restricted

From its liquid into its solid form eg: rock salt

From its gaseous into its solid form eg: sassoline, cinnabar, NH4Cl

From one hard form into another.

The crystallization of HALITE (Rock salt / common salt ) during the evaporation of sea water serve as a good example for the formation of minerals from solutions

The formation of Ammonium Chloride ( NH4Cl );

sassoline (H3BO3 ) or Native boric acid;

Cinnabar (HgS) ie mercury sulphide etc

clearly indicates the emergence of minerals from a gaseous phase.

The formation of minerals during the transition from one solid state into another solid state is typical of the process of RECRYSTALLIZATION; METAMORPHISM & METASOMATISM.

Eg: Limestone is transformed into marble

Quartz in sandstone becomes into quartzite

Clay changes into Phyllites & mica schists.

The majority of the minerals in the earth’s crust have been formed by crystallization of molten melt ie magma. It is estimated that 95% of the earth’s crust is composed of igneous rocks which were resulted from solidification of magma. The chief modes of formation of minerals are .

From Fusion ( solidification from fused rock material ie magma )

From solution ( crystallization from a solution )

From Vapour ( crystallization from a gas )

**Formation of minerals from Fusion:** An igneous magma ( complex solution ) in which the various elements present are free to circulate under the proper conditions to form mineral molecules.

The composition of the magma determine the character of the minerals. The elements O, Si, Al, Fe, Mg, Ca, Na, Na, K etc occur in varying proportions in igneous magmas.

Eg: quartz, feldspars, olivine, Enstatite, hypersthenes, Augite silicates

Hornblende, biotite, muscovite

Apatite, monazite ….. Phosphates

Magnetite, ilmenite, chromite …… oxides

Pyrite, pyrrhotite ….. sulphides

Platinum, diamond …. Elements

**Formation of minerals from vapours:**

The formation of minerals from vapours is confined such volcanic regions where mineral gases are discharged from **fumeroles**.

Minerals deposited in this way include sulphur, Tellurium, Arsenic sulphides, boric acid, chlorides etc…

Eg: quartz, opal, zeolites …. Silicates

Gypsum … sulphates

Haematite, magnetite … oxides

Halite … halides

Pyrite, cinnabar, stibnite … sulphides

Sulphur …,, elements

**Formation of minerals from solutions :** By the evaporation of saline water (sea water / salt lakes) causing certain mineral deposits.

Eg: carbonates of lime ( CaCO3 ) and magnesia ( MgCO3)

Calcium sulphate ( CaSO4) and Sodium Chloride ( NaCl)

Sodium Sulphate ( NaSO4) and Potassium Chloride ( KCl)

The factors of concentration, temperature, proportion of various constituents in the solution control the character of the minerals formed.

Eg: Quartz, feldspars, muscovite, chlorite, hornblende,

Tourmaline, zeolites, topaz silicates

Barytes .. sulphates

Calcite, Magnesite …. Carbonates

Magnetite, haematite, rutile, Brookite … oxides

Fluorite .. halides

Galena, pyrite, Cinnabar .. sulphides

Gold, silver, arsenic, bismuth …. Elements

**MINERALS**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S no | Mineral | hardness | Density (sp gr) | Cleavage |  |
| 1 | Feldspar | 6 – 6.5 | 2.6 – 2.73 | 2 sets |  |
| 2 | Quartz | 7 | 2.6 – 2.7 | Absent |  |
| 3 | Flint | 7 | 2.65 | Absent |  |
| 4 | Jasper | 6.5 – 7 | 6.5 – 7 | Absent |  |
| 5 | Olivine | 6.5 | 3.34 | Absent |  |
| 6 | Augite | 5 – 6 | 5 – 6 | 2 sets |  |
| 7 | Hornblende | 5 – 6 | 5 – 6 | 2 sets |  |
| 8 | Muscovite | 2.5 – 3 | 2.8 – 2.9 | 1 set |  |
| 9 | Biotite | 2.5 – 3 | 2.7 – 3.3 | 1 set |  |
| 10 | Asbestos |  | 2.9 – 3.2 | Perfect |  |
| 11 | Chlorite | 1.5 – 2. 5 | 2.7 – 3.0 | 1 set |  |
| 12 | Kyanite | 4- 5 length & 6–7breadth | 3.6 - 3.7 | 2 sets |  |
| 13 | Garnet | 6.5 – 7.5 | 3.5 – 4.3 | Absent |  |
| 14 | Talc | 1 | 2.7 | 1 set |  |
| 15 | Calcite | 3 | 2.7 | 3 sets |  |

**ECONOMIC MINERALS**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S no | Mineral | hardness | Density ( sp gr) | Cleavage |  |
| 1 | Pyrite | 6 – 7 | 5 | 2 -3 sets |  |
| 2 | Haematite | 5 – 6 | 5. 2 | Absent |  |
| 3 | Magnetite | 5 – 6 | 5. 2 | Absent |  |
| 4 | Chromite | 5.5 – 6 | 4.1 – 5.1 | Absent |  |
| 5 | Galena | 2.5 – 3.0 | 7.5 | Perfect |  |
| 6 | Pyrolusite |  | 4.5 – 5 | Indistinct |  |
| 7 | Graphite | 1 – 2 | 2 – 2.3 | indistinct |  |
| 8 | Magnesite | 4 – 5 | 3.0 – 3.2 | 3 sets |  |
| 9 | Bauxite | 2 - 4 | 2 – 3.5 | Absent |  |

***Degree of Transparency***: This is also known as “diaphaneity”. Depending up on the resistance offered by the minerals to the **passage of light through them**, they may be classified as transparent, translucent and opaque. This character of a mineral depends on chemical composition, impurities, inclusions, weathering and also thickness.

Rock-forming minerals usually appear to be opaque when they are thick, but lose this opaque character if they are made thinner. But metallic ore minerals remain mostly opaque, even when they are made thinner. Therefore, the distinction between a really opaque mineral and other not opaque minerals will help to distinguish ore minerals from rock-forming minerals.

**Relative advantages and disadvantages of different methods of study:** Among different methods of study made in the identification of a mineral, **definitely x-ray analysis is best, because it is accurate and there is no scope for wrong identification**. But disadvantage is that for such study many facilities, a lot of infrastructure, costly equipment and accessories are necessary.

The constraints, in the study by optical properties method, are (i) opaque minerals are not amenable for study under ordinary petrological microscopes, special reflective ore microscopes are needed for their study (ii) amorphous minerals, by virtue of their irregular arrangement, cannot be identified by optical methods. (iii) cost involved in procuring the required equipment

The method of chemical analysis, this is **fairly good in giving correct identification of minerals,** but the constraints are (i) impossible to identify the mineral exclusively based on chemical analysis (ii) cost of equipment, reagents, and facilities required

Lastly coming to the method of study of minerals by physical properties, it is **most suitable** for the following reasons

1. The unique advantage is that it makes possible the study of rocks or minerals in the field itself.
2. It does not require any equipment worth mentioning.
3. It does not involve the use of chemicals and it does not need additional facilities.
4. It involves no loss or wastage
5. It is the quickest, simplest and least tedious method for identification of minerals i.e., money, energy, and time are spent to the minimum extent.

However, the disadvantages in this method are

1. In some cases even slight variation in chemical composition results in considerable change in colour.
2. Weathering alters many physical properties significantly and makes identification difficult.
3. Further, some minerals formed under different conditions show light variations in physical properties.

***Polymorphism*:** polymorphism is a phenomenon where by different minerals possessing different physical properties occur despite having the same chemical composition. For example: Al2SiO5 is the composition of different minerals like Andalusite, sillimanite and kyanite.

**Study of physical properties of rock forming minerals:** It is necessary to know about the common minerals which actually make up different rocks and determine their properties.

Name of the Mineral: 1. **Feldspar**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Tabular |
| 2 | Color | Pale pink, whitish blue, grayish |
| 3 | Streak |  |
| 4 | Lustre | Vitreous |
| 5 | Fracture | Uneven |
| 6 | Cleavage | 2 sets |
| 7 | Hardness | 6 – 6.5 |
| 8 | Density (Sp gravity) | 2.6 – 2.73 |
| 9 | Varieties | Plagioclase feldspars include:   |  |  |  | | --- | --- | --- | | ALBITE; | OLIGOCLASE | ANDESINE | | LABRADORITE | BYTOWNITE | ANORTHITE. |   Potash feldspars include:    Hyalophane (KAlSi3O8)  Orthoclase (KAlSi3O8)  Microcline (KAlSi3O8)  Anorthoclase (Na KAl Si3 O8) |
| 10 | Occurrence | In granites, Syenites, diorite, rhyolite, Trachyte, sandstones, schists, gabbros, gneisses. |
| 11 | Uses | In the manufacture of porcelain & pottery, earthernware, sanitary ware, bricks manufacture, glasses, electronic products etc. |
| 12 | Chemical composition | NaAlSi3O8 to CaAl2Si2O8 |

Name of the Mineral: 2. **Quartz**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Massive, crystals |
| 2 | Color | Quartz occurs in different colors. Common colors are white, grey, purple, brown, pink etc |
| 3 | Streak | Colorless ( harder than streak plate ) |
| 4 | Lustre | Vitreous |
| 5 | Fracture | Conchoidal |
| 6 | Cleavage | Absent |
| 7 | Hardness | 7 |
| 8 | Density (Sp gravity) | 2.6 – 2.7 |
| 9 | Varieties | Flint, Jasper, Amethyst (purple or violet color), Opal, rose quartz ( pale pink color). Milky quartz ( milky white in color ) . |
| 10 | Occurrence | Occurs in almost igneous( granites, rhyolites), sedimentary (sandstones) and metamorphic rocks ( quartzites ). |
| 11 | Uses | Glass making, optical materials, polishing / grinding compounds, components in electronic products, |
| 12 | Chemical composition | SiO2 |

