Component-I (A)- Personal Detail

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Component-I (B) Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Geomorphology**
Module Name/Title	**Rocks: Types and Formation Processes**
Module Id	**GEO-26**
Pre-requisites	**Mountain Building, Volcanoes, Constitution of the interior of the earth, Karst Topography, Glacial and periglacial landforms.**
Objectives	**Total Four**
Keywords	**Primary Rocks, Extrusive Rocks, Intrusive Rocks, Tuffs, Plutonic Rock, Pyroclastic Rock, Granite, Basalt, Andesite, Sedimentum, Loess, Argillaceous Rocks, Regional Metamorphism, Rock Cycle**

Rocks: Types and Formation Processes

The earth's crust is made of rocks which may be hard or soft, and may have varied colours. The word rock has different meaning to different people. For example, for an engineer the rock is a material which can be blasted to make dames, roads and so on; a builder equates it with a hard resistant building material. Similarly a layman can imagine rocks as the pebbles on beach. However, geologists define a rock as a **collection of mineral grains** (Alam and Mohammad, 2008).

In the present module we are going to discus about following aspects of rock:

(A) Igneous Rocks

(B) Sedimentary Rocks

(C) Metamorphic Rocks

(D) Rock Cycle

On the basis of mode of formation, rocks may be grouped into the three families i.e., (A) Igneous Rocks; (B) Sedimentary Rocks and ; (C) Metamorphic Rocks. Let us discuss each one in detail.

(A) IGNEOUS ROCKS

The term 'igneous' is derived from the Latin word 'ignis' means fire. Igneous rocks are formed through cooling, solidification and crystallisation of molten materials i.e. magma. They are sometimes called as **primary rocks** these rocks were organised first of all the rocks at the time of origin of earth and especially during the formation of lithosphere. In other words, igneous rocks represent the rocks from which all other rocks directly or indirectly have been derived. That is why these rocks are also called as **parent rocks**. Igneous rocks are characterised as the **hardest rock** as resistant to weathering, fine to coarse grained texture with absence of fossils and no strata like sedimentary rocks.

Classification of Igneous Rocks

1. Classification on the Basis of Mode of Occurrence

Igneous rocks can be divided into groups depending upon the conditions under which they solidify. One group is termed as **extrusive rocks** and another one is **intrusive rocks**. These groups of igneous rocks are discussed as follows:

1.1 Extrusive Rocks

Extrusive rocks are those rocks which have are ejected from a volcano or some other vent and are accumulated and solidified **on the surface of the earth.** These rocks may be further subdivided into two parts on the basis of the way of eruption.

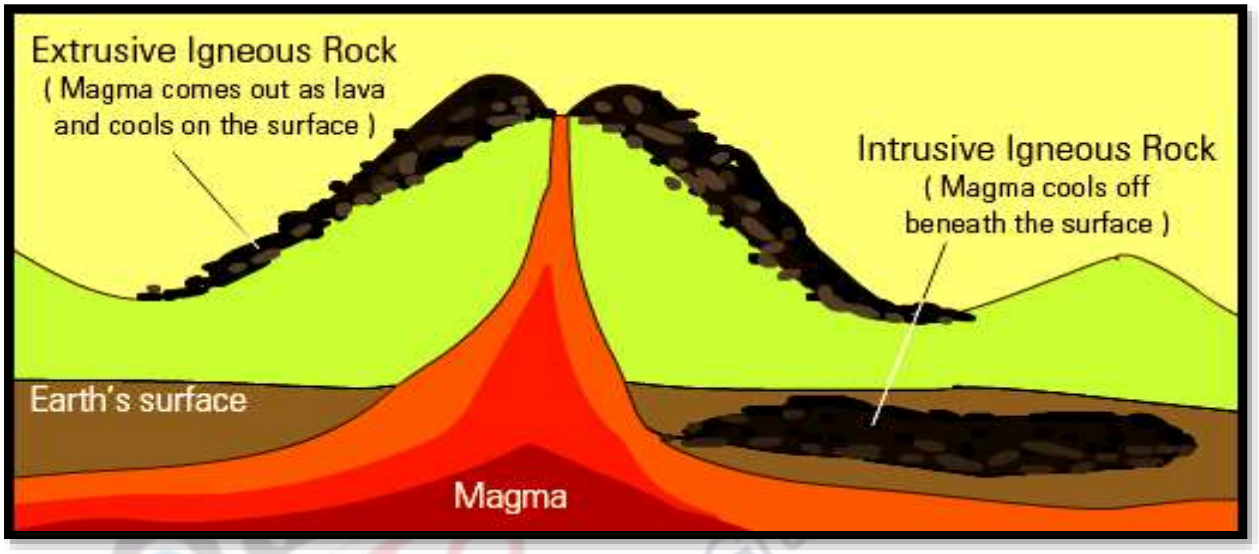

Figure 1: Mode of Occurrence of Igneous Rocks

1.1.1. Explosive Type

Explosive type of volcanic eruption ejects accumulated gases and lavas which are **thrown violently into the air**. Volcanic materials include bombs which are big fragmented rocks; those about the size of a walnut are lapilli and very fine materials are called ash or volcanic dusts. Fine volcanic materials when deposited in aquatic condition, are called **tuffs**. **'Breccia'** or 'agglomerates' are formed after deposition of coarse and fine materials.

