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College of Engineering



## **MODULE-2** *Earth Resources*



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# Contents

- Colour
- Streak
- Lustre
- Crystal system
- Structure
- Specific gravity
- Hardness
- Cleavage
- Fracture
- Tenacity
- Form
- Odour
- Feel
- Mineral groups(quartz,feldspars)

# TENACITY

The behavior of the mineral when subjected to pressure is known as Tenacity. The terms used to describe the tenacity are.

- **Brittle:** A mineral that breaks and powders easily (Sulfides, Carbonates, Silicates and Oxides),
- **Malleable:** A mineral that can be hammered out without breaking, into thin sheets. (Native metals- Copper, Silver, Gold)
- **Sectile:** A mineral that can be cut with a knife into thin shavings (Native metals),
- **Ductile:** A mineral that can be drawn into wire (Native metals),
- **Flexible:** A mineral that bends but retains its bent form. Does not resume its original shape  
® permanent deformation (Asbestos, clay minerals, Chlorite, Talc)
- **Elastic:** A mineral that after bending springs back and resumes its original position. (Muscovite).

## FORM

- Form or crystal habit is the characteristic external shape of an individual crystal or crystal group. It is the characteristic of natural internal shape of mineral.
- When minerals form under unfavorable conditions become amorphous (shapeless) due to a random arrangement of their atoms or molecules

- Forms showing One Dimensional Growth
  - **Acicular** – minerals showing needle like crystals (Natrolite, Actinolite)
  - **Fibrous** – minerals showing and aggregation of long thin fibers (Asbestos)



- **Radiating** – mineral made up of needle like crystals which appear originating from a common point giving radiating appearance. (Zeolite, Limonite)
- **Columnar** – mineral showing columnar crystal. (Beryl)

- Forms showing Two Dimensional Growth
  - **Bladed** – minerals showing bladed habit occur as small knife blades. (Kynite)
  - **Tabular** – minerals showing broad flat surface. (Orthoclase)
  - **Foliated** – minerals with platy habit commonly occur as foliated aggregates containing thin separable sheets/ the individual sheets are paper thin or even thinner and can be easily separated. (Muscovite, Biotite)
  - **Lamellar or Platy** – mineral is made up of thick flexible, separable plates. (Vermiculite)



### DIAPHANEITY: ( Degree of transparency)

- Diaphaneity is the amount of light transmitted or absorbed by a solid. It is used strictly for hand specimens because most minerals that are opaque as hand specimen becomes transparent when very thin.
- **Transparent:** When light is transmitted through mineral and object behind it can be seen clearly, E.g., Quartz, Calcite.
- **Translucent:** When the light is transmitted through mineral but the object cannot be seen. E.g. Feldspar
- **Opaque:** Minerals are opaque when no is transmitted even through thin edges or layers of minerals, light is wholly absorbed. E.g., All Metals and some non-metallic minerals.

- **ODOR:**
- Some minerals give characteristic odor (Smell) when rubbed or heated.
  - Aresenical – like odor of Garlic. (Orpiment / Arsenic Mineral)
  - Sulfurous – like odor of burning sulfur. (pyrite)
  - Argillaceous – like odor of clay. (Kaolin)
- **FEEL:**
- It is feel to touch or sensation. The terms used are smooth, harsh, greasy, rough, cool, soapy etc..



# Mineral Groups:

Sl. No.	Mineral Group	Examples
1.	Oxides	Quartz, Magnetite, Hematite, Limonite, Etc.
2.	Silicates	Feldspar, Mica, Hornblende, Olivine, Etc.
3.	Carbonates	Calcite, Dolomite, siderite, Etc.
4.	Sulfides	Pyrite, Galena, Sphalerite, Etc.
5.	Sulfates	Gypsum, Anhydrite, Etc.
6.	Chlorite	Rocksalt, Etc.

## Quartzs and its varities

	Rock Crystal	Amethyst	Smokey Quartz	Rosy Quartz	Jasper
<b>Colour</b>	Colourless	Purple / Violet	Smokey Brown	Rose Pink	Reddish brown
<b>Streak</b>	Absent	Absent	Absent	Absent	Absent
<b>Lusture</b>	Vitreous shining	Sub – Vitreous	Sub – Vitreous	Vitreous shining	Earthy, Dull
<b>Diaphaneity</b>	Transparent	Transparent	Translucent	Translucent	Opaque
<b>Hardness</b>	7	7	7	7	7
<b>Sp. Garvity</b>	2.6	2.6	2.6	2.6	2.6
<b>Cleavage</b>	Absent	Absent	Absent	Absent	Absent
<b>Fracture</b>	Conchoidal	Uneven	Subconchoidal	Uneven	Uneven
<b>Tenacity</b>	Brittle	Brittle	Brittle	Brittle	Brittle
<b>Form</b>	Crystalline massive	Crystalline massive	Crystalline massive	Crystalline massive	Crystalline massive
<b>Chemical Composition</b>	SiO <sub>2</sub>	SiO <sub>2</sub>	SiO <sub>2</sub>	SiO <sub>2</sub>	SiO <sub>2</sub>
<b>Crystal System</b>	Hexagonal	Hexagonal	Hexagonal	Hexagonal	Hexagonal







5



- **Occurance**

- Found in acid igneous rocks, in Veins & in Sedimentary & Metamorphic rocks.
- Occure in cavities of volcanic rocks, Hydro thermal cavity filling deposits.
- Founds in Acid Igneous Rocks
- Found in Veins of igneous rocks
- Found in Sedimentary deposits

- **Uses**

- Glass Manufacture, Ceramic Industry, Electric equipments, As Flux, Radars, pre- stressed concrete.
- Glass manufacturing, Ornamental Stone, Gem Stone.
- Semiprecious stone, Optical Glass.
- Precious Stone, Microscope, Glass Manufacture.
- Ornamental & decorative stone





Rutilated Quartz



Prasiolite



Carnelian



Smoky quartz



Milky Quartz



Rose Quartz



Tiger's Eye



Chalcedony



Citrine



Mtorolite



Aventurine



Onyx



Agate



Amethyst



Jasper



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FELDSPAR GROUP



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# INTRODUCTION

Ceramic is an inorganic compound consisting of a metal (or semi-metal) and one or more nonmetals

A ceramic may be crystalline, partly crystalline structure or may be amorphous (eg:glass)

- Important examples:
  - *Silica* - silicon dioxide ( $\text{SiO}_2$ ), the main ingredient in most glass products
  - *Alumina* - aluminum oxide ( $\text{Al}_2\text{O}_3$ ), used in various applications from abrasives to artificial bones
  - More complex compounds such as hydrous aluminum silicate ( $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ ), the main ingredient in most clay products



- Types of ceramic products
  - structural (bricks, pipes, floor, and roof tiles)
  - refractories (gas firing radiants, steel and glass)
  - white wares (table ware , cookware, walltiles)



# Feldspar

•  $\text{KAlSi}_3\text{O}_8$  - Orthoclase  $\text{KAlSi}_3\text{O}_8$  - Microcline  
 $\text{NaAlSi}_3\text{O}_8$  -  $\text{CaAl}_2\text{Si}_2\text{O}_8$  - Plagioclase *In the manufacture of high-class, colourless glass, feldspar should have a maximum of 0.1%  $\text{Fe}_2\text{O}_3$  though upto 0.3% is permissible.*



# Colour

**Orthoclase** - usually light colored white, pink, yellow, or cream, and not transparent. The gem variety is clear to pale yellow, and some called "noble orthoclase"

**Microcline** - white, pink, pale yellow, or sometimes green-blue, and not transparent. The green-blue variety is called "amazonite"

**Plagioclase** - gray to grayish-white is common, but may also be white, pink or pale yellow. More semi-opaque than the other feldspars on average, and contains striations on some crystal faces or cleavage surfaces.





# classification

- Potash feldspar:

- » Orthoclase
- » Sanidine
- » microcline

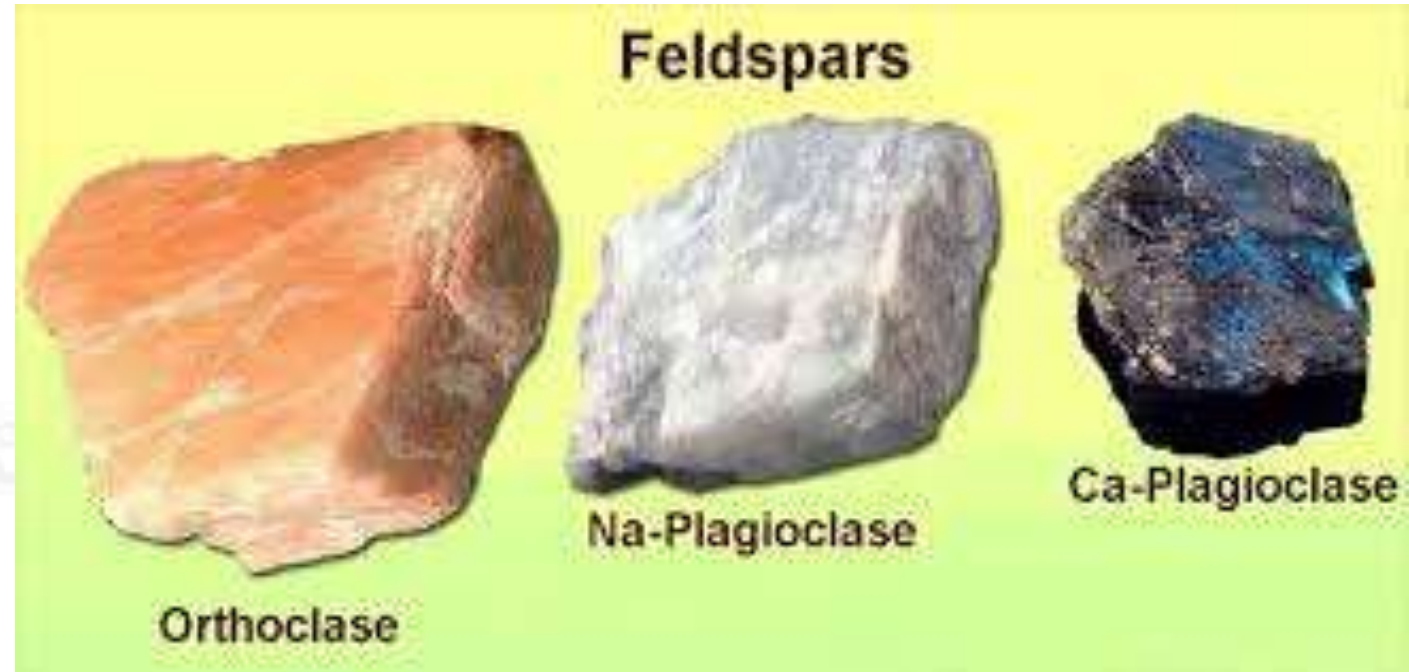
- Sodalime-feldspar:

- » Albite
- » Oligoclase
- » Andesine

- Crystallographically:

- monoclinic

- » Orthoclase
- » Sanidine Triclinic Microcline
- Albite-anorthite



### Feldspar Group of Minerals

	Plagioclase	
Absent	White, Smokey Gray	Pinkish/ Greyish White
Sub - Vitreous	Absent	Absent
Translucent	Sub - Vitreous	Sub - Vitreous
6	Translucent	Transparent to translucent
2.5	6	6 to 6.5
2 sets Perpendicular to each other	2.5 to 3	2.56
Uneven	2 sets Perpendicular to each other	Two sets of perfect cleavage
Brittle	Uneven	Uneven
Tabular massive	Brittle	Brittle
$KAlSi_3O_8$	Tabular Massive	Tabular Massive, Crystalline
Monoclinic	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$	$KAlSiO_3$
Mostly found in acid igneous rock, since it is most essential Mineral in it.	Triclinic	Triclinic
Ceramic industry, Flooring tiles, Glass	Found in Basic Igneous rocks since they are the essential minerals present in them.	Acid igneous rocks, Granite and pegmatite.
	Ceramic industry, Flooring tiles.	Ceramic industry, Flooring tiles.