Name of the Mineral: 3. **Flint**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Irregular nodules, massive |
| 2 | Color | Grey, brownish, black |
| 3 | Streak | Colorless ( harder than streak plate ) |
| 4 | Lustre | Resinous |
| 5 | Fracture | Conchoidal |
| 6 | Cleavage | Absent |
| 7 | Hardness | 7 |
| 8 | Density (Sp gravity) | 2.65 |
| 9 | Varieties | Hornstone, Chert |
| 10 | Occurrence | In sedimentary rocks such as Limestones |
| 11 | Uses | Used in tube mills, pottery industry, as road and building material. |
| 12 | Chemical composition | SiO2 |

Name of the Mineral: 4. **Jasper**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Massive |
| 2 | Color | Red, Grey, brown |
| 3 | Streak | Colorless ( harder than streak plate ) |
| 4 | Lustre | Dull, vitreous, greasy |
| 5 | Fracture | Conchoidal |
| 6 | Cleavage | Absent |
| 7 | Hardness | 6.5 - 7 |
| 8 | Density (Sp gravity) | 2.57 – 2.65 |
| 9 | Varieties |  |
| 10 | Occurrence | In Igneous, sedimentary & metamorphic rocks |
| 11 | Uses | Ornaments, gemstones |
| 12 | Chemical composition | SiO2 |

Name of the Mineral: 5. **Olivine**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | MASSIVE or no definite shape |
| 2 | Color | OLIVE GREEN. Mg rich types are PALE whereas iron rich types are DARK COLOURED |
| 3 | Streak | WHITE |
| 4 | Lustre | VITREOUS but OFTEN DULL |
| 5 | Fracture | EVEN TO UNEVEN |
| 6 | Cleavage | ABSENT |
| 7 | Hardness | 6 – 7 |
| 8 | Density (Sp gravity) | 3.2 – 4.3 |
| 9 | Varieties | FORSTERITE IS MAGNESIUM OLIVINE  FAYALITE IS FERROUS IRON TYPE  PERIDOT is a gem variety of olivine. |
| 10 | Occurrence | IGNEOUS ROCKS such as Peridotites, Dunites, Gabbro, Basalt, Dolerites. |
| 11 | Uses | PERIDOT IS a GEM VARIETY  manufacture of REFRACTORY BRICKS |
| 12 | Chemical composition | (Mg,Fe)2 SiO4 |

Name of the Mineral: 6. **Augite**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | granular, prismatic crystals |
| 2 | Color | Greenish black TO Brownish black |
| 3 | Streak | WHITE TO GREY |
| 4 | Lustre | VITREOUS TO SUB VITREOUS |
| 5 | Fracture | UNEVEN |
| 6 | Cleavage | 2-SETS |
| 7 | Hardness | 5 – 6 |
| 8 | Density (Sp gravity) | 3.2 – 3.5 |
| 9 | Varieties | Diallage |
| 10 | Occurrence | Basalts, Andesites, Tuffs, Gabbros, Pyroxenites, Andesites |
| 11 | Uses |  |
| 12 | Chemical composition | (Ca, Na) (Mg,Fe+2, Fe+3, Al) [(Si Al)2 O6] |

Name of the Mineral: 7. **Hornblende**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | GRANULAR OR PRISMATIC or AGGREGATE |
| 2 | Color | DARK GREENISH BLACK |
| 3 | Streak | GREY TO GREENISH GREY |
| 4 | Lustre | VITREOUS TO SUB VITREOUS |
| 5 | Fracture | UNEVEN |
| 6 | Cleavage | 2 sets |
| 7 | Hardness | 5 – 6 |
| 8 | Density (Sp gravity) | 3 – 3.47 |
| 9 | Varieties | Edenite, Paragasite |
| 10 | Occurrence | In IGNEOUS ROCKS such as Granites, Syenites, Diorites, Hornblendite and in METAMORPHIC ROCKS such as Gneisses, Schists, Amphibolites. |
| 11 | Uses | 1.DECORATION  2.USED AS INSULATING MATERIAL  3.USED AS ELECTRIC COMMUTATORS |
| 12 | Chemical composition | (Ca, Mg, Fe, Na, Al)7-8 (Al Si)8 O22 (OH)2 |

Name of the Mineral: 8. **Muscovite**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | LAMELLAR (layers are separable and occurs in book form ); some occur as flaky minerals. |
| 2 | Color | Brownish black, silver white, brownish yellow |
| 3 | Streak | white |
| 4 | Lustre | Vitreous, pearly |
| 5 | Fracture | EVEN / HACKLY |
| 6 | Cleavage | 1 set |
| 7 | Hardness | 2 - 2.5 |
| 8 | Density (Sp gravity) | 2.76 - 3.0 |
| 9 | Varieties | PARAGONITE- SODIUM MICA  LEPIDOLITE- LITHIUM MICA  *SERICITE* is a fine grained muscovite type found in gneisses and schists.  Gilbertite ……  Illite, a variety of mica is found in sedimentary rocks |
| 10 | Occurrence | found in igneous rocks such as Granites, Pegmatites and Phlogophites.. |
| 11 | Uses | Electrical industry,, wall finishes, thin transparent sheets are used as an insulator and used in circuit boards. |
| 12 | Chemical composition | KAl2(Si3Al)O10(OH,F)2 |

Name of the Mineral: 9. **Biotite**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | LAMELLAR (layers are separable and occurs in book form ); some occur as flaky minerals. |
| 2 | Color | dark brown, black, dark greenish black |
| 3 | Streak | white to gray |
| 4 | Lustre | Vitreous, pearly |
| 5 | Fracture | EVEN / HACKLY |
| 6 | Cleavage | 1 set |
| 7 | Hardness | 2.5 - 3 |
| 8 | Density (Sp gravity) | 2.7 - 3.1 |
| 9 | Varieties | LEPIDOMELANE  PHLOGOPITE: Mg .MICA  ZINNWALDITE: LITHIUM MICA (pale white) |
| 10 | Occurrence | found in igneous ROCKS such as Granites, Diorites, Gabbros, and in metamorphic rocks viz., Biotite gneisses, Schists, Hornfels. |
| 11 | Uses | 1.USED AS INSULATING MATERIAL  2.USED AS ELECTRIC COMMUTATORS |
| 12 | Chemical composition | K(Mg,Fe)3(Si3Al)O10(OH,F)2 |

Name of the Mineral: 10. **Asbestos**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Fibres / FIBROUS |
| 2 | Color | Pale green / whitish green |
| 3 | Streak | white |
| 4 | Lustre | SILKY |
| 5 | Fracture | UNEVEN TO HACKLY |
| 6 | Cleavage | Perfect |
| 7 | Hardness | 5 – 6 |
| 8 | Density (Sp gravity) | 2.9 – 3.2 |
| 9 | Varieties | Nephrite, Uralite |
| 10 | Occurrence | Occurs in actinolite schistose rocks |
| 11 | Uses | Fire proof fabrics, brake linings, manufacture of asbestos sheets, boards, roofing tiles, fire proof paints. |
| 12 | Chemical composition | Ca2 (Mg Fe)5 Si8 O22 (OH)2 |

Name of the Mineral: 11. **chlorite**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | FOLIATED |
| 2 | Color | GREEN usually dark grass green |
| 3 | Streak |  |
| 4 | Lustre | Vitreous to earthy |
| 5 | Fracture |  |
| 6 | Cleavage |  |
| 7 | Hardness | 2.5 |
| 8 | Density (Sp gravity) | 2.6 - 3.3 |
| 9 | Varieties | Chamosite ( iron-rich chlorite),  Ripidolite, Penninite, Clinochlore. |
| 10 | Occurrence | In igneous rocks due to alteration of biotite and in metamorphic rocks such as chlorite Phyllites, chlorite schists. |
| 11 | Uses |  |
| 12 | Chemical composition | Mg,Fe, Al (Al, Si3) O10 (OH)8 |

Name of the Mineral: 12. **Kyanite**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Long blades, fibres |
| 2 | Color | Light blue |
| 3 | Streak | White |
| 4 | Lustre | Vitreous to pearly |
| 5 | Fracture | Uneven |
| 6 | Cleavage | 2 sets |
| 7 | Hardness | 4-5 along length and 6 – 7 along breadth |
| 8 | Density (Sp gravity) | 3.6 – 3. 7 |
| 9 | Varieties | Andalusite |
| 10 | Occurrence | In Gneisses, Schists, Eclogites |
| 11 | Uses | In refractories. As heating element, in ceramic industry. |
| 12 | Chemical composition | Al2 Si O5 |

Name of the Mineral: 13. **Garnet**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Rhombohedron / Rhombododecahedron |
| 2 | Color | Red, brownish red, pink |
| 3 | Streak | Colorless |
| 4 | Lustre | Vitreous |
| 5 | Fracture | Uneven or sub-conchoidal |
| 6 | Cleavage | Absent |
| 7 | Hardness | 6.5 – 7.5 |
| 8 | Density (Sp gravity) | 3.5 – 4.3 |
| 9 | Varieties | Grossularite; Pyrope, Almandine, Spessartite, Andradite, Uvarovite |
| 10 | Occurrence | In Syenites and in Gneisses, schists, |
| 11 | Uses | An abrasive and as a gemstone |
| 12 | Chemical composition | (R2+3, R3+ 2 (SiO4)3  where  R2+ = Ca, Mg, Fe, Mn) and R3+ = Fe, Al, Cr, Ti |

