ENGINEERING GEOLOGY

UNIT - I

INTRODUCTION TO GEOLOGY

Geology (in Greek, Geo means Earth, Logos means Science) is a branch of science dealing with the study of the Earth. It is also known as earth science. The study of the earth comprises of the whole earth, its origin, structure, composition and history (including the development of life) and the nature of the processes.

DIFFERENT BRANCHES OF GEOLOGY

For studying the earth in detail, the subject of Geology has been divided into various branches as follows:

1. Physical Geology
2. Crystallography
3. Mining Geology
4. Mineralogy
5. Petrology
6. Paleontology
7. Hydrology
8. Structural Geology
9. Indian Geology
10. Stratigraphy
11. Civil Engineering Geology
12. Resources Engineering
13. Photo Geology
14. Historical Geology
15. Economic Geology

SCOPE OF GEOLOGY

Engineering Geology: A well established interdisciplinary branch of Science and Engineering has a scope in different fields as outlined below:

a) In Civil Engineering: Geology provides necessary information about the site of construction materials used in the construction of buildings, dams, tunnels, tanks, reservoirs, highways and bridges. Geological information is most important in planning stage, design phase and construction phase of an engineering project.

b) In Mining Engineering: Geology is useful to know the method of mining of rock and mineral deposits on earth’s surface and subsurface.

c) In Ground Water: Resources development geology is applied in various aspects of resources and supply, storage, filling up of reservoirs, pollution disposal and contaminated water disposal

IMPORTANCE OF GEOLOGY FROM CIVIL ENGINEERING POINT OF VIEW:

Before constructing roads, bridges, tunnels, tanks, reservoirs and buildings, selection of site is important from the viewpoint of stability of foundation and availability of construction materials. Geology of area is important and rock-forming region, their physical nature, permeability, faults, joints, etc. Thus, geology is related to civil engineering in construction jobs with economy and success.
The role of geology in civil engineering may be briefly outlined as follows:

1. Geology provides a systematic knowledge of construction materials, their structure and properties.

2. The knowledge of Erosion, Transportation and Deposition (ETD) by surface water helps in soil conservation, river control, coastal and harbor works.

3. The knowledge about the nature of the rocks is very necessary in tunneling, constructing roads and in determining the stability of cuts and slopes. Thus, geology helps in civil engineering.

4. The foundation problems of dams, bridges and buildings are directly related with geology of the area where they are to be built.

5. The knowledge of ground water is necessary in connection with excavation works, water supply, irrigation and many other purposes.

6. Geological maps and sections help considerably in planning many engineering projects.

7. If the geological features like faults, joints, beds, folds, solution channels are found, they have to be suitably treated. Hence, the stability of the structure is greatly increased.

8. Pre-geological survey of the area concerned reduces the cost of engineering work.

BRIEF STUDY OF CASE HISTORIES OF FAILURE OF SOME CIVIL ENGINEERING CONSTRUCTIONS DUE TO GEOLOGICAL DRAW BACKS.

This is one of the most common causes of dam failures and has do with the geology of the dam site. Includes with the following considerations

1. Failure due to earthquake

2. Failure due to landslide

3. Failure due to chemical weathering of foundation rocks (Effect Of Alkali-Silica Reaction, Sulfate & Chloride On Concrete)

4. Failure due to physical weathering (temperature variations, or by heavy rain, or by physical breaking)

5. Failure due to increase of fractures in geological structures (fault, folds & unconformities)

Brief study of case histories of failure of some civil engineering constructions:

1. Kaila Dam, Gujarat, India

The Kaila Dam in Kachch, Gujarat, India was constructed during 1952 - 55 as an earth fill dam with a height of 23.08 m above the river bed and a crest length of 213.36 m. The storage of full reservoir level was 13.98 million m³. The foundation was made of shale. The spillway was of ogee shaped and ungated. The depth of cutoff was 3.21 m below the river bed. Inspite of a freeboard allowance of 1.83 m at the normal reservoir level and 3.96 m at the maximum reservoir level the energy dissipation devices first failed and later the embankment collapsed.
due to the weak foundation bed in 1959.

2. Kodaganar Dam, Tamil Nadu, India

This dam in India was constructed in 1977 on a tributary of Cauvery River as an earthen dam with regulators, with five vertical lift shutters each 3.05 m wide. The dam was 15.75 m high above the deepest foundation, having a 11.45 m of height above the river bed. The storage at full reservoir level was 12.3 million m³, while the flood capacity was 1275 m³/s. A 2.5 m free board above the maximum water level was provided. The dam failed due to overtopping by flood waters which flowed over the downstream slopes. Hydraulics Prof. B.S. Thandaveswara Indian Institute of Technology Madras of the embankment and breached the dam along various reaches. There was an earthquake registered during the period of failure although the foundation was strong. Water gushed over the rear slopes, as a cascade of water was eroding the slopes. Breaches of length 20 m to 200 m were observed. It appeared as if the entire dam was overtopped and breached.

3. Tigra Dam: (Sank, Madhya Pradesh, India, 1917 - 1917)

This was a hand placed masonry (in time mortar) gravity dam of 24 m height, constructed for the purpose of water supply. A depth of 0.85 m of water overtopped the dam over a length of 400 m. This was equivalent to an overflow of 850 m³·s⁻¹ (estimated). Two major blocks were bodily pushed away. The failure was due to sliding. The dam was reconstructed in 1929.

4. Vaiont Dam (USA)

This is an arch dam, 267 m high. During the test filling of the dam, a land slide of volume 0.765 Mm³ occurred into the reservoir and was not taken note of. During 1963, the entire mountain slide into the reservoir (the volume of the slide being about 238 Mm³, which was slightly more than the reservoir volume itself). This material occupied 2 km of reservoir up to a height of about 175 m above reservoir level. This resulted in an overtopping of 101 m high flood wave, which caused a loss of 3,000 lives.

5. Baldwin Dam (USA)

This earthen dam of height 80 m, was constructed for water supply, with its main earthen embankment at northern end of the reservoir, and the five minor ones to cover low lying areas along the perimeter. The failure occurred at the northern embankment portion, adjacent to the spillway (indicated a gradual deterioration of the foundation during the life of the structure) over one of the fault zones. The V-shaped breach was 27.5 m deep and 23 m wide. The damages were estimated at 50 million US dollar.

IMPORTANCE OF PHYSICAL GEOLOGY

As a branch of geology, it deals with the “various processes of physical agents such as wind, water, glaciers and sea waves”, run on these agents go on modifying the surface of the earth continuously. Physical geology includes the study of Erosion, Transportation and Deposition (ETD).

The study of physical geology plays a vital role in civil engineering thus:

(a) It reveals constructive and destructive processes of physical agents at a particular site.
It helps in selecting a suitable site for different types of project to be undertaken after studying the effects of physical agents which go on modifying the surface of the earth physically, chemically and mechanically

IMPORTANCE OF PETROLOGY

As a branch of geology it deals with ‘the study of rocks’. A rock is defined as “the aggregation of minerals found in the earth’s crust”. The study of petrology is most important for a civil engineer, in the selection of suitable rocks for building stones, road metals, etc. Petrology is the study of the nature of rocks and the processes that form the rocks that comprise the Earth. The rock-forming processes we will consider — those that produce igneous, sedimentary and metamorphic rocks — reflect, either directly or indirectly, the production and redistribution of heat within the earth. Since plate tectonics operates as an efficient heat-loss mechanism for the Earth, the study of petrology is fundamental to understanding the large-scale geodynamics of our planet.

The goals is to give:

1) A meaningful sampling of the approaches and philosophy behind petrologic studies for stability of civil engineering constructions;

2) An appreciation for the diversity, complexity and geological significance of the rocks that comprise the earth for long durable constructions;

3) A basis for understanding the importance of petrology in the civil engg. constructions; and

4) To provide you with an opportunity to further development for particular construction.