# OCCURRENCE

- Feldspar is found in igneous rock particularly in granite and pegmatite.
- Pegmatite's are often zoned into distinct bands of quartz and feldspars
- In India the pegmatites of famous mica belt in Rajasthan , Bihar , Andhra Pradesh are the major source of ceramics grade feldspars
- Tiruchanapalli districts of Tamil nadu Burdwan and purulia district west Bengal and Hassan district of Karnataka

## Feldspar is generally used for three purposes

- Feldspar are used as fluxing material in the preparation of ceramic bodies.
- Feldspar used in ceramic industry should contain a minimum of 65-72%  $\text{SiO}_2$  and not less than 4%  $\text{Na}_2\text{O}$
- As a bonding agent in the manufacture of bonded abrasives like wheels and discs of garnet, corundum, emery etc.
- The glass and ceramic industries are the major consumers of feldspar and account for 95% of the total consumption.



Feldspar is used in varying proportions in porcelain, china and earthenware.

Earthenware contains on an average 12% feldspar

25% ball clay

28% china-clay

35% quartz

This proportion of feldspar varies in different products like Wall tile -5%

Floor tile -30% Statutory porcelain -50% Sanitary ch  
bodies -30%





# ANORTHITE

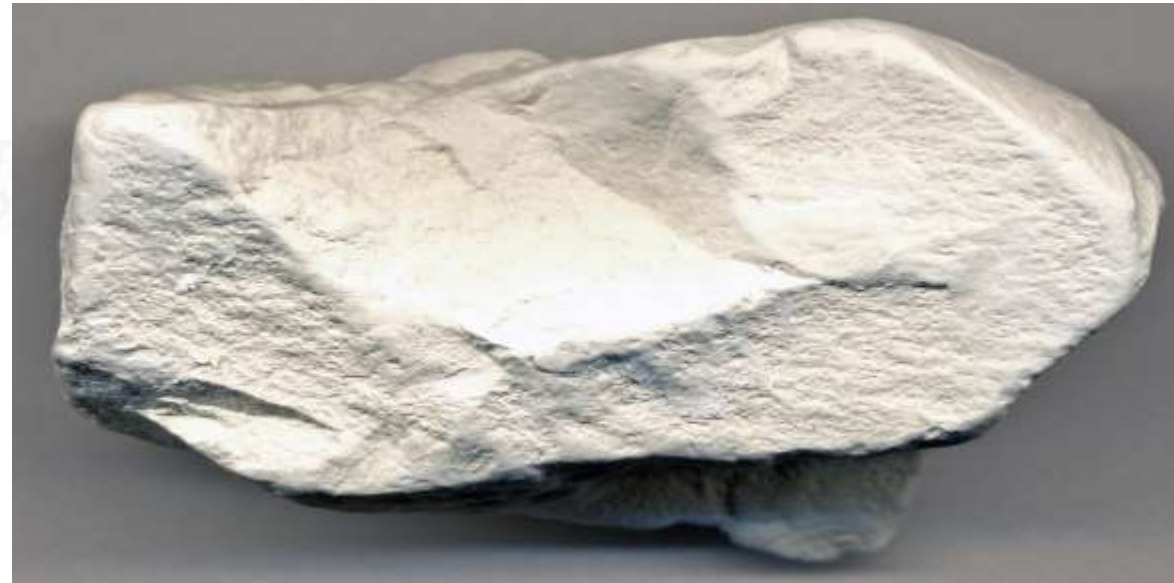
Crystal System	<b>Triclinic.</b> It is the last member of the isomorphous <b>plagioclase series</b> of feldspars. Crystals are commonly prismatic.
Cleavage	<b>Present in two directions;</b> the one parallel to basal pinacoid (001) is <b>perfect.</b>
Colour	Generally <b>white</b> ; may also occur in reddish and light grey shades.
Streak	Colourless.
Lustre	Semi-vitreous.
Composition	$\text{CaAl}_2\text{Si}_2\text{O}_8$ – 100 to 90%.
Optical	Optically (–)
Occurrence	An important constituent of many basic types of igneous rocks.
Varieties	Composition of other members of plagioclase feldspars has already been given above. These may be broadly considered the varieties of plagioclase feldspars.



# ALBITE

Crystal System	<b>Triclinic.</b> It is the first member of the isomorphous <b>plagioclase series</b> of feldspars the Albite- Anorthite series.
Cleavage	Present in two directions; the <b>one parallel to basal pinacoid</b> (001) is perfect.
Colour	Commonly <b>whitish or pinkish white</b> but shows shades of grey, green and blue.
Streak	Colourless.
Lustre	<b>Vitreous to pearly.</b> Some varieties show play of colours on the cleavage surface.
Hardness	6 – 6.5
Sp. Gravity	2.60 – 2.62
Composition	Sodium aluminium silicate with $\text{NaAlSi}_3\text{O}_8$ – 100 – 90 percent and $\text{CaAl}_2\text{Si}_2\text{O}_8$ , 0 – 10 percent.
Optical	Optically (+)
Occurrence	It is an essential constituent of many igneous rocks, such as granites, syenites, rhyolites and dacites
Economic Use	(i) As a ceramic material (ii) As an ornamental stone in polished form.

## KAOLIN GROUP



## Contents

- Introduction
- Clay
- Types of clay
- Physical Properties of kaolin
- Beneficiations
- Uses
- Occurrence



# INTRODUCTION

- It is a layered silicate mineral
- Rocks that are rich in **kaolinite** are known as **kaolin** / or **china clay**. ...  
It is a soft, earthy, usually white, **mineral** produced by the chemical weathering of aluminium silicate **minerals** like feldspar.
- Kaolinite is a clay mineral(kaolin), part of the group of industrial minerals with the chemical composition  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ .



# CLAY

- Clays have been classified based on their physical properties and industrial usage as:
  - 1) ball clay
  - 2) china clay
- Both belongs to kaolin group and the primary constituent is Kaolinite.

# BALL CLAY

- Ball clays possess high plasticity and lesser refractoriness owing to the presence of Montmorillonite
- Reported from Khajwara, Indawar, Jodhpur, and some areas in Rajasthan
- Rampurda, Vagedia, Bagabela and Thoangadh, areas in Gujarat
- Kundra in Kerala,
- parts of Chinglepet district in Tamil Nadu and
- Dwarka – Tirumala in Andhra Pradesh.





## CHINA CLAY

- China clay is used to achieve greater strength and the required plasticity
- These clays are a product of weathering processes of feldspathic rock
- Good deposits are in Bhagalpur , Ranchi, singbhum and monghyr district in Bihar.Bankura and birbhum district in W.bengal.Banda district in Uttar Pradesh,Ajmer district in Rajasthan
- Salem dist in Tamilnadu ,Adila bad, anantapur , Nellore and Guntur district in Andhra Pradesh
- Shimogga and hasan district of Karnataka



# Physical properties of minerals

## Kaolin(Clay)

- **Colour-** Buff white
- **Streak-** White
- **Luster-** Earthy Dull
- **Diaphaneity-** Opaque
- **Hardness-** Less than 1
- **Specific gravity-** 2.6
- **Cleavage-** Absent
- **Fracture-** Uneven
- **Tenacity-** Crumples between fingers
- **Form-** Fine Massive
- **Chemical composition-**  $\text{Al}_4\text{Si}_4\text{O}_{10}(\text{OH})_8$
- **Crystal system-** Triclinic
- **Occurrence-** Found in Coal Seams as an altered product of Feldspar rich Rocks
- **Uses-** Paper, Paint, Textile, Stiffner in Cement, Chinaware, Bricks.



## Cont.....

- Kaolin as found in nature usually contains varying amounts of other minerals such as muscovite, quartz, feldspar, and anatase. In addition, crude kaolin is frequently stained yellow by iron hydroxide pigments. It is often necessary to bleach the clay chemically to remove the iron pigment and to wash it with water to remove the other minerals in order to prepare kaolin for commercial use.

# Uses

- Kaolin, also called china **clay**, soft white **clay** that is an essential ingredient in the manufacture of china and porcelain and is widely used in the making of paper, **rubber**, paint, and many other products.
- Major uses of kaolinite are in the paper and paint industries. It is also used in the making of plastics, rubber, and as ink extender.
- Approximately 40 percent of the kaolin produced is used in the filling and coating of [paper](#).





# Occurrence

- **Kaolinite** can be formed as a residual weathering product, by hydrothermal alteration, and as an authigenic sedimentary **mineral**. ... The alteration results from surface weathering, groundwater movement below the surface or action of hydrothermal fluids.
- **Kaolinite** clay occurs in abundance in soils that have formed from the chemical weathering of rocks in hot, moist climates—for example in tropical rainforest areas.

# Limestone( $\text{CaCO}_3$ )

- Colour- milky white, small portions of impurities give various tints
- Lustre- vitreous. Earthy in massive varieties
- Cleavage- highly perfect
- Hardness- 3
- Sp gravity- 2.7
- Crystal system- hexagonal, rhombohedral.
- Occurrence- calcite is one of the most rock forming minerals in sedimentary rocks. Calcite is principally a secondary mineral formed from the carbonate rich water of sea and oceans.
- Uses- Cement industries.



# Carbonate Rocks

- Carbonate rocks - limestones composed of calcite ( $\text{CaCO}_3$ ) or dolostones composed of dolomite ( $\text{CaMgCO}_3$ ).
- Form through biological and biochemical processes and through inorganic precipitation from seawater
- A few carbonate minerals are very important as rock forming minerals in sedimentary and metamorphic groups. These include calcite, dolomite and magnesite.

## Dolomite $\text{Ca, Mg}(\text{CO}_3)_2$

- Colour- white, also occurs in shades of brown.
- Cleavage-perfect, Rhombohedral
- Hardness- 3.3-4
- Sp gravity- 2.8-2.9
- Lustre- vitreous
- Crystal system- Hexagonal, Rhombohedral
- occurrence- As a mineral, it is found in veins of igneous origin, commonly occurs in massive form extending several kilometers across.





# Magnesite( $\text{MgCO}_3$ )

- **Colour-** shades of gray , white
- **Cleavage-** hexagonal
- **Crystal system-** hexagonal
- **Hardness-**3.5-4.5
- **S.g-** 3.0-3.1
- **Lustre-** vitreous
- **Occurrence-** magnesite is formed from magnesium bearing waters of sea on their coming in contact with other carbonate rocks.
- **Uses-** as refractory material and for chemical compounds of magnesium.



## Mica Group of minerals

- Minerals of mica group are characterized with the presence of a micaceous structure by the virtue of which these can be split into very thin sheets along one direction.
- Micas are very common rock forming minerals
- Mica group of minerals show a great variation in their chemical composition.

## Biotite Mica

- **Colour**-Dark brown or Black.
- **Streak**-Brown
- **Luster**-Pearly
- **Diaphaneity**-Transparent
- **Hardness**-2 to 3
- **Sp. Gravity**-2.7
- **Cleavage**-One set of perfect Basal Cleavage
- **Fracture**-Uneven
- **Tenacity**-Elastic
- **Form**-Foliated/ Extremely thin
- **Chemical Composition**- $K(MgFe)_3(AlSi_3)O_{10}(OH,F)_2$
- **Crystal System**-Monoclinic
- **Occurrence**-Found in intermediate Igneous Rocks, Sedimentary & metamorphic rocks.
- **Uses**-Electrical industries , Insulators, Light weight Concrete.



## Muscovite Mica

- **Streak**-White
- **Luster**- Pearly
- **Diaphaneity**-Transparent
- **Hardness**- 2.3 to 2.5
- **S.G**- 2.6
- **Cleavage**-One set of perfect Basal Cleavage
- **Fracture**- Uneven
- **Tenacity**- Elastic
- **Form**- Foliated/ Extremely thin
- **Chemical composition**-  $\text{KAl}_2(\text{AlSiO}_3)\text{O}_{10}(\text{OH},\text{F})_2$
- **Crystal system**- Monoclinic
- **Occurrence**- Found in Acid Igneous rocks like Pegmatites & Granites
- **Uses**- Electric & Electronic Insulators, Fancy Paints, Window Screens, Furnace, Spark plugs , Lubricants





## Gypsum

- **Streak**-White
- **Luster**- Sub – Vitreous
- **Diaphaneity**-Translucent
- **Hardness**- 2
- **Specific gravity**- 2.3 to 2.5
- **Cleavage**- One set Basal Cleavage
- **Fracture**- Uneven
- **Tenacity**- Non Elastic,
- **Form**- Flexible Fibrous
- **Chemical composition**-  $\text{CaSo}_4 \cdot 2\text{H}_2\text{O}$
- **Crystal system**- Monoclinic
- **Occurrence**- Found in Sedimentary deposits, also occurs as evaporate deposits.
- **Uses**- POP, Gypsum sheets, cement & ceramic industry, as filler.



