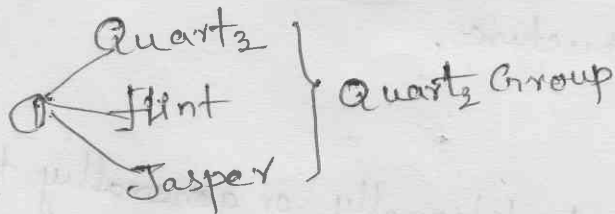


## Unit II Mineralogy

- Definition of mineral.
- Importance of study of minerals.
- Different methods of study of minerals.
- Advantages of study of minerals by physical properties.
- Role of study of physical properties of minerals in the classification of minerals.
- Study of physical properties of following common rock-forming minerals:

### Rock forming minerals



② Olivine

③ Augite

④ Hornblende and Asbestos.

⑤ Feldspars

⑥ Muscovite  
Biotite

} Mica Group

⑦ Chlorite

⑧ Kyanite

⑨ Garnet

⑩ Talc

⑪ Calcite

### Economic minerals / ores

- Pyrite

- Hematite

- Magnetite

~~- Chert~~

- Galena

- Pyrolusite

- Graphite

- Magnesite

- Bauxite

## ① Definition of mineral :-

Mineral :- Mineral is a naturally occurring homogeneous substance which is having a definite chemical composition and regular atomic structure, formed by inorganic processes.

That means

- It must have been formed by natural processes.
- It must be an inorganic substance
- It must be homogeneous.
- It must be solid & have a definite chemical composition
- It must be having <sup>regular</sup> atomic structure.

### Exceptions :-

Some substances which are traditionally or generally treated as minerals do not conform with one or other aspect of the definition. A few exceptions to the mineral definition are as follows:

- ⇒ Precious gemstones like diamonds, rubies, and emeralds are synthetically produced under controlled laboratory conditions and are treated as minerals.
- Coal, amber, petroleum, Natural gas etc., are typical organic substances which are considered minerals.
- Bauxite, coal etc are not homogeneous; but minerals.
- Isomorphous minerals do not have a definite chemical composition but have a definite range of composition  
Ex: Anorthite  $\leftrightarrow$  Albite

## ② Importance of Study of minerals :-

From the civil engineering point of view, knowledge of rock-forming minerals is very much necessary because:

- The civil engineers need to know the properties of rocks precisely to enable them to consider different rocks for any required purpose. That is as foundation rock, as road metal, as concrete aggregate, as building stones, as flooring and roofing material.
- All properties of rocks are, in turn, dependent on the properties of their constituent minerals.
- Thus properties of civil engineering importance such as strength, durability and appearance of rocks can be assessed only with the knowledge of the minerals that form rocks.
- The economic minerals are scarce and do not influence the properties of rocks and are hence irrelevant from the civil engineering point of view.
- But if they occur in large quantities, their economic value will not permit them to be used ~~together~~ as construction materials or as foundation sites.

Because of that we should know/study about rock-forming minerals very detailed manner as a Civil engineer.



### ③ Different methods of study of minerals:

Common methods of study and identification of minerals are based on

- (i) Their physical properties.
- (ii) Their chemical composition.
- (iii) Their optical properties.
- iv) Their x-ray analysis.

#### (i) Study of physical properties:

→ physical properties of minerals like colour, shine (lustre), resistance to scratching (hardness), density, fissility (cleavage). Can be studied with mere observation and feeling of small mineral specimens.

→ These properties are dependent on chemical composition ~~remains~~ the same, and atomic structure.

→ ~~this~~ set of physical properties is never exhibited by any other mineral.

→ From the civil engineering point of view it is very important to know more about these physical properties by studying different minerals practically.

→ [Ex: Galena mineral occurs in nature with lead grey colour, bright metallic shine, opaque character, high density, tendency to break easily along three different directions and is scratched easily by a knife but not by a fingernail.]

## (ii) Study of Chemical Composition :-

→ Every mineral <sup>to</sup> have its own distinctive chemical composition, which is not to be found in any other mineral.

Therefore, by chemical analysis, if the composition is known it should be possible to identify the mineral.

→ This principle is the basis for this type of study of minerals.

Ex: Galena composition is lead sulphide (PbS)

If the composition of an unknown mineral is found to be lead sulphide, then the mineral must be only Galena.

## (iii) Study of Optical properties :-

→ Different optical properties are studied under polarized light and under crossed nicols under the petrological microscope.