1.1.2. Quiet Type

The molten materials come out through **minor cracks** on the earth's surface which is called lava flows. It may happen that the successive flows give rise to layers of lavas after being piled one on another. These lavas after being cooled and solidified from form **basaltic igneous rocks**. Such kind of flood basalts is formed by several episodes of lava flow during fissure flow of volcanic eruption that further forms lava plateaus and lava plains.

1.2. Intrusive Rocks

The rising magma solidifies below the earth's surface during a volcanic activity and remains surrounded by older, pre-existing rocks, is called intrusive rocks. They further sub-divided into two major groups on the basis of depth and place of cooling:

1.2.1. Plutonic Igneous Rocks

They are formed due to cooling of magmas at **deep inside** the earth where surrounding rocks totally covers the hot magma and consequently slow down the rate of cooling. Due to the situation at the greater depth, magma may require many thousands of years for complete cooling and the mineral crystals in the rocks can grow to relatively larger size that can be seen with naked eye.

1.2.2. Hypabyssal Igneous Rocks

When the rising magmas are come just below the surface of the earth from the interior with the cracks, pores crevices and hollow places during the volcanic eruption, the resultant cooled and solidified rocks are known as hypabyssal igneous rocks or volcanic rocks. The mineral crystals in volcanic rocks are so small as to be invisible without microscopic inspection. **Black or dark grey coloured** and fine grained basalt rock is the suitable rocks examples of hypabyssal igneous rocks. There are some important forms of these rocks according to the solidification depending on hollow places such as **batholiths, laccoliths, phacoliths, lopoliths, sills, dykes, necks** etc. For detail you can also refer module number 11 Volcanoes.

