

What are igneous rocks & classify them and describe various types of igneous rocks

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Basalt

06, '07

ROCKS

Rock is an aggregate of one or more minerals. Rock may be loose or consolidated, soft or hard. The branch of geology dealing with the study of rocks is known as petrology. Crustal rocks are broadly classified on the basis of their origin in three groups namely

1. Igneous rocks or primary rocks,
2. The sedimentary or secondary rocks,
3. The metamorphic rocks.

Igneous rocks - it has been established by a number of different observations that temperature increases with depth. It may become so high at certain depth that materials can acquire a molten state. The molten material formed under certain condition of temperature and pressure is termed magma. When the same material erupted out at the earth surface is known as lava. Cooling and consolidation of magma or lava give rise to solid rocks known as igneous rocks. They are distinguishing as "intrusive igneous rocks" when formed beneath the surface from magma; and "extrusive rocks" when formed over the surface from lava. Extrusive rocks would become exposed to the surface only when covering rocks are removed by destructive process of weathering, erosion, denudation etc. or by diastrophic movements.

Different systems for classification for igneous rocks are based on different factors.

- Chemical composition
- Mineralogical composition
- Textural characters

The factor of texture indicates the condition under which the rocks have formed in general. It is a megascopic or field classification. Here igneous rocks are classified in to three types: 1. Plutonic, 2. hypabyssal and 3. volcanic.

→ The plutonic rocks are formed at the great depths in the zones under conditions of slow cooling. As a result, crystallization occurs and solid rocks are formed with holocrystalline, coarse and medium grained textures. At times fine-grained textures are also developed. Common example to this type is Granite. ✓

→ The volcanic or extrusive rocks are formed from lava erupted at the surface. The cooling and crystallization conditions are totally different from those exist at depth, hence textures also differ due to extreme rapid cooling holohyaline texture is developed or fine-grained texture is developed. Under the condition of escape of gases vesicular structure and on the filling of vesicles amygdaloidal structures is developed in these rocks. The best example for this is basalt. Sometimes earlier formed crystals are accompanied along with the eruption which are found enclosed with fine grained material gives porphyritic texture. Basalt shows all these textures. ✓

→ The hypabyssal rocks are formed by cooling of magma at intermediate depths in the crustal zones. They show features intermediate of plutonic and volcanic rocks. Textures ✓

are fine grained similar to basalt. The example is dolerite and coarse grained example is pegmatite.

IMPORTANCE OF IGNEOUS ROCKS

Many of the igneous rocks especially granites and related varieties are extensively used for construction works. Granites, syenites and dolerites have high crushing strengths and can be used in construction works. Basalt and similar dark colored rocks are preferred only as road stones. The igneous rocks being crystalline compact and of impervious character are safe for the foundation rock, Abutment of dams and wall and roof rocks in tunnels. They are the most suitable rocks for holding ground water reserves when they are weathered. Some like pegmatites and peridotites are of special economic importance as they contain valuable ores and minerals.

TEXTURE	EXAMPLES
Holocrystalline	Granite, gabbro, syenite
Holohyaline	Obsidian, pitchstone
Vesicular	Vesicular basalt, scoria
Amygdaloidal	Amygdaloidal basalt
Fine grained	Basalt
Porphyritic	Porphyritic basalt.

IMPORTANT IGNEOUS ROCKS

① GRANITE ✓

Latin word "granum- grain"

Granites are plutonic, light colored and acidic igneous rock. They are the most common igneous rocks containing granitic texture. Common constituent minerals are quartz and feldspars. Among other minerals mica and/or hornblende may be present giving the name mica granite or hornblende granite to the rock.

Texture

Granites are generally coarse to medium grained and even grained rocks. Holocrystalline or granitic, graphic, porphyritic and inter-growth textures are the most common types.

Volcanic Equivalents

Rhyolite is the volcanic equivalent of granites. It is fine grained with porphyritic texture. Quartz and alkali feldspar are chief constituents. Flow structure is very common in this type of rocks.

Occurrence

They are the most widely distributed type of igneous rocks. They usually occur as deep-seated intrusions like sills, bosses, stocks and batholiths.

Uses

They find extensive use in architectural work in ^{monuments} mountains and memorials as columns, and steps in buildings, may also be used as concrete aggregate after crushing. It takes an excellent polish and hence used as decorative purpose.

SYENITE

Syenites are the igneous plutonic even grained rocks with more of alkali feldspars and less of quartz. Among other minerals are biotite, hornblende, augite and some accessories such as apatite, zircon and sphene. [Sometimes the feldspathoids make their appearance].

Texture

Syenites have textures similar to that of granites, i.e. they are also coarse to medium grained, holocrystalline in nature.

Volcanic Equivalents

Trachyte is the volcanic equivalent of syenites. It is fine grained with trachytic texture. Alkali feldspar is chief constituent. Phonolite is volcanic equivalent of nepheline syenites.

DIORITE

Diorite is an intermediate igneous rock of plutonic origin with a silica percentage ranging between 52 and 66%.

Diorites are typically rich in plagioclase of sodic group. Alkali feldspar is also present. Among other minerals are hornblende, biotite and some pyroxenes. Quartz is also present in some Diorites – known as Quartz Diorites.

Texture

Granitic texture – they are coarse to medium grained.

Occurrence

Diorites usually occur as dykes, sills, stocks and similar intrusive bodies or as margins of large granite masses.

Volcanic Equivalents

Volcanic equivalents of diorites are 'Andesites'.

ANDESITE

Andesites are the intermediate igneous rocks of volcanic origin. They are rich in plagioclase of sodic and sub-calcic varieties. Potash feldspar is subordinate. There may be a small amount of quartz, biotite, hornblende, augite, olivine and hypersthene.

Occurrence

Andesites are known to be the most abundant volcanic rocks next to the basalts and in form of huge dimensions.

GABBRO

These are coarse-grained, dark coloured, plutonic igneous rock of basic character. Plagioclase (calcic) is the chief constituent. Other mafic minerals are augite, olivine, iron oxides etc.

Texture

Variable, generally granitic – medium to coarse grained holocrystalline. (Reaction rims are frequently observed).

BASALT ✓

These are dark coloured, volcanic igneous rocks of basic character. They are composed of calcic plagioclase and augite, olivine, iron oxides etc. They are most wide spread of all the volcanic rocks. They are characterized by amygdaloidal or compact structures and a variety of textures invariably fine grained but porphyritic textures are also common.

Many types are distinguished as to dominant minerals. They are chiefly composed of calcic plagioclase, ferro-magnesian minerals like augite, hypersthene, olivine, iron oxides etc.

They may occur in variety of forms – lava flows, lopoliths, stocks, plugs, dykes and sills.