Name of the Mineral: 14. **Talc**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | FOLIATED |
| 2 | Color | White, green, grayish |
| 3 | Streak | White |
| 4 | Lustre | Pearly |
| 5 | Fracture | Even |
| 6 | Cleavage | 1 set |
| 7 | Hardness | 1 |
| 8 | Density (Sp gravity) | 2.7 |
| 9 | Varieties | Steatite, soapstone |
| 10 | Occurrence | Peridotites, Gabbros, Dolomites, Schists, |
| 11 | Uses | Talcum powder industry, paper industry, as a filler in pains, rubber industry, in electrical industry. |
| 12 | Chemical composition | Mg3 ( Si4 O10) (OH)2 |

Name of the Mineral: 15. **Calcite**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Rhombic / tabular |
| 2 | Color | White |
| 3 | Streak | White |
| 4 | Lustre | Vitreous |
| 5 | Fracture | Even |
| 6 | Cleavage | 3 sets |
| 7 | Hardness | 3 |
| 8 | Density (Sp gravity) | 2.71 |
| 9 | Varieties | Iceland spar |
| 10 | Occurrence | In limestones and marbles |
| 11 | Uses | In cement industry, manufacture of bleaching powder,, as a calcium carbide , |
| 12 | Chemical composition | CaCO3 |

**STUDY OF COMMON ECONOMIC MINERALS**

**BAUXITE** is an amorphous mineral which consists of the metallic element of aluminum. Bauxite is formed under tropical weathering from different rocks. Such weathering results in leaching of all soluble matter and leaving behind enriched residues of oxides and hydroxides of aluminum , ferrous, ferric , manganese, titanium and silica. Aluminum is not found in a free state, but it is the most abundant metal in earth’s crust.

**Chemical composition**: Bauxite, a mixture of aluminum hydroxides such as diaspore ( H Al O2 ), boehmite (AlO (OH) ) and gibbsite (Al ( OH)3 ) together with impurities of iron oxide, phosphorus compounds and titania. The following is the range of oxide percentage of bauxite:

Al2O3 55 – 65%

Fe2O3 2 - 20%

SiO2 2 - 10 %

TiO2 1 – 3%

H2O 10 – 30%

**Physical Properties: mentioned separately**

**Occurrence**: Bauxite results from the decay and weathering of aluminum – bearing rocks.

**Uses**: For the manufacture of aluminum. Aluminum is used as abrasives; as refractory bricks.; in making cables ; household vessels, wrapping aluminum foil, cans, etc.. Owing to its low specific gravity 2.58, it is of great value in the manufacture of many articles .

**PYRITE :**Though there are no native sulphur deposits in India, Pyrite serve the purpose of producing sulphur by eliminating sulphur from iron pyrites ( FeS2), which contains 53 % of sulphur and 47% Fe. It has a brass yellow color. Pyrrhotite, which also contains iron and sulphur, has a formula of Fe11S12.

**Pyrite occurs**  as massive or lumps or as fines.

**Chemical composition**: Fe S2.

**Physical Properties**: mentioned separately

**Occurrence**: The principal sources of pyrites and pyrrhotite in India are the sedimentary pyrite deposits of Bihar and Rajasthan. Karnataka, also producing pyrite deposits and the deposits are restricted to ultra basic igneous rocks.

**Uses**: The main use of pyrite is to manufacture sulphuric acid, in the manufacture of phosphatic fertilizers.. Motion picture films consume a good amount sulphuric acid.

**GRAPHITE:** Graphite is one of the principal allotropic modifications of carbon, the other two are coal and diamond. Carbon is known in three different conditions –

Transparent and crystallized as diamond, Scaly and crystalline as Graphite and

Amorphous as charcoal, coal. These different forms, though chemically identical, vary in hardness, specific gravity and other physical properties.

**Native carbon** occurs as two important minerals viz., diamond and graphite while amorphous carbon is coal. Again, carbon forms with oxygen and hydrogen many series of compounds known as the Hydrocarbons.

The sp gravity of graphite is 2.1 and hardness varies between 1 and 2. It is absolutely opaque in character and resistant to heat and a very good conductor of heat and electricity.

**Chemical composition**: It is a pure carbon and sometimes contaminated with a small amount of silica, iron-oxides , clay etc.

**Physical Properties:** mentioned separately

**Occurrence**: Graphite is the stable form of carbon at a high temperature. The majority of graphite deposits are formed by the metamorphism of carbonaceous matters particularly anthracite coal. .

Graphite occurs in Bihar, Orissa, Tamil Nadu, Kerala, Rajasthan; WB; Sikkim; J & K; Karnataka and Andhra Pradesh. In A.P., East Godavari district ( kothala village ) is identified with veins in khondalites. In Bhadrachalam graphite deposits occur as veins in khondalites ( pulikonda area, Rachakonda area ).

**Uses**: Low grade graphite is used in the paint and varnish industries whereas the high grade variety is used in batteries, lubricants, and brushes.

Graphites are used for the manufacture of crucibles for melting of metals. It is required for lead pencil manufacturing industry. Graphite is also used for dry lubrication where oil or grease is harmful.

Graphite is very much in demand for the manufacture of electric motor brushes. ( eg: mixy motor or generators etc..)

**MAGNESITE :** Magnesite, which is a carbonate of magnesium ( MgCO3), contains about 47% of MgO and 53% of CO2. Magnesite is considered as an ore for the extraction of metallic magnesium.

**When**  Magnesite is Calcined at a temperature of 1500o C, the magnesia is converted to a crystalline form known as **Periclase** which has a sp gravity of 3.68.

**Chemical composition**: It is a magnesium carbonate ( Mg CO3). Magnesite is commonly massive and fibrous, sometimes very compact.

**Physical Properties**: ( mentioned separately )

**Occurrence**: Economically important deposits of Magnesite occur as irregular veins in serpentinite rocks and it is found as alteration of serpentinite rocks. In India Magnesite occurs extensively in Salem district of Tamil Nadu where the Magnesite deposits were formed in the ultra basic rocks of chalk hills. In addition, Magnesite occurs in Karnataka as a decomposition product of ultra basic rocks.

**Uses**: Magnesite required as fertilizer. It is also used as filler in paint and glass industries. Calcined magnesia is useful in manufacturing paper pulp from wood and bamboo.

Magnesia powder is used in furnace - linings and crucibles; also employed in the manufacture of special cements and sugar industries.

Name of the ECONOMIC MINERAL: 1. **PYRITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Cube, Granular |
| 2 | Color | Bronze yellow |
| 3 | Streak | greenish black / brownish black |
| 4 | Lustre | metallic |
| 5 | Fracture | Conchoidal / Uneven |
| 6 | Cleavage | 3 sets |
| 7 | Hardness | 6 – 6.5 |
| 8 | Density (Sp gravity) | 4.8 – 5.1 |
| 9 | Varieties | Marcasite, Pyrrhotite, Pyrrhotite |
| 10 | Occurrence | Accessory mineral in IGNEOUS ROCKS |
| 11 | Uses | PRODUCTION OF sulphur and sulphuric acid |
| 12 | Chemical composition | FeS2, |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 523 – 524)

Name of the ECONOMIC MINERAL: 2. **HAEMATITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Massive / Rhombohedron |
| 2 | Color | Steel grey |
| 3 | Streak | Cherry red / red to reddish brown |
| 4 | Lustre | Metallic to Sub-metallic |
| 5 | Fracture | Uneven |
| 6 | Cleavage | Absent / poor |
| 7 | Hardness | 5.5 - 6.5 |
| 8 | Density (Sp gravity) | 4.9 – 5.35.2 |
| 9 | Varieties | Specular iron, kidney ore, Reddle, Martite |
| 10 | Occurrence | IGNEOUS,SEDIMENTARY, METAMORPHIC |
| 11 | Uses | 1. Iron ore  2.PIGMENT |
| 12 | Chemical composition | Fe2O3, |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 518 – 519)

Name of the ECONOMIC MINERAL: 3. **MAGNETITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Granular / octahedral |
| 2 | Color | Iron black |
| 3 | Streak | Black |
| 4 | Lustre | Metallic to Sub-metallic |
| 5 | Fracture | Sub-conchoidal |
| 6 | Cleavage | Absent / poor |
| 7 | Hardness | 5.5 – 6.5 |
| 8 | Density (Sp gravity) | 5.18 |
| 9 | Varieties |  |
| 10 | Occurrence | In igneous / sedimentary rocks |
| 11 | Uses | Valuable ore of iron |
| 12 | Chemical composition | Fe3O4 |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 517 – 518)

Name of the ECONOMIC MINERAL: 4. **CHROMITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Granular |
| 2 | Color | Black / BROWNISH BLACK |
| 3 | Streak | Brown |
| 4 | Lustre | Sub-metallic |
| 5 | Fracture | Uneven |
| 6 | Cleavage | Absent |
| 7 | Hardness | 5.5 |
| 8 | Density (Sp gravity) | 4.5 – 4.8 |
| 9 | Varieties | Picotite, lead chromite m |
| 10 | Occurrence | In Peridotites, Serpentinites, gabbros |
| 11 | Uses | The only source of chromium |
| 12 | Chemical composition | FeCr2O4 |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 486 – 487)

Name of the ECONOMIC MINERAL: 5. **GALENA**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Cube or Rectangular Blocks or octahedral |
| 2 | Color | Lead Grey |
| 3 | Streak | Lead Grey |
| 4 | Lustre | Metallic but often dull |
| 5 | Fracture | Even, sub-conchoidal |
| 6 | Cleavage | 3 sets |
| 7 | Hardness | 2.5 |
| 8 | Density (Sp gravity) | 7.4 – 7.6 |
| 9 | Varieties | **Minium, Cerussite, Phosgenite, Leadhillite, anglesite** |
| 10 | Occurrence |  |
| 11 | Uses | ore of pb, cable covers, foils, lead sheets, piping, soldering, |
| 12 | Chemical composition | PbS |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 456 – 463)