## Asbestos

- **Colour-** White, grey
- **Streak-** White
- **Luster-** Silky
- **Diaphaneity-** Opaque
- **Hardness-** 2 to 3
- **S.g** -2.5 to 3.2
- **Cleavage-** Perfect Cleavage
- **Fracture-** Uneven Fracture
- **Form-** Flexible Fibrous
- **Chemical composition-**  $\text{Mg}_6\text{Si}_4\text{O}_{10}(\text{OH})_8$
- **Crystal system-** Monoclinic
- **Occurrence-** Found in metamorphic rock in serpentine
- **Uses-** Thermal Insulators, Oven Linings, AC sheets, Asbestos sheets, fire proof material, textile & ceramic industry



## PETROLOGY

- Rock: Rocks are the aggregates of minerals formed by the process of solidification of magma. Rocks provide a historical record of geological events. Most rocks at Earth's surface are silicates. Others, carbonates, are formed from minerals extracted from water.
- Petrology is a branch of Geology deals with the study of rocks. It mainly deals with the mode of formation, mineral constituents, textures and structure.

### **Rocks are classified into**

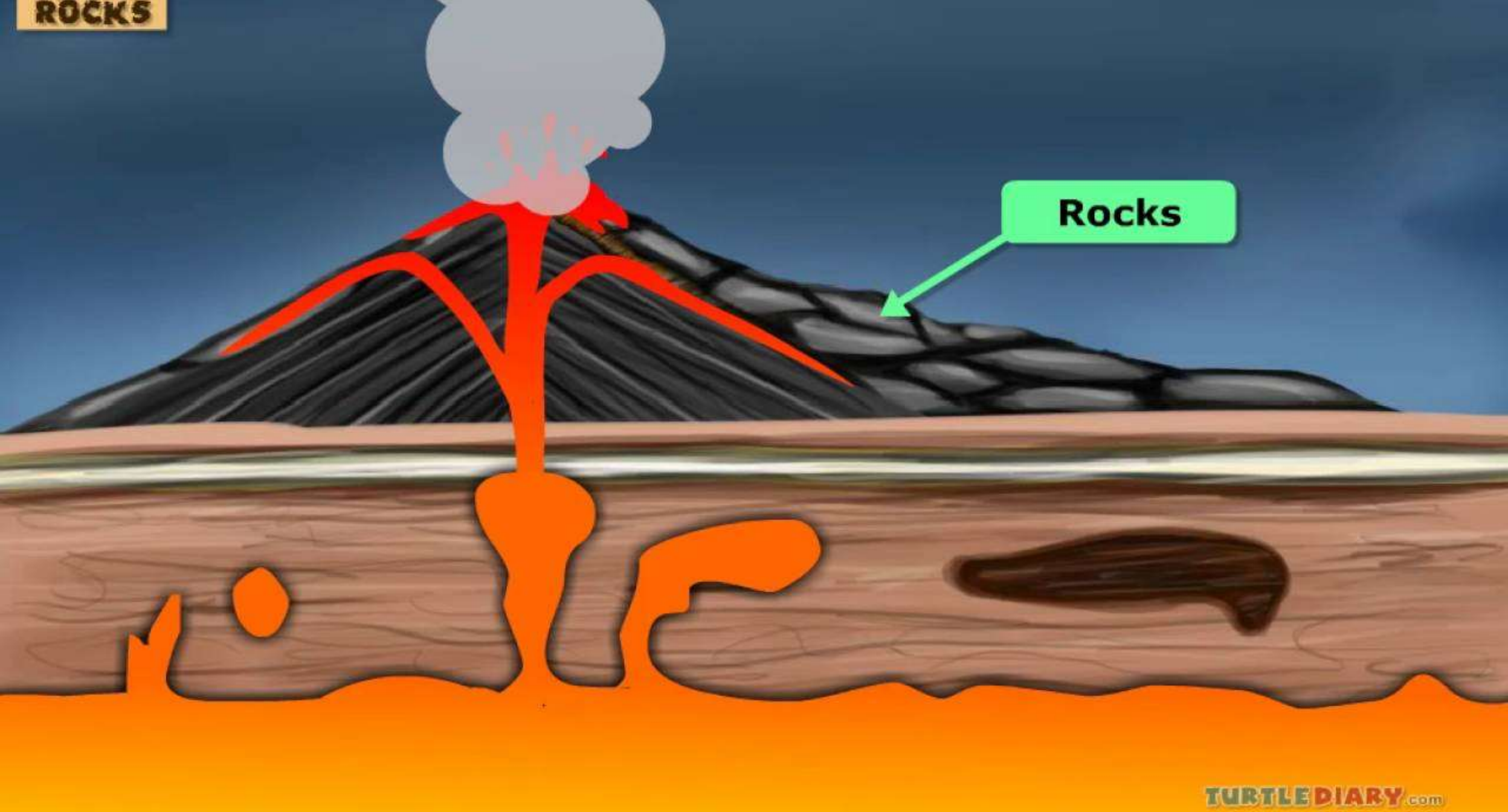
- **IGNEOUS:** These are primary rocks formed by solidifying from a molten magma
- **METAMORPHIC:** pre-existing rocks are altered due to pressure and/or temperature and fluid activity.
- **SEDIMENTARY:** result when fragments of pre-existing rocks accumulate and are cemented together or by the precipitation of mineral crystals out of water solutions.



- Igneous rocks are those, which are formed by direct solidification of liquid rock or magma. They are thus called primary rocks. Magma is a hot viscous silicate melt with gases occur in the deeper part of the Earth.
- This magma during its upward journey tries penetrate to thin crust. During this process magma sometimes successful in coming out and some time they arrest themselves within the crust.
- Lava: The magma which is successful in coming out on the Earth's surface, it is erupted out with a great force and spreads out on the surface of the Earth is called Lava.

**ROCKS**

**Rocks**



- Classification of Igneous rocks: They are classified on the basis of ‘silica’ content in the magma and ‘mode’ of occurrence.

Based on silica content:

- **Acidic Igneous rocks**: It is rich in silica content ( $>65\%$  of  $\text{SiO}_2$ )

Ex: Granite, Pegmatite

- **Intermediate Igneous rocks**: Silica percentage is 55-65%

Ex: Syenite, Diorite

- **Basic Igneous rocks**: Silica content is 45-55%

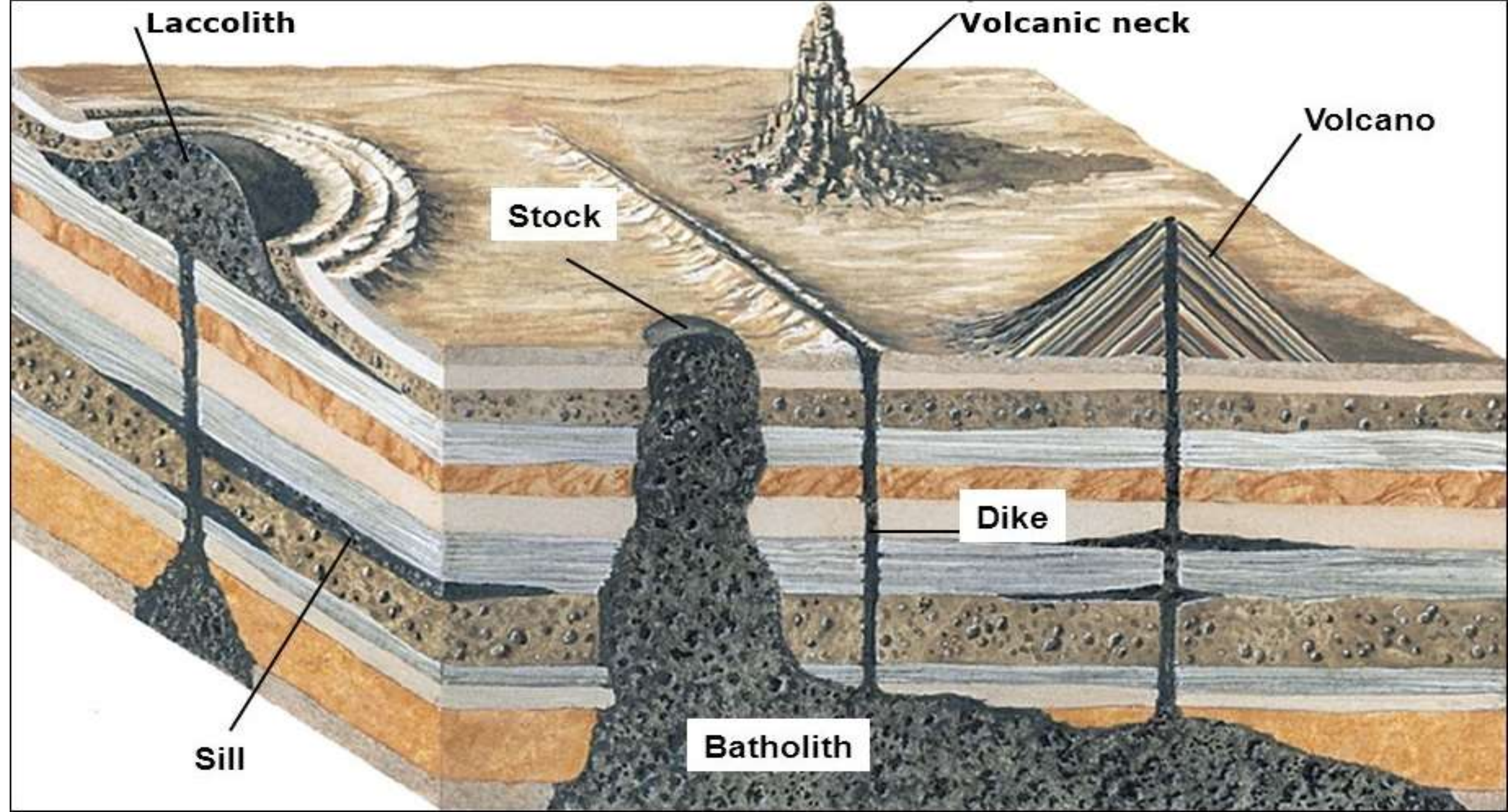
Ex: Dolerite, Gabbro.

- **Ultra-basic Igneous rocks**: Silica content is  $<45\%$

Ex: Dunite.