DOLERITE ✓

Dolerites are typical hypabyssal igneous rocks. They are roughly equivalent to gabbros on one hand and basalts on the other.

They are chiefly composed of calcic plagioclase (Anorthite, labradorite) and dark Fe-Mg mineral like augite, olivine iron oxide etc.

They are mostly fine grained to medium grained rocks. Typically ophitic and sometimes porphyritic textures are of common occurrence. They usually occur in form of sills and dykes.

PEGMATITE ✓

Pegmatites are exceptionally coarse grained igneous rocks. They are characteristically rich in big crystals of component minerals.

Pegmatites vary in their mineralogical composition. Most common varieties are similar to granites, hence called "granite pegmatite". They consist of feldspars (orthoclase, microcline, albite) and quartz as dominant minerals; associated with them may be muscovite, tourmaline, topaz, fluorite, beryl, (cassiterite, wolframite, columbite) etc. Granite pegmatites are commonly rich in muscovite and hence commonly from the source rock of industrial white mica.

They usually occur in form of veins, dykes or irregular patches of variable dimensions.

In general, pegmatites do not show any typical texture or structure. They are mostly coarse grained and inequigranular.

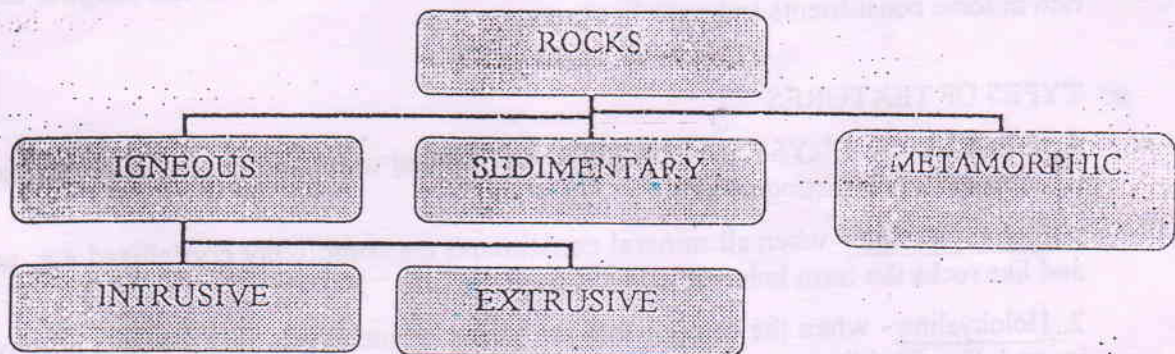
Many varieties are known - granite pegmatites, syenite pegmatites, diorite pegmatites; mineralogically two broad varieties are recognized

Simple Pegmatites- characterized by coarse crystals of felspars and quartz only.

Complex Pegmatites- Characterized by the additional presence of accessory minerals.

Uses- They are generally the source of rare minerals, source of economic minerals such as ores of uranium, lithium, mica, white mica, beryl, etc.

CLASSIFICATION OF ROCKS



PLUTONIC	HYPABYSSAL
<p>Greater depth High temperature, enormous pressure, presence of Gases, vapours, (volatiles). e.g. 1. Granite, 2. Syenite, 3. Gabbro. Texture- Holocrystalline (=granitic). Mineral constituent-</p> <ol style="list-style-type: none"> 1. Orthoclase and quartz (+ plagioclase) + muscovite \ biotite \ hornblende \ tourmaline \ hypersthene. 2. Orthoclase + mica \ hornblende. 3. Plagioclase and augite (+ olivine). <p>Localities Granite- Idar, Balaram, Godhra, Ambaji in Gujarat. Mt. Abu, Erinpura in Rajasthan.</p> <p>Uses-</p> <ol style="list-style-type: none"> 1. Construction works (granite and like rocks) mainly in monuments - receive excellent polish, durable. 	<p>Shallow depth Temperature + pressure + volatiles e.g. 1. Pegmatite, texture- very coarse grained 2. Dolerite, texture - fine grained or ophitic. Mineral constituent</p> <ol style="list-style-type: none"> 1. Quartz + orthoclase (+muscovite + tourmaline) 2. Plagioclase + augite. (+Olivine). <p>Localities 1. Pegmatite - Bihar, Rajasthan and Andhra Pradesh 2. Dolerite - Rajasthan (Arvali region)</p> <p>Uses-</p> <ol style="list-style-type: none"> 1. Economical minerals- muscovite 2. nil

TEXTURES OF IGNEOUS ROCKS

Definition - the term texture has been defined as the mutual relationship of different mineral constituents of the rock and is determined by their shape, size, and arrangement within the body of the rock.

Following factors are responsible for the development of various types of textures.

1. The process of crystallization.
2. Nature of lava (or magma).
3. Composition of magma.

Crystallization may be slow, rapid; magma may be viscous or mobile. Magma may be rich in some constituents and poor in others.

* TYPES OF TEXTURES

→ A. DEGREE OF CRYSTALLIZATION - depending upon the degree of crystallization three types can be distinguished.

1. Holocrystalline - when all mineral constituents are completely crystallized e.g. granite and like rocks the term holocrystalline is used.

2. Holohyaline - when the components are glassy or non crystalline the term holohyaline is used. E.g. Obsidian.

3. Porphyritic - (micro-crystalline) - The term porphyritic is used when some minerals are crystallized and others are either fine or glassy. E.g. porphyritic basalt, porphyritic granite.

→ B. GRANULARITY - depending upon the granularity textures can be described as follows

1. Coarse Grained - this term is used when the average size of different minerals of the rocks is more than 5 mm.

2. Medium Grained - here the average grain size is between 5 mm to 1 mm

3. Fine Grained - the average size is less than 1 mm.

→ C. FABRIC

Depending upon the fabric following types of textures are defined. Fabric is expressed by "relative" grained size of different minerals and also by the degree of perfection in form of crystal. As to the relative grain size there are two distinct types of textures.

1. Equigranular - when all minerals are of approximately equal dimension, e.g. granites, syenite.

2. Inequigranular - when some constituents are exceptionally larger or smaller than the others e.g. porphyritic basalt. [As to the perfection in the form of crystals, following types are known]

1. Panidiomorphic - when majority of crystals are perfect in their form - euhedral crystals

2. Hypidiomorphic - when the rock consists of mixture of semi-perfect crystals, i.e. some are euhedral, some are subhedral and others are anhedral.

3. Allotriomorphic- when most of the crystals in the rock are anhedral, i.e. irregular in their crystal forms.

Inequigranular textures may further be classified in to three sub types.

➤ Porphyritic- when the larger sized crystals enclosed within the fine-grained or glassy groundmass the term porphyritic is used. e.g. porphyritic granite, porphyritic basalt, granite porphyry, syenite porphyry etc.