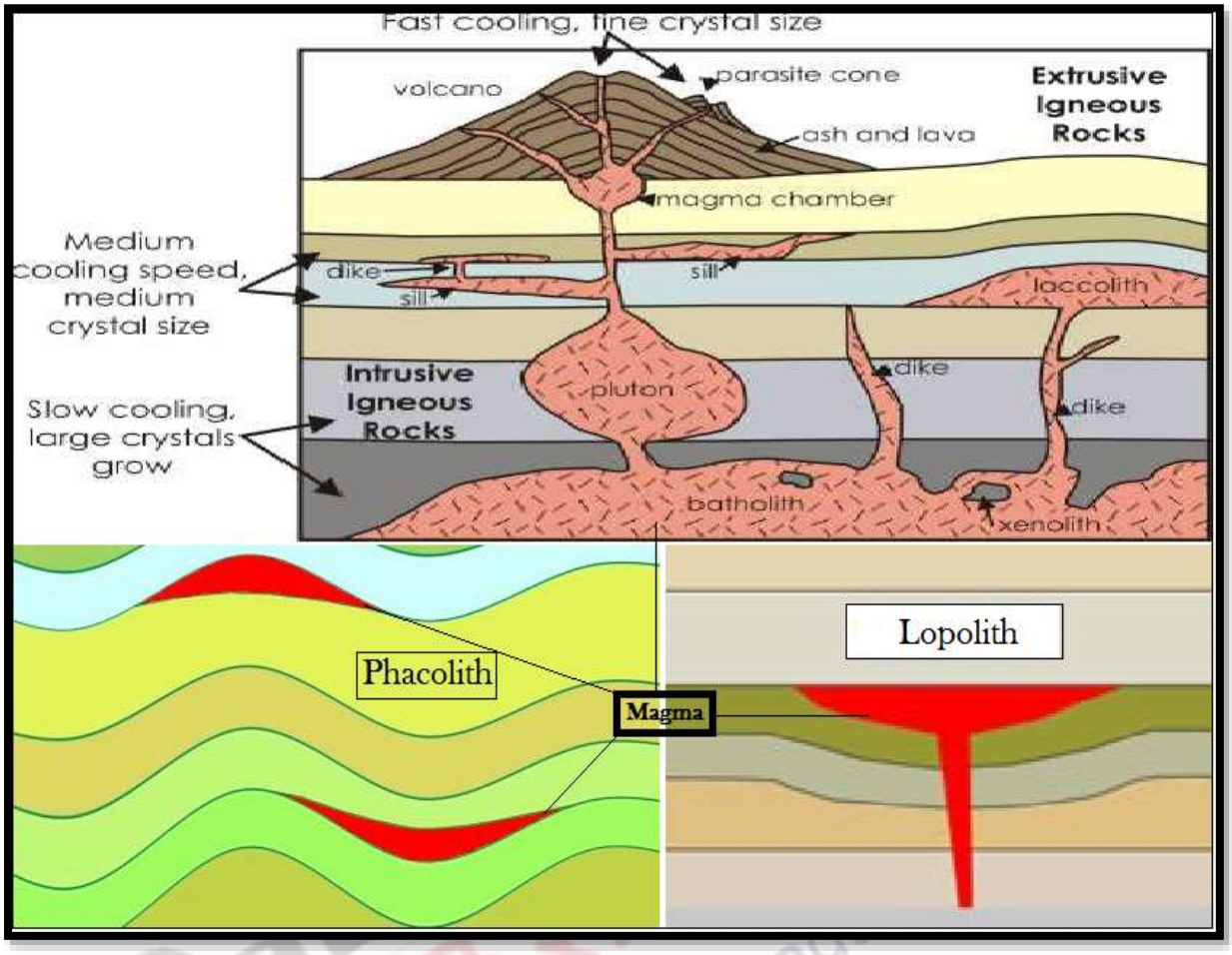

Figure 2: Intrusive Igneous Rocks on the Basis of Mode of Occurrence

2. On the basis of texture, igneous rocks can be divided into five parts such as:

2.1. Glassy Igneous Rocks

They are characterised by general absence of grains and is produced by very fast cooling of magma on surface of the earth. Obsidians, pitch stones, pumice perlite etc. are the most common example.

2.2. Aphanitic Igneous Rocks

The word ‘aphanitic’ has been derived from a Greek word ‘phaneres’ meaning thereby visible. These rocks are characterised by small grains that can be visible without a microscopic vision. Basalt, felsite and the rocks of sills and dykes are the example of this category.

2.3. Phaneritic Igneous Rocks

These rocks contain grains that is enough large to see it without microscope. As the equal size and form of grains, the equigranular texture represents a uniform rate of cooling and the large size of the crystals. For example, coarse grained and plutonic igneous rocks are such as granite, diorites etc. (See Figure 4).

Figure 3: Igneous Rocks on the Basis of Texture

2.4. Porphyritic Igneous Rocks

Porphyritic rocks contain two types of grains with different sizes. These are found two stages of cooling. In initial stage, the rate of cooling is slow resulting larger crystals but in next stage, the rate of cooling is faster than earlier that forms smaller crystals. Porphyritic texture occurs in both aphanitic and phaneritic rocks. For example, basalt, granite, felsite, diorite etc.

2.5. Pyroclastic Igneous Rocks

The word ‘pyroclastic’ has also been derived from the Greek word ‘klastos’ meaning thereby broken. These rocks are characterised by broken and fragmented rather than the interlocking or interconnected crystals. Such type of igneous rock constitutes bombs, lapilli, breccia, volcanic dusts, ashes, tuffs etc.

3. Classification of Igneous Rocks on the Basis of Chemical Composition

The dominant chemical present in igneous rock is silica (SiO2). Igneous rocks are divided into four types on the basis of silica content such as:

3.1. Acid Igneous rock

In these rocks, silica content ranges between 65 to 85 per cent and average density ranges between 2.75 to 2.8. Acid igneous rocks are composed of Quartz, white and pink feldspar. The most predominant example of such type of rock is granite (See Figure 4).

3.2. Basic Igneous Rocks

In these rocks, silica content ranges between 45 to 60 per cent and the average density varies between 2.8 to 3.0.These rocks are heavy and dark coloured because of the dominance of iron content. The significant examples are basalt, dolerite, gabbro etc. (See Figure 4).

3.3. Intermediate Igneous rocks

Silica content in these rocks is less than the amount present in the acid igneous rocks but more than basic igneous rocks. The most dominant rocks of this group are diorite and andesite (See Figure 4).

3.4. Ultra- Basic Igneous Rocks

These rocks contain less than 45 per cent of silica but their average density differs from 2.8 to 3.8 that mean the highest average density is found in this group of igneous rocks. Peridotite is the representative of this group of rocks.

Some Important Igneous Rocks and Their Distribution

Granite

The granite is a coarse grained plutonic intrusive rock which is formed deep within the earth. Since the rate of cooling and solidification of magmas inside the earth is very slow because of very high temperature prevailing underground and hence granites become coarse grained. According to chemical composition, granites are acidic rocks whereas silica content ranges

between 65 to 85 per cent. These rocks are generally light in weight as their density varies from 2.7 to 2.8.

Table 1: Mineral Composition of Granite

Sl. No.	Minerals	Percentage
1	Feldspar	52.3
2	Quartz	31.3
3	Mica	11.5
4	Hornblende	2.4
5	Iron	2.0
6	Others	0.5
7	**Total**	**100**

Source: *Physical Geography* by Savindra Singh

Rhyolite: It is the extrusive equivalent of granite and likewise, is composed essentially of light coloured silicates. This rock is fine grained and frequently contains glass fragmented and voids indicating rapid cooling in a surface environment.

Basalt

It is a very fine grained dark extrusive igneous rock which is formed due to cooling and solidification of molten lavas at the surface of the earth. Basaltic rocks contain a high percentage of dark silicate minerals, so geologists also refer to them **mafic**. If basalt is having small grains rather than minute, are called aphanitic basalt. Chemically basalt contains 45 to 65 per cent of silica content. Basaltic rocks are typically darker and denser than granitic rocks.