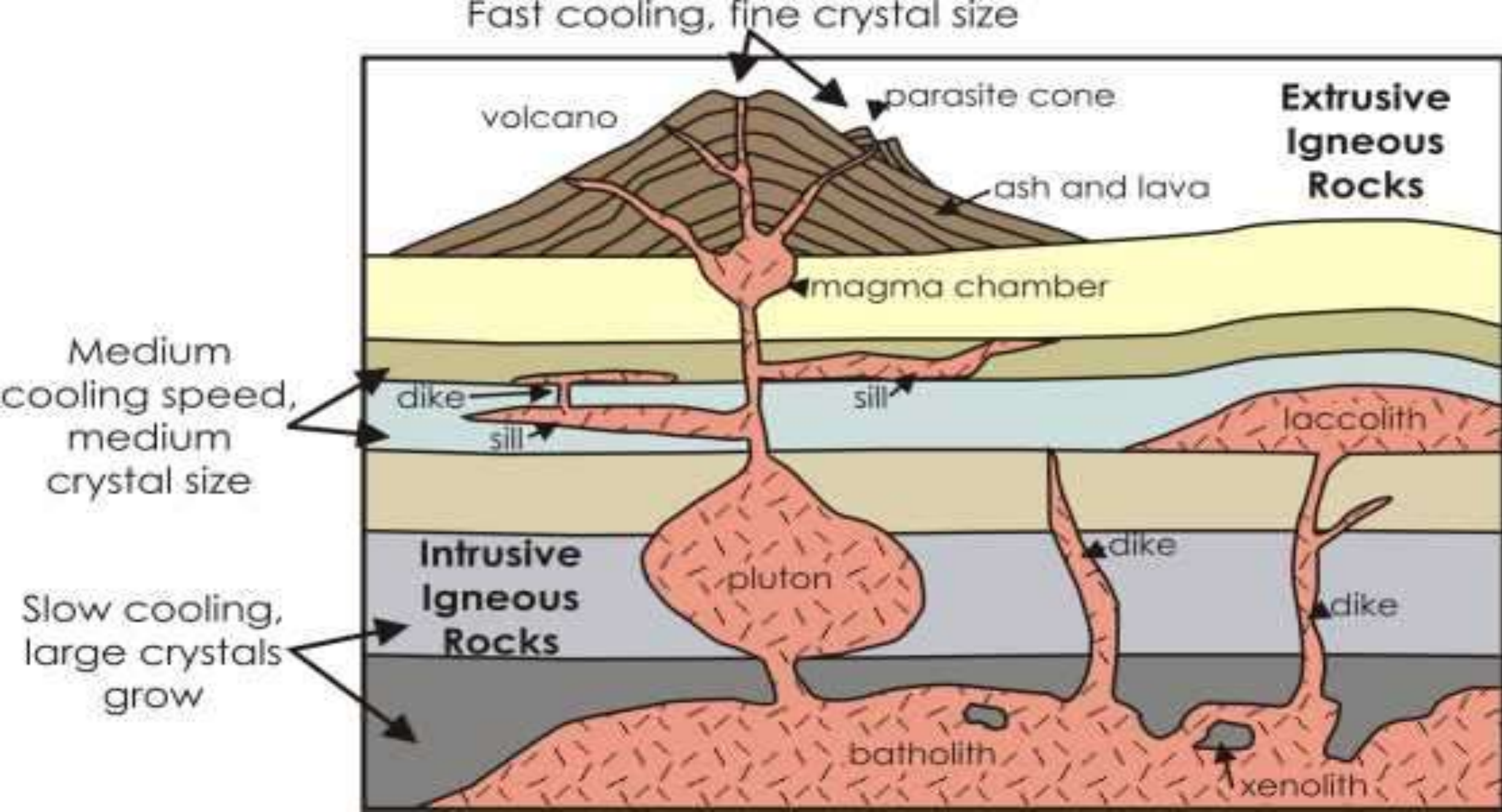
- **Based on mode of origin:**
  - **Plutonic rocks**: These are deep seated rocks formed under slow cooling and great pressure conditions. They exhibit equigranular texture because the magma has cooled slowly under uniform pressure. Ex: Granite, Syenite, Diorite, Gabbro
  - **Hypabyssal rocks**: They are formed by the solidification of magma nearer to the surface of the Earth's crust. They show porphyritic texture because of rapid cooling of magma. Ex: Pegmatite, Porphyry, Dolerite
  - **Volcanic rocks**: These are formed on the surface of the crust by the consolidation of the lava. Here, the minerals cannot be distinguished with naked eye because of very small grain size and is due to rapid cooling and chilling. Ex: Basalt, Rhyolite, Trachite, Basalt, Olivine basalt



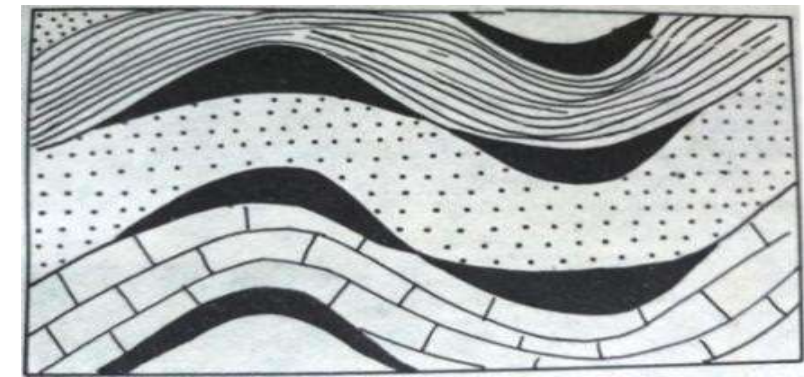
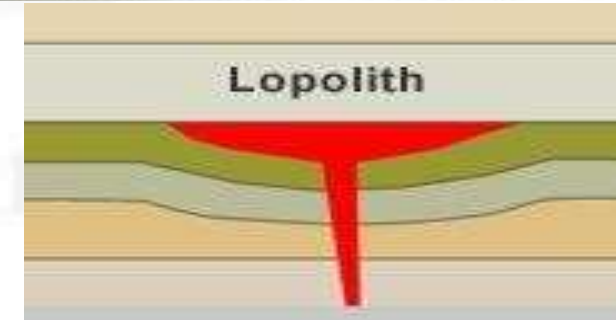


- Forms of Igneous rocks : classified into two groups
  - 1.Extrusive bodies
  2. Intrusive bodies
  - **Extrusive bodies**: Igneous rocks that cool and crystallize on the Earth's surface are called extrusive igneous rocks. Another name for extrusive igneous rocks is volcanic igneous rocks. Ex: Basalt
  - **Intrusive bodies**: Igneous rocks that cool and crystallize beneath the Earth's surface are called intrusive igneous rocks. Another name for intrusive igneous rocks is plutonic igneous rocks. Ex: Granite
- Intrusive igneous rocks are further classified based on the relations with enclosing rocks into two types
  - (a)Concordant
  - b) Discordant intrusive rocks





- **Concordant intrusive bodies**: If the intrusion is parallel to the structure of the country rock, they are called 'Concordant intrusive bodies'.  
Ex: Sill , Phacolith, Laccolith and Lopolith
- **Sill**: It is a concordant intrusive sheet like body which runs parallel to the bedding planes of the enclosing sedimentary rock. They are typical of basic magma and varies in thickness from few centimeters to several kilometers.
- **Phacolith**: It is a concordant intrusive lens shaped form found in crests and troughs of folded rocks.
- **Lopolith**: It is a concordant intrusive bowl-like bodies, which are sagged downwards due to the weight of the intruded magma
- **Laccolith**: It is a concordant intrusive mushroom like bodies which have a convex upper surface and relatively flat lower surface.

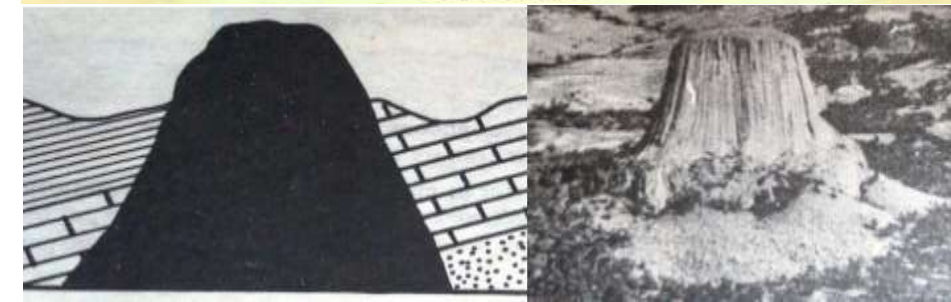
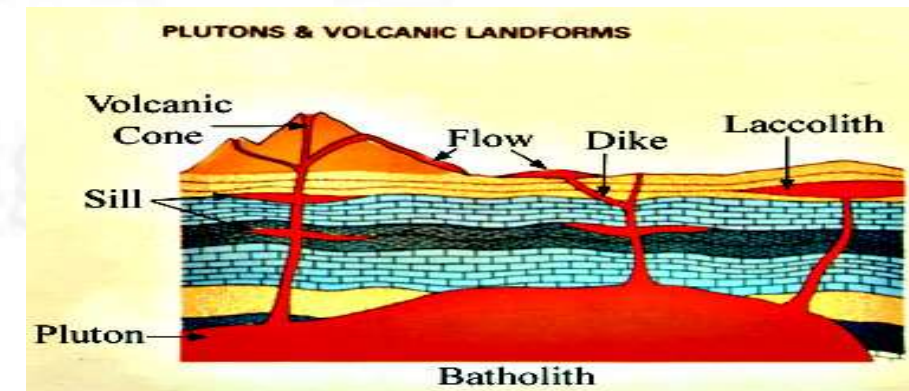
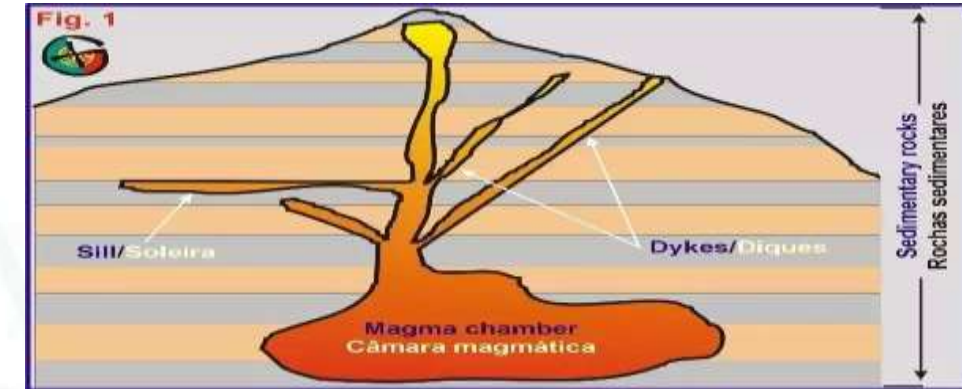




- **Discordant intrusive bodies**: If the intrusion is cut across the structure of pre-existing country rock, they are called 'Discordant intrusive bodies'

Ex: Batholith, Dyke, Volcanic Neck

- **Batholith**: Batholiths are known to be largest kind of discordant intrusive bodies which are spread over very large area covering several kilometers. They increase in size with depth and they are thought to be bottomless. A Stock is a small batholith of irregular and cylinder form. A stock having a circular form is called a Boss.
- **Dyke**: Dykes are discordant igneous body of more or less tabular shape and exhibit a cross-cutting relationship with the country rocks. If the rocks constituting the dyke are hard and compact, they can resist weathering and Erosional process.
- **Volcanic neck**: The vents of quiet volcanoes have become sealed with the igneous intrusions and is called volcanic necks/plugs.



- **Textures in igneous rocks:** Texture is an important character for identification of igneous rocks. It is defined as the size, shape and arrangement of minerals and mutual relationship between individual mineral grains.

Based on the degree of crystallization, the textures are described as

Holocrystalline, Holohyaline and Mesocrystalline

- **Holocrystalline:** The constituent minerals are crystallize slowly and visible to naked eye.
- **Holohyaline:** The constituent minerals are non-crystalline and are fine grained/ glassy and not visible for naked eye.
- **Mesocrystalline:** These are intermediate type where both crystalline and non-crystalline glassy material found in the same rock.

### Types of textures based on the grain size:

- Equigranular Texture: In this type, the mineral grains are all of approximately same size. This is because all the minerals are simultaneously get consolidated. Ex: Granite
- Inequigranular texture: In this type, the mineral grains show marked difference in their grain size. This is because different mineral grains consolidate at different level and hence different minerals exhibit different sizes. Ex: Syenite
- Porphyritic texture: It is a type of inequigranular texture, where tabular or large sized minerals called phenocrysts are fully embedded within the fine grained minerals known as matrix Ex: Syenite Porphyry
- Poiklitic texture: This is the inverse of porphyritic texture, which is characterized by the presence of fine grained crystals within the body of large sized crystals. Ex: Peridotite

- Ophitic texture: This is similar to porphyritic texture, which shows the phenocrysts are partially embedded within the matrix. Ex: Dolerite
- Pegmatitic / intergrowth texture: Here, two or more minerals crystallize simultaneously in a limited space. Here one crystal intrudes another. Ex: Pegmatite
- Vesicular / Amygdaloidal texture: The escape of these gases leads to the formation of different sizes / shapes of holes in the cooled volcanic rocks. The structure developed is called vesicular structure. Ex: Vesicular Basalt.





**A. Glassy texture**

Composed of unordered atoms and resembles dark manufactured glass. (Obsidian is a natural glass that usually forms when highly silica-rich magmas solidify.)