➤ Poikilitic- when fine grained or comparatively smaller sized crystals are found enclosed within the body of large sized crystals the term "poikilitic" is used. E.g. picrite, peridotite.

➤ Ophitic- when the laths or needles of some crystals are found partly penetrating some other bigger crystals the term "ophitic" is used. E.g. Dolerite.

OTHER TYPES OF TEXTURES.

Directive Textures-

During the formation of rocks some minerals are directed as to the flow of magma or lava. Minerals get oriented parallel or sub-parallel in the direction of the flow of magma. Such an arrangement of minerals gives rise to directive textures. E.g. Rhyolites, trachytes-sometimes shows trachytic or trachytoid texture.

Intergrowth Textures-

During the formation of rocks sometimes two or more minerals may simultaneously crystallize out resulting in to the arrangement of mixed crystals. Such an arrangement is known by the term intergrowth textures. Two types are known under this head.

1. Graphic intergrowth- when the intergrowth is found regular between quartz and feldspar, it is graphic intergrowth, e.g. graphic granite.

2. Granophyric intergrowth- when the intergrowth is irregular it is termed as granophyric, e.g. granophyre.

Intergranular Textures-

Some times during crystallization certain crystals are formed at an earlier stage than the other. As a result variously shaped interspaces are left over (may be trigonal or polygonal), and may later be filled up with crystalline or glassy mass. If the spaces are filled up with the crystalline material, the texture is intergranular and with glassy matter it is intersertal.

Sedimentary Rocks

[classification as to grain size]

Rudaceous = rudites = Psephites.

- e.g. 1. conglomerate [rounded]
- 2. breccia [Angular]

Arenaceous = Arenites = Psammites.

- e.g. 3. sandstone [rounded]
- 4. grit [angular].

Argillaceous = Lutites = Pelites

- e.g. 5. shale, mudstone

[Both are very fine, extremely fine grained.]

Texture: clastic.

Localities [1] Jhagadia, [Rajpipala, Bharuch]

[3, 5] Himmatnagar, Dhrangadhra, Jodhpur.

[4] Chittor, Jodhpur, Himmatnagar.

Uses- Construction work, pillars, columns.

SEDIMENTARY ROCKS-

Sedimentary rocks are the secondary rocks. This group includes wide variety of rocks formed by accumulation, compaction and consolidation of sediments or organic remains in the bodies of water. The sediments are derived in different ways from different sources. The great bulk of all sedimentary rocks are derived in form of rock waste from pre-existing rocks by the action of natural agencies such as wind, water and ice. These sediments are transported and deposited under bodies of water; similarly some sediment are derived as precipitates or formed as evaporites. Animal and vegetable life also contributes organic remains in fossilized form. Thus the processes of formation of sedimentary rocks are ever prevailing. Millions of tons of sediments are being broken from the rocks of lithosphere and transported to sea floor where they are being compacted by the load from the new layers of sediments.

Sedimentary rocks are known to cover as much as 75% of surface area of land, rest being covered by the igneous rocks, but they disappear with depth. In upper 16 kilometers of the crust, their volume is believed to be not more than 15% rest being all igneous rocks.

As to their processes of formation, sedimentary rocks are classified in to Detrital and Nondetrital rocks. Nondetrital rocks are again sub divided in to rocks of chemical origin and rocks of organic origin.

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coarse - $> 2 \text{ mm}$ in size
medium - $2 \text{ mm} - 0.0625 \text{ mm}$
fine - $< 0.0625 \text{ mm}$

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Detrital Rocks- (Clastic or mechanically formed rocks) :

Detrital rocks include those sedimentary rocks that have been formed from pre-existing rocks through mechanical action of denuding agents - wind, water, glaciers etc. Their formation involves erosion, transportation, deposition and lithification of the sediments.

The clastic (detrital) are further sub-divided into following three classes on the bases of average grain size of the sediments.

1. RUDITES OR RUDDACEOUS OR PSEPHITES.

They include coarse-grained clastic rocks of heterogeneous composition. The average grain size of the sediments is always more than 2 mm. They may be composed of boulders $> 200 \text{ mm}$, cobbles 200 to 50 mm, pebbles 50 to 10 mm and gravels 10 to 2 mm. These

geomorpho
logical
features
by wind
Loess, sand
dunes

by water
meander
pot holes

are held together by cementing material e.g. Breccias and Conglomerates.

2. ARENITES OR ARENUCEOUS OR PSAMMITES:

They include medium grained clastic rocks of heterogeneous composition. They are made up of sediments of grain size between 2 mm to 1/16 mm. Most commonly the grains are siliceous (SiO_2) in composition e.g.- Sandstones, Grits, Greywacke and Arkose. *mixture of some which does not have a uniform composition*

3. ARGILLACEOUS OR LUTITES OR PELITES:

They include the fine grained clastic rocks made up of sediments with average grain size less than 1/256 mm (between 1/16 - 1/256 mm are grouped as silt rocks) e.g. Shale, mudstone, clay and siltstone.

Non-detrital or Non-clastic or chemically formed rocks :

This group includes those sedimentary rocks that have been formed through precipitations or evaporation of material from solutions. This group also includes the sedimentary rocks which are of organic origin (biochemical in nature). Non-detrital rocks are generally homogenous in character. Thus they are divided into two classes - the precipitates and organic rocks.

PRECIPITATES:

On the basis of chemical composition they are further subdivided into:

i. Siliceous Deposits:

Chalcedony, Opal, Flint, Chert, Jasper etc.

ii. Carbonate Deposits:

limestone, dolomites, siderites etc.

iii. Ferruginous Deposits:

iron oxides and hydroxides, carbonates, silicates of iron. The iron ores are chemically precipitated hydroxides of iron.

iv. Phosphatic Deposits :

Rock phosphates, limestones and Shales rich in phosphates.

v. Evaporates :

Gypsum, rock salt, Anhydrite, Calcium Carbonates, Borates, rock Sulphur, Nitrates etc.

Organic deposits:

These are sedimentary rocks in which animals and plants have played a prominent part in their formation.

1. Carbonate Rocks:

Accumulated remains and skeletons of sea animals and by

activities of some plants. Some limestones are purely organic in origin.

2. Carbonaceous Rocks:

Rich in carbon contents. Raw materials supplied by plants. E.g. coal.

3. Phosphatic Deposits:

Guano is an example of the phosphatic deposits of organic origin. Accumulation of phosphatic excreta of certain birds that inhabited islands and live on fishes.

4. Ferruginous Deposits:

Iron deposits formed by action of bacteria. e.g. bog iron ore.

Miscellaneous deposits.

These are residual in nature and accumulated by decomposition of pre-existing rocks.

