2 Petrology

Introduction :

Petrology is the branch of geology, which deals with the study of rocks. The term petrology is derived from the Greek word ‘petros’ meaning rocks and ‘logos’ meaning study. Petrology, therefore, includes the mineralogical, textural and chemical description of rocks along with their geological origin, mode of occurrence and their relation to the physico-chemical environment of the Earth. Petrological studies are carried out under two major heads as follows, viz,

a) **Petrography :** Description and systematic classification of rocks

b) **Petrogenesis :** Studies of the origin / genesis of the rocks

Rock is an aggregate of minerals. Most rocks are composed of two or more minerals (e.g. granite). However, a few are composed of a single mineral (e.g., dunite). Some rocks may also contain fossil remains of plants and animals (fossiliferous limestone) or they may be formed by recrystallization of pre-existing rocks (e.g. marble).

IGNEOUS PETROLOGY

The first formed rocks on the Earth are igneous/ primary rocks. The term igneous, is derived from the Latin word ‘igneus’ meaning fire. They are formed through cooling and solidification of magma or lava. These rocks may form with or without crystallization either below the surface, as intrusive (plutonic) rocks or on the surface as extrusive (volcanic) rocks. Magma, may be derived from melting of pre-existing rocks either in the mantle or in crust. One or more processes such as increase in temperature, decrease in pressure, or change in composition cause melting.

Minerals of the igneous rock are broadly classified into two groups viz. i) Primary and ii) Secondary. Primary minerals are the minerals which have developed as a result of crystallization from magma or lava (i.e., pyrogenetic minerals), while secondary minerals are those which are formed after the solidification of the rock either by alteration of the primary minerals or by precipitation from solution, in voids or vesicles of rocks.

Primary minerals can be grouped into two, viz., 1) essential and 2) accessory.

Essential minerals are necessary for the classification, identification or nomenclature of the rock. Accessory minerals are present in small amounts and are therefore, not important in the nomenclature e.g., in granite, quartz and feldspar are essential minerals, while biotite and / or hornblende are accessory minerals. Presence or absence of accessory minerals does not make any difference in nomenclature of rocks.

Secondary minerals are those which are formed from secondary solutions in cavities of igneous rocks, most commonly found in volcanic igneous rocks, e.g., calcite, zeolites etc.

The minerals may be felsic or mafic. The felsic minerals are light in colour, with low specific gravity, e.g., minerals from silica and feldspar groups. Mafic minerals are dark coloured, with higher specific gravity, e.g., minerals belonging to pyroxene, amphibole, mica, olivine groups and iron ores.

Rocks are described as a) phaneric or phanero-crystalline, if their minerals can be distinguished separately with the naked eye, e.g. a coarse grained rock like granite. b) rocks, in which the mineral grains cannot be distinguished by the naked eye, are described as aphanitic, e.g. a fine grained rock like basalt or rhyolite. (fig. 2.1)

Classification of Igneous rocks :

1) **Based on mode of occurrence :** Igneous rocks formed at great depths inside the Earth are called plutonic rocks. The name is derived from Greek God of underworld – Pluto. They have a slow rate of cooling and are characterized by a coarse grained, equigranular texture. Granite is a typical plutonic rock.

   Rocks, which solidify on the Earth's surface from lava, are described as volcanic rocks. The lavas may have erupted either from a volcano or through fissures. A very rapid rate of cooling of the lava makes these rocks fine grained or even glassy. They show characteristic features such as vesicles, amygdales and flow structure. Volcanic rocks may show inequigranular textures under the microscope, e.g., basalt.

   The hypabyssal rocks consolidate at a depth in between volcanic and plutonic depths. They show characters which are intermediate between plutonic and the volcanic rocks, e.g., dolerite.

2) **Based on SiO_2 percentage :** The percentage of SiO_2 in a rock decides the nomenclature of the igneous rock as :

a) Acidic with SiO_2 greater than 65% e.g. granite;

b) Intermediate with SiO_2 - 55 - 65%; e.g. syenite

c) Basic with SiO_2 - 45 - 55% e.g. basalt and

d) Ultrabasic with less than 45% SiO_2 e.g. peridotite

3) **Based on colour index :**

a) Rocks rich in felsic minerals are often light coloured and are termed as leucocratic i.e., acidic rocks which contain essentially quartz and alkali feldspar (e.g., granite).

b) Intermediate igneous rocks have a colour index between acidic and basic rocks and are called mesocratic (e.g., syenite).

c) Rocks rich in mafic minerals are dark coloured and are called melanocratic, such as, basic rocks which are rich in augite, hornblende and olivine (e.g., basalt).

d) Ultrabasic rocks are very dark in colour and hence, are classified as hyper-melanocratic (e.g. peridotite).

a) Phaneric

b) Aphanitic

Fig 2.1 : Degree of crystallinity

Textures of Igneous rocks :

Texture describes the mutual relationship of the minerals and /or glass, contained in a rock. It takes into account relative amounts of crystalline and glassy matter, as well as the size, shape and the arrangement of minerals.

a) **Equigranular texture :** If rock consists of mineral grains of almost equal size, it is said to possess an equigranular texture. As this texture is characteristically exhibited by granite it is also known as Granitic texture (fig. 2.2).

b) **Inequigranular texture :** If the rock possesses mineral grains and other constituents like glass having different sizes, it is said to exhibit inequigranular texture e.g. porphy-ritic texture, where large crystals called phenocrysts are embedded in a matrix of finer grains or glassy groundmass.