IMPORTANCE OF STRUCTURAL GEOLOGY

As a branch of geology, it deals with ‘the study of structures found in rocks’. It is also known as tectonic geology or simply tectonics. Structural geology is an arrangement of rocks and plays an important role in civil engineering in the selection of suitable sites for all types of projects such as dams, tunnels, multistoried buildings, etc. Structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories. The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain and geometries.

WEATHERING OF ROCKS

Weathering is the breaking down of rocks, soils and minerals as well as artificial materials through contact with the Earth’s atmosphere, biota and waters. Weathering occurs in situ, or "with no movement", and thus should not be confused with erosion, which involves the movement of rocks and minerals by agents such as water, ice, wind, and gravity.

Two important classifications of weathering processes exist –

1. Physical weathering
   a) Thermal stress
   b) Frost weathering
2. Chemical weathering
   a) Dissolution / Carbonation
   b) Hydration
   c) Hydrolysis on silicates and carbonates
   d) Oxidation
   e) Biological weathering

Mechanical or physical weathering involves the breakdown of rocks and soils through direct contact with atmospheric conditions, such as heat, water, ice and pressure.

Chemical weathering, involves the direct effect of atmospheric chemicals or biologically produced chemicals in the breakdown of rocks, soils and minerals.

IMPORATANCE OF WEATHERING WITH REFERENCE TO DAMS, RESERVOIRS AND TUNNELS

Weathering transports rocky material after the process of weathering has broken bedrock down into smaller, moveable pieces. Through erosion the surface of the earth is constantly being sculptured into new forms. The shapes of continents are continuously changing, as waves and tides cut into old land while silt from rivers builds up new land. Weathering initiates the erosion of rock, causing alterations in the surface layers.

Weathering is a process that applies major role of engineering mechanics, e.g. kinematics, dynamics, fluid mechanics, and mechanics of material, to predict the mechanical behavior of erosion. Rock mechanics & weathering process are plays a theoretical and the mechanical behaviour of rock and rock masses; it is useful in the branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment. The fundamental processes are all related to the behaviour of erosions. Together, soil and rock mechanics are the basis for solving many engineering geologic problems with references to dam-reservoir and tunnels.

WEATHERING OF COMMON ROCK LIKE “GRANITE”:

Granite is a common and widely occurring type of intrusive, felsic, igneous rock. Granites usually have a medium- to coarse-grained texture.

Weathering processes affecting granite

1. Chemical Weathering—Hydrolysis, oxidation and hydration

2. Physical Weathering—Freeze thaw Weathering, insolation (Sudden prostration due to exposure to the sun or excessive heat) Weathering, salt crystal growth and pressure releases.
i. Deep weathering in tropic areas

- Rapid chemical weathering to a depth of up to 60m
- Result deep layers of weathered material
- Thickness of the weathered mantle: 30 to 60 m

Factors promoting deep weathering in the tropics:

- Climate—high prevailing temp. favoring rapid rates of chemical reaction, for e.g. Hydrolysis is speeded up 2 ½ times for every 100 C rise in temp.
- Long periods of tectonic stability—for e.g. large parts of the ancient African land mass has experienced little uplift over long periods of geologic time
- Basal surface of weathering—often the weathered layer has very clearly defined base with a sharp change from highly weathered to completely un-weathered rock. This boundary or surface that separates altered (decomposed or disintegrated) rock form, un-weathered rock is referred to as the basal surface of weathering (BSW) or weathering front. It marks the downward limit to deep weathering.

ii. Ruxton and berry (1957) model of deep weathering granite in tropical areas

- Based on actual weathering observation horizon in Hong Kong
- The gradual decomposition of granite from the surface downward will produces in 4 zones

Those are

Zone 1

- Uppermost zone of residual debris
- Structure-less mass of clay minerals such as kaolinite and quartz sand
- Vary in thickness form 1-25 m
- Results from protracted and complete decay of the granite over a long period

Zone 2.

- Less decomposed
- Comprises some residual debris, some gruss and a number of floating and rounded core stones.
- Referred to as zone of residual debris and gruss together with rounded core stones.
- Occupy up to 50% of the zone may up to 60 m in thickness

Zone 3
- Dominated by large number of rectangular core stones separated from each other by partially decomposed gruss.
  
- Up to 17 m thick

Zone4

- Base of weathering profile
  
- Up to 30 m thick
  
- Partially weathered rock, resulting from the initial penetration of acidulated water and opening of joints

OBJECTIVE TYPE QUESTIONS
Unit-I:
INTRODUCTION
1. The term geology was coined by ______( Ulisse Aldrovandi in 1603)
2. The three common types of rocks include (Igneous, Sedimentary & Metamorphic)
3. Common structures associated with rocks include (Folds, Faults & Joints)
4. Name the 2 classes of minerals (Rock forming minerals & Ore forming minerals.)
5. Light coloured minerals are known as ______( Leucocratic minerals )
6. Dark coloured minerals are known as ______( Melanocratic minerals )
7. The common geological agents of weathering include (Wind & Water)
8. The processes of disintegration and decomposition of rocks is called ____ (Weathering)
9. The process of mechanical breakdown of rocks is called ____ (Disintegration)
10. The process of chemical breakdown of rocks is called ____ (Decomposition)
11. The process of weathering depends upon ____ (Nature of Rock, Climate)
12. Common examples of Leucocratic minerals include (Quartz, Feldspars)
13. Common examples of Melanocratic minerals include (Pyroxenes, Amphiboles, Micas)
14. The process of weathering+transportation is called (Erosion)
UNIT - II

MINERALOGY

A mineral is a naturally occurring solid chemical substance formed through biogeochemical processes, having characteristic chemical composition, highly ordered atomic structure, and specific physical properties. In simple words, it is a naturally occurring, homogeneous substance with a defined chemical composition.

COMPOSITION OF CRUST AND DOMINANT MINERALS

Over 7000 minerals, more each day. Fortunately, we don't need to be concerned with most of these (about 20-30 will do). These geologically important minerals are primarily silicate minerals. The dominance of silicate minerals can be understood if we examine the composition of the bulk earth and of the continental crust.

Fe:35% (wt) O: 46% 0:30% Si: 28%
Si:15% Al: 8%
Mg:13% Fe: 5%
Ni, S, Ca, Al Ca (3.6%), Na (2.8%), K(2.6%), Mg (2.1%), Ti (0.4%)

The bulk earth composition can be estimated from a variety of lines of evidence including:

1) analogy with meteorites (same composition as for planetary accretion)
2) average density - compare that with density of crustal materials must be a lot of Fe in interior

Minerals may be classified according to chemical composition. They are here categorized by anion group. The list below is in approximate order of their abundance in the Earth's crust. The list follows the Dana classification system which closely parallels the Strunz classification.

1. Silicate
2. Carbonate
3. Sulfate
4. Halide
5. Oxide
6. Sulfide
7. Phosphate
8. Native minerals
**Silicates**

The largest group of minerals by far are the silicates (most rocks are ≥95% silicates), which are composed largely of silicon and oxygen, with the addition of ions such as aluminium, magnesium, iron, and calcium. Some important rock-forming silicates include the feldspars, quartz, olivines, pyroxenes, amphiboles, garnets, and micas.

The silicate minerals make up the largest and most important class of rock-forming minerals, constituting approximately 90 percent of the crust of the Earth. They are classified based on the structure of their silicate group. Silicate minerals all contain silicon and oxygen.