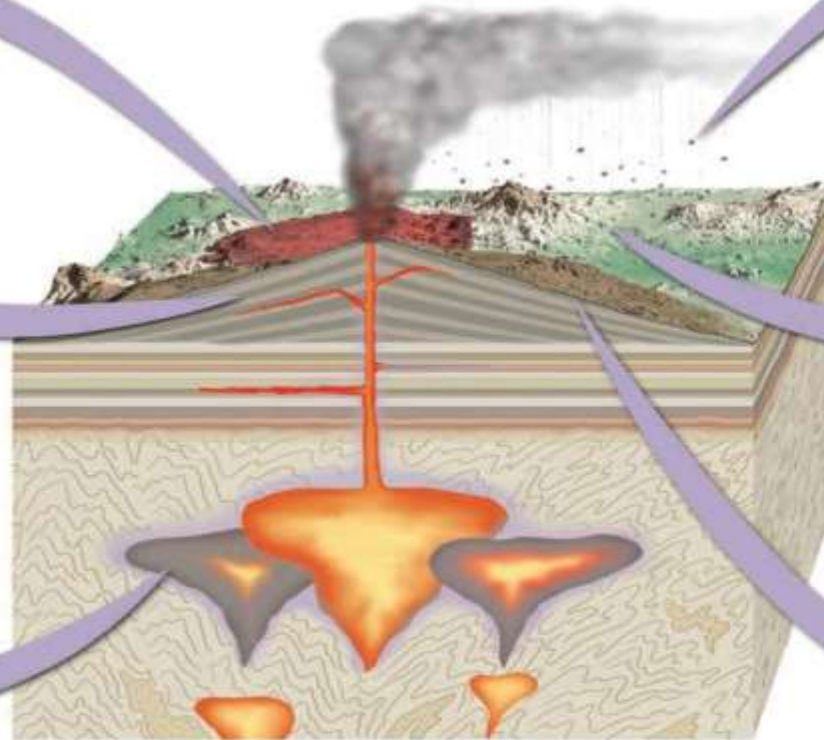
**B. Porphyritic texture**

Composed of two distinctly different crystal sizes.



**C. Phaneritic (coarse-grained) texture**

Composed of mineral grains that are large enough to be identified without a microscope.



**D. Vesicular texture**

Extrusive rock containing voids left by gas bubbles that escape as lava solidifies. (Pumice is a frothy volcanic glass that displays a vesicular texture.)



**E. Pyroclastic (fragmental) texture**

Produced by the consolidation of fragments that may include ash, once molten blobs, or large angular blocks that were ejected during an explosive volcanic eruption.



**F. Aphanitic (fine-grained) texture**

Composed of crystals that are too small for the individual minerals to be identified without a microscope.

## Description of igneous rocks:

- **Granite:** It is the most common type of plutonic group of igneous rocks which appears in white or pink in color. These are observed in the form of dykes, batholiths with coarse grained to medium grained crystals. Essential minerals are quartz, feldspars with few varieties of mica, hornblende, garnet and magnetite. Granite is one of most important building stones specially used for decorative and architectural purposes. It takes fine polish and strongest among all the variety of all building stone extensively for roads.





granite and often contains  
ocean ridges. It cools in  
zones below a volcano.

in basalt. It cools  
in magma

- **Basalt:** It's a volcanic group of igneous rock having dark brown in color having fine crystalline essential minerals of plagioclase and augite. The crushed basalt is used as road metal, concrete aggregates and also used for construction of bridges and other engineering works.



- **Granite Porphyry:** A hypabyssal rock differing from quartz porphyry by the presence of sparse phenocrysts of mica, amphibole, or pyroxene in a medium- to fine-grained groundmass.
- **Syenite:** It is a plutonic rock of light colored coarse grained texture. The essential minerals are orthoclase, plagioclase, quartz, augite and hornblende. Syenite shows shades of blue and green colors due to presence of feldspar.
- **Pumice:** The igneous rock shows cellular and vessicular texture formed on the surface of the acid lava which floats on water.





## **ENGINEERING PROPERTIES AND USES OF IGNEOUS ROCKS**

- These are typically impervious, hard, strong and form very strong foundations for most of Civil Engineering projects such as dams and reservoirs.
- Granite, syenite and dolerite possess very high crushing strength and most suitable for construction works.
- Basalts are recommended for foundation of structures and roads only.
- Many of the igneous rocks are used extensively as materials for constructions.
- Joints and fractured granitic rocks permit passage for groundwater accumulation.
- Diorite porphyry is extensively used as decorative wall rock because of the texture.



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# Sedimentary rocks

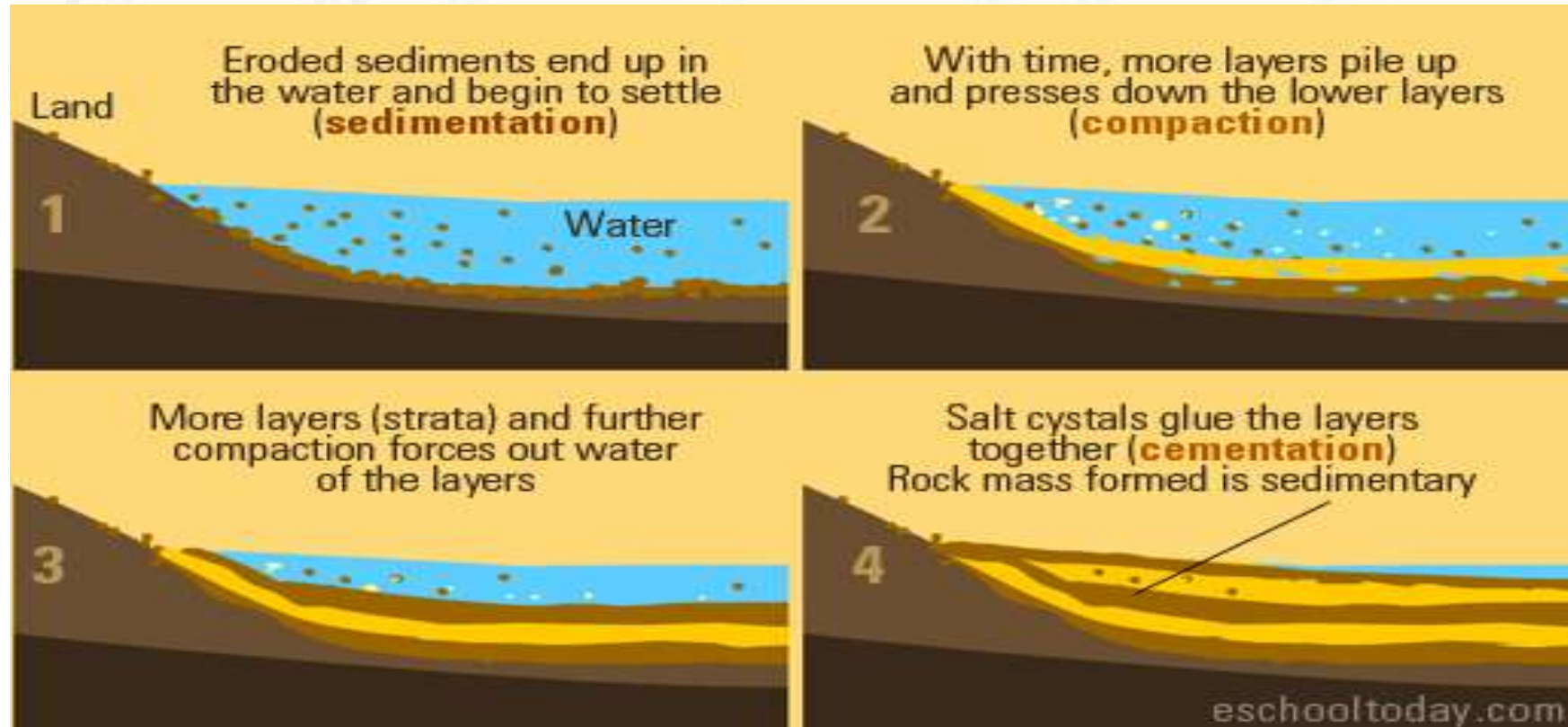
## TOPICS COVERED

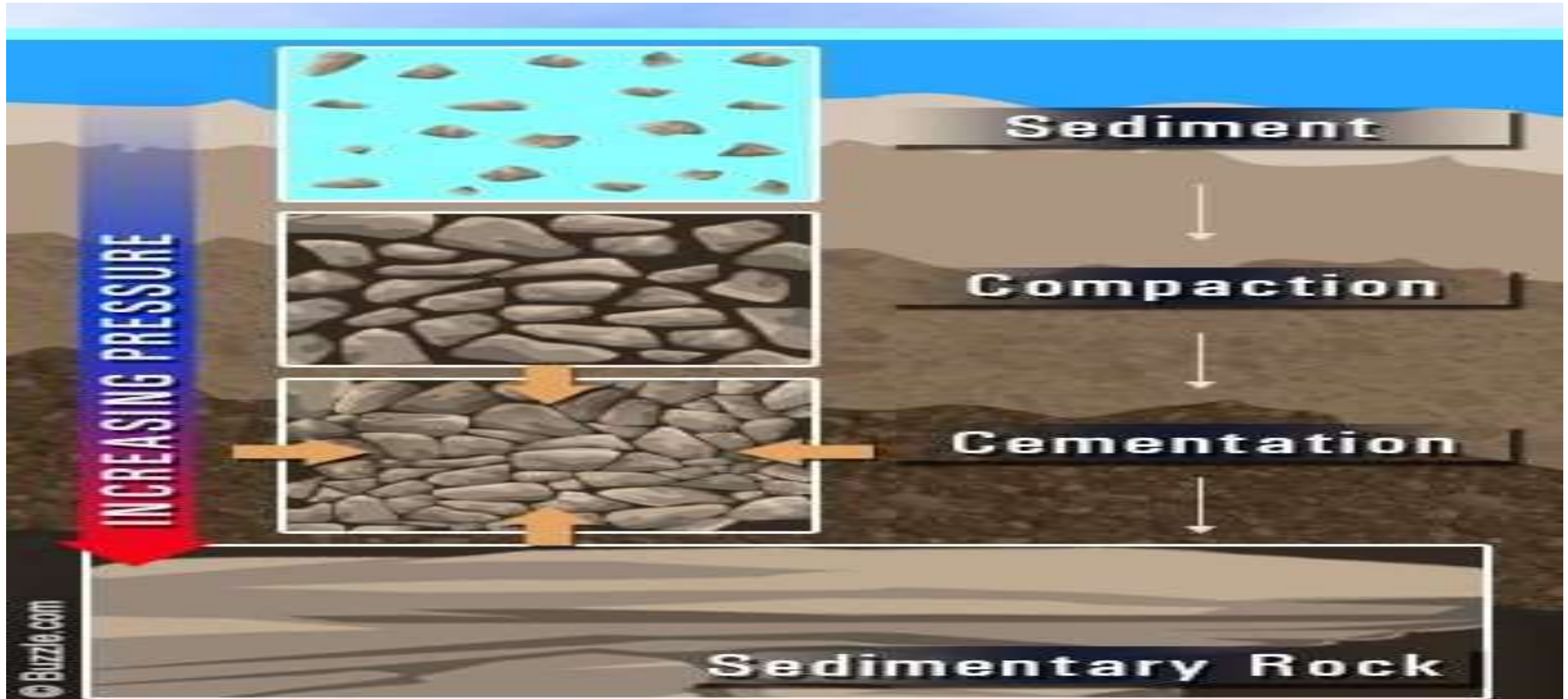
- INTRODUCTION
- FORMATION
- CLASSIFICATION
- TEXTURES
- STRUCTURES
- DESCRIPTION OF SEDIMENTARY ROCKS
- ENGINEERING PROPERTIES

- Sedimentary rocks are the type of rocks that are formed by the deposition of sediments on the surface of the earth.
- Sediments are the rock fragments which are the products of weathering (Process of disintegration and decomposition of the rocks.) of pre-existing rocks.
- These sediments after transportation and deposition are consolidated by the process called lithification and diagenesis to form a sedimentary rock. These are also called as secondary rocks.



- Contributes about 8% of total volume of crust.
- The study of sedimentary rocks and rock strata provides information about the subsurface that is useful for civil engineering. Eg- construction of roads, houses, tunnels, canals, etc....