Porphyritic texture is typically shown by some volcanic rocks like basalt (fig. 2.3).

Fig. 2.2 : Equigranular

Fig. 2.3 : Inequigranular (Porphyritic)

Tabular Classification of Igneous rocks :

Depth of occurrence	Acidic	Interme-diate	Basic	Ultra-basic
	Silica> 65%	Silica 55 - 65 %	Silica 45 -55 %	Silica <45%
Plutonic	Granite	Syenite	Gabbro	Dunite
Hypa-byssal	Pegma-tite		Dolerite	
Volcanic	Rhyolite	Trachyte	Basalt	
Mineral content	Ess-Quartz, Feld-spar. Acc-Bi-otite, Horn-blende	Ess-Feld-spar. Acc-Quartz	Ess-Feldspar, Augite Acc-Ol-ivine Quartz absent	Olivine
Colour Index	Leuco-cratic	Meso-cratic	Melano-cratic	Hyper melano-cratic

Texture becomes finer

[Ess - essential, Acc - Accessory]

Quartz content reduces as Silica % decreases

Structures of Igneous Rocks :

They are large and easily recognizable features to the naked eye. Structures provide information about genesis of the rock.

Some of the common igneous structures are as follows :

i) **Vesicular structure :** Magma erupts on the surface in the form of lava . When lava is rich in gaseous content i.e., volatiles it erupts and gases escape into the atmosphere leaving behind the cavities of various shapes and sizes. These cavities are called vesicles and the resulting structure is called vesicular structure e.g. vesicular basalt. Vesicles can also be pipe shaped.

ii) **Amygdaloidal structure :** Vesicles can subsequently get filled by secondary minerals such as calcite, zeolites and varieties of silica. Such filled vesicles are called amygdales. The rock is then said to exhibit amygdaloidal structure e.g. Amygdaloidal basalt (fig. 2.4)

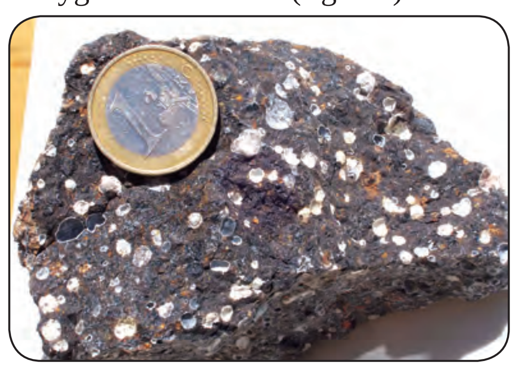

Fig. 2.4 : Amygdaloidal basalt

iii) **Ropy structure :** Lavas of basic composition are mobile, due to low viscosity and can flow greater distances. During this process, their upper surface gets wrinkled resembling ropes. This structure is termed as ropy structure.

iv) **Columnar structure :** During rapid cooling of basic lava, number of cooling centres are developed. Lava tries to aggregate around these centres. It is the result of contraction of lava during cooling. Due to this, tensile stress is developed. At right angles to the stress direction, vertical joints or cracks are formed. Such joints results in the formation of hexagonal or polygonal columns, giving rise to columnar structure e.g. Columnar basalt.

v) **Pillow structure :** This structure is most commonly observed when hot lava erupts under water. In this structure, the volcanic igneous body appears as pile of numerous overlapping pillows or sacks stacked one above the other.

As the lava flows, its upper surface gets solidified immediately due to contact with water, hence crust of a pillow shows glassy texture.

Types of Igneous bodies :

The magma rising from mantle may or may not reach the surface of the Earth forming extrusive or intrusive igneous bodies respectively (fig. 2.5)

A) Extrusive bodies :

When lava travelling through fissures and volcanoes cools rapidly at the Earth's surface it forms Extrusive igneous bodies.

Lava flows :

The only extrusive form of igneous bodies is lava flows. Their thicknesses may range from few centimetres to hundreds of meters and cover an area from a few meters to many square kilometers. The Deccan plateau of western India is the example of lava flows.

B) Intrusive bodies :

The forms of Intrusive bodies are dependent upon viscosity of magma and the structure of the rocks they intrude. Igneous intrusive bodies are classified as concordant and discordant depending on their structural relation with the host rock. Concordant bodies are more or less parallel to the structure of the host rocks and discordant bodies cut across the host rocks.

1) Concordant igneous bodies :

a) **Sill :** Sill means shelf or slab of stone. It is a tabular sheet of igneous rock intruded between and parallel to the existing strata. They are thin tabular sheets of magma which have been intruded along the bedding planes or foliations. They show nearly parallel upper and lower margins and pinch out with distance. Their thickness may vary from a few meters to hundreds of meters and may extend laterally for few kilometres. On the basis of their origin, sills are differentiated into simple, multiple and composite types. Simple sill is formed by a single intrusion. Multiple sills are formed by two or more intrusions. Composite sills consist of more than one rock type, formed