Name of the ECONOMIC MINERAL: 6. **PYROLUSITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Massive, reniform, fibrous |
| 2 | Color | Iron grey or dark steel-grey |
| 3 | Streak | Black / bluish black |
| 4 | Lustre | Metallic |
| 5 | Fracture | Uneven |
| 6 | Cleavage | Indistinct |
| 7 | Hardness | 2 - 2.5 |
| 8 | Density (Sp gravity) | 4.8 |
| 9 | Varieties | **Polianite, Psilomelane, Rhodochrosite, Rhodonite** |
| 10 | Occurrence | In Sedimentary |
| 11 | Uses | Important manganese ore |
| 12 | Chemical composition | MnO2 |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 503 – 510)

Name of the ECONOMIC MINERAL: 7. **GRAPHITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Crystalline , scaly, masses, granular |
| 2 | Color | Iron grey to dark steel grey |
| 3 | Streak | Black |
| 4 | Lustre | Metallic |
| 5 | Fracture |  |
| 6 | Cleavage | Perfect |
| 7 | Hardness | 1 – 2 |
| 8 | Density (Sp gravity) | 2 – 2.3 |
| 9 | Varieties |  |
| 10 | Occurrence | In igneous rocks. |
| 11 | Uses | Facings in foundry moulds, paints, crucibles, stove polish, lead pencils, electrodes |
| 12 | Chemical composition | Pure C |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 340-341)

Name of the ECONOMIC MINERAL: 8. **MAGNESITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Massive, compact, crystals |
| 2 | Color | White, grayish white, yellowish, brown |
| 3 | Streak | Blacken |
| 4 | Lustre | Vitreous / dull/ earthy |
| 5 | Fracture | Conchoidal |
| 6 | Cleavage | Present but not distinct |
| 7 | Hardness | 3.5 – 4.5 |
| 8 | Density (Sp gravity) | 2.8 – 3.0 |
| 9 | Varieties | Broocite, Epsomite, Periclase Kieserite |
| 10 | Occurrence | As irregular veins in serpentine masses |
| 11 | Uses | To produce CO2 , magnesium salts, refractory bricks, furnace linings, crucibles |
| 12 | Chemical composition | MgCO3 |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 296 – 297)

Name of the ECONOMIC MINERAL: 9. **BAUXITE**

|  |  |  |
| --- | --- | --- |
| **S No** | **Properties** | **Observations** |
| 1 | Form | Pisolitic Spongy, amorphous |
| 2 | Color | Dirty white , grayish, brown, yellow, reddish brown |
| 3 | Streak |  |
| 4 | Lustre | Dull, |
| 5 | Fracture | Earthy , uneven |
| 6 | Cleavage | Absent |
| 7 | Hardness | 3 - 4 |
| 8 | Density (Sp gravity) | 2.35 – 2.58 |
| 9 | Varieties | Corundum, spinel, diaspore, boehmite, Gibbsite, Cryolite, alunite, leucite |
| 10 | Occurrence | Weathering of igneous rocks |
| 11 | Uses | In manufacture of aluminum, refractory bricks, in furnace linings |
| 12 | Chemical composition | Al2O32H2O |

( refer RUTLEY’S elements of Mineralogy by HH Read, pp 322 – 325)

**PETROLOGY**

The study of rocks in all their aspects including their mineralogies, structures / textures ( systematic description of rocks in hand specimen and thin sections ); their origin and their relationships to other rocks.

A Rock is a mineral aggregate consist of one mineral or many.

**Role of Magma:** If the molten material is below the Earth’s surface, it is called magma or else it comes out about the surface , it is known as lava.

Magma is a complex mixture of liquid, solid, and gas.  The main elements in magma are oxygen (O), silicon (Si), aluminum (Al), calcium (Ca), sodium (Na), potassium (K), iron (Fe), and magnesium (Mg).  However, two major molecules found in magma that controls the properties of the magma.  These two molecules are silica (SiO2) and water (H2O).  Silica comprises as much as 75 percent of the magma.

When rock melts deep underground, the magma rises through the earth's crust because the molten rock is less dense than solid rock.  In many cases, the magma is unable to reach the surface, and it will cool in place many miles under the ground.  This underground cooling produces the largest crystal sizes, because it cools more slowly.  Sometimes the magma extrudes onto the surface, either on land or underwater.

The heat generated by processes such as radioactive mineral disintegration. Magma doesn’t occur every where below the earth because when temperature increases with depth, pressure also increases with depth due to overburden.

Magma is always associated with huge quantities of various volatiles, whereas these volatiles are absent in case of lava since these volatiles escape into the atmosphere in case of lava. volatiles consists of dominantly water vapour, CO2.

The rise in temperature tends to increase the volume of the material whereas the rise in pressure tends to decrease the volume of the material. Hence, the effects of these two mutually are different.

Depending upon local conditions where the pressure effect is more than the effect of temperature, MAGMA is formed.

**Rocks:** The solid Earth (the mantle and crust) is made of rock. There are three types of rocks those that form from molten material or magma (**igneous**rocks), those that are deposited from air or water (**sedimentary** rocks), and those that have formed by altering another rock (**metamorphic** rocks). The chemical composition of a rock is expressed in terms of oxides for eg: SiO2; Al2O3; Fe2O3; FeO; MgO; CaO; TiO2 etc

**CLASSIFICATION OF IGNEOUS ROCKS**: Igneousrocks are the first formed rocks in the earth’s crust and hence these are called PRIMARY ROCKS, even though igneous rocks have formed subsequently also.

Igneous rocks are the most abundant rocks in the earth crust and are formed at a very high temperature directly as a result of solidification of magma since magma is the parent material of igneous rocks. The temperature increases proportionately with the depth --- this is one of the reasons for the formation of igneous rocks.

Igneous rocks are usually massive, unstratified, unfossiliferous and often occur as intrusive cutting across other rocks ( country rocks or host rocks ). The igneous rocks are classified based on silica%, silica saturation and depth of formation

1. **CLASSIFICATION BASED ON SILICA % :**

|  |  |  |
| --- | --- | --- |
| **Nature** | **Silica %** | **Rock examples** |
| Acidic | * 65 | Granite, Pegmatites; (coarse) ; Rhyolite (fine ) |
| Intermediate | 55 – 65 | Syenite (coarse) ; Trachyte (fine ) |
| Basic | 45 – 55 | Gabbro (coarse ); Basalt ( fine ) |
| Ultrabasic | < 45 | Picrite, Peridotite , Dunite ( coarse ) |

**Acidic igneous rocks:**

* Composed of quartz, alkali feldspars, mica minerals and compositionally rich in Si, Al, Na, K etc but are poor in Ca, Mg, Fe
* Leucocratic due to the presence of light coloured minerals.
* Relatively lighter rocks and have a slightly higher specific gravity of 2.6

**Intermediate igneous rocks:**

* Lacking of quartz or a little quartz present but dominantly composed of alkali feldspars and compositionally rich Na, K.
* Mesocratic in colour due to the presence of dark colored minerals.

**Basic igneous rocks:**

* Dominantly composed of ferro-magnesium minerals(mafic minerals) such as hypersthenes, feldspars (plagioclase), pyroxene (Augite), amphiboles (hornblende) , biotite and compositionally rich in Ca, Mg, Fe.
* Melanocratic in color
* Quartz or olivine is generally absent or occur in small quantities.
* Due to the presence of mafic minerals, these rocks to have a slightly higher specific gravity of 3.1

**Ultra basic igneous rocks:**

* Composed of mafic minerals and quartz is almost absent and compositionally rich in Mg, Ca.
* Melanocratic in color.
* Higher density of about 3.6

1. **CLASSIFICATION BASED ON SILICA SATURATION**:

Depending on the silica content in parent magma; the mineral associations are categorized as:

**Oversaturated igneous rocks**: when the parent magma is **rich in silica**, saturated minerals like feldspars and the surplus quantity ofsilica crystallizes as quartz.

Unsaturated minerals like olivine, nepheline, leucite never occur in over saturated rocks. Eg: granites, granodiorites, dacite, rhyolites .

**Saturated igneous rocks:** when the parent magma has **enough silica** for the formation of minerals, the resulting rocks possess neither quartz nor any unsaturated mineral. Presence of saturated minerals (feldspars) are seen in Syenite, Diorite, Anorthosite, Gabbro.

**Unsaturated igneous rocks** : when the parent magma has **silica less than what is required for the formation of saturated minerals**. Quartz is possible to the extent, and feldspars, olivine, nepheline, leucite are present usually.

This group represents Dunites, Peridotites, Phonolite

Oversaturated rocks are equivalent to acidic igneous rocks. Saturated rocks are equivalent to intermediate igneous rocks. Under saturated rocks are roughly equivalent to basic / Ultrabasic rocks.

**Doliomorphic rocks**: Rarely do quartz and olivine coexist, if so such igneous rocks are described as doliomorphic rocks.

1. **CLASSIFICATION BASED ON DEPTH OF FORMATION:**

In terms of modes of occurrence ie depth of formation, igneous rocks can be either intrusive (plutonic), extrusive (volcanic) or hypabyssal.