Important Sedimentary Rocks :

(A). Clastic (Detrital) Rocks :

Rudites (Rudaceous) Rocks :- *Pebbles*

1. Breccia :

Breccias are mechanically formed sedimentary-rudaceous type of rocks. They consist of angular fragment of heterogeneous composition embedded in a matrix of cement. The fragments are more than 2mm in diameter. The angularity indicates little or no transport after their disintegration from parent rocks.

Details :

Breccias are of following types :

1. Basal Breccias :

Formed by sea action under advancing sea water.

2. Fault Breccias :

Formed by cementation of fragments produced due to the breakage of the rocks by the processes of faulting - also called Crushed Breccia.

3. Tectonic Breccias :

Under tectonic processes like folding and intrusions, Breccias are likely to be formed; these are also taken under Fault Breccia.

4. Agglomerate Breccias :

Angular fragments of volcanic origin enclosed within similar type of eruptive material.

2. Conglomerates :

These are the rudaceous type of sedimentary rocks of clastic nature and consist of rounded pebbles, gravels, boulders, etc, cemented together. The fragments range in size from 2mm and above. The roundness is indicative of the fact that they have undergone a good deal of transport by water, where by angularity is removed. The pebbles may be mineral pieces or rocks pieces. Cementing material may be siliceous or calcareous or ferruginous.

As to the size of fragments, Conglomerates are distinguished as boulder-Conglomerate (>256mm diameter), cobble-Conglomerate (64-256mm) and pebble-Conglomerate (2-64mm). As to the source material, they are distinguished as, volcanic Conglomerate, basal Conglomerate (sea-action) and glacial Conglomerate.

ARENITES :

(Arenaceous Rocks): Ps or v. d. 106

Sandstones :

These are arenaceous type of sedimentary rocks formed mechanically from sand-grains by compaction and consolidation. The grain size vary from 2mm to 1/16 mm. Silica is a common constituent in sandstones.

Quartz is the most common mineral. Other minerals (like feldspar, garnet, magnetite, mica) may be present in certain proportions. Cementing material is also present-may be calcareous, siliceous, ferruginous or argillaceous.

Sandstones are medium grained clastic rocks. The grains may be round or angular in shape, fine or medium or coarse in size, loosely or densely packed. These factors are responsible for porosity and permeability in these rocks.

Colour depends upon the nature of cementing material. Iron oxide gives yellow, red or brown colour; calcareous content gives white colour.

As to the cementing material, following four varieties are recognized:

1. Siliceous sandstones.
2. Calcareous sandstones.
3. Argillaceous sandstones.
4. Ferruginous sandstones.

On the basis of mineralogical composition, following four types are recognized :

1. Arkose is a sandstone with felspars
2. Greywacks are the impure sandstone, argillaceous in nature and contains Quartz, feldspar and bits of granites, Shales etc.
3. Flagstone is rich in mica.
4. Freestones are massive sandstones with no or little divisional planes, assuming on the whole a compact character.

Use :

Building stones, glass sands, pavines, roofing, pillars, statues and for variety of house hold purpose.

LUTITES :

(Argillaceous Rocks): pelites LA '06

Shale :

Shales are the argillaceous type of fine grained sedimentary rocks. They are generally characterized by a distinct fissility (lamination or parting) parallel to the Bedding. These rocks are made up of fine clay particles less than 1/256 mm diameter. Thus they are extremely fine-grained in texture.

Many types are known - as to the presence of the accessories :

1. Calcareous Shales contain some carbonates.
2. Carbonaceous Shales contain carbon content.
3. Alum Shales are rich in iron sulphide (pyrite) or sulphate.
4. Oil Shales are the carbonaceous Shales that yield oil on destructive distillation.

Use :

Bricks and Tiles; source of alumina, paraffin and oil. They serve as impervious capping in oil bearing structures-reservoirs.

(B). Non-Clastic (non detrital or chemical) Rocks :

1. Limestones :

* 107 Limestones are very important and widespread calcareous type of sedimentary rocks that have formed from chemical as well as organic processes.

Pure Limestones are composed of calcite grains. Common Limestones have impurities like clay, feldspars, Quartz and pyrite. In some limestone, magnesium carbonate predominates and the rock is then termed Dolomite.

Limestones exhibit great variety of textures and structures. They may be compact or loosely packed, hard or soft and may show clastic, non-clastic concretionary or organic structures.

Many varieties are known - organic limestones and chemically precipitated limestones. The common varieties are :

Chalk :

Purest form of Limestone characterized by fine-grained earthy texture. Usually white. some are forminiferal.

Argillaceous Limestones :

Considerable clay proportion, when carbonate and clay are present in roughly equal amounts, it is MARL.

Fossiliferous or Shelly Limestones :

Rich in fossil, i.e. when it is composed of more of shells, it is termed Coquina, otherwise it is fossiliferous Limestones.

Lithographic Limestones :

Compact, homogeneous, extremely fine grained.

Kankar :

Nodular or concretionary formed by evaporation of sub soil water rich in CaCO_3 just near the surface.

Calc-Sinter :

Formed by precipitation from carbonate rich spring water. Also known as Travertine or Calc-tuffa.

Formation of Limestones :

Limestones may be 'organic' or 'inorganic' in origin. The organic limestones are formed by the accumulation of Shells or other organisms. Corals, Molluscs, Foraminifera, contribute in the formation. The inorganic limestones are formed as a result of precipitation. (precipitation is affected by a decrease of CO_2 content in water under the influence of heat or of the activity of the bacteria or changed conditions of temperature and pressure. Temperature and pressure are directly affecting the solubility of CO_2 .)

Such conditions are most favorable in the seas. Nearly all limestones are marine in origin.

Dolomite; Coals; Iron-ore rocks, Gypsum, Rock-salt, Flint and Chert etc, are also sedimentary types.

Importance of Sedimentary Rocks :

Sedimentary rocks cover a great part of earth's crust in its horizontal extension. i.e. 75% of the total area of the appear surface of the earth.

These are the most important reservoir rocks for holding oil and water supplies. Some of the rocks are utilized as building stones and road metal, e.g. Sandstone. Limestones are mainly utilized for the manufacture of Lime and Cement.