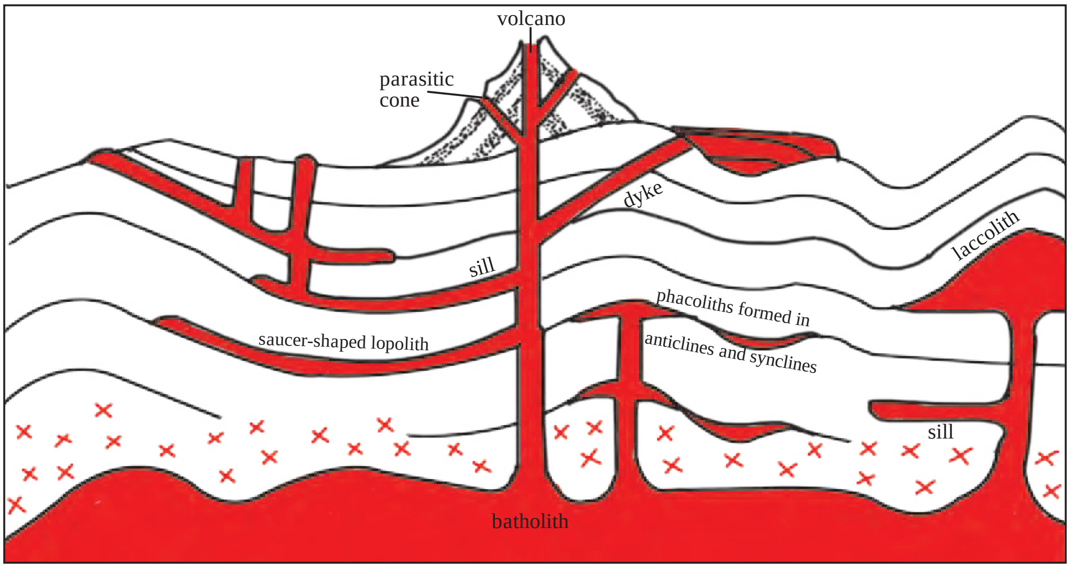

Fig. 2.5 : Concordant and discordant Igneous bodies

by more than one intrusive episode.

b) Laccolith : The term laccolith is derived from the Greek word ‘lakkos’ meaning a cistern and ‘litho’ meaning stone. It is a bun shaped structure having a flat base and domed top and does not spread very far, tends to heaps itself up around the orifice of the eruption. The strata above it are generally lifted up in the form of an inverted bowl. Laccolith may be a few Kilometers in diameter and about thousands of meters thick.

c) Lopolith : Lenticular, centrally sunken saucer or basin-like concordant igneous bodies are called as lopoliths. In Greek ‘lopos’ mean basin. Generally, their thickness varies by 1/10th to 1/20th of their width, and diameters range from tens to hundreds of kilometers. The characteristic shape is the result of sagging caused by the weight of intruding magma.

d) Phacolith : The Greek word ‘phaco’ meaning lens. These are crescent shaped structures found in highly folded regions. They are formed at the crests and troughs of folds which are regions of weakness and tension. They exhibit doubly convex lens-like form.

2) Discordant igneous bodies :

Discordant igneous bodies show cross cutting relationship with the structures of the host rocks. They are described as follows :

a) Dyke : The word Dyke is derived from the Scottish term ‘dike’ meaning a wall of stone. Dyke is a vertical or near vertical wall-like body of igneous rock intruded into the older rocks. They cut across the foliation or bedding of the country rocks. It is a narrow, elongated, parallel sided wall of igneous rock. Its thickness varies from a few centimetres to many meters. Similarly its length can vary from a few meters to several kilometres.

Dykes are frequently more resistant to erosion than the enclosing rocks and tend to project as ‘walls’ above the surface. However, dykes can also be excavated out to form a ‘trench’ due to weathering and erosion. Many a times dykes bake and harden the adjacent country rock on either side. They may occur as isolated bodies or as ‘swarms’. Dykes may be vertical, inclined, ring shaped, radiating or arcuate in nature. Outwardly dipping dykes from a common centre are called as ‘cone sheet’.

b) Batholith : The term Batholith is derived from Greek word ‘bathos’ meaning depth. Batholiths are large scale igneous intrusions. They have extremely large dimensions, with steeply dipping walls. They extend on the surface up to thousands of kilometres with irregular outline. They are generally granitic in composition. Stock and boss are offshoots of batholiths where stock is irregular in shape and boss is more or less circular and both are less than 100 sq. kms in aerial extent. A roof pendant is a pendant shaped body of country rock hanging from the roof of the batholith. Xenoliths are fragments of country rocks found within the batholiths.

SEDIMENTARY PETROLOGY

Sedimentary rocks are one of the three main rock groups, along with igneous and metamorphic rocks. They are formed as a result of :

1) Deposition of the weathered remains of other rocks.
2) Biogenic activity and.
3) Precipitation from solution.

Formation of Sedimentary Rocks :

Formation of sedimentary rocks is a slow process that may require millions of years. Sedimentary rock formation begins when the pre-existing rocks are exposed to weathering processes.

The formation of sedimentary rocks involves five different processes as nshown in fig. 2.6 :

1) **Weathering :** The first step is transforming solid rock into smaller fragments or dissolved ions by physical and chemical weathering.
2) **Erosion :** Erosion begins with the transportation of the weathered products from their original location. This can take place by gravity, running water, wind, or moving ice.
3) **Transportation :** Sediment can be transported by sliding down slopes, being picked up by the wind, or carried by running water. Longer transportation of sediments results in to finer sediments.
4) **Deposition :** Sediments are deposited when the energy of the transporting medium drops resulting in their settling. The final sediment thus reflects the energy of the transporting medium.
5) **Lithification and cementation :** Lithification is the process that converts sediments into sedimentary rock. The processes of compaction and cementation are involved in this change. Increased load of overlying sediments results in reduction of pore spaces and water within them. The dissolved minerals get precipitated in these pore spaces to act as cement binding the minerals.