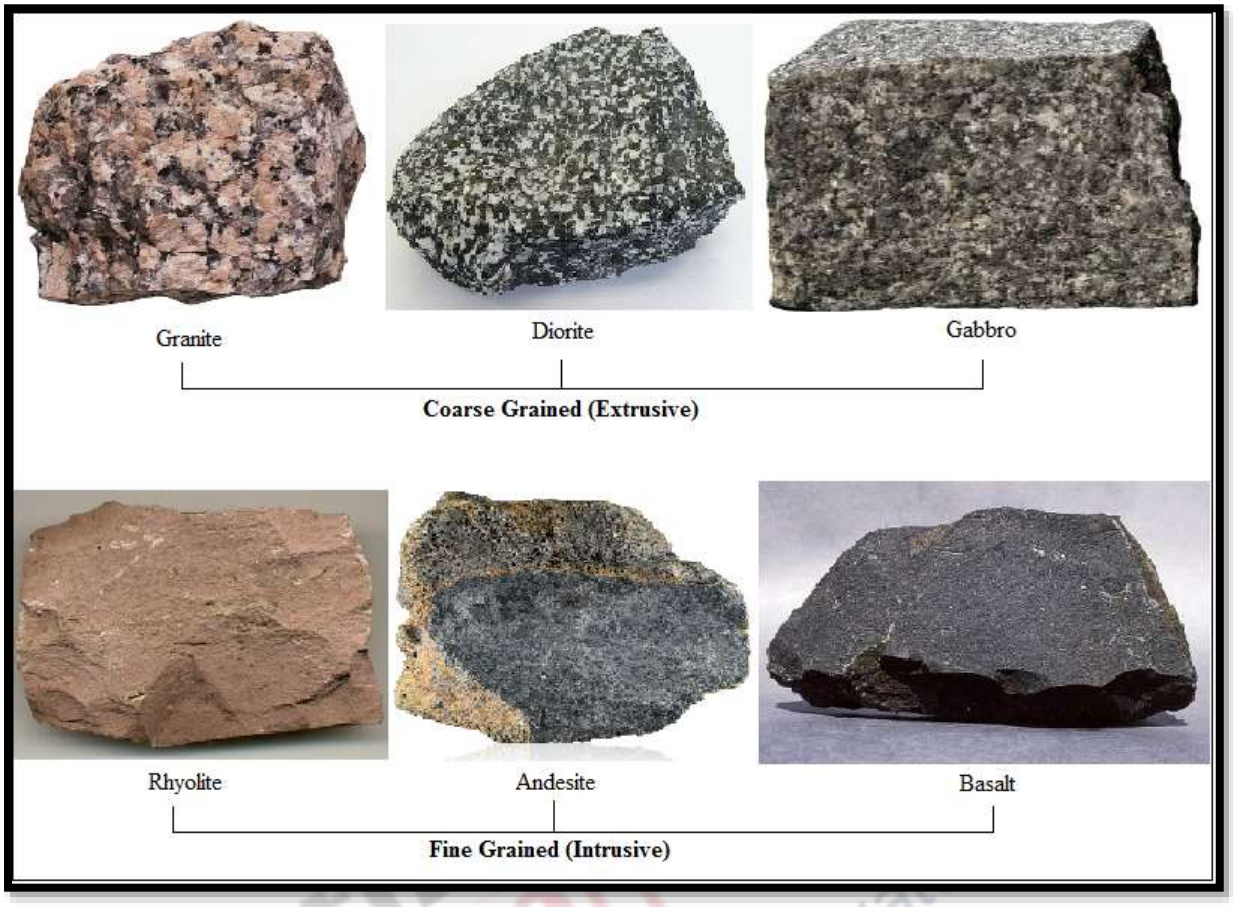

Figure 4: Some Important Igneous Rocks on the Basis of Texture and Composition

Table 2: Mineral Composition of Basalt

Sl. No.	Minerals	Percentage
1	Feldspar	46.2
2	Augite	36.9
3	Olivine	7.6
4	Mineral Iron	9.3
5	**Total**	**100**

Source: *Physical Geography* by Savindra Singh

Due to cooling of lavas, polygonal cracks are developed in basalts where it give birth peculiar uneven landforms. Many volcanic Islands such as the Hawaiian Islands and Iceland are composed mainly of basalt.

Gabbro: The coarse grained intrusive equivalent of basalt is gabbro. Although gabbro is not commonly exposed at the surface, it makes up a significant percentage oceanic crust. Olivine may occur in considerable amount but biotite and hornblende are rarely present in gabbro.

Andesite

It contain a mixture of both light and dark coloured minerals mainly amphibole and plagioclase They are typically confined to continental margins.

Diorite

When magma of intermediate composition are crystallised at depth, it forms the coarse grained rock called as diorite. Diorites are composed of hornblende and various feldspars.