→ The properties like colour, relief, cleavage, shape and pleochroism are studied under polarized light.

Ex: Quartz shows anhedral shape, clear, colourless, no cleavage, transparent, low relief, non-pleochroic, grey or yellow interference colour etc.

### iv) X-ray Analysis :-

- X-ray analysis makes use of the definite atomic structure, found in every mineral.
- X-rays are similar to light waves but have a much shorter wavelength, comparable to the distances between atoms in a crystalline mineral.
- They are useful in identification of minerals.

Among all these methods physical properties study is more useful <sup>in</sup> the civil engineering point of view.

## Advantages of study of minerals By physical properties

The method of the study of minerals by physical properties is the most suitable for the following reasons:

- The unique advantage is that it makes possible the study of minerals (or) rocks in the field itself.
- It does not require any equipment worth mentioning.
- No need of chemicals and additional facilities.
- It involves no loss or wastage of material and can be study any number of times.
- It is a simple and quickest method of identifying the minerals.
- It is the cheapest, simplest and least tedious method for identification of minerals. That is money, energy and time are spent to the maximum extent.

This method of study is fairly satisfactory in identifying the minerals, therefore in the engineering geology laboratory minerals are identified by this method only.



## Role of study of physical properties of minerals :

The chief physical properties are colour, streak, lustre, hardness, habit, cleavage, fracture, odor, feel, tenacity, fluorescence, phosphorescence, magnetism, specific gravity and crystal forms.

Colour :- Colour of a mineral is due to absorption of certain wave lengths of light.

→ Some minerals possess characteristic and fairly constant colour

Ex: Lead-grey - Galena.

brass-yellow - Pyrite.

Green - Chlorite.

→ Presence of small amounts of impurities can give a variety of colours to white or colourless minerals

Ex: amethyst - ~~rose~~ .

rose-quartz } changes because of titanium impurity.

Streak :- The colour of the mineral powder is called streak.

It is more consistent and reliable than the body colour of the mineral.

→ The streak is obtained by rubbing a mineral against an unglazed porcelain plate called "streak plate"

Ex: hematite <sup>appears</sup> black colour, gives a red coloured streak

→ It is white colour in silicate, carbonate and transparent minerals, because <sup>that</sup> it is less useful in mineral



Lustre :- is very characteristic and useful property of minerals. It is a measure of the reflectivity of the mineral surface.

(or)

The lustre may be defined as the general appearance of mineral surface in reflected light.

The various types of lustres are

- (i) Metallic lustre  $\rightarrow$  metal appearance Ex: Pyrite & galena.
- (ii) Vitreous lustre  $\rightarrow$  like broken glass Ex: Quartz
- (iii) Pearly lustre  $\rightarrow$  like pearls Ex: muscovite, talc and calcite.
- (iv) Silky lustre  $\rightarrow$  silk like fibrous Ex: Asbestos
- (v) Resinous "  $\rightarrow$  resin like surface Ex: Sphalerite.
- (vi) Greasy lustre  $\rightarrow$  Grease like Ex: Nepheline.
- (vii) Earthy lustre  $\rightarrow$  Dull or Earthy like Ex: Kaolin (clay)

Hardness :- is one of the most useful diagnostic properties of a mineral. It is defined as the resistance of mineral to abrasion or scratching.

A numerical value is obtained by using the "Mohs Scale of hardness". In this scale there are ten minerals which are arranged in the order of their increasing hardness.

- 1 Talc } scratched by a fingernail  $\Rightarrow \leq 2.5$
- 2 Gypsum }
- 3 Calcite } scratched by a knife  $\Rightarrow \leq 5$
- 4 Fluorite }
- 5 Apatite }
- 6 Orthoclase } Hardly scratched by a knife  $\Rightarrow \leq 6.5$
- 7 Quartz }
- 8 Topaz } Not scratched by a knife,  $\Rightarrow \geq 7$
- 9 Corundum }
- 10 Diamond }

Form/Habit :- Habit/Form of a mineral is defined as size & shape of the crystals or masses.

The chief habit/forms shown by minerals are

- (i) Fibrous → aggregate of long thin fibres Ex: Asbestos.
- (ii) Tabular → minerals show broad flat surfaces Ex: Feldspar.
- (iii) Bladed → as small knife blades Ex: Kyanite.
- (iv) Botryoidal → as like bunch of grapes Ex: Chalcedony.
- (v) Massive :- That means non crystalline or cryptocrystalline (half crystalline) minerals occur as structureless mass they are massive Ex: Flint.

cleavage :- is the tendency of a mineral to break more easily with smooth surface along planes of weak bonding.