Classification of sedimentary rocks :

By considering the manner in which the detritus (particles of sediment) is distributed, transported and deposited, a simple, tabular classification for sedimentary rocks, based on the products of weathering is depicted in table 2.1.

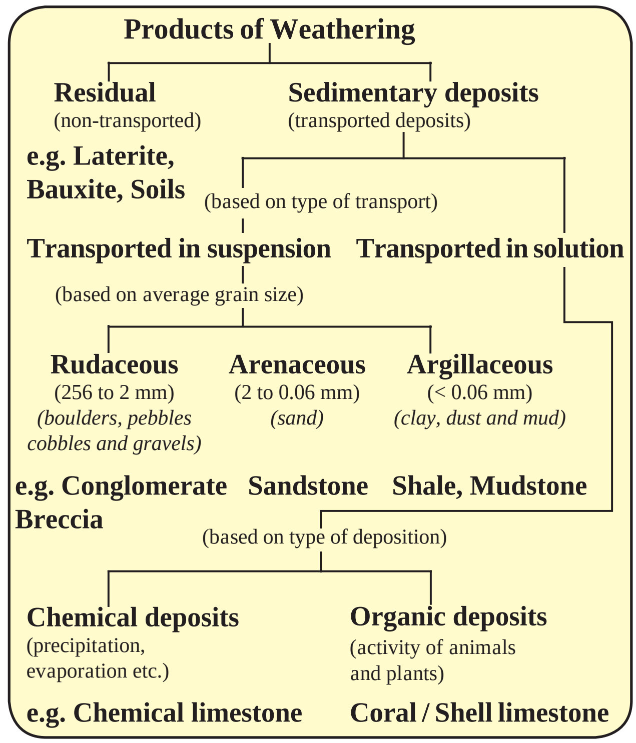

Table 2.1: Products of Weathering

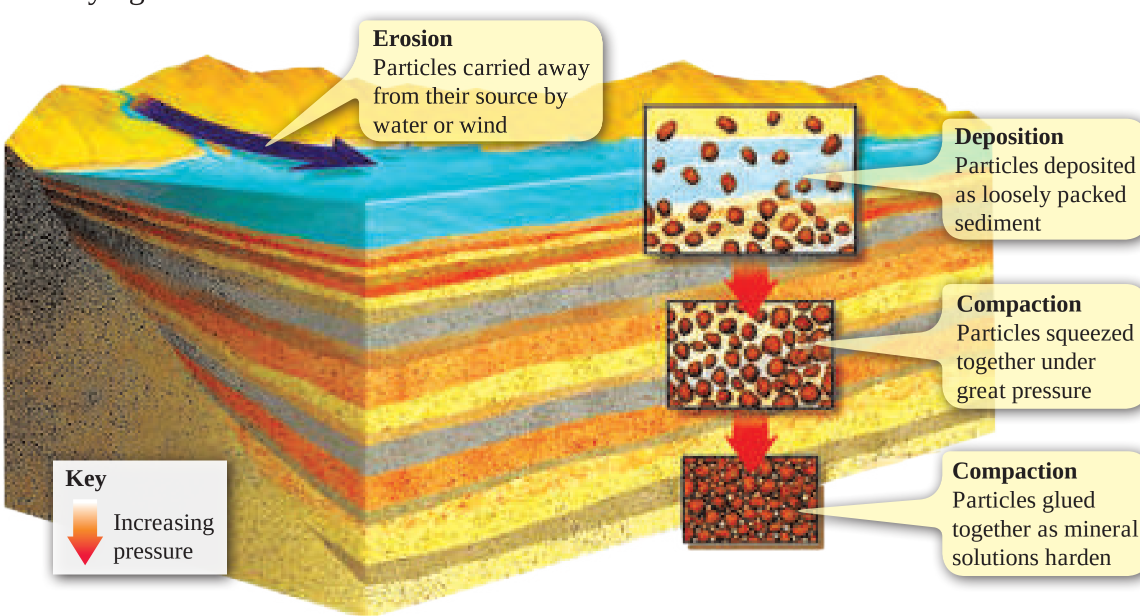

Fig. 2.6 Processes involved in formation of sedimentary rocks

1) Non-transported (Residual deposits)

2) Transported deposits

1) Non-transported (Residual deposits) : These are also known as sedentary deposits formed due to accumulation and consolidation of the materials which were left behind as residue. These are the insoluble products of rock weathering. e.g. Laterite and bauxite (fig. 2.7. a and b).

a) Laterite

b) Bauxite

Fig. 2.7 : a and b : Examples of residual deposits

2) Transported deposits : They are formed from the materials that have been transported mechanically by saltation, traction and suspension or chemically in solution. Besides, some organic processes also play an active role in the formation of transported deposits. These are classified into two groups :

A) Clastic rocks B) Non-clastic rocks

A) Clastic rocks : These detrital rock fragments are carried and deposited by mechanical means and later cemented. On the basis of grain size, the clastic rocks are further classified as :

(i) Rudaceous rocks (Rudites) : Very coarse grained rocks with grain size more than 2 mm in diameter. Boulders, cobbles, pebbles and gravel are transported by traction i.e. by rolling or creeping. e.g. Conglomerates- in which constituent grains are rounded, (fig. 2.8 a) and breccia in which constituent grains are angular (fig. 2.8 b).

a) Conglomerate

b) Breccia

Fig. 2.8 : a and b : Examples of Rudaceous rocks

(ii) Arenaceous rocks (Arenites) : These rocks consist of sand-sized grains. They are transported by either saltation or suspension. Grain size ranges between 2 mm and 1/16 mm. e.g. siliceous sandstone and (b) ferruginous sandstone (fig. 2.9. a and b)

a) Siliceous sandstone

b) Ferruginous sandstone

Fig. 2.9 : a and b: Examples of arenaceous rocks

Do you know?