Structural features associated with Sedimentary Rocks :

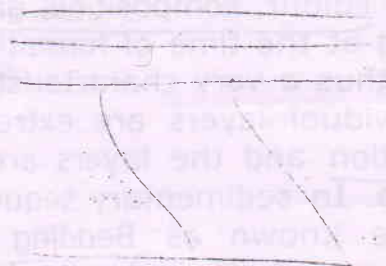
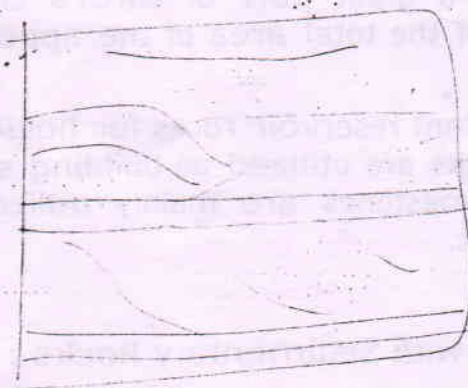
✓ Sedimentary rocks usually occur in form of layers. Different layers may vary in colour, composition, grain size, texture etc. Such a variation prevailing at the time of formation. This layering or Bedding or stratification is thus a very characteristic feature of all sedimentary rocks. If the individual layers are extremely thin, the structure is known as Lamination and the layers are described as laminae and each one is lamina. In sedimentary sequence, the surface separating different beds are known as Bedding planes or junction-planes. Sometimes flaky minerals like mica lie parallel to the Bedding planes. due to this reason, the rock can easily fractured or separated along that direction. This property is known as fissility of the sedimentary rocks.

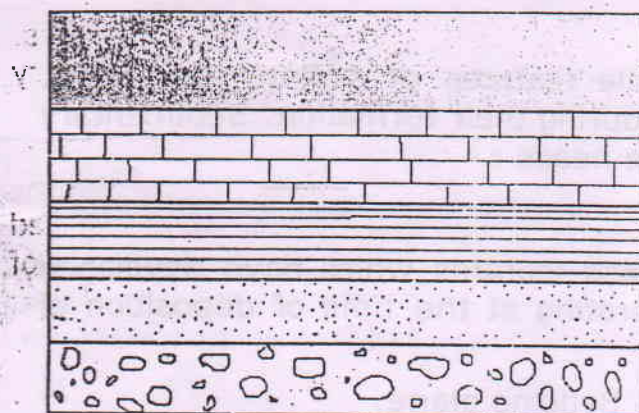
Sometimes within a sequence, some beds may have their grains arranged obliquely to the Bedding and not parallel to one another. This structure is known as Current Bedding. This is formed due to the

change in the velocity of water and direction of flow of streams when laid down. Sometimes deposition takes in such a manner that thin horizontal beds made up of fine materials are found to lie in alternation with coarse and current bedded position; the resulting structure is known as Torrential Bedding. This is generally produced due to the deposition of coarser material, during periods of flood, with intervening layers of finer silt or clay accumulates at other times.

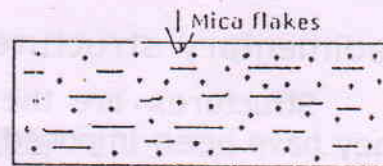
✓★ River deltas : 07

River deltas are formed due to deposition of sediments and show a characteristic structure of their own. There are generally three sets of beds. The upper and lower ones show a very gentle slope towards the sea, in conformity with the slope of the floor on which they settle down. These are known respectively as the Topset and Bottomset beds. In between these two sets lie the third set which exhibits a considerable amount of slope towards the sea. These are known as Foreset beds.

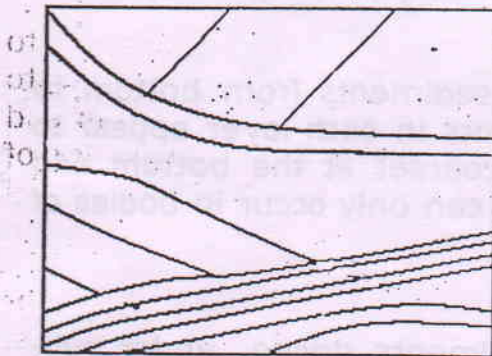




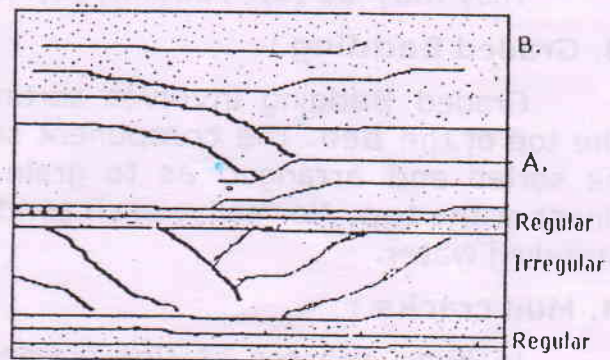
stratification or Bedding



Fissility

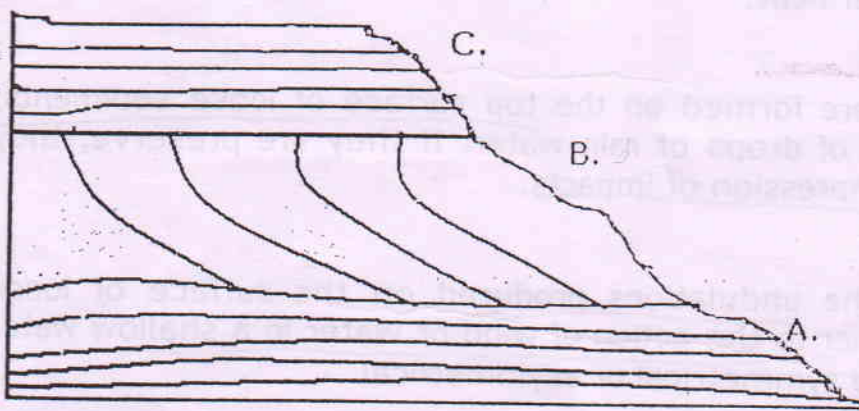


Current Bedding



Torrential Bedding

A = Irregular current bedded layering.
B = Regular horizontal layering.



Delta Structure

A = Bottom Beds
B = Foreset Beds
C = Topset Beds

Structures are the large scale features of sedimentary rocks. They have been imposed on them during their formation. Sedimentary structures are classified under three heads :

Mechanical structures are those features which have developed because of physical processes operating at the time of deposition of sediments:

- ## 2. Cross Bedding or Current Bedding or False Bedding.

They may be (a). Tabular, (b). Lenticular, (c). Wedge shaped.

Graded Bedding involves sorting of sediments from bottom to the top of the bed. The component sediments in each layer appear to be sorted and arranged as to grain-size-coarset at the bottom and finest at the top. Normally, such conditions can only occur in bodies of standing water.

In huge masses of fine-grained sediments drying, under sub-aerial conditions, may bring about the development of mud-cracks. These are otherwise known as sun-cracks, since they are formed due to the effect of solar heat.

Rain prints are formed on the top surface of loose sediments, due to the impact of drops of rain water. If they are preserve; they would appear as impression of impacts.

These are the undulations produced on the surface of loose sediments due either to the action of wind or water in a shallow water body. They may be symmetrical or asymmetrical.

These may be classified as follows :

1. Concretionary structures :

Concretions are rounded, nodular or irregularly shaped material present in some rock masses. Their chemical and mineralogical composition is generally different from the enclosing rocks.