PLUTONIC ROCKS: The igneous rocks which have **formed under high temp & pressure at greater depths in the presence of volatiles** in the earth’s crust are called plutonic rocks. Greater pressure ensure total crystallization of minerals formed and the hot surroundings slow down the process of solidification. The net result of all these processes is the development of coarse grained texture. Eg: Granite

SLOW COOLING & SLOW CRYSTALLIZATION OF MAGMA eg; Granite

VOLCANIC ROCKS: The igneous rocks which have formed **under low temp & pressure at shallow depths in the absence of volatiles** in the earth’ crust are called volcanic rocks. Rapid cooling and quick crystallization of lava makes faster the process of solidification due to heat difference. The net result of all these processes is the development of fine grained texture. Eg: basalt

HYPABYSSAL ROCKS: The igneous rocks which have formed **under moderate temp & pressure at shallow depths** are called hypabyssal rocks. Medium rate of cooling causes for the formation of medium grained rocks. Eg: dolerite

Igneous rocks are also classified based on their cooling history (texture) and on the nature of the magma (felsic or mafic).  A diagram for classification would be...

|  |  |  |  |
| --- | --- | --- | --- |
| Composition►  Texture▼ | Felsic (light color) | Intermediate | Mafic  (dark color) |
| Phaneritic | Granite | Diorite | Gabbro, Peridotite |
| Aphanitic | Rhyolite | Andesite | Basalt |
| Vesicular | Pumice |  | Scoria |
| Glassy | Obsidian | |  |

**STRUCTURES & TEXTURES OF IGNEOUS ROCKS**

Structures and textures are physical features associated with the rocks. These occur along with the formation of rocks and are important in view of civil engineering point because

* They contribute to the strength of rocks.
* They contribute to the weakness of rocks
* They reveal mode of origin of rocks.

NOTE: The structures such as folds and faults are exempted though they are also structures since these develop after the formation of rocks due to tectonic forces.

The term structure refers to **certain large scale features**

1. Vesicular structure: 2. Amygdaloidal structure

3. Columnar structure 4. Sheet structure

5. Flow structure

**VESICULAR STRUCTURE:** This structure is due to porous in nature commonly observed in volcanic rocks. Most of the lava contains volatiles (gasses like CO2, water vapour) which escapes into the atmosphere by creating various sizes and shapes of cavities near the surface of lava flow. These cavities are called vesicles.

**Eg: SCORIA** is avolcanic rock of highly porous.

**Eg: PUMICE,**  a light rock with porosity even that floats on water.

**AMYGDALOIDAL STRUCTURE**: when secondary minerals such as calcite, zeolites, hydrated forms of silica (chalcedony, agate, amethyst, opal) are filled in vesicles, in such a case it is said Amygdaloidal structure. Eg: Deccan traps of India.( ie basalts).

**COLUMNAR STRUCTURE**: with uniform cooling and contraction causes a regular or hexagonal form, which may be interested by cross- joints. Eg: Columnar basalts, around 40 mts high are seen at Andheri, Bombay.

**SHEET STRUCTURE**: In this structure, the rocks appear to be made up of a number of sheets, because of the development of horizontal cracks. When erosion takes place, the overlying strata gradually disappear and ultimately the plutonic rocks exposed to the surface resulting the development of joints / cracks parallel to the surface. Thus, the horizontal joint planes are sometimes so closely spaced as to produce a sheet structure. Eg: granite.

**FLOW STRUCTURE**: After eruption of the lava flows, some of the bands or lines are drawn over the surface of lava to the direction of lava flow. Eg: Rhyolite.

**The texture of a rock refers to the individual mineral grains of size, shape, and** mutual relations of mineral constituents and glassy matter in a rock. Depending on the nature of cooling, the TEXTURES in igneous rocks are categorized into:

1. ***Degree of crystallinity*** - Rocks composed entirely of crystals are called holocrystalline; those composed entirely of glass are holohyalline; rocks that contain both crystals and glass are hypocrystalline / hemicrystalline .
2. ***Grain size*** - Overall, there is a distinction between the grain size of rocks that have crystallized at depth are medium to coarse grained (eg: gabbros) and those that crystallized at shallow depth are finer grained (eg: basalts).

**Phaneric texture:** if minerals in the rock are big enough to seen by the naked eye, the texture is said to be Phaneric. Eg: granite.

**Aphanitic texture**: if minerals are too fine to be seen the texture is said to be aphanitic. Eg: basalts.

1. **Based on growth of crystals / Rock fabric** - Fabric is the shape and mutual relationships among rock constituents:
2. Euhedral, refer to grains that are bounded by crystal faces
3. Subhedral grains that are bounded partly by some crystal faces
4. Anhedral, when crystal faces are absent, it is called anhedral

***Hypidiomorphic /***  ***granular*** **texture** - the most common granular texture in which a mixture of euhedral, subhedral, and anhedral grains are present.

***Ophitic texture*** - is one where random plagioclase laths are enclosed by pyroxene or olivine. If plagioclase is larger and encloses the ferromagnesian minerals, then the texture is subophitic . eg: basalt.

***Porphyritic texture:*** Large crystals that are surrounded by finer-grained matrix are referred to as phenocrysts. If the matrix or groundmass is glassy, then the rock has a **vitrophyric** texture.

***Poikilitic texture***- Small euhedral crystals that are enclosed within a large mineral.

***Glassy Texture***.  The rock displays with sharp edges like broken glass is known as Glassy Texture.  No individual crystals can be seen. Eg: **obsidian**.

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| OPHITIC TEXTURE | POIKILITIC TEXTURE |

**GRANITE** isa plutonic igneous rock, compact, massive and hard rock. Granites are unstratified but characterized by joints. It is a holocrystalline (completely crystalline) and leucocratic (light coloured) rock .

**Composition:** Granite consists of quartz ( > 20 – 30 %), Feldspars (60%) include alkali feldspars (orthoclase, microcline) and plagioclase feldspars (oligoclase), micas as essential minerals and accessory minerals are mafic minerals such as hornblende, biotite / muscovite , pyroxenes of hypersthenes; augite ; diopside ; magnetite / haematite, rutile, zircon, apatite, garnet..

**Texture:** Granites exhibit phaneric texture ( coarse grained ), or graphic texture (similar to Arabic writing ). Granites are usually equigranular but some times show inequigranular texture in case of Porphyritic texture (feldspars occur as phenocrysts).

**Hand specimen:** Granite is grayish or pinkish in color. Feldspar appears with white or brownish – red color. Quartz looks colorless. Biotite is jet black and is found as small shining flakes. Hornblende is dark greenish black.

**Varieties:** When quartz decreases and increase in mafic minerals, granite passes over to **GRANODIORITE** and then **DIORITE**.

When both the alkali feldspars and plagioclase feldspars are equal in quantity, the granite rock is called as **ADAMELLITE.**

If hypersthene is more in granite then it is known as **CHARNOCKITE.**

If feldspars and quartz are very large in size and exhibit interlocking texture, then it is called as **PEGMATITE.** Occurrence of large sized beryl, tourmaline crystals is another diagnostic feature of pegmatite.

**RHYOLITE** is very fined grained rock and is the volcanic equivalent of granite.

When the accessory minerals present more in quantity than normally such rocks are named as eg; **biotite-granite, hornblende-granite.** Based on the color of feldspars, the granites are termed as Pink granite; grey granite.

**SPECIAL FEATURES:**

Specific gravity of granite is 2.6 – 2.8

Density = 2500 – 2650 kg/cm3; compressive strength = 1000 – 2500 kg /sq cm

**ENGINEERING POINT OF VIEW:** By virtue of many desirable qualities, granite can be used in foundations of civil structures, building stone, road metal,. Tunneling through granite does not require any lining.

**PEGMATITE**

It is a holocrystalline (completely crystalline ) and coarse grained igneous rock .

**Composition:** Pegmatite resemble granites in mineralogy and hence it is described as **Granite**  **Pegmatite**. When pegmatites are rich in alkali feldspars, it is called as **Syenite** **pegmatites.** Occurrence of large sized beryl, tourmaline crystals is another diagnostic feature of pegmatite.

**Granite pegmatite** consists of alkali feldspars and quartz and rich in biotite/ muscovite of micas. In addition, rare minerals of cassiterite (tin - Sb); mispickel (arsenic–Ar); niobium, tantalum etc are also present and hence pegmatites are economically very important.

**Syenite pegmatites** contain rare earth elements like zirconium, cerium, lanthanum, uranium and thorium.

In Andhra Pradesh, muscovite deposits in commercial quantities occur in pegmatites of Nellore district. This mica is generally light green in color.

**Texture:** Pegmatite exhibit an interlocking texture.

**Hand specimen:** Pegmatite is generally coarse grained consist of larger sized minerals of feldspars and quartz. Feldspars are often light coloured and may appear as red, white or green . Muscovite and biotite are easily identified by their color and cleavage. Hornblende looks dark greenish black and tourmaline is jet black, and prismatic.

**ENGINEERING POINT OF VIEW:** Since pegmatite minerals are large in size and the rock mass cannot behave uniform throughout. Further, the presence of mica which has excellent cleavages obviously makes the rock weak. So it is unsuitable to be used as a building stone and also undesirable at the site of foundation of major constructions. However, pegmatites are economically very important due to the presence of rare and valuable minerals.

**DOLERITE**

Dolerite is a dark, fine grained black or dark greenish black igneous rock. It is intermediate in composition and melanocratic (dark coloured) rock . Mineralogically and chemically, dolerite is similar to Gabbro and basalt.

**Composition:** Dolerite consists of Plagioclase Feldspars and pyroxene (augite). Iron oxides, hypersthene and biotite occur as common accessory minerals. Olivine is some times found if the parent magma was deficit of silica.