**Nesosilicates or orthosilicates**

Nesosilicates (from Greek νησος nēsos, island), or orthosilicates, have isolated (insular) \([\text{SiO}_4]^{4-}\) tetrahedra that are connected only by interstitial cations. Nickel-Strunz classification:

- Phenakite group
- Olivine group
- Garnet group
- Zircon group
- \(\text{Al}_2\text{SiO}_5\) group
- Humite group

**Sorosilicates**

Sorosilicates have isolated double tetrahedra groups with \((\text{Si}_2\text{O}_7)^{6-}\) or a ratio of 2:7. Nickel-Strunz classification: 09.B

- Epidote group (has both \((\text{SiO}_4)^{4-}\) and \((\text{Si}_2\text{O}_7)^{6-}\) groups)

**Cyclosilicates**

Cyclosilicates, or ring silicates, have linked tetrahedra with \((\text{Si}_x\text{O}_{3x})^{2x-}\) or a ratio of 1:3. These exist as 3-member \((\text{Si}_3\text{O}_9)^{6-}\), 4-member \((\text{Si}_4\text{O}_{12})^{8-}\) and 6-member \((\text{Si}_6\text{O}_{18})^{12-}\) rings. Nickel-Strunz classification: 09.C

- 3-member ring
- 4-member ring
- 6-member ring
  - Beryl/Emerald - \(\text{Be}_3\text{Al}_2(\text{Si}_6\text{O}_{18})\)
  - Tourmaline - \((\text{Na},\text{Ca})(\text{Al},\text{Li},\text{Mg})_3(\text{Al},\text{Fe},\text{Mn})_6(\text{Si}_6\text{O}_{18})(\text{BO}_3)_3(\text{OH})_4\)

**Inosilicates**
Inosilicates (from Greek ινος [genitive: ινοίνος], fibre), or chain silicates, have interlocking chains of silicate tetrahedra with either \( \text{SiO}_3 \), 1:3 ratio, for single chains or \( \text{Si}_4\text{O}_{11} \), 4:11 ratio, for double chains. Nickel-Strunz classification: 09.D

Single chain inosilicates

- Pyroxenegroup

Double chain inosilicates

- Amphibolegroup

Phyllosilicates

Phyllosilicates (from Greek phyllon, leaf), or sheet silicates, form parallel sheets of silicate tetrahedra with \( \text{Si}_2\text{O}_5 \) or a 2:5 ratio. Nickel-Strunz classification:

- Serpentine group
- Clay mineralgroup
- Micagroup
- Chlorite group

Tectosilicates

Tectosilicates, or "framework silicates," have a three-dimensional framework of silicate tetrahedra with \( \text{SiO}_2 \) or a 1:2 ratio. This group comprises nearly 75% of the crust of the Earth. Tectosilicates, with the exception of the quartz group, are aluminosilicates. Nickel-Strunz classification: (Quartz/ silica family)

- Quartz group
- Feldsparfamily
- Feldspathoidfamily
- Scapolitegroup
- Zeolitegroup

Carbonates

The carbonate minerals consist of those minerals containing the anion \( (\text{CO}_3)^{2-} \) and include calcite and aragonite (both calcium carbonate), dolomite (magnesium/calcium carbonate) and siderite (iron carbonate). Carbonates are also found in evaporitic settings (e.g. the Great Salt Lake, Utah) and also in karst regions, where the dissolution and re-precipitation of carbonates leads to the formation of caves, stalactites and stalagmites.

Sulfates
Sulfate minerals all contain the sulfate anion, $\text{SO}_4^{2-}$. Sulfates commonly form in evaporitic settings where highly saline waters slowly evaporate, allowing the formation of both sulfates and halides at the water-sediment interface. Sulfates also occur in hydrothermal vein systems as gangue minerals along with sulfide ore minerals. Another occurrence is as secondary oxidation products of original sulfide minerals. Common sulfates include anhydrite (calcium sulfate), celestine (strontium sulfate), barite (barium sulfate), and gypsum (hydrated calcium sulfate).

**Halides**

The halide minerals are the group of minerals forming the natural salts and include fluorite (calcium fluoride), halite (sodium chloride), and sal ammoniac (ammonium chloride). Halides, like sulfates, are commonly found in evaporite settings such as salt lakes and landlocked seas such as the Dead Sea and Great Salt Lake. The halide class includes the fluoride, chloride, bromide, and iodide minerals.

**Oxides**

They commonly occur as precipitates close to the Earth's surface, oxidation products of other minerals in the near surface weathering zone, and as accessory minerals in igneous rocks of the crust and mantle. Common oxides include hematite (iron oxide), magnetite (iron oxide), chromite (iron chromium oxide), spinel (magnesium aluminium oxide – a common component of the mantle), ilmenite (iron titanium oxide), rutile (titanium dioxide), and ilce (hydrogen oxide). The oxide class includes the oxide and the hydroxide minerals.

**Sulfides**

Many sulfide minerals are economically important as metal ores. Common sulfides include pyrite (iron sulfide – commonly known as fools' gold), chalcopyrite (copper iron sulfide), pentlandite (nickel iron sulfide), and galena (lead sulfide). The sulfide class also includes the selenides, thetellurides, thearsenides, theantimonides, the bismuthinides, and the sulfosalts (sulfur and a second anion such as arsenic).

**Phosphates**

The phosphate mineral group actually includes any mineral with a tetrahedral unit $\text{AO}_4$ where A can be beryllium, antimony, arsenic, or vanadium. By far the most common phosphate is apatite which is an important biological mineral found in teeth and bones of many animals. The phosphate class includes the phosphate, arsenate, vanadate, and antimonate minerals.

**Native minerals**

The elemental group includes native metals and inter-metallic elements (gold, silver, copper), semi-metals, and non-metals (antimony, bismuth, graphite, sulfur). This group also includes natural alloys, such as eutectic (a natural alloy of gold and
PHYSICAL PROPERTIES OF MINERALS

The atomic structure evidenced in a number of physical properties. We will examine these links between atomic structure and hardness, density, cleavage, habit. Emphasize those properties underlined, as these are the most useful in identifying minerals.

1. **Crystal habit [NaCl model]** The shape of crystals (habit) is closely linked to the atomic structure. Note that well formed crystal faces will be formed only under certain conditions (e.g. unimpeded growth into a cavity, early crystallization from a melt). In most rocks, crystals have to compete for space and so are not euhedral. Use NaCl model to illustrate resulting high symmetry (cubic).

2. **Cleavage** Definition = plane of weakness (always parallel to xtl face or possible xtl face) resulting from weaker bonds. NaCl has three planes of cleavage at right angles.

3. **Fracture** (breaking but not along cleavage)

4. **Hardness** Mohr’s scale:
   - 1. Talc
   - 2. Gypsum
   - 3. Calcite
   - 4. Fluorite
   - 5. Apatite
   - 6. K-Feldspar
   - 7. Quartz
   - 8. Topaz
   - 9. Corundum
   - 10. Diamond

   ^     ^
   fingernail   knife

5. **Specific gravity (density)** The density of a mineral is determined by the kind of atoms and how they are arranged. For example, metallic compounds (Fe in earth's core) have high atomic number and exhibit cubic closest packing (12 neighbors) resulting in a high specific gravity ~7.5.

6. **Luster** General surface appearance. For most practical purposes, it is most useful to distinguish only between metallic or nonmetallic.
7. **Color** The color of a mineral may be diagnostic (idio-chromatic - related to one of major constituents) or may simply be related to the presence of minor impurities [amethyst - Mn]

8. **Streak** The color of fine powder is often more diagnostic.

9. **Magnetism, Conductivity**

**FELDSPARS GROUP**

**Feldspars** \((\text{KAlSi}_3\text{O}_8 \to \text{NaAlSi}_3\text{O}_8 \to \text{CaAl}_2\text{Si}_2\text{O}_8)\) are a group of rock-forming tectosilicate minerals which make up as much as 60% of the Earth's crust. Feldspar is derived from the German *Feld*, "field", and *Spath*, "a rock that does not contain ore". "Feldspathic" refers to materials that contain feldspar.

Feldspars crystallize from magma in both intrusive and extrusive igneous rocks, as veins, and are also present in many types of metamorphic rock.\(^2\) Rock formed almost entirely of calcic plagioclase feldspar (see below) is known as anorthosite.\(^3\) Feldspars are also found in many types of sedimentary rock.