Wentworth's scheme of classification of grain size.

Size range (mm)	Name of particle	Group	Consolidated Rocks
>256	Boulder	Rudaceous	Conglomerate, Breccia
>64	Cobble		
>4	Pebble		
>2	Gravel		
>1	Very coarse sand		Sandstone, Arkose, Grit
>1/2	Coarse sand		
>1/4	Medium sand	Arenaceous	
>1/8	Fine sand		
>1/16	Very fine sand		
>1/32	Coarse silt	Argillaceous	Siltstone
>1/64	Medium silt		
>1/128	Fine silt		
>1/256	Very fine silt		
<1/256	Clay		Claystone

(iii) Argillaceous rocks (Argillite) :

(a) Siltstone : Constituent particles in siltstone are finer than sand and coarser than clay. These grains are transported by suspension. (fig. 2.10).

Fig. 2.10 : Siltstone

(b) Shale : It is made up of clay particles, usually transported in suspension e.g. Claystone, Mudstone, Shale etc. Their grain size is finer than Silt rocks i.e., less than 1/16 mm. Shales normally exhibit laminations (fig. 2.11).

Fig. 2.11 : Shale

B) Non-clastic rocks : These are the rocks formed due to chemical precipitation as well as due to the activity of biological agents. They are of two types :

i) Chemical deposits ii) Organic deposits

i) Chemical deposits : They may be formed a) Due to evaporation of saturated solutions, giving rise to deposits of Salt and Gypsum (fig. 2.12)

a) Salt

b) Gypsum

Fig. 2.12. a and b : Examples of chemical deposits

b) As a result of reaction between the components carried in solution e.g. siliceous (chert fig. 2.13 and flint), ferruginous and carbonate (limestone fig. 2.13 and dolomite) deposits.

Fig. 2.13 : a) Chert

Fig. 2.13 : b) Limestone

ii) **Organic deposits :** These are products of accumulation of organic matter preserved under suitable conditions. The deposition may be bio- chemical or bio-mechanical. Organic deposits are of five types :

a) **Siliceous :** Radiolarian ooze; diatomites.

b) **Calcareous :** These deposits are formed as a result of biomechanical as well as biochemical processes eg. Fossiliferous Limestone (fig. 2.14), Chalk, Marl etc.

c) **Phosphatic :** Calcium Phosphate is utilized by certain organisms, especially fish and brachiopod which are consumed by birds and bats. The bird and bats droppings accumulate in heaps and later get transformed into 'Guano'.

d) **Ferruginous :** These deposits are formed by biochemical oxidation of Fe carried in solution in bogs and deposited as bog-iron ore.

e) **Carbonaceous :** Coal is a product of deposition and burial of plant matter (fig. 2.15).

Fig. 2.14 : Fossiliferous Limestones

Fig. 2.15 : Coal

Texture and structures of sedimentary rocks :

1) Clastic texture :

Loose detrital fragments derived from weathering of pre-existing rocks undergo erosion and transportation. They are finally deposited and are bound together by fine grained particles known as the matrix. This arrangement of grains and the matrix after compaction gives rise to clastic texture (fig. 2.16).

Fig 2.16 : Conglomerate showing clastic texture

2) Sedimentary Structures :

The process of deposition usually imparts variations in layering, bed forms or other structures that give clues to the depositional environment.

I) Stratification and bedding :

a) **Stratification :** It is layering formed during deposition. Stratification results by changes in depositional conditions with time. (fig. 2.17)

Fig. 2.17 : Bedding in sedimentary rocks

b) **Bedding :** The beds in sedimentary rocks are evident because of differences in mineralogy, clast size and degree of sorting or colour of the different layers (fig. 2.17).

i) **Planer bedding :** It is the simplest sedimentary structure formed generally in all sedimentary environments and also under a variety of depositional conditions (fig. 2.18).

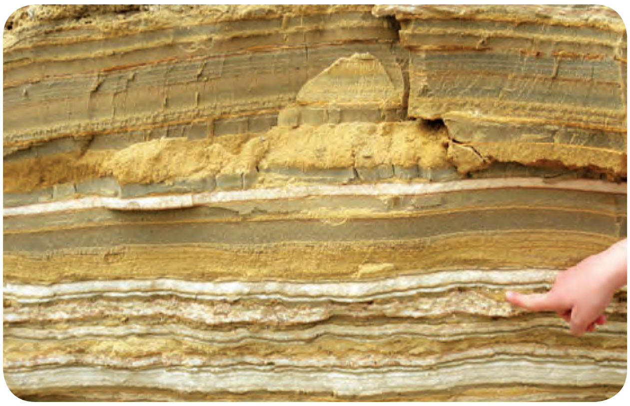

Fig. 2.18 : Planar bedding

ii) **Cross Bedding :** It consists of sets of beds that are inclined relative to each other. The beds are inclined in the direction of movement of the wind or water. Boundaries between sets of cross beds usually represent an erosional surface. It is very common in beach deposits, sand dunes and river deposits. Individual beds within cross-bedded strata are useful indicators of current direction and tops and bottoms of the beds (fig. 2.19).