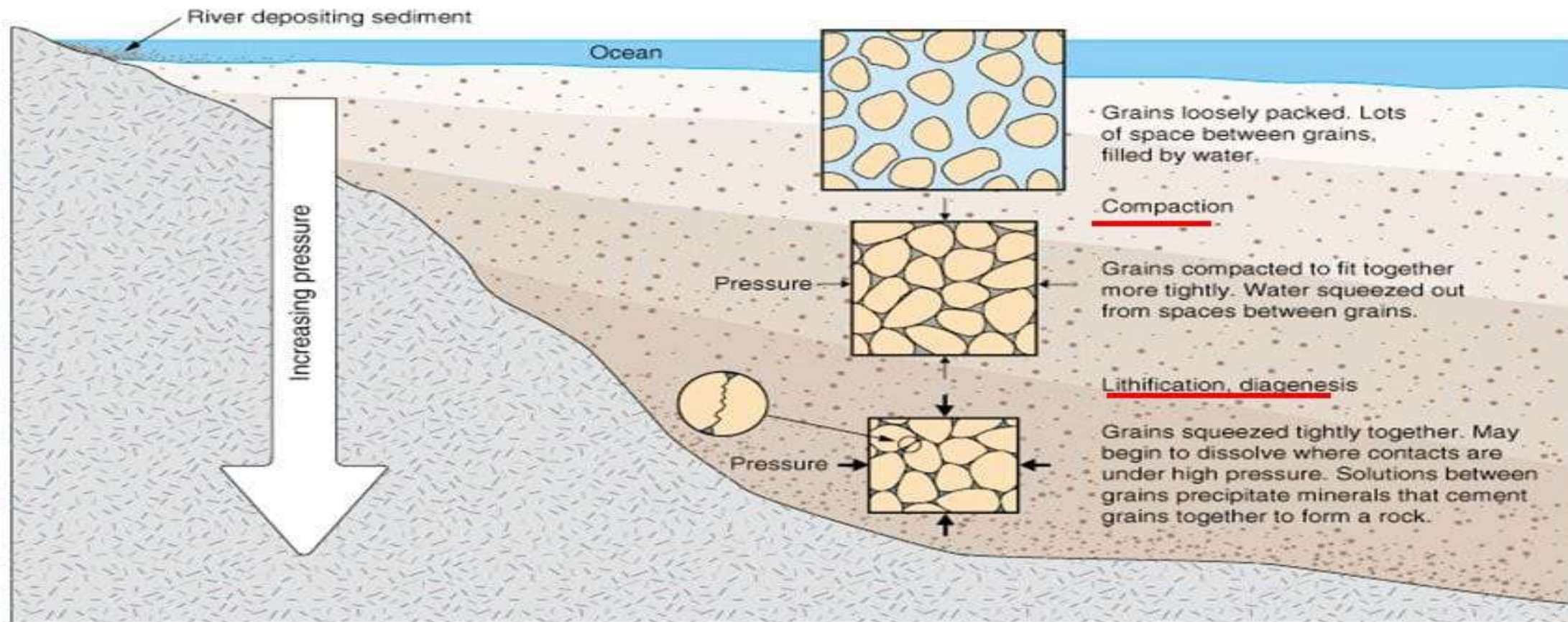
## FORMATION

- The formation of the sedimentary rock takes place in three stages
  1. Weathering and erosion of pre-existing rocks.
  2. Sedimentation
  3. Lithification and diagenesis
- 1. Weathering: During weathering and erosion, the pre-existing rocks and their constituent minerals are broken down. These sediments are usually transported and deposited in areas of accumulation by the geological agents..
- 2. Sedimentation: The process of accumulation of sediments at the site of deposition is called the sedimentation.
- 3. Lithification and diagenesis: Lithification is a process by which soft and loose sediments are converted into hard and firm rocks. This process is called as condensation. Physical and chemical changes takes place within the sedimentation is called diagenesis.
  - a) compaction
  - b) cementation
  - c) Recrystallization



# COMPACTION, LITHIFICATION, DIAGENESIS

## UNCONSOLIDATED SEDIMENT TURNS INTO HARD SEDIMENTARY ROCKS



Similar to snow turning to ice



## Classification Of Sedimentary Rocks

- I. Clastic Sediments
- II. Non-clastic sediments
- I. **Clastic Sediments:** Clastic sediments are broken fragments of pre-existing rocks ranging in size from minute clay particles to very large boulders. Clastic rocks are formed by mechanical accumulation of grains of clastic sediments.
  - a. **Rudaceous rocks (Rudites)** – These are formed by accumulation of bigger rock fragments such as gravels, pebbles and boulders. If the grains are rounded, the rock is called as “conglomerate” and if the grains are angular then the rock is called as “Breccia”.
  - b. **Arenaceous rocks (Arenites)** – These rocks are composed of almost entirely of sand grains. When individual grains are rounded the rock is called as “sandstone” and if the grains are angular it is called as “grit”.
  - c. **Argillaceous rocks (Lutites)** – These rocks are made up of very fine grained sediments. “Shale” and “mudstone” are typical argillaceous rocks, which are composed of clay sized sediments.

- **II. Non- clastic Sediments:** Non-clastic rocks include those sedimentary rocks which are formed by chemical precipitation of minerals from water or by accumulation of remains of animals and plants. They are classified into two groups.
  1. **Chemically formed rocks**
  2. **Organically formed rocks**
- **1. Chemically formed rocks:** Sediments are derived from the dissolution of minerals from older rocks and subsequent transportation of dissolved chemical substances into a sea or lake.
  - a) Carbonate rocks: some limestone
  - b) Evaporites: rock salt, gypsum and an hydrate
  - c) Ferruginous rocks: Ironstone
  - d) Siliceous rocks: chert , jasper and agate.

- **2. Organically formed rocks:** These rocks are composed mainly of remains of plants and animals.
- **a. Biochemical rocks** – Ex- Shell limestone.
- **b. Organic rocks** – Ex- Coal .These rocks are called as ‘carbonaceous rocks.

## Sedimentary Structures:

- sedimentary rocks contain sedimentary structures, features that developed during or after deposition of the sediments.

The important primary sedimentary structures are :

- **Lamination:** Thin bedding layers, less than 1 cm in thickness are called as lamination.



Lamination



- **Stratification or bedding:** Deposition of sediments into layers or beds is called stratification. The plane of junction between different beds is called the bedding plane.

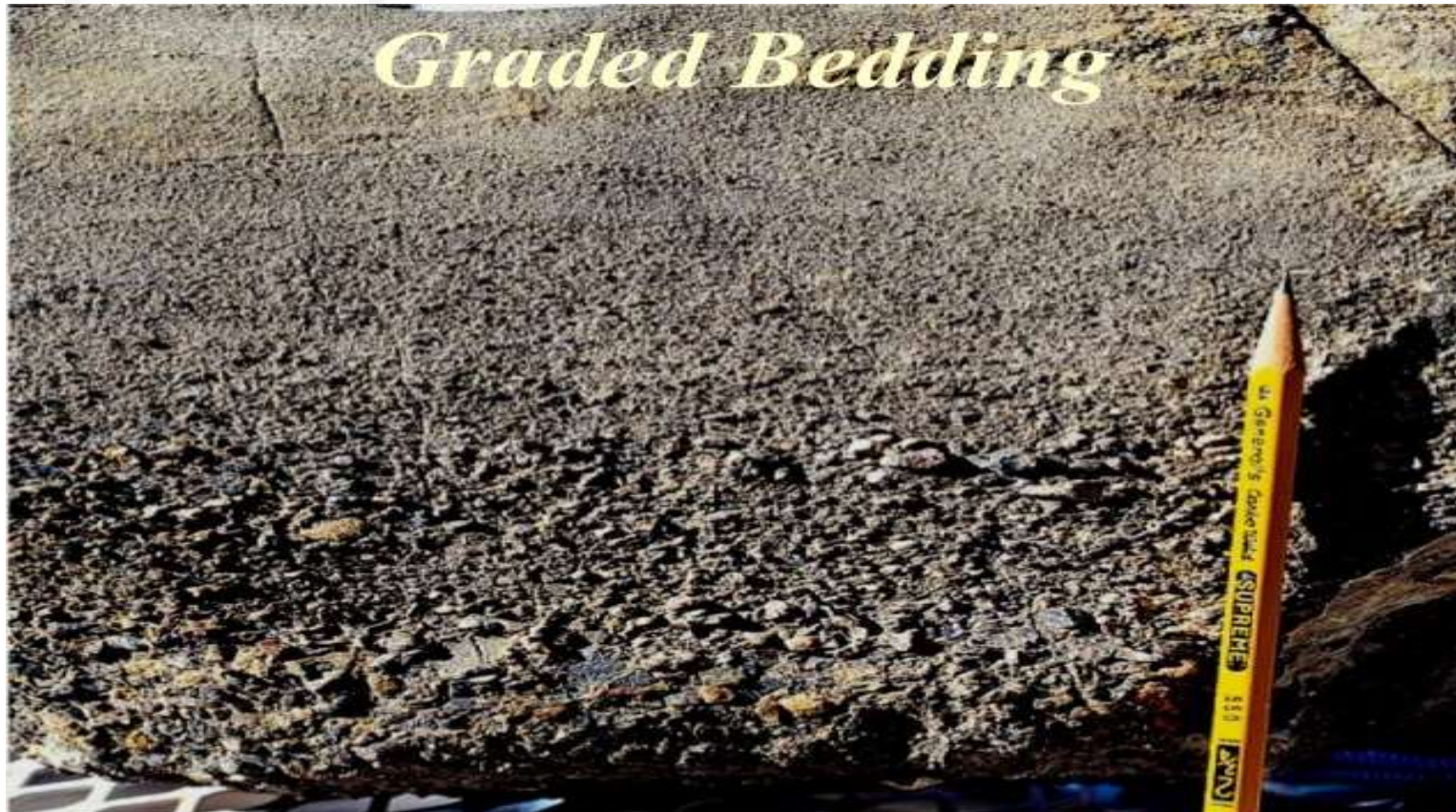


- **Cross-bedding:** Cross bedding consists of small beds or laminations laying at an angle to main sedimentary layering. Cross bedding is common in environment such as sands deposited by wind, streams, ocean current and waves on beaches.





- **Graded bedding:** In Graded bedding each bed shows a gradation in grain size. The largest grains collect at the bottom of a layer and the smaller grains collect at the top.



- **Ripple marks:** Ripple marks are the wavy undulations seen on the surface of bedding planes. They are produced by the action of waves and currents in shallow water or on the surface of deposits formed by wind.



- Beside these there are some minor structures such as Mud cracks, rain prints etc.



- **SANDSTONE**
- **Colour-** Occurs in varieties of colour such as pink, red, brown, grey, white, or buff.
- **Texture and Grain size-** · Clastic texture i.e. Arenaceous
- · Medium to fine Grain
- **Mineral Composition** It consists predominantly of quartz mineral, and small amount of garnet, feldspar, may also occur. The cementing material may be silica, calcite, or iron oxide.
- **Specific Gravity** – 2.6 to 3
- **Classification** –It is mechanically formed Arenaceous sedimentary rock
- **Occurrence** - It occurs as bedded deposits.
- **Special Property** – It is composed of medium to fine grains, it can be cut and carved.
- **Uses** – ornamental stone, monumental stone, Abrasive, road metal & concrete aggregate.



- **LIMESTONE**
- **Colour-** Multicolour, shows black, white & grey colour.
- **Texture and Grain size-** Massive , Very fine or amorphous Grain
- **Mineral Composition** It consists of calcite i.e.  $\text{CaCO}_3$  impurities like clay & quartz may be present. It is self cemented.
- **Specific Gravity – 2.7**
- **Classification –** It is chemically formed sedimentary rock.
- **Occurrence –** It may be crystalline, clastic, granular, or massive, depending on the method of formation..
- **Special Property –** It gives effervescence with dil. HCl or react readily with dil. HCl.
- **Uses –** it is used in the manufacture of cements, smelting of iron and used in toothpaste, cosmetics, paints, pigments, & some times in medicines.



- **SHALE**
- **Colour-** Multicolored, shows pink, green, white & grey colour.
- **Texture and Grain size** · Clastic texture.i.e.Argillaceous Fine Grain
- **Mineral Composition** Clay minerals like kaolin, & small amount of other minerals such as quartz and mica.
- **Specific Gravity** – 2.6
- **Classification** – It is mechanically formed Argillaceous sedimentary rock.
- **Occurrence** - It occurs as bedded deposits.
- **Special Property** – It shows laminations and consists of very fine materials.
- **Uses** – It is used as bricks, tiles, used in cement manufacture & building & road material.