**Compositions**

This group of minerals consists of framework tectosilicates. Compositions of major elements in common feldspars can be expressed in terms of three endmembers:

The alkali feldspars are as follows:

- orthoclase (monoclinic), \(\text{KAlSi}_3\text{O}_8\)
- sanidine (monoclinic), \((\text{K,Na})\text{AlSi}_3\text{O}_8\)
- microcline (triclinic), \(\text{KAlSi}_3\text{O}_8\)
- anorthoclase (triclinic), \((\text{Na,K})\text{AlSi}_3\text{O}_8\)

**Plagioclase feldspars**

The plagioclase feldspars are triclinic. The plagioclase series follows (with percent anorthite in parentheses):

- albite (0 to 10), \(\text{NaAlSi}_3\text{O}_8\)
- oligoclase (10 to 30), \((\text{Na,Ca})(\text{Al,} \text{Si})\text{AlSi}_2\text{O}_8\)
- andesine (30 to 50), \(\text{NaAlSi}_3\text{O}_8 \to \text{CaAl}_2\text{Si}_2\text{O}_8\)
- labradorite (50 to 70), \((\text{Ca,Na})\text{Al}(\text{Al,} \text{Si})\text{Si}_2\text{O}_8\)
- bytownite (70 to 90), \((\text{NaSi,} \text{CaAl})\text{AlSi}_2\text{O}_8\)
- anorthite (90 to 100), \(\text{CaAl}_2\text{Si}_2\text{O}_8\)

**Barium feldspars**
The barium feldspars are monoclinic and comprise the following:

- **celsian** — \( \text{BaAl}_2\text{Si}_2\text{O}_8 \)
- **hyalophane** — \( (\text{K,Na,Ba})(\text{Al,Si})_4\text{O}_8 \)

Feldspar is a common raw material used in glassmaking, ceramics, and to some extent as a filler and extender in paint, plastics, and rubber. In glassmaking, alumina from feldspar improves product hardness, durability, and resistance to chemical corrosion.

In earth sciences and archaeology, feldspars are used for K-Ar dating, argon-argon dating, thermoluminescence dating and optical dating.

Physical properties of feldspar as whole

<table>
<thead>
<tr>
<th>Structure</th>
<th>tectosilicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>( \text{KAlSi}_3\text{O}_8 - \text{NaAlSi}_3\text{O}_8 - \text{CaAl}_2\text{Si}_2\text{O}_8 )</td>
</tr>
<tr>
<td>Color</td>
<td>pink, white, gray, brown</td>
</tr>
<tr>
<td>Crystal system</td>
<td>triclinic or monoclinic</td>
</tr>
<tr>
<td>Twinning</td>
<td>tartan, carlsbad, etc</td>
</tr>
<tr>
<td>Cleavage</td>
<td>two or three</td>
</tr>
<tr>
<td>Fracture</td>
<td>along cleavage planes</td>
</tr>
<tr>
<td>hardness</td>
<td>6</td>
</tr>
<tr>
<td>Luster</td>
<td>vitreous</td>
</tr>
<tr>
<td>Diaphaneity</td>
<td>opaque</td>
</tr>
<tr>
<td>Birefringence</td>
<td>first order</td>
</tr>
<tr>
<td>Pleochroism</td>
<td>none</td>
</tr>
<tr>
<td>Other characteristics</td>
<td>exsolution lamellae common</td>
</tr>
</tbody>
</table>

**QUARTZ GROUP**
Quartz is the second most abundant mineral in the Earth's continental crust, after feldspar. It is made up of a continuous framework of SiO₄ silicon–oxygentetrahedra, with each oxygen being shared between two tetrahedra, giving an overall formula SiO₂.

The word "quartz" is derived from the German word "quarz" and its Middle High German ancestor "twarc", which probably originated in Slavic (cf. Czech tvrdý ("hard"), Polish twardy ("hard")).

Crystal habit and structure

Quartz belongs to the trigonal crystal system. The ideal crystal shape is a six-sided prism terminating with six-sided pyramids at each end.

Varieties
1. Citrine
2. Rose quartz
3. Smoky quartz
4. Amethyst
5. Milky quartz
6. Jasper
7. Agate
8. Chalcedony

Occurrence

Quartz is an essential constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as sandstone and shale and is also present in variable amounts as an accessory mineral in most carbonate rocks. It is also a common constituent of schist, gneiss, quartzite and other metamorphic rocks.

<table>
<thead>
<tr>
<th>Category</th>
<th>Silicate mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>Silica (silicon dioxide, SiO₂)</td>
</tr>
<tr>
<td>Crystal habit</td>
<td>6-sided prism ending in 6-sided pyramid (typical), drusy, fine-grained to microcrystalline, massive</td>
</tr>
<tr>
<td>Crystal system</td>
<td>α-quartz: trigonal trapezohedral</td>
</tr>
<tr>
<td>Property</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Class</td>
<td>3; 2; (\beta)-quartz:hexagonal[1]</td>
</tr>
<tr>
<td>Twinning</td>
<td>Common Dauphine law, Brazil law and Japan law</td>
</tr>
<tr>
<td>Cleavage</td>
<td>{0110} Indistinct</td>
</tr>
<tr>
<td>Fracture</td>
<td>Conchoidal</td>
</tr>
<tr>
<td>Tenacity</td>
<td>Brittle</td>
</tr>
<tr>
<td>Mohs scale hardness</td>
<td>7 – lower in impure varieties (defining mineral)</td>
</tr>
<tr>
<td>Luster</td>
<td>Vitreous – waxy to dull when massive</td>
</tr>
<tr>
<td>Streak</td>
<td>White</td>
</tr>
<tr>
<td>Diaphaneity</td>
<td>Transparent to nearly opaque</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.65; variable 2.59–2.63 in impure varieties</td>
</tr>
<tr>
<td>Pleochroism</td>
<td>None</td>
</tr>
<tr>
<td>Melting point</td>
<td>1670 °C ((\beta)tridymite) 1713 °C ((\beta)cristobalite)[1]</td>
</tr>
<tr>
<td>Other characteristics</td>
<td>Piezoelectric, may betriboluminescent, chiral (hence optically active if not racemic)</td>
</tr>
</tbody>
</table>

**MICA GROUP**

The mica group of sheet silicate (phyllosilicate) minerals includes several closely related materials having highly perfect basal cleavage. All are monoclinic with a tendency towards pseudo-hexagonal crystals and are similar in chemical composition. The highly perfect cleavage,
which is the most prominent characteristic of mica, is explained by the hexagonal sheet-like arrangement of its atoms.

Mica classification

Chemically, micas can be given the general formula

\[ X_2Y_{4–6}Z_{8}O_{20}(OH,F)_4 \]

in which \( X \) is K, Na, or Ca or less commonly Ba, Rb, or Cs; \( Y \) is Al, Mg, or Fe or less commonly Mn, Cr, Ti, Li, etc.; \( Z \) is chiefly Si or Al but also may include Fe\(^{3+} \) or Ti.

Structurally, micas can be classed as dioctahedral (\( Y = 4 \)) and trioctahedral (\( Y = 6 \)). If the \( X \) ion is K or Na the mica is a common mica whereas if the \( X \) ion is Ca the mica is classed as a brittle mica.

**Trioctahedral micas**

Common micas:

- Biotite
- Lepidolite
- Muscovite
- Phlogopite
- Zinnwaldite

Brittle micas:

- Clintonite

Occurrence

Mica is widely distributed and occurs in igneous, metamorphic and sedimentary regimes. Large crystals of mica used for various applications are typically mined from granitic pegmatites.

Uses

1. Thin transparent sheets of mica called "isinglass" were used for peepholes in boilers, lanterns, stoves, and kerosene heaters because they were less likely to shatter compared to glass when exposed to extreme temperature gradients.

2. Another use of mica is in the production of ultraflat thin film surfaces (e.g. gold surfaces) using mica as substrate.