Fig. 2.19 : Cross bedding

iii) **Graded Bedding :** As current velocity decreases, the larger or heavier particles are deposited first, followed by finer particles (fig. 2.20 a and b). This results in bedding showing a decrease in grain size from the bottom of the bed to the top of the bed. This helps in determining top and bottom of beds.

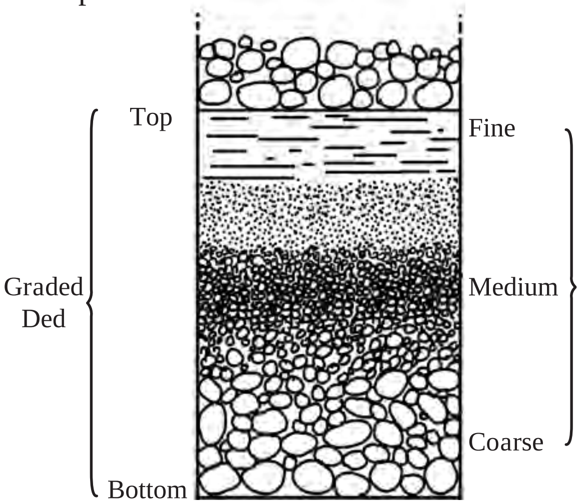

Fig. 2.20 : a) - Graded bedding

Fig. 2.20 : b) Graded bedding in sedimentary rocks

IV) Ripple marks : It is the wavy pattern seen on mud or sand deposits. Ripple marks are produced by wave action when the sand is moved up and down in an oscillatory motion by wind or water. Ripples can be symmetrical or asymmetrical (fig. 2.21).

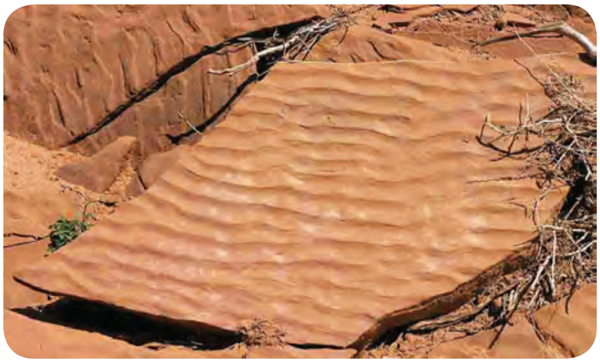

Fig. 2.21 : Ripple marks in Sedimentary rocks

METAMORPHIC PETROLOGY :

Metamorphic, (Meta=other; morph=form) rocks are formed when pre-existing rocks are transformed into new rocks by heat, pressure and chemically active fluids below the Earth's surface or along the boundary of tectonic plates. In general, metamorphism means a partial or complete re-crystallisation of minerals in the pre-existing rocks and the production of new structures. Therefore, metamorphic rocks result when the pre-existing rocks lose their stability due to the pronounced changes of temperature, pressure and chemical environments, below the shell of weathering and have re-established stability by adjusting to the new environment.

Thus, metamorphism is 'response of solid rocks to the pronounced changes in temperature, pressure and chemically active fluids'.

Agents of metamorphism :

Metamorphism results because of the changes in the physical and chemical environment of the original or pre-existing rock. The agents responsible for metamorphic changes are :

(a) Temperature, (b) Pressure and (c) Presence of chemically active fluids.

Temperature plays a major role in the chemical processes of metamorphism such as dehydration and melting of the earlier minerals.

Types of metamorphism :

The predominant agent of metamorphism defines the kind of metamorphism. Thus, the major kinds of metamorphism are :

(a) Cataclastic, (b) Thermal or contact and (c) Dynamo-thermal metamorphism.

(a) Cataclastic metamorphism : It is a metamorphism in which directed pressure (or stress) plays the major role. The directed pressure mechanically breaks down the pre-existing rocks giving rise to crushing and fracturing, but without the formation of any new mineral in the affected rock. This causes the lamination of the argillaceous rocks to get deformed with the development of slaty cleavages (e.g. shale metamorphoses into slate).

(b) Thermal or contact metamorphism : Rocks are thermally metamorphosed when they are intruded by magma and the high temperature of the magma heats the country rocks. The pressure (either directed or uniform) effects are almost negligible and recrystallization occurs due to thermal metamorphism. Hence, the calcareous rocks like limestone and arenaceous rocks like sandstone develop a granulose structure when thermally metamorphosed. Limestone forms Marble and Sandstone forms Quartzite.

(c) Dynamothermal metamorphism : Dynamothermal metamorphism involves both high temperature and high pressure effects at a high level. The pre-existing rocks are therefore, subjected to more or less complete recrystallisation and result in the development of new structures. Foliation is a characteristic feature and the typical rocks are schists and gneisses.

Intensity of dynamothermal metamorphism increases with depth. Hence, in the initial stages of metamorphism, the argillaceous rocks like shales are altered to Phyllites and with further increase in temperature and pressure, schists are developed. At much higher temperature and pressure gneisses are formed.

Structures of metamorphic rocks :

The structures of metamorphic rocks are formed by the deformation and recrystallisation of the minerals in the preexisting rocks. The different metamorphic structures are 1) slaty cleavage, 2) granulose, 3) schistose and 4) gneissose.