### LATERITE

- **Colour-** Multicolor, reddish brown, brick red, at some places yellowish.
- **Texture and Grain size** · Concretionary and porous. Nodules
- **Mineral Composition** Laterites are essentially clays, rich in alumina and iron hydroxide with minor amount of silica.
- **Specific Gravity** – 2.6 to 2.8
- **Classification** –It is residual sedimentary rock.
- **Occurrence** - It occurs as capping rock of Basalt & Granite.
- **Special Property** – It is concretionary & porous. When fresh it is very soft, when sun dries it become hard stone.
- **Uses** – used as building stone, road metal & poor grade iron ore.





- **CONGLOMERATE**
- **Colour-** Multicolored, shows of shades of pink, grey, reddish brown.
- **Texture and Grain size** Clastic texture i.e. Rudaceous · Coarse Grained
- **Mineral Composition** -The rock may be heterogenous or homogenous in composition, mineral fragments in heterogynous verities are flint, chert, jasper, quartz etc. The matrix may be silicic or ferruginous in composition.
- **Specific Gravity** – 2.7 to 2.8
- **Classification**– It is mechanically formed Rudaceous sedimentary rock
- **Occurrence** - It occurs as bedded deposits.
- **Origin** – it is mechanically formed Rudaceous rock
- **Special Property** – The pebbles are smooth and rounded.
- **Uses** – It is worked for jasper, and other valuable minerals present, sometimes used as building & decorative stone, road metal & concrete aggregate.





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# METAMORPHIC ROCKS



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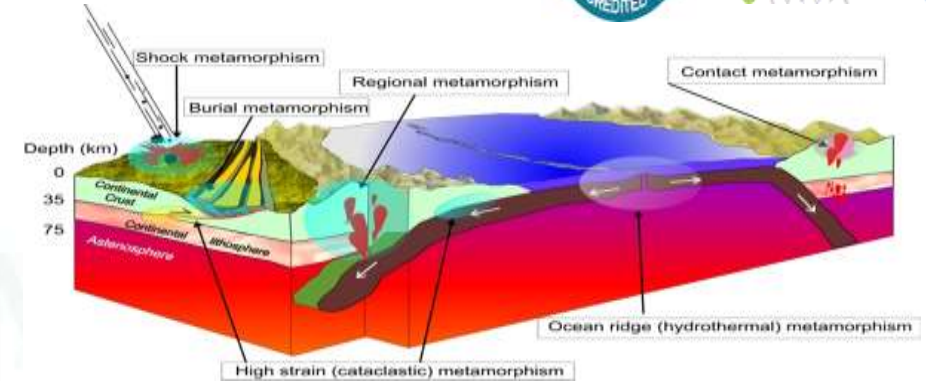


## Contents

- INTRODUCTION
- AGENTS OF METAMORPHISM
- KINDS OF METAMORPHISM
- TEXTURES AND STRUCTURES OF METAMORPHISM
- DESCRIPTION OF METAMORPHIC ROCKS
- ENGINEERING PROPERTIES OF ROCKS

➤ **Metamorphism:-** Metamorphism is the process in which rocks are altered in composition, internal structure or texture by extreme heat, pressure, and the introduction of new chemical substances.

➤ **Metamorphic rock:-** The rocks which have formed by various types of metamorphic processes on the pre-existing igneous and sedimentary rocks involving changes in structures, textures and mineralogical composition.



metamorphosed



metamorphosed





## ***Agents Of Metamorphism***

### ***Heat:***

- Most important agent of metamorphism.
- It provides the energy to drive the chemical reactions that recrystallize minerals.

### ***Pressure:***

- The weight of the material above which causes compressional forces to act equally in all directions
- Stress caused by compressional forces as tectonic plates push against one another. These forces are directional and cause the rock to be squeezed which may result in folds and a foliated texture

### ***Chemically Active Fluids:***

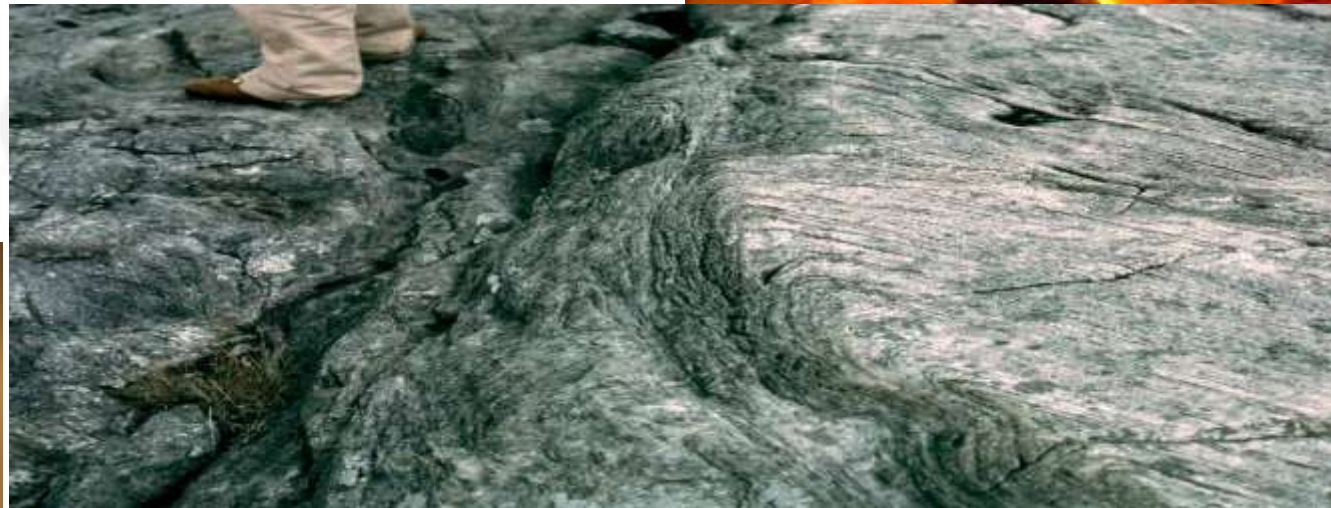
- Has a strong influence on the metamorphism of rocks
- Water located in pore spaces of rocks is perhaps the most common fluid involved in metamorphism.

## *Agents of metamorphism*

**Heat**

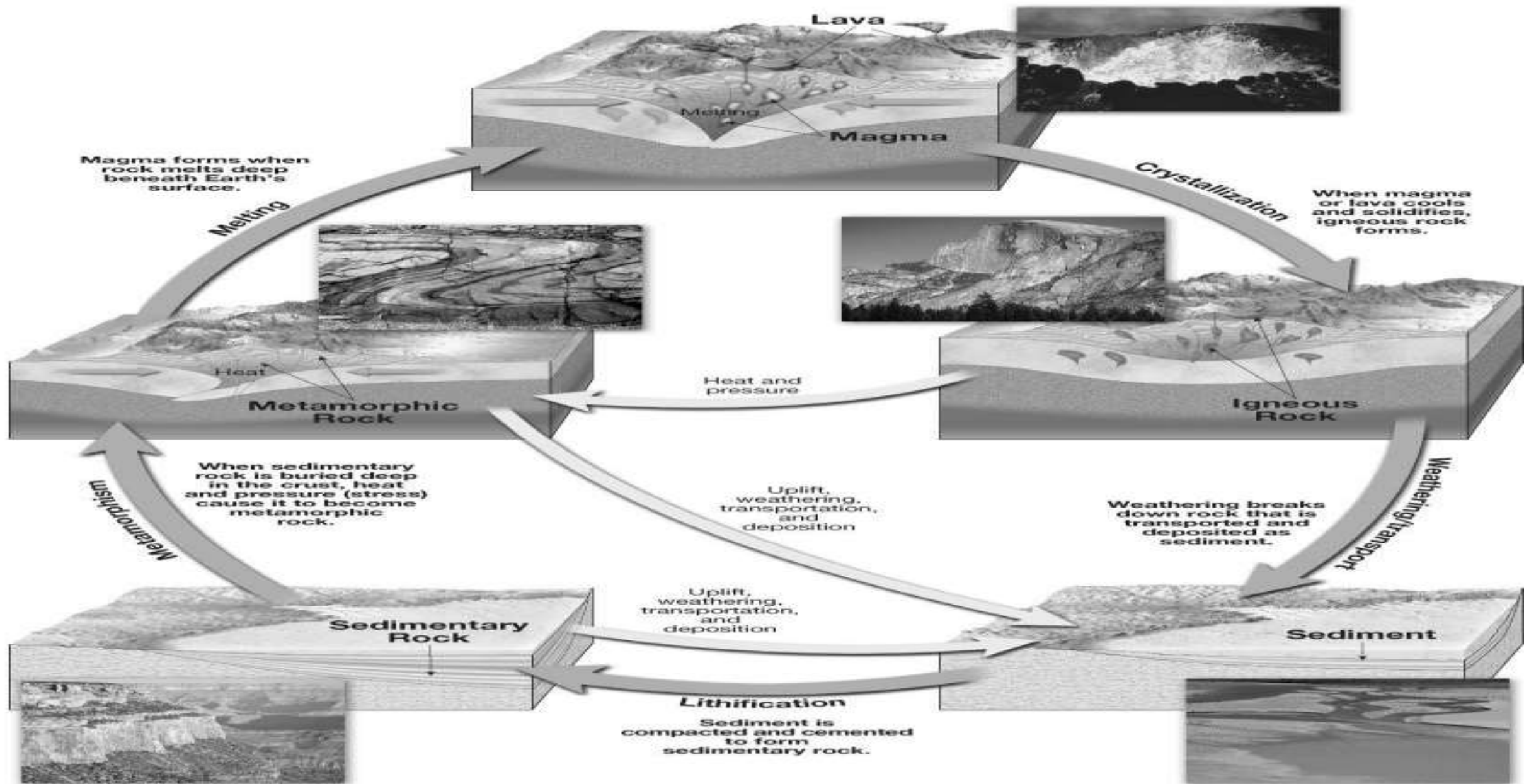


**Pressure**



**Chemically Active Fluids**



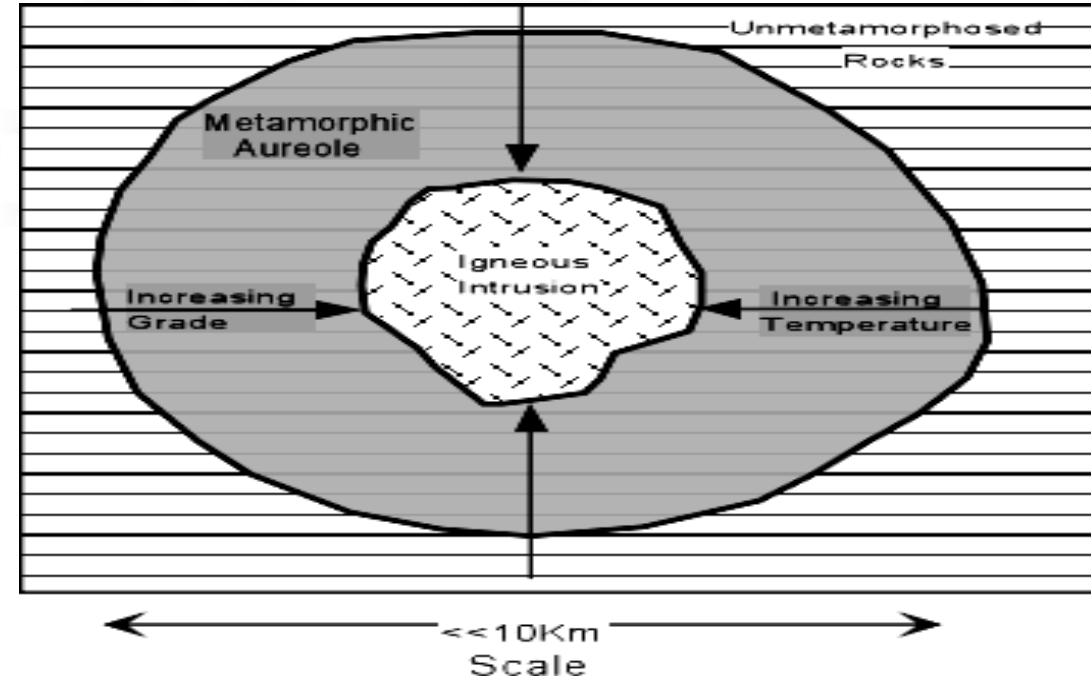


## KINDS OF METAMORPHISM:

- **THERMAL METAMORPHISM:** All those metamorphic processes, in which heat is the chief agent of metamorphism, and pressure and fluids play a secondary role, are included under the term thermal metamorphism.
- **Thermo-dynamic metamorphism:-** It is also called dyno-thermal metamorphism which is a process of formation of metamorphic rocks in which both heat & pressure are the dominating factors. This results in crystallization and deformation of the rocks and forms a new mineral.