**Texture:** Dolerite is a massive and compact rock. It is neither porous nor permeable. The texture in dolerites is generally equigranular. Interlocking texture is also common in dolerite. Under the microscope dolerite exhibit Ophitic or subophitic texture.

**Hand specimen:** Dolerite is a fine grained rock with greenish black or black coloured. Presence of pyroxene (augite) contributes the black color of a rock. Feldspars can be observed by means of their cleavage surfaces and biotite if present appears as small, jet black..

**Varieties:** When all the minerals of dolerite are totally altered for eg: plagioclase into zoisite or epidote and augite into chlorite / hornblende and olivine into serpentine then the rock is **called DIABASE**.

Plutonic equivalent of dolerite is called Gabbro.

Volcanic equivalent of dolerite is called Basalt.

Glassy equivalent of dolerite is called trachylyte.

**SPECIAL FEATURES:** The compact nature and rich in mafic minerals make the rock emit metallic sound when hit with a hammer. Dolerite occurs in nature as an intrusive rock ie as dyke.

**ENGINEERING POINT OF VIEW:** Dolerites are not common as building stones. They are suitable as road metal, railway ballast, bitumen aggregate, concrete purposes. At foundation sites of dam like structures, the presence of dolerite is considered undesirable as they become a cause for weak planes.

**BASALT**

**BASALT** is a black volcanic, massive, fine grained, melanocratic rock. .

**COMPOSITION**: Basalt consist of plagioclase feldspars ( labradorite), Pyroxenes (Augite) and iron oxides (magnetite or ilmenite). Biotite, hornblende and hypersthenes are the other accessory minerals. Pyrite may also seen sometimes. Either quartz or olivine may appear in small amounts depending on the silica content of parent lava.

**Structures & Textures:** Vesicular and amygdaloidal structures are common in basalts. However, Columnar and flow structures are also observed in some cases. Basalts exhibit aphanitic texture in hand specimens. ( ie the minerals are too fine).

**Appearance in Hand specimens**: Basalt is typically black or greenish grey or greenish black. Non-vesicular, massive in nature. Exhibit a typical aphanitic texture ie extremely fine grained with or without vesicles. Basalts are always unstratified, unfossiliferous and do not react with acids.

**VESICULAR BASALT**: it is characterized by the presence of empty cavities or vesicles.

**AMYGDALOIDAL BASALTS** is a vesicular basalt with cavities filled up by secondary minerals of silica (quartz, amethyst, opal, agate); zeolites, calcite. Among these, silica minerals may be used as semi-precious gemstones.

**SPILLITE** is a soda-rich basalt in which plagioclase feldspar is albite or oligoclase in stead of labradorite.

Dolerite is the hypabyssal equivalent of basalt .

Gabbro is plutonic equivalent of Basalt .

Trachylite is equivalent of glassy basalt

Alkali Basalt is unsaturated basalt

Tholeite is oversaturated basalt

**Uses**: Massive basalts are highly durable and strongest having highest load bearing capacity. Used as building stones. Basalts are excellent for macadam and bitumen Roads.

A number of tunnels have been made across through the Deccan traps for railway lines near Bombay. They need no lining except sealing where the weak planes or joints are observed to prevent seepage.

**Dykes and sills**

Igneous rocks are formed out of hot magma or lava. The lava on solidification over the earth’s surface gives rise to Extrusive igneous rocks while the magma on solidification below the earth’s surface gives rise to intrusive igneous rocks.

Igneous intrusions occur in different sizes and forms depending on the conditions during the formation of intrusion. eg: Dykes and Sills are the common forms.

If the intrusion is parallel to the layering in the host rock, it is called as a sill whereas the intrusion cutting across the trend of the host rock, it is called as a Dyke.

**Dykes** are the common form of igneous rocks and are vertical or inclined intrusive igneous bodies. Dykes occur cutting across the bedding planes of the country rocks in which they are found. Due to forceful pressure, magma intrudes through the fractures, cracks, joints, shear zones, weak planes and subsequent solidification of this gives rise to dykes.

The dimensions of dykes vary widely. They may be long (50-60 kms ) and thick (upto 30 mts). eg: dyke of midland of Scotland or t hey may be short upto to a few mts and thin a few cms.

Though different rocks may appear as dykes, dolerite dykes are the most common. Dykes are important from Civil Engg point of view for the following reasons:

1. They are undesirable at the sites of foundations of dams as their sides (contacts ) turn out to be weak planes.
2. They act as barriers and interrupt the ground water movement in a region.
3. They may give rise to springs.
4. Since, the dykes are hard, durable (resisting to weathering), black in color, fine grained, they are used in making of statues, sculptures etc.

**Sills** are similar to dykes but are formed due to penetration of magma into bedding planes of country rocks. The spreading capacity depends on the viscosity of magma, its temperature and the weight of the overlying rocks. Sills which spread over large areas are generally thin with uniform thickness.

* Eg: 1 The great whin soil of England spreads over 3900 sq.kms
* Eg: 2 Karroo sills (dolerite composition ) spreads over 510000 sq kms in South Africa.

Sills act sometimes as mineralizing bodies. eg: Barytes, Asbestos deposits of cuddapah. Sills occur as horizontal and inclined bodies.

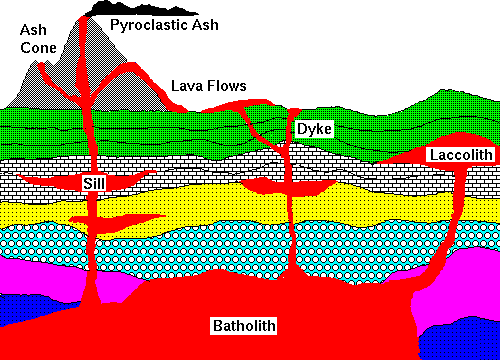
Lava flows may resemble sills closely because both are relatively thin, horizontal sheet like igneous bodies spreading over large areas. But they can be distinguished from one another as follows:

* Lava flows show an irregular lower surface whereas sills have more or less flat on both sides.
* Lava flows shows vesicular character on the upper surface, whereas sills present no such characters.
* Lava flows undergo quite cooling producing fine grained rocks whereas sills cool slowly causing coarse to medium grained rocks.
* Sills give out tongues (minor intrusions) into the overlying rock masses, whereas lava flows do not.

**Other intrusives:** If the intrusion takes place forcibly in stratified rock, resulting a mushroom shaped intrusive in the host rock, it is termed as **Laccoliths.**

In the folded rocks, if the intrusion takes place at a later stage, it occupies the openings at the crest ( in case of anticlines ) and trough ( in case of synclines ) of folds, the resulting form of intrusive is denoted as **Phaccolith.**

Large igneous intrusions of several kilometers in extent having a form which is the top in nearly flat and the bottom is convex downwards is known as **Lopolith.**

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**Batholiths**: The term is applied to any large intrusive mass of igneous rock (eg granite). Batholiths, occupy a large area of out crop extending to greater depths with the presence of Roof Pendants and Xenoliths.

Batholiths occur usually in mountain regions and are parallel to the folded regions. Compositionally, batholiths are either granites or granodiorites. Eg: British Colombia batholiths of 1250 miles extension and a width of 50 miles. The **roof pendants; Stocks; Bosses** offering evidence.

**Roof pendants:** cover rocks of batholiths

**Stocks:** off shoot that means possessing a more or less circular cross-section

**Bosses:** circular & occur at the top portion of batholiths

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**SEDIMENTARY ROCKS**

**Sedimentary Rocks** are those formed due to weathering ( which is a natural process of disintegration and decomposition ) and / or erosion of the pre-existing rocks. Also formed due to chemical precipitation or due to accumulation of organic remains such as plants and animal hard parts. Since, the sediments represent secondary , these rocks are also called as “**Secondary rocks**”. By volume, the secondary rocks constitute about 5% of the lithosphere.

**SIZES OF SEDIMENTS**

|  |  |  |  |
| --- | --- | --- | --- |
| **GRADE** | **GRAIN SIZE** | **GRADE** | **GRAIN SIZE** |
| Boulders | * 200 mm | Coarse sand | 1 – 2 mm |
| Cobbles | 50 – 200 mm | Fine sand | 0.1 – 0.25 mm |
| Pebbles | 10 – 50 mm | Silt | 0.01 - 0.1 mm |
| Gravel | 2 – 10 mm | Clay | < 0.01 mm |

**TRANSPORTATION OF SEDIMENTS**: The sediments are transported by natural agencies by wind action or running water action (most common agency for transportation) or Glacial action.

During the process of transportation, the disintegrated constituents undergo initial differentiation (change in the shape, volume, size etc) thus loosing their original characters.

The soluble constituents during transportation are carried away to long distances and are ultimately deposited as CHEMICAL PRECIPITATES or ORGANIC DEPOSITS. The soluble materials are generally chlorides, sulphates and carbonates.

The insoluble constituents during transportation are carried to considerable distances, ultimately giving rise to ARGILLACEOUS DEPOSITS. Insoluble residues are generally aluminium silicates.

Finally, the constituents that are resistant to weathering ( unaltered ) are transported to lesser distances to be accumulated as ARENACEOUS DEPOSITS. The resistant material is mainly silica.

**Sedimentary structures:** Several primary structures are evidenced in sedimentary rocks. These structures offer significant evidences of depositional conditions (environments ). These are:

**Stratification**  indicates the time period involved in their deposition (Rocks which display layering or bedding) Eg; shales

**Cross-bedding**  indicates shallow water deposits. Eg: sandstone ( A series of inclined bedding planes having some relationship to the direction of current flow.

**Graded bedding** indicates deeper water deposits. Eg: Greywacks ( Coarser material at base and the finest material at the top due to involvement of a river or stream flow is called as graded bedding).