(B) SEDIMENTARY ROCKS

The word 'sedimentary' has been derived from Latin word **'sedimentum'** which means 'settling down'. The word settling down indicates of solid minerals into a fluid. Most of the sediments are deposited in this fashion. According to **P.G Worcester** (1948), "Sedimentary rock, as the word sediment implies, are composed largely of fragments of older rocks and minerals that have been more or less thoroughly consolidated and arranged in layers or strata."

According to the geologists, sedimentary rocks account for only **5 per cent of earth's surface** or 16 kilometres (10 miles) of outer earth's surface. Each and every alluvial plain on the global earth's surface is **agriculturally more prosperous** than igneous and metamorphic rocks. For example, Indo-Gangetic plain in India, Nile River plain in Egypt, Mississippi-Missouri Plain in North America, Amazon River plain in South America, Hwang Ho-Yangtze Si Kiang plain in China, Rhine River valley in Europe, Murray- Darling valley in Australia etc. Many sedimentary rocks are also economically important. Coal is burned to generate and provide energy. Other major resources like petroleum and natural gas are found in pores within sedimentary rocks. Iron, aluminium and manganese are used in construction while fertilizers are used in agriculture. It contains fossils which can be used as vital evidence in the study of past. Sedimentary rocks contain most of the earth's groundwater aquifers which are very essential for life sustenance.

Classification of Sedimentary Rocks

1. On the Basis of the Nature of Sediments

1.1. Mechanically Formed or Clastic Rocks

The rocks of the lithosphere are decomposed and broken up by mechanical agents like water, wind, glaciers etc. Fragments of many different kinds of rocks and minerals accumulate on

the earth's surface in the form of soils, dust and coarser fragments with variable size and shape. These fragments are classified into **five** different rocks with respect to their size, shape and contents.

1.1.1. Sandstone

Sandstones are formed mostly due to deposition, cementation and consolidation of sand grains. These rocks are composed of quartz grains. On the basis of their size they can be divided into following categories.

Table 1: Classification of Sands by Grain Size

Sand Types	Grain Size (mm)
Very Coarse Sand	1.0 to 2.0
Coarse Sand	0.5 to 1.0
Medium Sand	0.25 to 0.5
Fine Sand	0.125 to 0.25
Very Fine	0.625 to 0.125

Source: *Physical Geography* by Savindra Singh

1.1.2. Conglomerates

These rocks are also composed of coarser sand grains with pebbles and boulders of varying sizes. The term '**conglomerate'** is applied to cemented fragmental rocks containing rounded fragments such as pebbles and boulders; if the fragments are angular in shape, the rock is called **breccia**. When the rounded fragmented materials are cemented by quartz, the resultant rocks become conglomerates.

1.1.3. Clay Rock

Clay rocks are formed due to the deposition and cementation of sediments. These rocks are composed of fine grains with the size of 0.03 mm to 0.004 mm are called silts whereas, clays are formed when the sediments of the grain size of 0.004 mm to 0.00012 mm are cemented and consolidated. Both the rocks are impervious but they are soft. Clays are composed of almost entirely of kaolin.

1.1.4. Shale

Shales are formed of laminae which are easily separated. These rocks are impure clays which contain a considerable proportion of minerals other than kaolinite.

1.1.5. Loess

It is very fine grained materials which are deposited by wind on the land. These rocks are very poorly stratified that means there is an absence of layers. The colour varies from light brown to dull yellow. A peculiar property of loess is its ability to stand vertical cliffs. Loess is generally poorly consolidated are **very prone to erosion**. Due to its finely divided condition and to the remarkable wealth of soluble mineral plant foods which it contains, loess soils are very fertile.