1) **Slaty cleavage :** The slaty cleavage results from the flattening and rotation of mineral fragments under the action of directed pressure (fig. 2.22). When the argillaceous rocks are subjected to cataclastic metamorphism it results in the formation of slates, which are generally rich in micaceous minerals.

Fig. 2.22 : Slate exhibiting slaty cleavage

2) **Granulose structure :** This structure is developed by thermal metamorphism in which original rock undergoes only re-crystallisation. As there is no action of directed pressure, the sedimentary rocks like limestones and sandstones simply recrystallize to give marble (fig. 2.23 a) and quartzite (fig. 2.23 b) respectively.

a) Marble

They show interlocking grains of calcite and quartz respectivelyof almost equal size with polygonal shapes.

b) Quartzite

Fig 2.23 : Examples of Granulose structure

3) **Schistose structure :** This structure is marked by the linear or parallel arrangement of minerals in a direction perpendicular to the maximum stress (fig. 2.24)

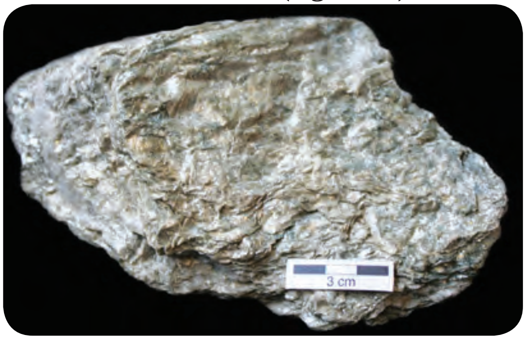

Fig. 2.24 : Muscovite exhibiting Schistose structure

The schistose structure is developed due to the unidirectional alignment of the minerals such as biotite, muscovite, chlorite and talc, which are flaky and hornblende which is prismatic with a columnar or rod-like appearance. These structures are developed with high temperatures and with strong directed pressures or stress. Because of directed pressure, the minerals form layers or folia arranged in parallel layers or bands. This parallel alignment of the flaky or the platy minerals characteristically gives rise to foliation in metamorphic rocks, which is also called as schistose structure.

4) **Gneissose Structure :** This structure is developed when the original rock possesses both flaky minerals and quartz. The flaky minerals like mica give rise to a schistose

band while the hard and resistant minerals like quartz and feldspar recrystallize to form a granulose band.

When both, granulose and schistose bands alternate with each other, they give rise to gneissose structure which is a composite structure (fig. 2.25).

Fig. 2.25 : Gneissose structure

This structure develops due to the effect of high temperature and directed pressure on the pre- existing rock.

4) Importance of petrology in civil engineering :

In engineering geology, knowledge of rock properties is important for the construction of large structures. Rocks, which are competent, durable and free from weak planes, are suitable for foundation (e.g. granite, syenite, gabbro, Quartzite sandstone). For flooring purpose, they should be resistant to abrasion. i.e. able to withstand wear and tear. e.g. limestone and marble. Rocks durable to weathering are appropriate for roofing e.g. slate, limestone. Owing to its attractive colour and softness, marble is used for decorative purpose and for sculpture or face work of buildings. Laterites are suitable for small-scale constructions. Neatly dressed sandstone can be suitable for walls. For superstructure construction, rock should be easily workable and available in plenty. Thus, different rocks are suitable for different purposes, by virtue of their special physical properties which are inherent and characteristic to them.

Building stones :

For construction of large civil structures like dams, highways, bridges, tunnels etc, an engineer must know the engineering properties of rocks, such as strength, durability, colour, appearance, workability etc. These properties are very important because different rocks are suitable for specific purposes and no rock is ideal or best suited for all kinds of constructions. According to the need of construction a building stone is cut and shaped. All tests are performed in the geotechnical lab in accordance with the Bureau of Indian Standards Code (BIS).

For selection of good qualities of building stones, following properties are important. 1) Crushing strength, 2) Transverse strength, 3) Porosity, 4) Density, 5) Abrasive resistance, 6) Frost and fire resistance, 7) Durability and 8) Appearance.

1) **Crushing strength / Compressive strength :** It is the maximum load per unit area which a rock can withstand without undergoing failure/fracturing. Crushing strength should be greater than $100 N/mm^2$.

2) **Transverse strength :** It is the capacity of a stone to withstand bending loads. Shear strength is determined when the stone is used as a column.

3) **Porosity :** It is the ratio between the total volume of pore spaces and total volume of rock sample.

4) **Density :** Density of a rock is the weight per unit volume. Bulk density refers to weight per unit volume of a rock with natural moisture content.

5) **Abrasive resistance :** It is the resistance offered by a rock to mechanical wear and tear i.e. abrasive resistance refers to hardness of rocks.

6) **Frost and Fire resistance :** The freezing of water in cracks may break rock into angular fragments known as frost action. Fire resistance of rocks becomes necessary

when they are used near furnaces.

7) **Durability :** It refers to the life of a structure. Durability of a building stone is also susceptibility or resistance to the weathering.

8) **Appearance :** Rocks which are to be used for face work should be decent, uniform in colour, capable of retaining polish and free from clay, cavities, spots of other colour, bands etc. Light colours are pleasing.

Summary :

The study of rocks provide us with important information about the nature of the Earth's crust and mantle. In addition, it enables us to gain a sense of the Earth's history, including tectonic processes that occurred over the long course of geological time. Petrology relies heavily on the principles and methods of mineralogy because most rocks consist of minerals and are formed under the same conditions. It can be studied under the branches of igneous, metamorphic, and sedimentary petrology.