**Ripple marks** indicate the shallow water deposition.

**CONGLOMERATES**: It is a Rudaceous sedimentary rock which is made up of round or sub-rounded pebbles and gravel. Occasionally, cobbles and boulders also are encountered in some conglomerates. Mineralogically, pebbles are usually jasper, flint, quartz. The cementing material may be siliceous, ferruginous, calcareous…

The rounded nature of pebbles indicates that the source of rocks from which pebbles of the conglomerate have been derived far away from the place of occurrence of the conglomerate.

**Sandstones** are abundant amongsedimentary rocks but are next to shales. Sandstones are made up of sand and described as Arenaceous rocks. Sandstones are stratified and sometimes fossiliferous too. Compositionally, sandstones consist of sand grains ( 90% quartz ) with accessory minerals of such as mica, ilmenite, magnetite, garnet, zircon, rutile, feldspars cover the rest.

In a hand specimen of sandstone, the size of sand grains may be coarse, medium or fine grained and other grains appear in different colors due to the presence of cementing material:

|  |  |
| --- | --- |
| Grains | Appears as |
| Quartz | Colorless, fresh with vitreous lustre |
| Mica flakes | White colour with perfect cleavage |
| Ilmenite / magnetite | Jet black |
| Garnet | Red with shining |
| Zircon; rutile | White color with shining |
| Feldspars | Pale colours of brown, red, white, grey with a dull lustre |
| Pyroxenes & amphiboles | Pale colors |

**Sandstones**  are generally porous and permeable and considered one of the best aquifers. By virtue of their porosity and permeability, they are not only capable of holding a good quantity of groundwater but also yield the same when tapped.

**Varieties in sandstones:**

|  |  |
| --- | --- |
| Arenite | A consolidated lithified sand with < 10% of matrix |
| Arkose | Formed by mechanical disintegration of granitic rocks and is considerably rich in feldspars and sand grains and unsorted. |
| Flagstone | A thinly bedded sandstone. |
| Greywacke | A dark, tough, rich in clay & contains less of quartz and unsorted |
| Grit | A sandstone composed of coarse angular grains. |

|  |  |
| --- | --- |
| Siliceous sand stone | Cementing material is also silica ( porosity is less ) |
| Ferruginous sandstone | Cementing material is a mixture of oxides & hydroxides of Fe |
| Calcareous sandstone | Cementing material is calcium carbonate |
| Argillaceous sandstone | Cementing material s clay |

**SHALES :**  Shales are more abundant than all other sedimentary rocks put together. These rocks are formed out of mechanically transported and deposited sediments. Shales are made up of solid particles of extremely fine grained silt and clay.

Stratification of lamination is best seen in shales because the individual layers are very thin. Shales often contain fossils of flora and fauna. Compositionally, shales are Hydrous aluminium silicates which the products of weathering of feldspars and other silicate minerals.

Field samples show different colours such as white, red, yellow, grey, brown and black. Shales are compact and extremely fine grained. Cross –bedding; ripple marks, mud cracks and fossil content are observed in some specimens of shales.

Mineralogically, shales are mainly made up of montmorillonite, kaolinite; Illite; halloysite; pyrophillite minerals.

Varieties in shales:

|  |  |
| --- | --- |
| Siliceous shale | With considerable amount of silica |
| Calcareous shale | With increasing calcium carbonate content |
| Bituminous shale | With organic matter |
| Carbonaceous shale | Black color with rich in vegetal / organic matter |
| Mud stone | Similar to shale |

Shales are highly porous ( due to the presence of various clays with porosity 50 – 60% ); impermeable rocks (do not yield water due to surface tension phenomenon ) called as AQUICLUDES means shales contain water but do not yield groundwater when tapped.

CIVIL ENGINEERING POINT OF VIEW:

Shales are soft, fine; thin layered and unable to resist overburden. Therefore, these are unsuitable at the site of foundation of civil structures such as dams, tunnels etc.. Since shales are incompetent rocks, they may undergo subsidence.

LAFAYETTE dam in USA which was constructed over argillaceous rocks (shales) had sunk by 20’ and caused for collapse / failure of a dam. Similarly, the Srisailam dam was constructed across the river Krishna resting over quartzites and shales causing slippery under water pressure. Of course, high pressure concrete grouting had been introduced to avoid leakages.

Shales are also unsuitable for road metal, railway ballasts..

**CHEMICAL DEPOSITS** are limestones; Dolomites, Flint, Chert, salt beds, iron-bearing rocks (iron ore). Limestone consists of over 95% calcite whereas dolomite consists of 90% of dolomite and 10% calcite and belonging to **Carbonate rocks**. Quartz, Chalcedony, Opal are three varieties of CHERT formed as chemical precipitate and is known as **Siliceous rocks**

**LIMESTONES:**  In hand specimens, limestones show different colours of white, gray, buff, cream, pink, yellow and black. In nature, limestones occur both as porous and massive types. On the other hand, shell limestones care common and may be porous.

**Types of Limestones:**

**Chalk:** A soft, white fine grained calcareous deposit with dull lustre. It is also consists of fossils viz., foraminifera.

**Stalactites**  result from the process when surface water with dissolved calcium carbonate pass through minute fractures and grows downwards from the roof of a cave.

If the rate of percolation of solution is excess than required evaporation, the solution falls on floor and form as a cone like deposit which grows upwards from the floor is called as **Stalagmites.**

If growth continues stalactites and stalagmites may come together after some time producing a pillar like structure , called a **DRIP STONE**.

Fossiliferous or Shell limestone: These are formed organically with hard parts of marine organisms of coral reefs or gasteropods or lamellibranchs or brachiopods etc…

**CIVIL ENGINEERING POINT OF VIEW:** Massive and compact limestones are reasonably competent to support civil structures. But, these are undesirable for foundation if pores or cavities are present. They are suitable as road metal, railway ballast and as construction material.

**ORGANIC DEPOSITS**  are formed out of active involvement of plants and other organisms. Eg: Phosphoritic deposits (guano deposits) / Rock Phosphates

Guano deposits are formed from fish eating sea birds which live in some isolated islands where there is no rain fall. West coast of America; South Africa; Australia have vast deposits of Guano.

**METAMORPHIC ROCKS**

Igneous and sedimentary rocks which are formed under a certain physico-chemical environment, (they were in equilibrium) in terms of temperature, pressure and chemically active fluids. Subsequent to their formation if any of these factors changes, the existing equilibrium gets disturb in the constituent minerals of parent rocks by metamorphism. As a result of Metamorphism

1. Granite changes to Granitic Gneiss
2. Peridotite (Ultrabasic) changes to Serpentine / Talc Schist.
3. Gabbro / Dunite changes to Hornblende Schist.
4. Sandstone changes to Quartzite.
5. Limestone changes into Marble.
6. Shale changes into Slate

The process of metamorphism occuring in rocks due to the effect of high temperature, pressure and chemically active fluids and are known as metamorphic agents. These three act together to cause metamorphism and sometimes any one or two of them dominate and play an active role.

**Temperature:** Metamorphic changes mainly take place in the temperature range of 350°C to 850°C.

**Pressure:** Uniform pressure ( vertically downwards) increases with depth and effect on liquids and solids at greater depths whereas the **direct pressure (stress)** due to tectonic forces acts in any direction i.e., upwards, downwards and side wards and effect only on solids.

**Chemically inactive fluids:** The most common liquid is water. Also the magma or hot hydrothermal solutions (containing various chemicals) may react directly with those rocks when they come in contact.

**Types of Metamorphism:**

1. **Thermal Metamorphism (Heat predominant)**
2. **Dynamic/Cataclastic Metamorphism:** When direct pressure is predominant and acts, rocks are forced to move past resisting in their crushing and granulation.
3. **Geo-Thermal Metamorphism:** Uniform pressure is predominant alongwith heat brings changes in oceanic salt deposits but not changes in silicate rocks.
4. **Metasomatic Metamorphism (chemically active fluids predominant):** This Metamorphism alters the composition of the rock significantly. Hydrothermal solutions are hot (upto 400°C) and cause for providing new minerals such as Pb, Zn, Mn etc. Tourmaline, topaz and fluorspars are produced when the volatiles involved .

Eg: When Granite is attacked by watervapour, Boron, fluorine will suffer mineralogical changes where by feldspars replaced by tourmaline, the resultant rock may be Tourmaline Granite.

1. **Dynamothermal Metamorphism: (Direct pressure and Heat pressure):** When an argillaceous rock (shale) undergo Dynamo Thermal Metamorphism different minerals are produced. Eg. Gneisses and schists.

Chlorite Biotite Garnet Staurolite Kyanite Sillimanite

* The presence of chlorite and biotite in a metamorphic rock indicates that it had been formed under low grade Metamorphism.
* Presence of Garnet and Staurotite indicates medium grade of Metamorphism.
* Occurrence of Kyanite and Sillimanite indicates high grade of Metamorphism.

**Mineral Composition:** Following are the common minerals found in metamorphic rocks:

Cordite, Staurotite, Andaulusite; Sillimanite, Kyanite, idocrase formed during Metamorphism. Garnet, Chlorite, Talc, Epidote, Quartz, Feldspars, Pyroxenes, Calcite, Mica, Hornblende also occur in different ways due to Metamorphism.

**Metamorphic Textures:**

**1. Foliation:** When Chlorite, Mica, Talc etc orient themselves parallel to one another is called as foliation ie the arrangement of in-equidimensional minerals.

**2. Lineation:** when Hornblende, Tourmaline, Actinolite, Tremotie orient themselves parallel to one another is called Lineation ie the arrangement of equidimensional minerals.