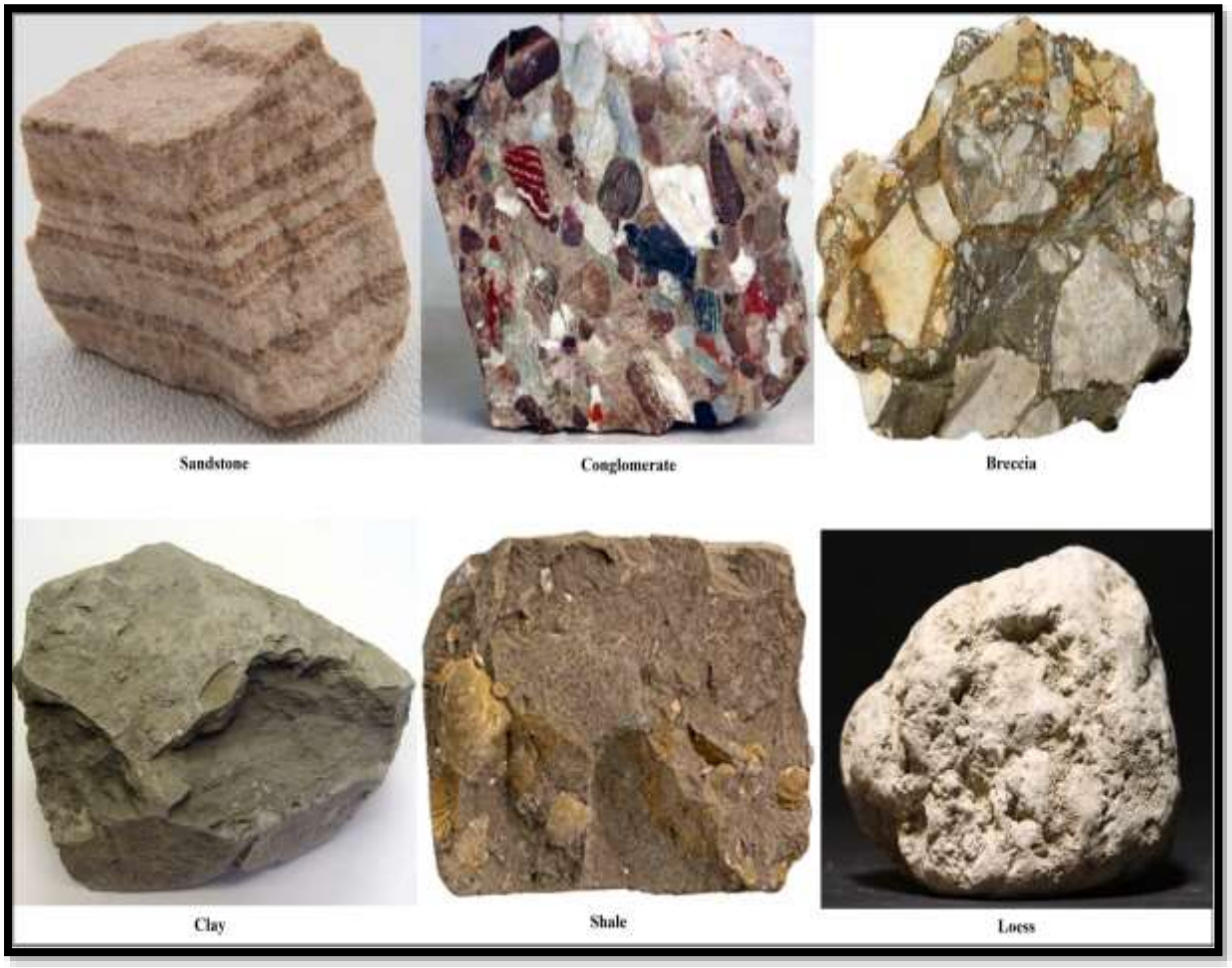

Figure 5: Representation of Different Mechanically Formed or Clastic Sedimentary Rocks

1.2. Chemically Formed Sedimentary Rocks

Chemical materials are contained by running water. When such chemical active water comes in contact with the continental rocks, soluble materials are removed from the rocks. These materials are called chemically formed sediments. For example, gypsum and salt rock.

Figure 6: Representation of Different Chemically Formed or Non-Clastic Sedimentary Rocks

1.3. Organically Formed Sedimentary Rocks

These rocks are formed due to disintegration and decomposition of sediments by bot animals and plants. These sediments after being deposited and consolidated form organic sedimentary rocks. On the basis of lime and carbon content, these rocks are divided in three groups.

1.3.1. Calcareous Rocks

These rocks are firmed by sediments which are derived from the skeletons and remains of those animals and plants containing large portion of lime. For example, **Limestone and Chalk.**

Figure 7: Types of Calcareous Rocks

Figure 8: White Chalk Cliff, East Sussex, England

1.3.2. Carbonaceous Rocks

Unlike other sedimentary rocks groups, these are direct vegetation origin. These rocks are formed due to transformation of vegetation because of their burial during earth's movement and consequent weight and pressure of overlying deposits. Finally this results different grades of coals. For example, Peat, Lignite, Bituminous and Anthracite.