→ It is classified as "Perfect", "good", "poor" and "indistinct".

The minerals showing perfect cleavage are Mica, Galena, Calcite and Fluorite.

\* Quartz has no cleavage at all.

Fracture :- Minerals which do not exhibit cleavage, break with an irregular surface.

→ The nature of this broken surface is called fracture.

\* It should be other than cleavage plain.

(i) Conchoidal Fracture :- It is a curved fracture surface showing concentric lines like a shell.

Ex: Quartz & Glass

(ii) Even fracture :- It is a fracture surface which is almost flat.

Ex: Flint.

(iii) Uneven fracture :- It is a fracture surface which is irregular.

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Specific gravity :- is a number which represents the ratio of the weight of a mineral to the weight of an equal volume of water.

The specific gravity of  
Silicate minerals is about 2.65  
Ore minerals - 4.5 to 10.0.

A rough estimate about the specific gravity of minerals can be made up hefting them in our hand.

$$\text{Specific gravity} = \frac{W_1}{W_1 - W_2}$$

where,  $W_1$  = weight of the mineral  
 $W_2$  = weight of water.

Distinguishing / Diagnostic properties :-

The set of physical properties which are consistently observed in a particular mineral are called as distinguishing or diagnostic properties.

→ As a group these properties reveal the identity of the mineral.

Ex: Quartz :- pale colour, vitreous lustre, absence of cleavage.

$H=7$ , not opaque and medium sp-gr. All these properties, as a whole, will be observed in every quartz specimen, but never in any other mineral.

But all the physical properties are not distinguishing / diagnostic properties.



## ① Quartz Group ( $\text{SiO}_2$ ) :-

① Quartz  $\rightarrow$  Crystalline form

② Jasper  
Flint  $\rightarrow$  Crypto Crystalline form

① Quartz :- It is the most common rock-forming mineral.

$\rightarrow$  It is silica ( $\text{SiO}_2$ ) in composition.

$\rightarrow$  Structurally it is a Tectosilicate

Physical properties:-

$\rightarrow$  Fresh appearance, vitreous lustre, absence of cleavage,  $H = 7$ , medium spgr, non-magnetic and not opaque, colourless and is a beautiful crystal form.

② Flint & Jasper

② Flint :- is a variety of Quartz. It is massive in nature and remaining properties are like Quartz. Yellow in colour.

② Jasper :- It is usually red; opaque and conchoidal fractures.

Occurrence:-

$\rightarrow$  Quartz is a very important mineral in granites and many pegmatites.

$\rightarrow$  It is last mineral <sup>drawn</sup> from the crystallization of magmas.

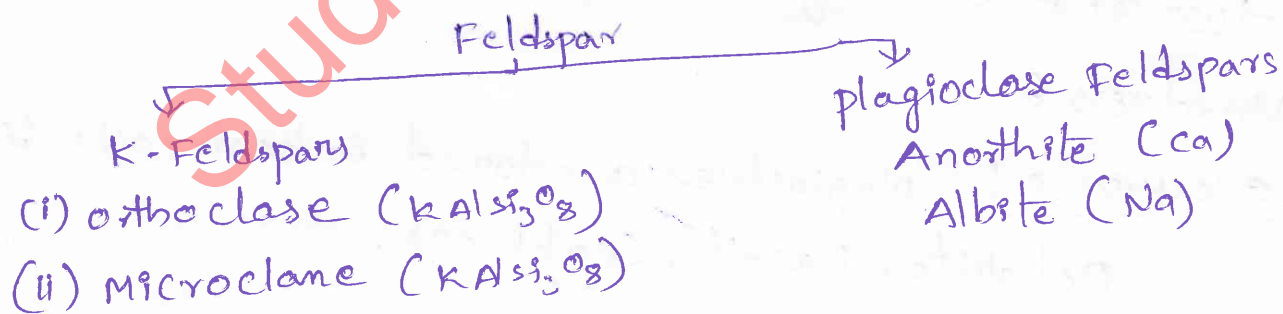
$\rightarrow$  Sandstones, Quartzites are 90% of Quartz rocks.

- Uses :-
- Quartz is used in the manufacture of glass, ceramics, silica wool, ferrosilicon, and refractories.
  - It is used as an abrasive and as filler.
  - Used as precious stones.
  - Fused silica is used in making dishes, crucibles.
  - In quartz watches it is used to ensure accurate measurement of time.
  - It is also used as a flux in metallurgy.