3. Sheet mica is used principally in the electronic and electrical industries. Its usefulness in these applications is derived from its unique electrical and thermal insulating properties and its mechanical properties, which allow it to be cut, punched, stamped, and machined to close tolerances.
4. Sheet mica is used in electrical components, electronics, isinglass, and atomic force microscopy. Other uses include diaphragms for oxygen-breathing equipment, marker dials for navigation compasses, optical filters, pyrometers, thermal regulators, stove and kerosene heater windows, and micathermic heater elements.

<table>
<thead>
<tr>
<th>Category</th>
<th>Phyllo Silicate mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>$X_2Y_{4-6}Z_{8}O_{20}(OH,F)_4$</td>
</tr>
<tr>
<td>Crystal habit</td>
<td>flaky</td>
</tr>
<tr>
<td>Crystal system</td>
<td>pseudo-hexagonal</td>
</tr>
<tr>
<td>Twinning</td>
<td>Common Dauphine law, Brazil law and Japan law</td>
</tr>
<tr>
<td>Cleavage</td>
<td>Perfect basal</td>
</tr>
<tr>
<td>Fracture</td>
<td>Flaky</td>
</tr>
<tr>
<td>Tenacity</td>
<td>Brittle</td>
</tr>
<tr>
<td>Mohs hardness</td>
<td>1</td>
</tr>
<tr>
<td>Luster</td>
<td>Vitreous – waxy to dull when massive</td>
</tr>
<tr>
<td>Streak</td>
<td>White</td>
</tr>
<tr>
<td>Diaphaneity</td>
<td>Transparent</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>Light</td>
</tr>
</tbody>
</table>

**OLIVINE GROUP**

The mineral *olivine* (when gem-quality also called *peridot*) is a magnesium-iron silicate with the formula $(Mg,Fe)_2SiO_4$. It is a common mineral in the Earth's subsurface but weatheres quickly on the surface.
Olivine gives its name to the group of minerals with a related structure (the **olivine group**) which include stephroite (Mn$_2$SiO$_4$), monticellite (CaMgSiO$_4$) and kirschsteinite (CaFeSiO$_4$).

**Identification and paragenesis**

Olivine is named for its typically olive-green color (thought to be a result of traces of nickel), though it may alter to a reddish color from the oxidation of iron.

Translucent olivine is sometimes used as a gemstone called peridot, the French word for olivine. It is also called chrysolite, from the Greek words for gold and stone. Some of the finest gem-quality olivine has been obtained from a body of mantle rocks on Zabargad island in the Red Sea.

Olivine/peridot occurs in both mafic and ultramafic igneous rocks and as a primary mineral in certain metamorphic rocks. Mg-rich olivine crystallizes from magma that is rich in magnesium and low in silica.

**Extraterrestrial occurrences**

Olivine has also been identified in meteorites, the Moon, Mars, in the dust of comet Wild 2, within the core of comet

**Crystal structure**

Minerals in the olivine group crystallize in the orthorhombic system (space group Pbnm) with isolated silicate tetrahedra, meaning that olivine is a nesosilicate. In an alternative view, the atomic structure can be described as a hexagonal, close-packed array of oxygen ions with half of the octahedral sites occupied with magnesium or iron ions and one-eighth of the tetrahedral sites occupied by silicon ions.

**Uses**

The aluminium foundry industry uses olivine sand to cast objects in aluminium. Olivine sand requires less water than silicon based sand while providing the necessary strength to hold the mold together during handling and pouring of the metal. Less water means less gas (steam) to vent from the mold as metal is poured into the mold.

<table>
<thead>
<tr>
<th>Category</th>
<th>Mineral Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>(Mg, Fe)$_2$SiO$_4$</td>
</tr>
<tr>
<td>Color</td>
<td>Yellow to yellow-green</td>
</tr>
<tr>
<td>Crystal habit</td>
<td>Massive to granular</td>
</tr>
<tr>
<td><strong>Crystal system</strong></td>
<td>Orthorhombic</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------</td>
</tr>
<tr>
<td><strong>Cleavage</strong></td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Fracture</strong></td>
<td>Conchoidal – brittle</td>
</tr>
<tr>
<td><strong>Mohs scalehardness</strong></td>
<td>6.5–7</td>
</tr>
<tr>
<td><strong>Luster</strong></td>
<td>Vitreous</td>
</tr>
<tr>
<td><strong>Streak</strong></td>
<td>White</td>
</tr>
<tr>
<td><strong>Diaphaneity</strong></td>
<td>Transparent to translucent</td>
</tr>
<tr>
<td><strong>Specific gravity</strong></td>
<td>3.27–3.37</td>
</tr>
</tbody>
</table>

**PYROXENES GROUP**

The pyroxenes are a group of important rock-forming inositelsilicate minerals found in many igneous and metamorphic rocks. They share a common structure consisting of single chains of silicate tetrahedra and they crystallize in the monoclinic and orthorhombic systems. Pyroxenes have the general formula $XY(Si,Al)_2O_6$ (where $X$ represents calcium, sodium, iron$^{+2}$ and magnesium and more rarely zinc, manganese and lithium and $Y$ represents ions of smaller size, such as chromium, aluminium, iron$^{+3}$, magnesium, manganese, scandium, titanium, vanadium and even iron$^{+2}$).

**Pyroxene structure**

The chain silicate structure of the pyroxenes offers much flexibility in the incorporation of various cations and the names of the pyroxene minerals are primarily defined by their chemical composition. Pyroxene minerals are named according to the chemical species occupying the $X$ (or $M_2$) site, the $Y$ (or $M_1$) site, and the tetrahedral $T$ site. Cations in $Y$ ($M_1$) site are closely bound to 6 oxygens in octahedral coordination. Cations in the $X$ ($M_2$) site can be coordinated with 6 to 8 oxygen atoms, depending on the cation size.
Pyroxene minerals

- Clinopyroxenes (monoclinic)
  - Aegirine (Sodium Iron Silicate)
  - Augite (Calcium Sodium Magnesium Iron Aluminium Silicate)
  - Clinoenstatite (Magnesium Silicate)
  - Diopside (Calcium Magnesium Silicate, CaMgSi2O6)
  - Esseneite (Calcium Iron Aluminium Silicate)
  - Hedenbergite (Calcium Iron Silicate)
  - Jadeite (Sodium Aluminium Silicate)
  - Jervisite (Sodium Calcium Iron Scandium Magnesium Silicate)
  - Johannsenite (Calcium Manganese Silicate)
  - Kanoite (Manganese Magnesium Silicate)
  - Kosmochlor (Sodium Chromium Silicate)
  - Namansilite (Sodium Manganese Silicate)
  - Natalyite (Sodium Vanadium Chromium Silicate)
  - Omphacite (Calcium Sodium Magnesium Iron Aluminium Silicate)
  - Petedunnite (Calcium Zinc Manganese Iron Magnesium Silicate)
  - Pigeonite (Calcium Magnesium Iron Silicate)
  - Spodumene (Lithium Aluminium Silicate)

- Orthopyroxenes (orthorhombic)
  - Hypersthene (Magnesium Iron Silicate)
  - Donpeacorite, (MgMn)MgSi2O6
  - Enstatite, Mg2Si2O6
  - Ferrosilite, Fe2Si2O6
Nchwaningite (Hydrated Manganese Silicate)

<table>
<thead>
<tr>
<th>Category</th>
<th>Chain silicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>(Mg,Fe₂)Si₂O₆</td>
</tr>
<tr>
<td>Color</td>
<td>dark</td>
</tr>
<tr>
<td>Crystal habit</td>
<td>Massive to granular</td>
</tr>
<tr>
<td>Crystal system</td>
<td>Orthorhombic, monoclinic</td>
</tr>
<tr>
<td>Cleavage</td>
<td>good</td>
</tr>
<tr>
<td>Fracture</td>
<td>even</td>
</tr>
<tr>
<td>Mohs scale hardness</td>
<td>6.5–7</td>
</tr>
<tr>
<td>Luster</td>
<td>Vitreous</td>
</tr>
<tr>
<td>Streak</td>
<td>Blackish green</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>3.27–3.37</td>
</tr>
</tbody>
</table>

GARNET GROUP

The garnet group includes a group of minerals that have been used since the Bronze Age as gemstones and abrasives. The name "garnet" may come from either the Middle English word gernet meaning 'dark red', or the Latin granatus ("grain"), possibly a reference to the Punica granatum ("pomegranate"), a plant with red seeds similar in shape, size, and color to some garnet crystals.