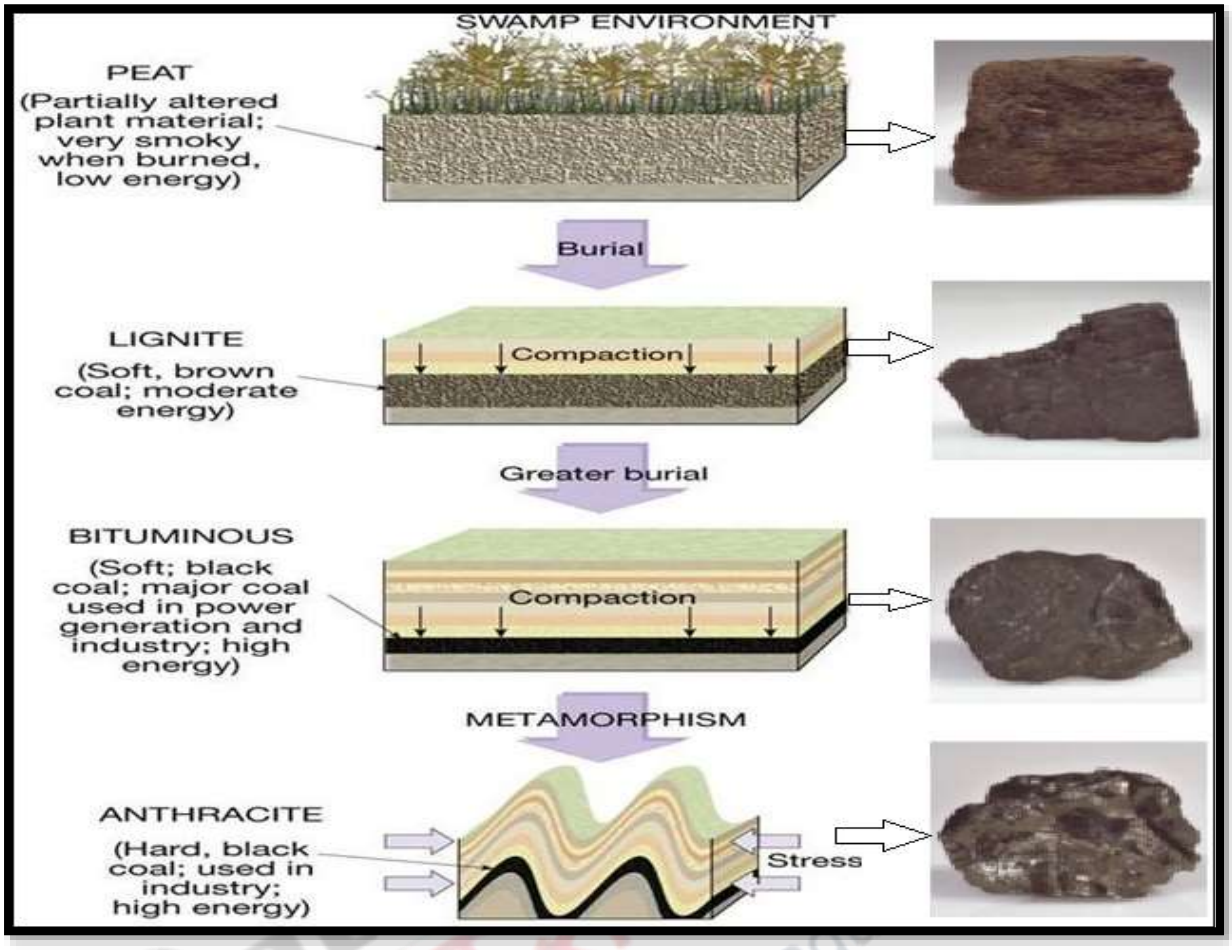

Figure 9: Different Grades of Coal in Successive Stages of Coal Formation

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Coals are also found in stratified layers wherein coal layers are known as Coal Seams. Carbonaceous rocks are more important economically than geographically.