## Feldspar Group :-

It refers to a group of different minerals which possess similar chemical composition, atomic structure, physical properties and optical properties.

There are very few rock types which are completely free from feldspar or their products of weathering.



### K-Feldspars :-

(i) Orthoclase :- It is white to off white in colour,

chemical composition is  $KAlSi_3O_8$ ;

→ crystallize in orthorhombic system.

(ii) Microcline :-  $KAlSi_3O_8$ .

→ Triclinic system

→ cleavage is perfect.

→ pink in colour.

→ pink colour is generally due to fine iron dust the crystal lattices,

\* A variety of microcline is known Amazon stone

\* A variety of orthoclase is Adularia.

Occurrence:- The K-feldspar occurs in Igneous rocks such as granites, pegmatites, syenites, rhyolites and tachytes.

### plagioclase Feldspar :-

plagioclase series has got two end members

① Albite  $\text{NaAlSi}_3\text{O}_8$  → Sodium plagioclase

② Anorthite  $\text{CaAl}_2\text{Si}_2\text{O}_8$  → Calcium plagioclase

plagioclase are all triclinic in crystal system. They are Tabular in form, vitreous, Even to uneven fracture.

two set of cleavage and they are mutually perpendicular.

Hardness 6.

occurrence:- plagioclases are found in basic rocks like Dolomite, Basalt, Gabbros.

Uses:- Feldspars are used in the manufacture of opal, Lascant glass, Porcelains and enamel.

→ And used Ornamental stone.

→ 95% of feldspars are consumed in glass and ceramic industries.



Olivine :- Olivine are mafic minerals.

→ Olivine is first forming mineral from the magma.

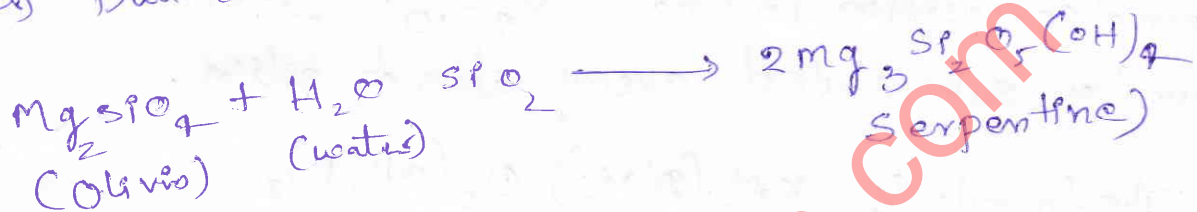
→ General formula is  $R_2SiO_4$

$R = Mg, Fe$

$Mg_2SiO_4 \rightarrow$  Forsterite.

$Fe_2SiO_4 \rightarrow$  Fayalite.

→ Massive form; Olive green colour, 'white streak';  
cleavage: basent; Fracture: uneven to even; 6.5 hardness  
Dull lusture.



Occurrence :- Olivine occurs in Quartz-free igneous rocks. Dunite = 95% Olivine.

Pierite; Peridotite = Olivine rich rock.

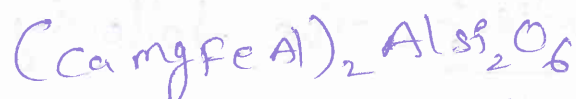
\* Olivine undergoes to weathering quickly

Uses :- peridot is a gem variety of Olivine, It is transparent and green coloured.

→ By virtue of its high melting point, Olivine is used in the manufacture of refractory bricks.

Augite :- Chief mineral in Pyroxene family

- It is silicate Ca, Mg, Fe & Al



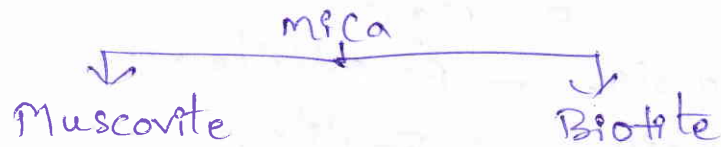
black in colour, vitreous lustre; massive

⑧ (or) lamellar

→ Augite occurs in gabbros, basalts, dolerites

## Mica Group

Micas are phyllosilicates.



Muscovite :- It is also known as white mica. The normal composition will have  $\text{Si}_7\text{O}_{10}$ . In silica on atom of alumina substituted every atom of silica.