2. Oolitic and Pisolitic structures :

The presence of small, more or less symmetrical particles-ranging in size between 0.1mm to 1.0mm, called Oolites. Their combination in to an aggregate gives rise to oolitic structures. Sometimes these particles are of bigger size, more than 2mm- they are termed Pisolites - the structure produced is called pisolitic. Some limestones and bauxites show both of these structures

3. Nodular structure :

This is generally exhibited by some limestones. It is characterized by the development of irregularly shaped nodules of chert, iron oxides, iron carbonates and clay ironstone. Sometimes on account of the effect of pressure, nodules show an elongation or flattening parallel to the Bedding plane.

4. Geode structure :

A Geode is actually a hollow shell, the interior of which is lined with inwardly projecting crystals. Generally, the outer shell is made of chalcedony and the inner crystallizations are of quartz crystals. The formation of Geode requires presence of an original cavity.

C. Organic structures :

These structures include those structural features that have been imposed, directly or indirectly, by the organism on the sedimentary rocks. The rock is described as fossiliferous if it contains remains of some organisms in it. Limestones are sometimes highly fossiliferous. Another type of structures which are produced by some kind of algae are termed Stromatolites.

Movements of organisms on loose surface of soft sediments may cause the markings, impressions of footprints etc. These are called Tracks and Trails.

All such minor features are preserved in sedimentary rocks under suitable conditions and often helpful in establishing the order of superposition of beds occurring in a region of complicated geological structure.

Geologists use a universally accepted scale of particle size-

Size Range of Sedimentary Particles.	
Wentworth scale in millimeters	Name of Particle
256	Boulders.
256	
128	Cobbles.
64	
32	Pebbles.
16	
8	
4	
2	Granules (Gravels).
1.0	Very coarse sand.
0.5 (1/2)	Coarse sand.
0.25(1/4)	Medium sand.
0.125 (1/8)	Fine sand.
0.0625(1/16)	Very fine sand.
0.0313 (1/32)	Silt.
0.00156 (1/64)	
0.0078 (1/128)	
0.0039 (1/256)	
Clay	

Tabular Classification of Sedimentary Rocks :-

	Composition	Mechanically formed or clastic or Detrital rocks	Chemically formed or Non-clastic or Non-detrital	Organic Rocks	Residual Rocks
a.	Siliceous	1. Rudites, e.g., i). Breccia ii). Conglomerate 2. Arenites, e.g. Sandstone	i). Flint ii). Chert iii). Siliceous sinter	Radiolarian rocks and Diatomaceous earth.	--
b.	Argillaceous	3. Lutites, e.g. i). Clay ii). Shales iii). Siltstones iv). Marl	--	--	Terra-rosa
c.	Calcareous	Calcareous Conglomerates and Sandstones	i). Limestones ii). Kankar. iii). Travertine	i). Limestones ii). Chalk	--
d.	Carbonaceous	Carbonaceous Shales	Coal i). Lignite ii). Bituminous iii). Anthracite	--	--
e.	Ferruginous	Ferruginous Sandstones	Bog-iron ores, other iron deposits	Some iron ores	--
f.	Miscellaneous	--	Salts. i). Gypsum ii). Anhydrite iii). Rock salt iv). Cal____ v). Phosphate rock	i). Phosphate rock ii). Gauno	Bauxite and Laterite

Sedimentary structures :

Primary sedimentary structures :

Primary sedimentary structures are formed during the deposition of sediments. (In contrast, secondary sedimentary structures are formed subsequent to the deposition). Bedding or stratification, lamination, mud-cracks, ripple marks, graded Bedding and similar others are the examples of primary sedimentary structures while folds and faults are the secondary sedimentary structures. Primary structures are useful to geologists in the reconstruction of ancient environments. For example, mud-cracks indicate drying after deposition. This conditions are commonly found on valley-flats and in tidal zones. Mud-cracks develop by shrinkage of mud or clay on drying and are most abundant on marine environment.

Cross - Bedding :

Cross-Bedding is an arrangement of beds or laminations in which one set of layers is inclined relative to the others. Cross-Bedding is also formed by the advance of a delta or a dune. Such an arrangement is formed by the change in the direction and velocity of water bringing the sediment particles. Thus the depositional environment is inferred from cross-Bedding.

Textures and Structures of Sedimentary Rocks :

Texture of a rock is determined by the shape, size, and arrangement of the grains with the rock. These are the bases of classification.

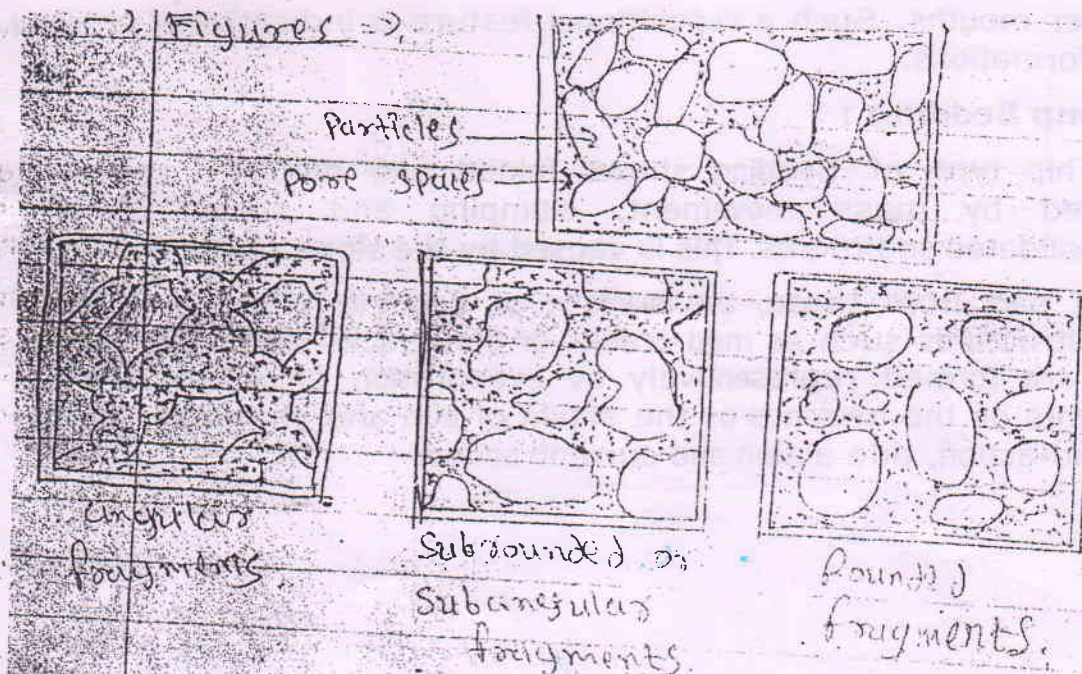
Three basic shapes are recognized angular, sub-angular and rounded for clastic rocks; and oolitic and pisolitic for non-clastic rocks.