Crystal structure

Garnets are...silicates having the general formula X₃Y₂(SiO₄)₃. The X-site is usually occupied by divalent cations (Ca²⁺, Mg²⁺, Fe²⁺) and the Y-site by trivalent cations (Al³⁺, Fe³⁺, Cr³⁺) in an octahedral/tetrahedral framework with [SiO₄]⁴⁻ occupying the tetrahedral.

Garnet group endmember species

Pyralspite garnets - Aluminium in Y site

- Almandine: Fe₃Al₂(SiO₄)₃
- Pyrope: Mg₃Al₂(SiO₄)₃
- Spessartine: Mn₃Al₂(SiO₄)₃
**Ugrandite group - calcium in X site**

- Andradite: $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$
- Grossular: $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$
- Uvarovite: $\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$

Garnet structural group

Formula: $X_3Z_2(\text{T}O_4)_3$ ($X = \text{Ca, Fe, etc., } Z = \text{Al, Cr, etc., } T = \text{Si, As, V, Fe, Al}$)

All are cubic or strongly pseudocubic.

**Genesis**

The Garnet group is a key mineral in interpreting the genesis of many igneous and metamorphic rocks via geothermobarometry. Diffusion of elements is relatively slow in garnet compared to rates in many other minerals, and garnets are also relatively resistant to alteration.

**Uses of garnets**

1. Garnet sand is a good abrasive, and a common replacement for silica sand in sand blasting. Alluvial garnet grains which are rounder are more suitable for such blasting treatments. Mixed with very high pressure water, garnet is used to cut steel and other materials in water jets.
2. Garnet paper is favored by cabinetmakers for finishing bare wood.
3. Garnet sand is also used for water filtration media.

<table>
<thead>
<tr>
<th>Category</th>
<th>Nesosilicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>The general formula $X_3Y_2(\text{SiO}_4)_3$</td>
</tr>
<tr>
<td>Color</td>
<td>Virtually all colors</td>
</tr>
<tr>
<td>Crystal habit</td>
<td>Rhombic dodecahedra or cubic</td>
</tr>
<tr>
<td>Crystal system</td>
<td>Cubic-rhomboic dodecahedron, icositetrahedron</td>
</tr>
<tr>
<td>Cleavage</td>
<td>Indistinct</td>
</tr>
<tr>
<td>Fracture</td>
<td>Conchoidal to uneven</td>
</tr>
<tr>
<td>Mohs scale hardness</td>
<td>6.5 - 7.5</td>
</tr>
</tbody>
</table>
KYANITE GROUP

Kyanite, whose name derives from the Greek word kuanos sometimes referred to as "kyanos", meaning deep blue, is a typically bluesilicate mineral, commonly found in aluminium-rich metamorphic pegmatites and/or sedimentary rock. Kyanite in metamorphic rocks generally indicates pressures higher than 4 kilobars. Although potentially stable at lower pressure and low temperature, the activity of water is usually high enough under such conditions that it is replaced by hydrous aluminosilicates such as muscovite, pyrophyllite, or kaolinite. Kyanite is also known as diasthenite, rhaeticite and cyanite.

Kyanite is a member of the aluminosilicate series, which also includes the polymorph andalusite and the polymorph sillimanite. Kyanite is strongly anisotropic, in that its hardness varies depending on its crystallographic direction. In Kyanite, this anisotropism can be considered an identifying characteristic.

At temperatures above 1100°C kyanite decomposes into mullite and vitreous silica via the following reaction: $3(\text{Al}_2\text{O}_3\cdot\text{SiO}_2) \rightarrow 3\text{Al}_2\text{O}_3\cdot2\text{SiO}_2 + \text{SiO}_2$. This transformation results in an expansion.

Occurrence

Kyanite occurs in gneiss, schist, pegmatite, and quartz veins resulting from moderate to high-pressure regional metamorphism of principally pelitic rocks. It occurs as detrital grains in sedimentary rocks. It occurs associated with staurolite, andalusite, sillimanite, talc, hornblende, gedrite, mullite and corundum.

Uses of kyanite

1. Kyanite is used primarily in refractory and ceramic products, including porcelain plumbing fixtures and dishware. It is also used in electronics, electrical insulators and abrasives.

2. Kyanite has been used as a semiprecious gemstone, which may display cat's eye chatoyancy, though this use is limited by its anisotropism and perfect cleavage.

Color varieties

<table>
<thead>
<tr>
<th>Luster</th>
<th>vitreous to resinous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streak</td>
<td>White</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>3.1 - 4.3</td>
</tr>
<tr>
<td>Polish luster</td>
<td>vitreous to subadamantine</td>
</tr>
<tr>
<td>Category</td>
<td>Silicate mineral</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Chemical formula</td>
<td>Al$_2$SiO$_5$</td>
</tr>
<tr>
<td>Crystal symmetry</td>
<td>Triclinic pinacoidal H–M</td>
</tr>
<tr>
<td></td>
<td>Symbol: P1</td>
</tr>
<tr>
<td>Color</td>
<td>Blue, white, rarely green, gray, yellow, pink, orange, and black, can be zoned</td>
</tr>
<tr>
<td>Crystal habit</td>
<td>Columnar; fibrous; bladed</td>
</tr>
<tr>
<td>Crystal system</td>
<td>Triclinic</td>
</tr>
<tr>
<td>Twinning</td>
<td>Lamellar on {100}</td>
</tr>
<tr>
<td>Cleavage</td>
<td>[100] perfect [010] imperfect with 79° angle between</td>
</tr>
<tr>
<td>Fracture</td>
<td>Splintery</td>
</tr>
<tr>
<td>Tenacity</td>
<td>Brittle</td>
</tr>
<tr>
<td>Mohs hardness</td>
<td>4.5-5 parallel to one axis</td>
</tr>
<tr>
<td></td>
<td>6.5-7 perpendicular to that axis</td>
</tr>
<tr>
<td>Luster</td>
<td>Vitreous to pearly</td>
</tr>
<tr>
<td>Streak</td>
<td>White</td>
</tr>
<tr>
<td>Diaphaneity</td>
<td>Transparent to translucent</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>3.53 - 3.65 measured; 3.67</td>
</tr>
<tr>
<td>Colour</td>
<td>Transparent</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Lustre</td>
<td>Vitreous</td>
</tr>
<tr>
<td>Form</td>
<td>Crystalline</td>
</tr>
<tr>
<td>Streak</td>
<td>White</td>
</tr>
<tr>
<td>Hardness</td>
<td>7-hardly scratch-able by glass</td>
</tr>
<tr>
<td>Cleavage</td>
<td>Absent</td>
</tr>
<tr>
<td>Fracture</td>
<td>Uneven-conoidal</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.65-medium</td>
</tr>
<tr>
<td>Diagnostic property</td>
<td>Cleavage is absent &amp; hardness</td>
</tr>
<tr>
<td>Name</td>
<td>Based on the megascopic observation the specimen is identified as <strong>quartz (rock crystal)</strong> showing hexagonal system</td>
</tr>
<tr>
<td>Chem. Com</td>
<td>SiO₂</td>
</tr>
<tr>
<td>Occurences</td>
<td>Quartz is an essential constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as sandstone and shale and also present in variable amounts as an accessory mineral in most carbonate rocks. It is also a common constituent of schist, gneiss, quartzite and other metamorphic rocks.</td>
</tr>
<tr>
<td>distribution</td>
<td><strong>Quartz</strong> is the second most abundant mineral in the Earth’s continental crust, after feldspar.</td>
</tr>
<tr>
<td>Colour</td>
<td>Black</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Lustre</td>
<td>Vitreous</td>
</tr>
<tr>
<td>Form</td>
<td>Crystalline</td>
</tr>
<tr>
<td>Streak</td>
<td>White</td>
</tr>
<tr>
<td>Hardness</td>
<td>7-hardly scratch-able by glass</td>
</tr>
<tr>
<td>Cleavage</td>
<td>Absent</td>
</tr>
<tr>
<td>Fracture</td>
<td>Uneven-concoidal</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.65-medium g/cc</td>
</tr>
<tr>
<td>Diagnostic property</td>
<td>Cleavage is absent &amp; colour</td>
</tr>
<tr>
<td>Name</td>
<td>Based on the megascopical observation the specimen is identified as <strong>flint</strong>. Showing hexagonal system</td>
</tr>
<tr>
<td>Chem. Com</td>
<td>SiO₂</td>
</tr>
</tbody>
</table>
### Occurrences