**3. Xenoblastic Texture:** The constituent minerals of the rock have no well developed crystal faces.

**4. Idioblastic Texture:** The constituent minarals have well developed crystals.

Textures of Metamorphic rocks also depends on the shape of minerals, on their mode of growth and mutual arrangement. Some of the textures are seen under microscope.

1. **Porphyroblastic :** large crystals embedded in fine grained ground mass.
2. **Granoblastic:** the mineral granules are equidimensional.
3. **Ophitoblastic:** small crystals embedded in phenocryst

**Structures:**

1. **Gneissose Structure:** Both equidimensional ( qtz, feldspars, pyroxenes, calcite) and other platy and prismatic minerals occur in considerable proportions and they appear in alternating bands. Eg: Granitic Gneiss.
2. **Schistose Structure:** If a rock consists of only prismatic or platy minerals without any segregation is called a Schistose structure. (equidimensional minerals will be negligible) Eg: Mica schist, Chlorite schist, Hbl schist, Kyanite schist.
3. **Grannulose Structure:** Only equidimensional minerals present in the Metamorphic rocks. Prismatic or platy minerals will be either negligible or absent. Eg: Marble, Quatzite.
4. **Cataclastic structure:** It is produced under the influence of directed pressure (shearing stres) upon hard and brittle materials in the upper zones of the earth crust. Eg: Hornfels

**DESCRIPTIVE STUDY OF COMMON METAMORPHIC ROCKS:**  The most commonly occurring metamorphic rocks in nature are Gneiss, Schist, Quartzite, Marble, Slate and Khondalite.

**GNEISS**: A name is generally given to any metamorphic rock when shows a gneissose structure. A few details of its physical description are as follows:

**Diagnostic character**: Foliation present.

**Color**: grey and pink but generally pale coloured

**Grain size**: medium to coarse grained

**Texture and Structure**: Generally equigranular but sometimes porphyroblastic.

**Minerals present**: Feldspars and quartz usually make up the bulk of a gneiss. In addition, garnet, rarely pyroxenes occur in such bands.. If hornblende and biotite are present, then the rock appear as dark or black coloured bands. The other minerals which may also occasionally occur in gneisses are chlorite, sillimanite, kyanite, staurolite, talc, serpentine etc..

***Types*: Based on texture, mineral content etc different varieties of gneisses are named.**

**Orthogneiss**: This is a gneiss derived from igneous rock

**Paragneiss**: This is a gneiss derived from sedimentary rock

**Granitic gneiss:** if a gneiss, which has minerals similar to that of granite.

**Augen gneiss**: This is a gneiss in which quartz and feldspars appear as thick elongated lens shaped (resemble to eye).

**Origin:** Gneisses are usually formed out of Dynamothermal metamorphism of granites, Syenites, Sandstones.

**Properties and uses of civil engineering importance**: Due to non-porous and impermeable, it has a good strength. The foliation to some extent, improves the workability of gneiss. It may be used as building stone in addition to road metal, as railway ballast, as load bearing beams. In case of tunneling, the presence gneiss doesn’t require any lining.

**SCHIST:**  Like a gneiss, schist is also a very common metamorphic rock due to schistose structure. A few details of its physical description are as follows:

**Diagnostic character**: schistose structure is present.

**Color**: silvery white ( mica-schist ), jet black ( biotite schist ), dark green ( chlorite schist )

**Grain size**: fine to medium and sometimes even coarse grained

**Texture and Structure**: Lineation or foliation texture occurs depending on when prismatic or platy minerals occur predominantly..

**Minerals present**: Actinolite, tremolite, hornblende, sillimanite, tourmaline make up the bulk of a schist. In addition, chlorite, muscovite, biotite, talc, kyanite etc are the common platy minerals occuring in schists.. garnet, quartz, staurolite, cordierite also occur as other minerals ..

***Types*: Depending on the grade of metamorphism, schists are named as Low Grade Schists (** Mica schist: Chlorite schist: Talc Schist; Hornblende Schist; Mica–Garnet Schist; Mica–Quartz Schist**)** and  **High grade schist** (Sillimanite schist; Eclogite Schist; Staurolite Schist).

**Origin:** Schists are usually formed due to Dynamothermal metamorphism of different kinds of igneous and sedimentary rocks and the nature of combination of metamorphic agents. For eg:

Mica schist is formed out of shale

Mica – quartz schist is formed out of feldspathic sandstone

Talc schists are formed out of magnesia rich Ultrabasic igneous rocks like peridotite.

Hornblende Schists are formed from basic igneous rocks under high stress and high temperature..

Chlorite schist is formed under high stress and low temperature.

Eclogite Schist consists of pyroxenes, garnet and quartz formed under low stress and moderate temperature.

**Properties and uses of civil engineering importance**: Schists are considered weak, incompetent and undesirable rocks. The minerals of schists such as talc, chlorite, biotite, muscovite and serpentine are relatively very soft and are not strong and durable. Presence of cleavage in the minerals cause weakness of rocks. Schists are unsuitable for foundations, as building stone, as aggregate for concrete making, as road metal and as railway ballast. Schists are also unsuitable in case of tunneling.

One of the main factors for the failure of St. Francis dam was that it was constructed over Schists.

**Comparison of Gneiss and Schist.**

|  |  |  |  |
| --- | --- | --- | --- |
| **S No** | **Kind of difference** | **Gneiss** | **Schist** |
| 1 | Appearance | Alternating colour bands occur | Alternating colour bands do not occur |
| 2 | Minerals present | More than one mineral | Usually one mineral after which the schist is named eg: talc - schist |
| 3 | Color | Pale grey or pink | White, black, green |
| 4 | Parent rock | Granite in more cases | Igneous and sedimentary rocks |
| 5 | Proportion of platy or prismatic minerals | Relatively less | Make up bulk of the rock |
| 6 | strength | Reasonably strong | Weak and incompetent |
| 7 | Suitability for civil engineering works | Suitable | Unsuitable. |

**QUARTZITE:**

*Color*: white or pale color. Red, brown, grey, green colours also may be seen.

*Grain size*: fine to coarse grained

*Texture and Structure*: Granulose structure is common. No alternating color bands. No foliation occurs.

*Minerals present*: quartz usually make up the bulk of a quartzite. The other minerals which may also occasionally occur in quartzites are mica, garnet, feldspar, pyroxenes; chlorite, kyanite, epidote, magnetite etc..

***Types*: Based on mineral content different varieties of quartzites are named as** Micaceous quartzite and Quartzite Schist .

Important feature of quartzites: Lord Venkateshwara temple is located on nagari quartzites at Tirupathi – Tirumala hills as thick beds for many kilometers.

Natural bridge is seen in the same quartzites which is a unique feature.

Origin: Quartzites are formed due to dynamic or thermal or Dynamothermal metamorphism of sandstones. They occur as usually as bedded formations.

**Properties and uses of civil engineering importance**:

It is a silica–rich and makes highly durable and resist to weathering. The predominance of quartz makes the rock very hard. Due to less porosity and permeability, the rock is made more competent. It may be used as building stone in addition to road metal, as railway ballast, as load bearing beams. In case of tunneling, the quartzites doesn’t require any lining.

**MARBLE:**  It is a calcareous metamorphic rock and not hard or strong or durable. Its value is due to its pleasant color, good appearance, easy workability and the ability to take an excellent polish.

*Color*: Milky white. However, pleasant shades of green, yellow, brown, ;blue or grey colours also seen.

Acid test: Marbles react vigorously even with cold and dilute acids.

*Grain size*: Fine to medium or even coarse grained and the rock is equigranular.

*Texture and Structure*: Granulose structure is common. . No foliation occurs.

*Minerals present*: calcite usually make up the bulk of Marble. The other minerals which may also occasionally occur in marbles are serpentine, olivine, garnet, graphite, mica, talc, tremolite, pyrite. mica, garnet, feldspar, pyroxenes; chlorite, kyanite, epidote, magnetite etc..

***Types*: Based on their colors, different varieties of marbles are named as white marble; pink marble; green marble.**

Important feature of marble: The famous Taj Mahal of Agra constructed out of marble, is regarded as one of the Seven Wonders of the World.

Origin: Marbles are formed due to thermal metamorphism of limestones.

**Properties and uses of civil engineering importance**: Physically, the mineral calcite is not only soft but also has three sets of well developed cleavages. This inherent weakness makes the rock split or break easily under loads. Marbles provide aesthetic beauty and a pleasing appearance to the constructions and specially chosen for face works, wall panels; flooring, statue making etc. Marbles are not used as road metal, aggregate for concrete due to soft and weak characters.

**SLATE**: It is a fine grained metamorphic rock. By virtue of its cleavage character, it splits into very thin sheets of considerable size.

***Diagnostic character***: Extreme fine grain size, absence of reaction with acid, slaty cleavage and shining on surfaces are diagnostic characters of slate. .

***Color***: black or grey coloured

***Grain size***: fine grained

***Texture and Structure*:** Foliation is clearly visible

***Minerals present***: Slates are made up of mica (sericite) and quartz. Other minerals which may also occur are biotite, muscovite, talc, chlorite, feldspars, calcite, pyrite, magnetite..

***Types*: Based on colors different varieties of slates are named as** Black slate, grey slate etc. Phyllite is similar to slate in appearance and represents slate itself which is further metamorphosed. When Calcium is present, slate is described as calcareous slate.

**Origin**: Generally,it is formed due to Dynamic or regional metamorphism of shales.

**Properties and uses of civil engineering importance**: Since, slates are soft and incompetent, they cannot withstand great loads. So they are not suitable as site rocks for foundation purposes. Due to cleavage character and softness, they split easily and hence may be used as building stone.