Similarly, three categories for size are :

Coarse : Particles greater than 2mm in size.

Medium : Particles 2mm to 0.0625mm in size.

Fin e : Particles less than 0.0625mm in size.



Structures are the large scale features observed in the rock. Most sedimentary rock shows Bedding or layering -- expressed by variation in texture and mineralogy.

When a bed represents a single episode of sedimentation, it is found bordered by bottom and top Bedding planes. Such planes mark the pause and change in material. Similarly, a single bed may show lamination (similar to Bedding, but smaller in scale). Lamination represents minor variation in the nature of material during one single episode of deposition.

Four main forms of Bedding are recognized :

1. Regular Bedding :

The beds are separated by parallel Bedding planes and can be observed in horizontal, and tilted beds. Folded or faulted beds caused by post-depositional earth movements also show regular Bedding.

2. Graded Bedding :

In this type of Bedding, the grain size varies from coarse at the bottom to fine at the top. It results from rapid sedimentation of material in water; coarser grains settle more rapidly than the finer grained material.

3. Current Bedding :

In this type of Bedding, the beds show a distinctive cross-lamination. The lamination may vary from parallel to inclined to wedge shape, depending upon the direction and speed of water currents in

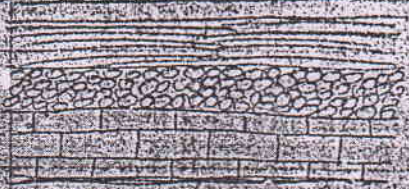
the river mouths. Such a depositional feature is indicative of shallow water formations.

4. Slump Bedding :

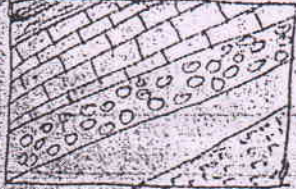
This type of Bedding shows folded and distorted structure, produced by mass movement, slumping and sliding of wet, unconsolidated sediments. This is caused by the slope of the sea-floor.

A part from these, the surface of Bedding planes may show minor structures such as mud-cracks or sun-cracks and ripple marks. These are formed representively by evaporation of water from the sediments on the beaches by the action of sun and shrinkage, and by the wind-action, tide action and current-action.

Regular bedding \Rightarrow



Horizontal bedding



(Tilted) regular bedding



(Faulted) regular bedding



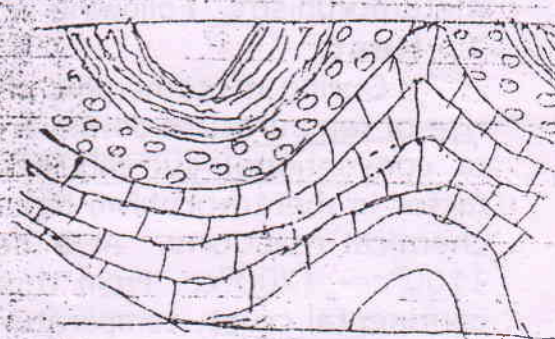
Graded bedding



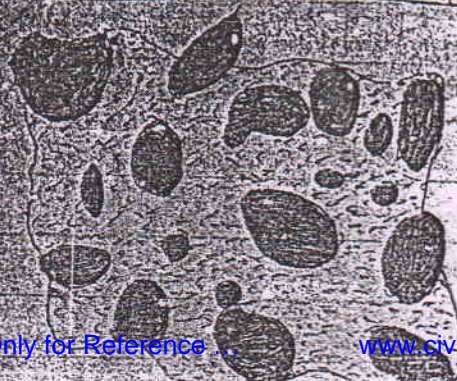
Current bedding,
(cross bedding or false bedding)



Slump bedding



Regular bedding
(folded)



Metamorphic Rocks :

Introduction :

Primary or secondary or other type of rocks may or may not undergo any physical or chemical changes after their formation. There will be no change in the set up of a given rock. This state of no change is called that the rock is in equilibrium. But, if there is any effective change in the surrounding environmental conditions, equilibrium is disturbed and the rock is unable to exist in its original form. The change of rock would be depending upon the nature of conditions surrounding the rock and also upon the nature of the rock involved in it. The new rock would be stable under new conditions. The changes are known as metamorphic changes and the process is termed Metamorphism.

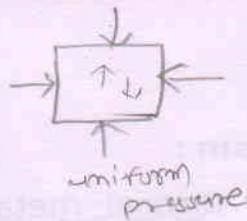
Factors or Agents of Metamorphism :

Metamorphic changes are due to a number of factors such as temperature. (-secular heat and magmatic heat-range is between 350. - 850.), pressure (-vertical pressure by the load of overlying material, pressure caused due to crustal disturbance-horizontal or lateral pressure), and chemically active fluids-in general known as chemical environment - water, CO_2 , HF, Bromine, Fluorine and some other cases. These factors induce metamorphic changes in the rocks.

Heat, pressure and chemically active fluids are the agents of metamorphism. Following is an account of these agents:

1. Heat:

During metamorphic changes heat may be supplied by a general rise of temperature downward or from magma or due to crustal friction or conventional currents of the mantle. Thus heat is an important factor in metamorphism because it helps crystallization and speeds up chemical reactions. At a depth of 100 km probable temperature is $1100^\circ\text{C} - 1200^\circ\text{C}$. From this, it is estimated that at the base of the continental crust, temperature is about 500°C . In regional or dynamo thermal metamorphism, temperatures commonly range from $300^\circ - 400^\circ\text{C}$ to $700^\circ - 800^\circ\text{C}$. The heat in regional metamorphism probably results primarily from internal radioactivity and conduction of heat from the mantle. As estimated, at a depth of 20kms, corresponding to deep burial in a geosynclines, temperatures of around 380°C to 500°C are expected. At a depth of 25 km the probable temperature would be from 450°C to 625°C .



2. Pressure: -

During metamorphic changes, pressure may be produced due to earth movements or gravity. It is found that two types of pressure are at work in metamorphism. They are directed pressure i.e. stress and uniform pressure. The uniform pressure may be applied to solids or liquids. It is known that when directed pressure is applied to a liquid, it is converted into uniform pressure. Further in metamorphic reactions, water vapor and CO₂ under pressure control the reaction direction. The effect of uniform pressure is to produce change of volume; while directed pressure gives rise to changes in shapes.

3. Chemically active fluids:

The liquids and gaseous emanations from magmas and ground water containing chemically active substances are included under this head. In metamorphism, heat and pressure are conditional agents while a chemically active fluid works as universal agent. In all kinds of metamorphism, part played by chemically active fluids is passive. That means they do not take active part in the actual process, but work as solvents.)