The formula is  $\text{KAl}_2(\text{AlSi}_3)\text{O}_{10}(\text{OH}, \text{F})_2$

- Crystallises in monoclinic system.
- Serrisite is a common variety of muscovite.
- Muscovite occurs in acid igneous rock and also pegmatites and in micaceous sandstone.
- In metamorphic rocks it is seen as muscovite schist.

Biotite :- It is also called as black mica.

→ Because of Mg/Fe that is present in this.

It is  $\text{K}(\text{MgFe})_2(\text{AlSi}_3)\text{O}_{10}(\text{OH}, \text{F})_2$

It also crystallises in monoclinic system.

Physical Properties :- The following physical properties for all mica minerals are

Colour :- muscovite - white  
Biotite - black

Form :- lamellar form. that means layers are separable.

Streak ~~book~~ pale colour

Lusture :- Pearly to resinous.

Fracture :- Uneven.

Hardness :- 2 to 3.

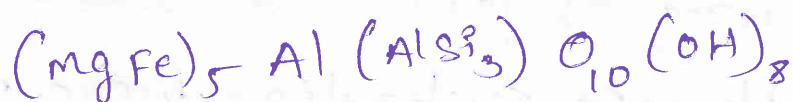
cleavage :- Excellent (perfect); One set of cleavage  
that's basal cleavage.

sp-gr :- medium. (2.7 - 3.1)

Uses of mica :-

- Electrical industry for condenser.
- Electrical commutator and also heat resistance.
- Lepidolite is mixed as an ore of lithium.  
(Lepidolite = lithium mica)

chlorite :- It is OH silicate of Al, Fe & Mg



→ green in colour; layers form; streak is pale  
in colour, Pearly to resinous lusture,

Fracture :- Uneven, cleavage one set.



H = 1.5 to 2.5; scratched by fingernail.  
Density : medium sp.gr 2.7 - 3.0.

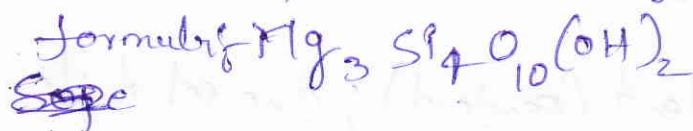
Occurrence:- It occurs commonly in chlorite schists and phyllites. In igneous rocks, it occurs as a mafic mineral alteration mineral.

Talc:- Talc is an extremely soft.

non-metallic economic mineral.

Form : foliated, Colour : white or pale coloured (green, yellow)

Uneven fracture, One set cleavage, hardness 1, Sg.gr = 2.7



→ Sope stone  
→ Pot stone  
→ French chalk } varieties of Talc.

Uses:- Talc is a valuable in industry because of its many useful properties. It is extremely soft and smooth.

→ Paper industry

→ Pesticide & insecticide industries.

→ Manufacture of talcum powder.

→ Textiles, ceramics, paints, rubber, foundry facing and other industries.

→ It will be interesting to know that seals of Mohenjo-daro and Harappa civilization were made from silicate.

Calcite  $\frac{1}{2}$  This is the most important rock-forming carbonate minerals.

→ Chemical composition is  $\text{CaCO}_3$  (calcium carbonate)

Usually colourless or white; Streak white Lustre Vitreous.

perfect Two @ 3 sets of cleavage.  $H=3$ .

Sp.gr 2.7.

Occurrence :- Calcite may be of Organic or Inorganic origin.

— as limestones and marbles.

Limestone  $\xrightarrow{\text{m.m}}$  marble

Uses :- → Rubber & textiles industries

→ Paint and distemper

→ Calcite is a chief raw-material for cement industry and calcium carbide and metal polish industry

Garnet  $\frac{1}{2}$  It is name of silicate mineral family.

General formula is  $R_3^{\text{II}} R_2^{\text{VI}} (\text{SiO}_4)_3$

$R^{\text{II}} = \text{Ca, Mg, Fe, Mn}$

$R^{\text{VI}} = \text{Fe, Al, Cr, Ti}$

massive form; reddish brown colour, white streak, vitreous lustre, uneven fracture, cleavage absent.

Sp-gr 3.5 to 4.3

Occurrence :- Garnets are more characteristic of medium grade rocks only because they are products of medium grade metamorphism.

Uses :- Using as abrasive; specially in wood polishing.

→ Gemstones.

→ Demantoid is a variety of garnet which is gemstone.