- Igneous petrology focuses on the composition, forms of igneous bodies and texture of igneous rocks. Igneous rocks include volcanic and plutonic rocks.
- Sedimentary petrology highlights the composition and texture of sedimentary rocks. They are classified as sandstone, siltstone and shale based on the grain size and are bound together in a matrix of finer material. These rocks are further classified based on the products of weathering into residual and transported deposits.
- Metamorphic petrology deals with the composition and texture of metamorphic rocks which have undergone chemical, mineralogical or textural changes due to change of pressure, temperature or both.

EXERCISE

Q. 1. Select and write the correct answer :

1) An example of a discordant igneous intrusion is ....

   a) Sill b) Lopolith
   c) Laccolith d) Batholith

2) The hypabyssal equivalent of basalt is ....

   a) Gabbro b) Dolerite
   c) Pegmatite d) Dunite

3) A sedimentary rock in which the constituent grains are rounded is ....

   a) Breccia b) Sandstone
   c) Conglomerate d) Laterite

4) One of the structures exhibited by sedimentary rocks is ....

   a) granitic b) schistose
   c) clastic d) cross bedding

5) Thermal metamorphism of sandstone results in the formation of ....

   a) Marble b) Slate
   c) Quartzite d) Mica schist

6) Foliation in rocks is a characteristic feature resulting from ....

   a) cataclastic metamorphism
   b) dynamothermal metamorphism
   c) thermal metamorphism
   d) plutonic metamorphism

7) a) Examples of concordant bodies are sill, dyke, laccolith, lopolith.

   b) Examples of concordant bodies are sill, laccolith, lopolith, batholith.

   c) Examples of concordant bodies are sill, laccolith, lopolith.

   d) Examples of concordant bodies are sill, dyke, laccolith, lopolith, batholith.

8) a) The wavy pattern seen on beach sands is called ripple marks.

   b) The wavy pattern seen on beach sands is called graded bedding.

   c) The wavy pattern seen on beach sands is called cross bedding.

d) The wavy pattern seen on beach sands is called stratification.

9) a) The epizone is characterized by low temperatures and strong uniform pressure.

b) The epizone is characterized by low temperatures and strong directed pressure.

c) The epizone is characterized by high temperatures and strong directed pressure.

d) The epizone is characterized by high temperatures and strong uniform pressure.

10) a) Syenite — i) Hypabyssal acidic rock.

b) Rhyolite — ii) Plutonic acidic rock.

c) Granite — iii) Plutonic intermediate rock.

d) Pegmatite — iv) Volcanic acidic rock.

A) a) – iv); b) – i); c) – iii); d) – ii).

B) a) – ii); b) – iii); c) – i); d) – iv).

C) a) – iii); b) – iv); c) – ii); d) – i).

D) a) – i); b) – ii); c) – iv); d) – iii).

11) a) Residual rock — i) Shale

b) Chemical deposit — ii) Phosphorite

c) Argillaceous rock — iii) Limestone

d) Organic deposit — iv) Bauxite

A) a) – i); b) – iv); c) – ii); d) – iii).

B) a) – iii); b) – ii); c) – iv); d) – i).

C) a) – ii); b) – i); c) – iii); d) – iv).

D) a) – iv); b) – iii); c) – i); d) – ii).

12) a) Slaty cleavage — i) alternate light and dark coloured bands.

b) Gneissose structure — ii) cataclastic metamorphism.

c) Schistose structure — iii) thermal metamorphism.

d) Granulose structure — iv) parallel arrangement of minerals.

A) a) – iv); b) – iii); c) – ii); d) – i).

B) a) – ii); b) – i); c) – iv); d) – iii).

C) a) – iii); b) – ii); c) – i); d) – iv).

D) a) – i); b) – iv); c) – iii); d) – ii).

Q. 2. Answer the following :

1) What is a rock?
2) What is meant by the term ‘textures of rocks’?
3) Name the texture of igneous rocks which exhibits a large variation in grain sizes and shapes.
4) Give two examples of evaporites.
5) What is stratification?
6) What is graded bedding?
7) What is meant by metamorphism of rocks?
8) Give the concept on the basis of which three zones of metamorphism have been recognized.

Q. 3. Answer in brief :

1) How are extrusive igneous rocks formed? Give an example.
2) What are sills? Describe with neatly labelled diagram.
3) Write a short note on clastic texture with example and diagram.
4) What are organic deposits? Give examples.
5) Describe slaty cleavage.
6) What is meant by thermal/ contact metamorphism?

Q. 4. Write short notes :

1) How is equigranular texture formed in igneous rocks? Explain with diagram.
2) What is a laccolith? Describe its characteristics with the help of a neatly labelled diagram.
3) What is meant by cross bedding? Explain in brief with the help of a diagram.
4) What are residual deposits? Describe with examples.
5) Which are the major agents of metamorphism? Describe their role in brief.
6) What is meant by cataclastic metamorphism?

Q. 5. Describe the following :

1) Classify igneous rocks on the basis of mode of occurrence/ depth of formation. Give examples.
2) How are vesicular and amygdaloidal structures formed? Describe with diagrams.
3) Describe in brief, the processes involved in the formation of sedimentary rocks.
4) Classify sedimentary rocks according to their grain size, giving examples of each.
5) Explain schistose and gneissose structures with the help of labelled diagrams.
6) Which are the three zones of metamorphism? Describe in detail with diagram and examples.