Kinds of metamorphism : ★ 106

1. Major factor of Temperature and minor role of pressure and fluids give changes in rock known as Thermal Metamorphism.

2. Factor of pressure ^{superior} dominant (-shearing stresses) known as Dynamic Metamorphism (also known as Kinetic Metamorphism). When the pressure is due to depth - it is known as Load Metamorphism.

3. Dynamothermal Metamorphism :

Here the temperature and pressure are the major factors working in bringing about metamorphic changes known as Dynamothermal Metamorphism. Fluids are also playing some role. This is characteristic of intense folding covering hundreds of kms of tectonic belts.

4. Plutonic Metamorphism :

Uniform pressure at depth and very high temperature are responsible for the bulk changes-the process is plutonic metamorphism-such conditions are available at greater depths in the crust.

5. Metasomatism :

A type of thermal metamorphism in which fluids, liquids and gases with high temperature react with the component of wall rocks along fractures-giving rise to a change of replacement.

Effects of Metamorphism

A great variation occurs in the nature of effects of metamorphic processes on different rocks. Depending upon the factors following effects would be found re-crystallization, granulation and rock-flowage and metasomatic replacement.

Definition:

Thus metamorphic rocks are those which have formed through the operation of various types of metamorphic changes on the pre-existing rocks, involving textural, structural, mineralogical and re-constructural changes.

Metamorphic rocks are distinguished from other types of rocks by the development of specific features like cleavage, foliation, schistosity or granulation, banding etc, and also by the presence of certain minerals which are known to be of metamorphic origin.

Important Metamorphic rocks :

Metamorphic rocks have been variously classified on the basis of texture and structure, degree of metamorphism, mineralogical composition and mode of origin. Most common classification is based upon pressure or absence of parallel structures.

1. Rocks with parallel structure - i.e. foliation and banding. e.g. Slates, Phyllites, Schists and Gneisses.
2. Rocks without parallel structures: Non foliated or granular structure. e.g. Quartzite, Marble, etc. and Hornfels, Amphibolites, Soapstone etc.

Slate:

Slate is a fine grained metamorphic rock with a perfect slaty cleavage. (Slaty cleavage is due to parallel arrangement of platy or flaky minerals under the influence of metamorphism.)

Slate is composed of fine grain of mica, chlorite, Quartz, Feldspars, iron oxides and others. All of these can not be identified even under microscope because of their extreme fine nature.

Slate is a product of low-grade regional metamorphism on argillaceous rocks like Shale. Further changes give rise to Phyllite and still further metamorphism changes to Schist.

Use :

Slate is locally used as a roofing material. (It has a low crushing strength, hence cannot be used as a building stone or road stone.)

Phyllite : ✓ 106

Phyllite is mostly a fine-grained metamorphic rock - (and represents an intermediate stage in the metamorphism of slate to schist).

It consists of chlorite, Muscovite and Quartz grains, all of them are so fine that they are not recognized by naked eye. The presence of Muscovite is easily indicated by the shining cleavage surface. The rock shows foliated structure.

Phyllites are formed as a result of Dynamo-thermal metamorphism of argillaceous rocks like Shale.

Use :

Phyllites are used as roofing material and locally for paving.

Schist:

Schists are megascopically crystalline metamorphic rocks characterized by schistose structure.

The constituent platy, flaky and rod-like minerals are arranged in irregular parallel layers or bands. (Micas, Chlorite, talc, Hornblende, Tremolite, Actinolite and Kyanite are common; Quartz and Feldspars are rare or absent, Staurolite, Garnet, Andalusite are also sometimes present). As to the presence of minerals, common types are Muscovite-schist, Biotite-schist, Tourmaline-schist, chlorite-schist, talc-schist, garnet-schist etc.

As to the grade of metamorphism, there occur low grade Schists and high grade Schists.

Schists are generally the product of Dynamo-thermal metamorphism of argillaceous rocks like Shales. Some may be formed from basic and ultra basic igneous rocks.

Schists are generally the product of Dynamo-thermal metamorphism of argillaceous rocks like Shales. Some may be formed from basic and ultra basic igneous rocks.

Use :

Schists are weak rocks and hence cannot be used for any purpose.

Gneiss :

A gneiss is megascopically crystalline metamorphic rock with alternate bands of light and dark coloured minerals.

Quartz and feldspar are more commonly present. Bands of mica or Hornblende alternate with Quartz and feldspar bands.

The most common structure is gneissose. Sometimes augen structure is also found.

Ortho-Gneisses, Para-Gneisses, Banded-Gneisses, Augen Gneisses, and Injection Gneisses are the varieties.

Gneisses are the products of advanced stages of (regional) metamorphosis. (of sandstone, Conglomerates and granitic rocks.)

Use :

Gneisses; when sufficiently strong, may be used as road stone or for common buildings, but not much utilized.

Quartzite : 106.

Quartzites are the fine-grained metamorphic rocks chiefly composed of recrystallised Quartz grains. It is thus a granular rock. (characterized by a tendency of fracturing through the grains under heavy loads).

The rock generally confines quartz. Besides Quartz some Quartzites contain minor amount of mica flakes, feldspar, garnet and other minerals. (all these minerals result from the impurities of the original sandstone during metamorphism).

Quartzite result from the re-crystallization of the sandstone under the influence of (contact and dynamic) metamorphism.

Marble :

Marble is essentially a metamorphic rock composed chiefly of re-crystallized calcite. It is characterized by a granulose structure. (The grain size shows extreme variations from finely saccharoidal to highly coarse).

The rock is composed mostly of calcite. Small amounts of Olivine, Serpentine, Garnet, Epidot and others may also be present. All these are formed from the impurities in the original limestone.

Variety of colours may occur in nature on account of impurities present.

Marbles result from the re-crystallization of limestones or dolomites under the influence of (contact and regional) metamorphism.

Use :

The rock is used extensively as building stone for decorative purpose. It is also used for statues and various house hold purpose.

Comparative Study :

Slate	Phyllite	Schist
Texture : Very fine grained, individual minerals not identified by unaided eye.	Texture : Fine grained, individual mineral not identified by unaided eye. Mica flakes better developed both in number and size.	Texture : Megascopically crystalline, components well arranged and easily recognizable.
Structure : Foliated structure; perfect slaty cleavage.	Structure : Foliated structure, foliation better than slate, cleavage poor.	Structure : Highly foliated schistose structure and flaky minerals irregularly parallel
Composition : Minerals recognized only under microscope (or possibly not); chiefly of clayey material.	Composition : Same as slates; but mica flakes increase in number and size and give shining appearance to the cleavage surfaces.	Composition : Micaceous minerals dominate ; porphyroblast of some minerals may be present. Chiefly Muscovite, Chlorite, Sericite, Garnet, Tourmaline etc.