| Quartz is an essential constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as sandstone and shale and is also present in variable amounts as an accessory mineral in most carbonate rocks. It is also a common constituent of schist, gneiss, quartzite and other metamorphic rocks. | Orthoclase is an essential constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as arkose, gneiss, and other metamorphic rocks. | Microcline is an essential constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as arkose, gneiss, and other metamorphic rocks. | Labrodorite is an essential constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as arkose, gneiss, and other metamorphic rocks. |

### Distribution

| Quartz is the second most abundant mineral in the Earth's continental crust, after feldspar. | Feldspar is the first abundant mineral in the Earth's continental crust. | Feldspar is the first abundant mineral in the Earth's continental crust. | Feldspar is the first abundant mineral in the Earth's continental crust. |

### Uses

| 3. It used as gem stone. 4. It used in electrical industry because of its piezoelectric effect. | It used in ceramic industries. | 2. It used in ceramic industries. | 3. It used in ceramic industries. |

### Physical Properties

<table>
<thead>
<tr>
<th>Colour</th>
<th>Greenish black</th>
<th>Creamy or white</th>
<th>Light green</th>
<th>Olive green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lustre</td>
<td>Vitreous</td>
<td>Dull</td>
<td>Dull</td>
<td>Vitreous</td>
</tr>
<tr>
<td>Form</td>
<td>Crystallized</td>
<td>Fibrous</td>
<td>Massive</td>
<td>Massive</td>
</tr>
<tr>
<td>Streak</td>
<td>Blackish green</td>
<td>White</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td>Hardness</td>
<td>6-Hardly scratch-able by pen knife</td>
<td>1-easily scratch-able by finger nail</td>
<td>Scratch-able by pen knife</td>
<td>Scratch-able by pen knife</td>
</tr>
<tr>
<td>Cleavage</td>
<td>Present two sets</td>
<td>Present</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>Fracture</td>
<td>Even</td>
<td>Hackly fracture</td>
<td>Uneven</td>
<td>Uneven</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>3-3.4 g/cm³</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium 3.27-3.37</td>
</tr>
<tr>
<td>Diagnostic property</td>
<td>Colour &amp; cleavage</td>
<td>Fibrous form &amp; hackly fracture</td>
<td>Colour and feel</td>
<td>Colour and cleavage</td>
</tr>
</tbody>
</table>
Name | Based on the megascopic observation the specimen is identified as **hornblende**. Showing hexagonal/ monoclinic system | Based on the megascopic observation the specimen is identified as **amphibole**. Is a phyllosilicate. | Based on the megascopic observation the specimen is identified as **serpentine**. | Based on the megascopic observation the specimen is identified as **olivine**. Crystallized in orthorhombic system.

Chem. Com | $Ca_2(Mg, Fe, Al)_{5} (Al, Si)_{8}O_{22}(OH)_2$ | $Fe_7Si_8O_{22}(OH)_2$ | $Mg_3(Si_2O_5)(OH)_4$ | $(Mg, Fe)_{2}SiO_4$

Occurrences | Hornblende occur in igneous and metamorphic rocks such as granite, syenite, diorite, gabbro, basalt, andesite, gneiss, and schist. It is the principal mineral of amphibolites. | Alteration of serpentine mineral. | Occurs as a alteration product of olivine mineral. | Livine/peridot occurs in both mafic and ultramafic igneous rocks and as a primary mineral in certain metamorphic rocks. Mg-rich olivine crystallizes from magma that is rich in magnesium and low in silica. That magma crystallizes to mafic rocks such as gabbro and basalt. Ultramafic rocks such as peridotite and dunite.

distribution | -------------------------- | | | |

uses | Amphibolite is a common dimension stone used in construction, paving, facing of buildings, etcetera especially because of its attractive textures, dark colour, hardersness and polishability and its ready availability | The most common use is within corrugated asbestos cement roof sheets typically used for outbuildings, warehouses and garages. Numerous other items have been made containing chrysotile including brake linings, cloth behind fuses (for fire protection), pipe insulation, floor tiles, and rope seals for boilers | It is more flexible than amphibole types of asbestos; it can be spun and woven into fabric. The most common use is within corrugated asbestos cement roof sheets typically used for outbuildings, warehouses and garages. | The aluminium foundry industry uses olivine sand to cast objects in aluminium. Olivine sand requires less water than silicon based sand while providing the necessary strength to hold the mold together during handling and pouring of the metal. Less water means less gas (steam) to vent from the mold as metal is poured into the mold.

colour | White/transparent | Black | Greenish black, brownsihred. | Chocolate brown

lustre | Vireous | vitreous | vitreous | Vitreous

Form | Flaky | Flaky | Flaky | Acicular

Streak | White | Blackish | Greenish black, brown | White

Hardness | 2-2.25 hardly scratch-able by finger nail | 2-2.25 hardly scratch-able by finger nail | 2-2.25 hardly scratch-able by finger nail | 9- scratch-able by admixture of topaz and corundum