- **Contact metamorphism:-** It is the process of formation of metamorphic rocks in which temperature is the dominating factor with negligible changes in pressure resulting in re-crystallization of the rocks and new minerals are formed.

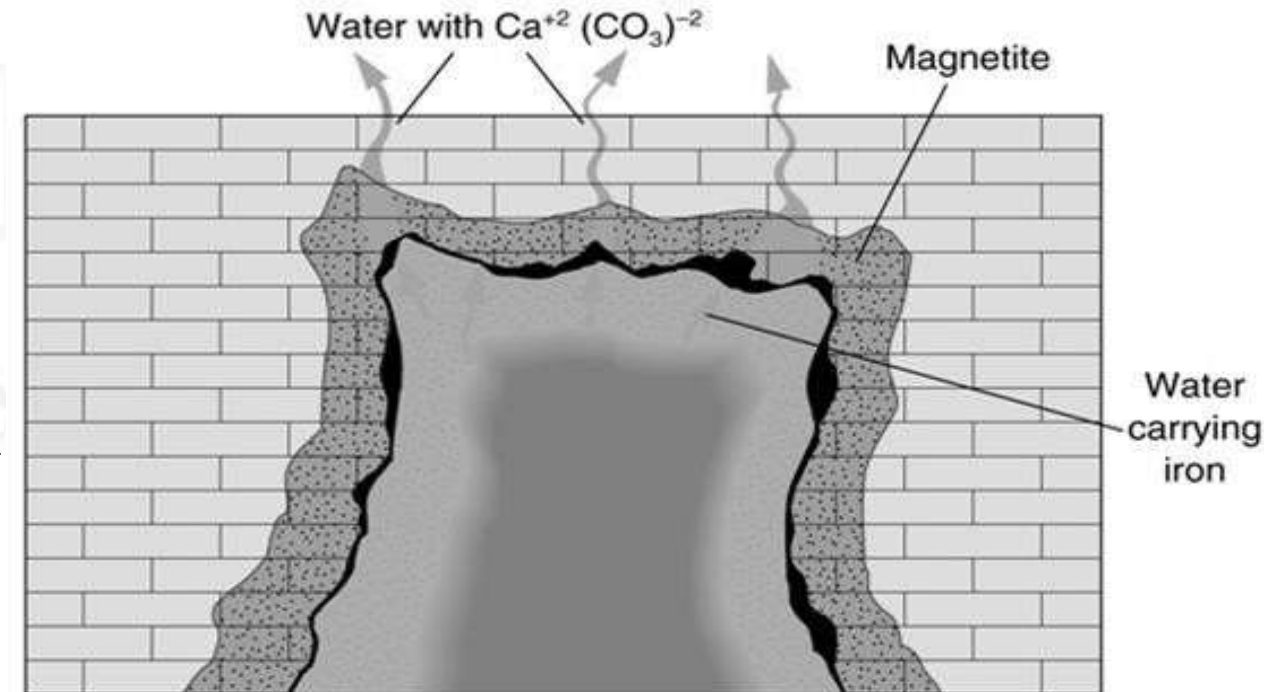


- **METASOMATISM:** It is a type of thermal metamorphism in which liquids and gases (at high temperature) attack the surrounding rocks, thus inducing certain metamorphic changes in them.

When the rocks are attacked by chemically active liquids or solutions, it is called **‘Hydrothermal metamorphism’**.

when the rocks are attacked by chemically active gases or vapors, it is called **‘Pneumatolytic metamorphism’**. This results in formation of new minerals.

When high temperature metamorphic mineral assemblages are changed to low temperature mineral assemblages, the process is called the **Retrograde metamorphism**.



- **Classification of metamorphic rocks based on foliation**
- The rocks that can split up into thin sheets are known as **foliated rocks**.  
E.g., Slate, Schist, Gneiss.
- Those who cannot split up into thin sheets are known as **non-foliated rocks**.  
E.g., Marble.

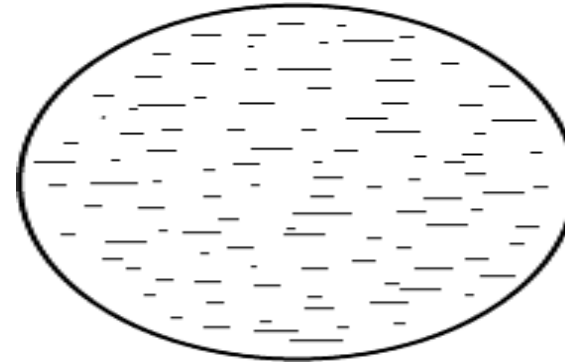


- **Examples of metamorphic rocks from metamorphism as follows:**

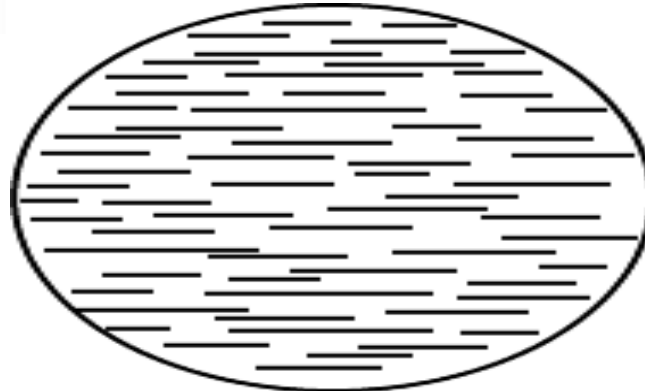
Metamorphic rocks have been variously classified on the basis of texture of rocks, structure of rocks, degree of metamorphism, mode of origin, mineralogical composition and foliation of rocks.

- Granite (Igneous rock) Gneiss
- Basalt (Igneous rock) Schist
- Sandstone (Sedimentary rock) Quartzite
- Limestone (Sedimentary rock) Marble
- Shale (Sedimentary rock) Slate
- Coal (Sedimentary rock) Graphite
- Clay Shale Slate

- **Slaty structures:** Slaty structures are also called as slaty cleavage which has unique property of splitting into thin sheets.



- **Schistose structures:** It is formed by parallel arrangement of flat, tabular, flaky minerals and tendency to split readily into flakes.



- **Gneissose structures:** Structures exhibit alternate light and dark color minerals as bands.



- **Granular structures:** The structure has produced due to predominance of equigranular minerals and producing a rough fracture surface.

- **Gneiss:-** It is a coarse grained foliated rocks formed by dynamic metamorphism of sandstone, granite and conglomerates showing great variety of colors.
- **Colour:** Variable, Grey, pink, white.
- **Texture and Grain size** Gneissose structure. i.e. alternative light and dark banding. It consists of equigranular and inequigranular grains which are medium grained.
- **Mineral Composition** Quartz, feldspar, orthoclase, pyroxene, mica, hornblende.
- **Occurrence** – It occurs as large body
- **Specific Gravity** – 2.7
- **Special Property** – it shows banded structure and can be cut carved and polished.
- **Classification** – formed by Dynamothermal metamorphism.
- **Uses** – Dimension stone for building facings, paving, Building stone, decorative stone, road metal, concrete aggregates, monumental stone etc.



- **Slate:-** they are produced by metamorphism of shale having very fine grained rocks which splits into thin smooth plates.
- **Colour:** It is dark coloured, grey or dark grey.
- **Texture and Grain size:** Fine Grained rock. Characterized by Slaty cleavages due to parallel arrangement of Platy and flaky Minerals.
- **Mineral Composition** Fine grain mixture of Mica & Chlorite with some amount of quartz and feldspar.
- **Specific Gravity** – 2.8 to 2.9
- **Classification** – formed by Dynamic metamorphism of shale under directed pressure.
- **Occurrence** – as bedded deposits
- **Special Property** – Slaty Cleavage and can be Split into thin Sheets.
- **Uses** – Flooring, Mosque tiles, Black Boards & slates, Table tops etc.

- **Muscovite & Biotite schist:-** It belongs to metamorphic groups of rocks formed by the dynamic metamorphism of shale
- **Colour:** Various shades of Black and white.
- **Texture and Grain size** Schistose Structure, Minerals are inequidimentinal which are Flaky arranged along Foliated plane. Medium to Coarsed Grained.
- **Mineral Composition** It consists platy and flakey minerals like Mica, Chlorite, talc, Hornblende, kyanite, actinolite etc. Depending on the mineral abundance rock can be called as Mica schist, Chlorite Schist, talc Schist, Granetiferous mica schist. Hornblende schist.
- **Specific Gravity – 2.6 Classification** – formed by Dynamothermal metamorphism of shale and basic & ultrabasic igneous rocks.
- **Special Property** – It is soft and shows Schistose structure.
- **Uses** – worked for extracting Garnet and also used as Building Material.

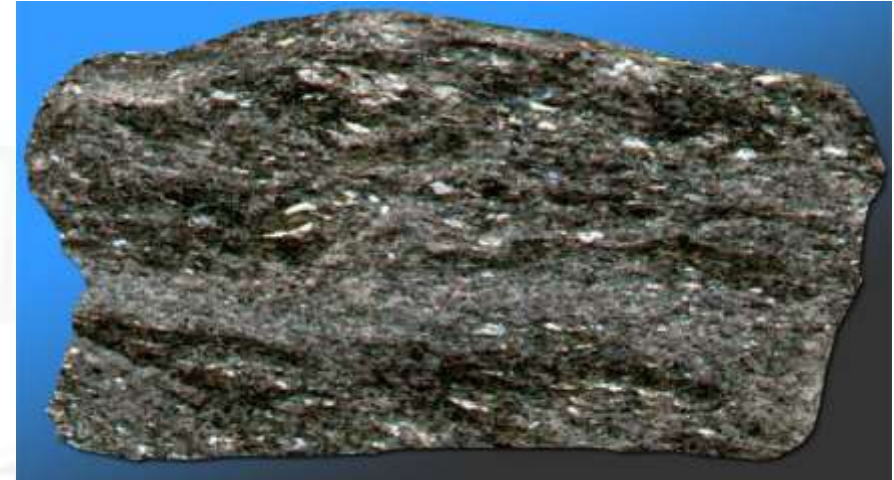


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- **Marble:-** It is crystallized metamorphic rock formed by contact metamorphism of limestone.
- **Colour:** White, shades of pink, grey, green, brown, black.
- **Texture and Grain size:** Granulose structure. Fine to medium grained.
- **Mineral Composition** Essentially made up of calcite and nearly dolomite.
- **Specific Gravity** – 2.6 to 2.8
- **Classification** – Formed by thermal metamorphism of limestone.
- **Occurrence** – as bedded deposits
- **Special Property** – React readily with dil. HCl and it can be cut and polish.
- **Uses** – Decorative, Monumental, Building and dimension stone, architectural fancies, Flooring, table tops, etc.



- **Quartzite:** It's a hard, non-[foliated metamorphic rock](#) which was originally formed by pure [quartz sandstone](#). Sandstone is converted into quartzite through heating and pressure usually related to [tectonic](#) compression within [orogenic belts](#).
- **Colour:** Variable, White, grey, pink.
- **Texture and Grain size:** Granulose structure, Granoblastic Texture. Medium to fine grain.
- **Mineral Composition** Quartz, with subordinant amount of mica and feldspar.
- **Specific Gravity** – 2.7
- **Classification** – Formed as a result of recrystallization of sandstone under the influence of thermal metamorphism.
- **Occurrence** – as bedded deposits, irregular masses & veins
- **Special Property** – it shows Granulose structure, it is brittle and shows vitreous lusture.
- **Uses** – Road metal, Glass cutting, Glass making, building stone, ceramic industry etc.



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## **ENGINEERING IMPORTANCE OF METAMORPHIC ROCKS**

- Marble is commonly used as decorative building stone, monuments and statues.  
Eg. Taj Mahal.
- Slate used as roof tiles, floor tiles, pool tables, blackboards etc.
- Augen gneiss make very attractive building materials and exteriors of office building when polished.
- Talc used in paints, rubber, paper, asphalt and cosmetics.
- Many economic deposits of gold, copper, tungsten and iron occur in metamorphic rocks.



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