Kyanite :- Kyanite is typical metamorphic mineral. It shows different hardness values in different directions.

Bladed form; Blue colour; white streak;

Two set of cleavage,  $H = 6-7$ . Sp-gr 3.6-3.7.

Occurrence :- Commonly occurs as kyanite schists and gneiss.

→ It also occurs in basic igneous rocks.

Uses :- Refractory material; manufacture of glass, burner tips, spark plugs & high voltage electrical insulator. and the ceramic industry.

Hornblende :- It is a silicate of

Ca, Na, Mg, Fe/Al.

$(Ca, Na, Mg, Fe, Al)_{7-8} (Al, Si)_8 O_{22} (OH)_2$



Serpentine :-  $Mg_3Si_2O_5(OH)_2$

Colour :- Shades of green also brownish

Habit :- Lamellar / Fibrous

Cleavage :- basal cleavage.

Hardness :- 3-4

Sp-gr :- 2.5-2.6.

Lusture :- greasy

Occurrence :- Serpentine is usually formed by the alteration of magnesium silicates such as Olivine, Pyroxene, & Amphibole.

\* Serpentine is rock

Uses :- Chrysotile variety of Serpentine is the chief source of asbestos.

- Asbestos products are used for fireproofing and as an insulation material against heat and electricity.

## Ore minerals / Economic minerals

### ① Pyrite $\text{FeS}_2$ :-

Brassy yellow colour; metallic lusture,  $H-6-6\frac{1}{2}$ ; Sp.gr-5.02;  
Fracture - conchoidal; massive granular

Occurrence :- It is most common sulfide mineral.  
It occurs in hydrothermal veins, metamorphic deposits

Uses :- It is used for the manufacture of sulfuric acid.

### ② Hematite :- $(\text{Fe}_2\text{O}_3)$

Colour :- Reddish brown to black.

Streak = Red.

cleavage = absent.

$H = 5-6$ .

Sp.gr = 5.26.

Lusture :- Metallic to dull.

Varieties :- Red earthy varieties are called "Red Ocher"

Occurrence :- The hematite is found in thick beds of sedimentary origin.

Uses :- (i) Mainly as iron ore

(ii) Red ocher is used as pigment.

## ① Magnetite :- ( $\text{Fe}_3\text{O}_4$ ).

Colour :- black

Streak :- black.

cleavage :- absent

H - 6.

sp-gr = 5.18.

Lusture = Metallic

special character - strongly magnetic

form :- massive

Occurrence :- Magnetite is a high temperature mineral.

- It occurs in igneous, metamorphic rocks.

Uses :- Magnetite is an important ore of iron.

## ② Galena :- (PbS)

colour & streak = Lead gray colour

cleavage - perfect.

fracture = conchoidal

H -  $3\frac{1}{2}$  - 4

sp-gr - 7.3 - 7.6

Lusture - resinous

Streak = brown to yellow.

form - massive

Occurrence :- Galena is commonly found in igneous rocks.

- It is associated with other silver minerals.

Uses :- An important ore of lead and silver.

## ① Pyrolusite $\frac{2}{3}$ ( $MnO_2$ )

Colour & streak = Iron black

Habit/Form = Reniform.

Cleavage = perfect.

Hardness = 1-2.

Sp-gr = 4.75.

Lustre = Metallic to Dull.

Occurrence:- It is a secondary mineral formed by the alteration of manganese.

Uses:- As an Ore of Manganese.

## ② Mangnesite $\frac{2}{3}$

Colour:- white / colourless / gray / brown @ yellow.

Streak:- white

Cleavage:- perfect.

Fracture:- Conchoidal.

Hardness:- 3.5 to 4

Sp-gr :- 3.0 to 3.2

Lustre & vitreous / Earthy.

Form = massive / fibrous.

Occurrence:- magnesite is formed by the replacement of limestone by solutions containing magnesium.

Uses:- Forming cement, refractory bricks, ~~and~~.



⑧ Graphite :-

⑨ Bauxite :- (Hydrous aluminium silicate) :-

Colour :- white / gray / yellow.

Streak :- yellow to brown

Form :- pisolitic / massive

Clearance :- none.

Fracture :- uneven

Hardness :- 2 - 2.5

Lustre :- dull / earthy.

Occurrence :- Bauxite is a secondary product; commonly formed under subtropical to tropical climatic conditions.

Uses :- (i) As an important ore of Aluminium.

(ii) As a refractory material.

(iii) As an abrasive material.

(13)