Cleavage | Perfect basal cleavage | Perfect basal cleavage | Perfect basal cleavage | Absent
<table>
<thead>
<tr>
<th>Fracture</th>
<th>Even-flaky</th>
<th>Even-flaky</th>
<th>Even-flaky</th>
<th>Concoidal to uneven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>Medium 2.76-3</td>
<td>Medium 2.76-3</td>
<td>Medium 2.76-3</td>
<td>3.92-4.10</td>
</tr>
<tr>
<td>Diagnostic property</td>
<td>Cleavage, form, &amp; hardness</td>
<td>Cleavage, form, &amp; colour</td>
<td>Cleavage, form, &amp; colour</td>
<td>Form and hardness</td>
</tr>
<tr>
<td>Name</td>
<td>Based on the megascopic observation the specimen is identified as <em>muscovite</em>. Showing monoclinic system</td>
<td>Based on the megascopic observation the specimen is identified as <em>biotite</em>. Showing monoclinic system</td>
<td>Based on the megascopic observation the specimen is identified as <em>phlogopite</em>. Showing monoclinic system</td>
<td>Based on the megascopic observation the specimen is identified as <em>corundum</em>. Crystallized inhexagonal system.</td>
</tr>
<tr>
<td>Chem. Com</td>
<td>$KAl_2{AlSi_3O_{10}}[F,OH]_2$</td>
<td>$K(Mg,Fe)<em>3{AlSi_3O</em>{10}}[F,OH]_2$</td>
<td>$K(Mg,Fe,Mn)<em>3{AlSi_3O</em>{10}}[F,OH]_2$</td>
<td>$Al_2O_3$</td>
</tr>
<tr>
<td>Occurences</td>
<td>Muscovite is the most common mica, found in granites, pegmatites, gneisses, and schists, and as a secondary mineral resulting from the alteration of topaz, feldspar, kyanite, etc.</td>
<td>Muscovite is the most common mica, found in granites, pegmatites, gneisses, and schists, and as a contact metamorphic rock or as a secondary mineral resulting from the alteration of topaz, feldspar, kyanite, etc.</td>
<td>Muscovite is the most common mica, found in granites, pegmatites, gneisses, and schists, and as a contact metamorphic rock or as a secondary mineral resulting from the alteration of topaz, feldspar, kyanite, etc.</td>
<td>Corundum occurs as a mineral in micaschist, gneiss, and some marbles in metamorphic terranes. It also occurs in low silicaigneous syenite and nepheline syenite intrusives.</td>
</tr>
<tr>
<td>distribution</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>uses</td>
<td>Used in electrical industry due to its electrical resistance.</td>
<td>Used in electrical industry due to its electrical resistance. Biotite is used extensively to constrain ages of rocks, by either potassium-argon dating or argon-argon dating</td>
<td>Used in electrical industry due to its electrical resistance.</td>
<td>The Verneuil process allows the production of flawless single-crystals sapphires, rubies and other corundum gems of much larger size than normally found in nature. Scratch-resistant optics, scratch-resistant watch crystals, instrument windows for satellites and spacecraft (because of its transparency from the UV to IR), and laser components.</td>
</tr>
<tr>
<td>Property</td>
<td>Gypsum</td>
<td>Calcite</td>
<td>Garnet</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------</td>
<td>--------------------------</td>
<td>-------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Lustre</strong></td>
<td>Wheat brown</td>
<td>Brown</td>
<td>Grey</td>
<td></td>
</tr>
<tr>
<td><strong>Vitreous</strong></td>
<td>Sub-vitreous</td>
<td></td>
<td>Sub-vitreous</td>
<td></td>
</tr>
<tr>
<td><strong>Form</strong></td>
<td>Crystalline or waxy</td>
<td>Massive</td>
<td>Massive/cubic or rohmbohedral</td>
<td></td>
</tr>
<tr>
<td><strong>Streak</strong></td>
<td>White</td>
<td>White</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>2-hardly scratch-able by finger nail</td>
<td>3-easily scratch-able by pen knife</td>
<td>6.5-7.5-Hardly scratchable by glass</td>
<td></td>
</tr>
<tr>
<td><strong>Cleavage</strong></td>
<td>Present</td>
<td>Present</td>
<td>Absent</td>
<td></td>
</tr>
<tr>
<td><strong>Fracture</strong></td>
<td>Uneven-conoidal</td>
<td>Concoidal</td>
<td>Concoidal</td>
<td></td>
</tr>
<tr>
<td><strong>Specific gravity</strong></td>
<td>2.31-2.33 medium g/cc</td>
<td>2.71</td>
<td>3.1-4.1</td>
<td></td>
</tr>
<tr>
<td><strong>Diagnostic property</strong></td>
<td>Hardness and form</td>
<td>Cleavage &amp; colour</td>
<td>Form and cleavage</td>
<td></td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td>Based on the megascopic observation the specimen is identified as <em>gypsum</em>. Showing monoclinic system</td>
<td>Based on the megascopic observation the specimen is identified as <em>calcite</em> Showing hexagonal system</td>
<td>Based on the megascopic observation the specimen is identified as <em>garnet</em>. Showing cubic system</td>
<td></td>
</tr>
<tr>
<td><strong>Chem. Com</strong></td>
<td>CaSO$_4$·2H$_2$O</td>
<td>CaCO$_3$</td>
<td>(Ca$^{2+}$, Mg$^{2+}$, Fe$^{3+}$, Cr$^{3+}$) (SiO$_4$)$_3$</td>
<td></td>
</tr>
<tr>
<td><strong>Occurences</strong></td>
<td>Gypsum is a common mineral, with thick and extensive evaporite beds in association with sedimentary rocks. Gypsum is deposited in lake and sea water, as well as in hot springs, from volcanic vapors, and sulfate solutions in veins. Hydrothermal anhydrite in veins is commonly hydrated to gypsum by groundwater in near surface exposures.</td>
<td>Calcite is a common constituent of sedimentary rocks, limestone in particular, much of which is formed from the shells of dead marine organisms. Approximately 10% of sedimentary rock is limestone. Calcite is the primary mineral in metamorphic marble. It also occurs as a vein mineral in deposits from hot springs, and it occurs in caverns as stalactites and stalagmites.</td>
<td>It occurs in rocks like associate and as staurolite and others</td>
<td></td>
</tr>
<tr>
<td><strong>Distribution</strong></td>
<td>Commercial quantities of gypsum are found in the cities of Araripina and Grajaú, Brazil, Pakistan, Jamaica, Iran (world's second largest producer), Thailand, Spain (the main producer in Europe), Germany, Italy, England, Ireland,</td>
<td>Calcite is found in spectacular form in the Snowy River Cave of New Mexico as mentioned above, where microorganisms are credited with natural formations.</td>
<td>In the US, the birthstone for January is garnet (garnet with rutile asterisms) is the state gemstone of Idaho</td>
<td></td>
</tr>
<tr>
<td>Uses</td>
<td>Gypsum Board(^{[14]}) primarily used as a finish for walls and ceilings; known in construction as Drywall. Plaster ingredient. Fertilizer and soil conditioner. In the late 18th and early 19th century, Nova Scotia gypsum, often referred to as plaster, was a highly sought fertilizer for wheat fields in the United States. It is also used in ameliorating sodic soils. A binder in fast-dry tennis court clay. Plaster of Paris (surgical splints; casting moulds; modeling).</td>
<td>Used as synthetic glass which may become opaque when electricity applies. Used in prism.</td>
<td>Pure crystals of garnet are still used as gemstones. The gemstone varieties occur in shades of green, red, yellow and orange.</td>
<td>Galena is a semiconductor with a small bandgap of about 0.4 eV which found use in early wireless communication systems. For example, it was used as the crystal in crystal radio sets, in which it was used as a point-contact diode to detect the radio signals. The galena crystal was used with a safety pin or similar sharp wire, which was known as a &quot;cat's whisker&quot;.</td>
</tr>
</tbody>
</table>
Unit-II: MINERALOGY

1. A naturally occurring inorganic substance with characteristic physical properties (Mineral)
2. Common examples of rock forming minerals (Quartz, Feldspars, Micas, Pyroxenes)
3. Common examples of ore forming minerals (Haematite, Galena, Sphalerite, Chalcopyrite)
4. The important physical properties of a mineral include (Form, Streak, Lustre, Hardness)
5. Streak of Black Haematite (Red)
6. Hardness of Talc on Mohs scale is (1)
7. Very hard mineral is (Diamond)
8. Hardness of Diamond on Mohs scale is (10)
9. Lustre of Quartz is (Vitreous)
10. Mineral with very high specific gravity (Barytes)
11. Micas are commonly used as (Insulators)
12. Common optical properties of minerals include (Birefringence, Extinction angle & Pleochroism)
13. Massive substance consisting of one or more minerals (Rock)
14. Igneous rocks are broadly classified into (Plutonic, Hypabyssal & Volcanic)
15. Sedimentary rocks are broadly classified into (Arenaceous and Argillaceous)
16. Metamorphic rocks are classified based on (Degree of metamorphism)
17. Examples of Plutonic igneous rocks include (Granite, Syenite, Gabbro)
18. Example of Hypabyssal igneous rocks include (Dolerite)
19. Example of Volcanic igneous rocks include (Rhyolite)
20. Examples of Rudaceous sedimentary rocks include (Breccia, Conglomerate)
21. Examples of Metamorphic rocks include (Schist, Gneiss, Quartzite, Phyllite, Marble)
22. Example of Arenaceous sedimentary rocks include (Sandstone)
23. Example of Argillaceous sedimentary rocks include (Shale)
24. Common structures in igneous rocks include (Joints)
25. Common structures in Sedimentary rocks include (Bedding, Lamination)
26. Common structures in Metamorphic rocks include (Schistosity, Gneissosity)
27. Columnar Jointing is commonly observed in (Basalts)