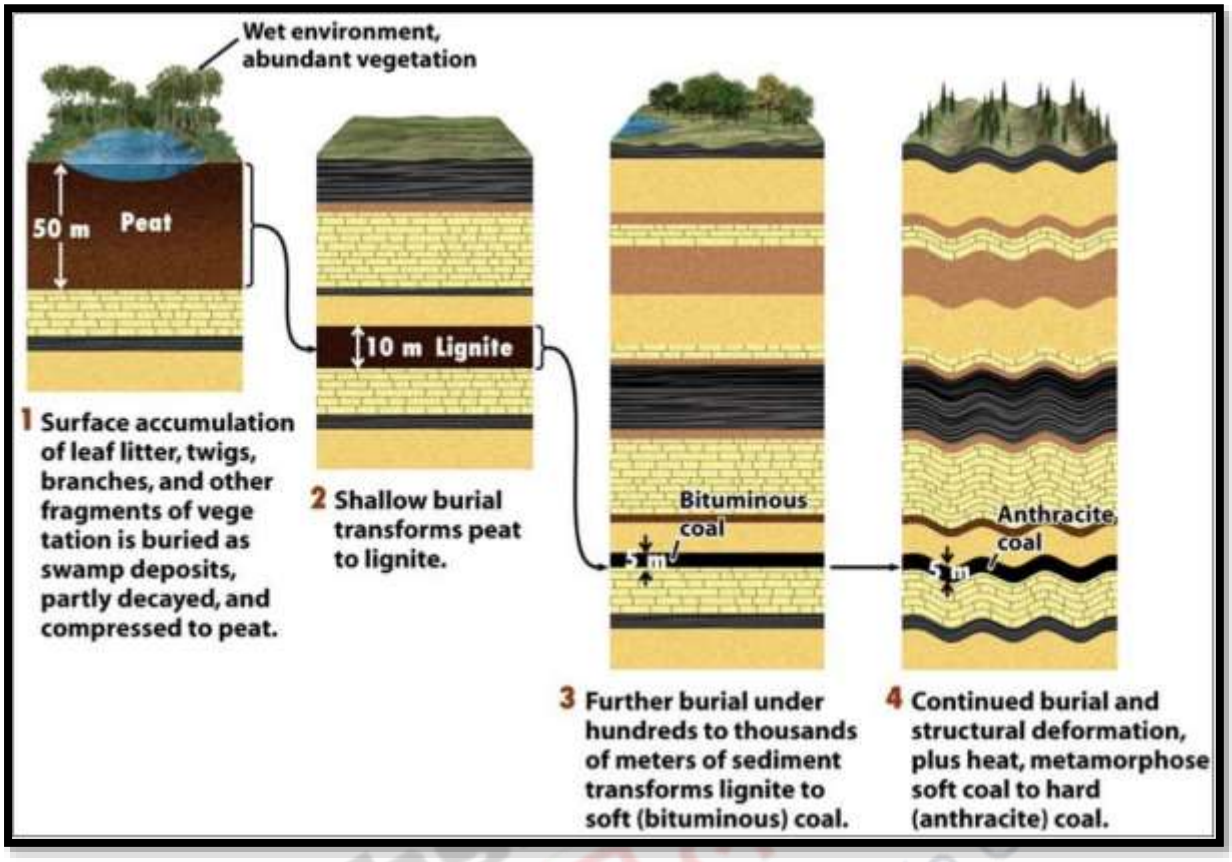

Figure 10: Coal Formation and its Depth of Occurrence

1.3.3. Siliceous Rocks

These rocks are formed due to dominance of silica content. Diatomaceous or infusorial earth is a loose in structure and white or grey or brown in colour in colour. Siliceous rocks are formed due to aggregation and compaction wastes derived from sponge, radiolarian organisms and diatom plants. Geyserite is the best example of these groups of rocks.

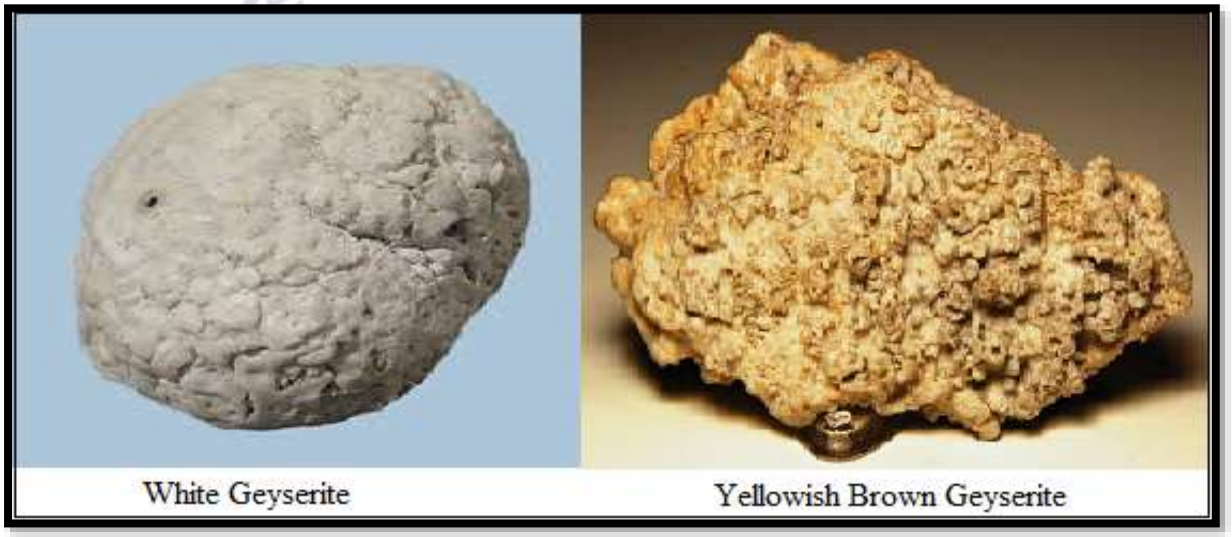

Figure 11: Types of Geyserite Rocks

2. Classification on the basis of Transporting Agents

2.1. Argillaceous Rocks

These rocks are also called as aqueous rocks due to their formation in water. Aqueous rocks become argillaceous because of dominance of clay in the rocks. These rocs are characterised by softness and imperviousness. It is further subdivided into three subdivisions i.e., Marine Argillaceous Sedimentary Rocks, Lacustrine Argillaceous Sedimentary Rocks and Riverine Argillaceous Sedimentary Rocks

2.2. Aeolian Sedimentary Rocks

These rocks are the result of deposition of sands which are brought down by the wind. They are formed with the absence of layers. Loess is the most important example.

Loess

It is formed due to the accumulation of fine materials of sands. In these rocks, water can easily percolate due to porousness. The most important characteristic of loessic rocks is that the entire mass may stand like a vertical cliff or wall. The most extensive loessic deposits are found in North China where the Yellow River (Hwang Ho) and its tributaries are the representators of loessic rocks. In India, the best example of loessic rocks is found on both banks of phaleochannel and valley of the Narmada River at Dhunwadhar falls (Bheraghat) near Jabalpur (Madhya Pradesh) where the loessic banks rise 20 to 25 m from the valley floor.

Figure 12: Loessic Plateau along the Yellow River (Hwang Ho), North China

2.3. Glacial Rocks

Fine to coarse sediments are deposited by glaciers and thus, it is called glacial rocks. These rocks are further subdivided into four subdivisions. Lateral Moraines, Medial Moraines, Ground Moraines and Terminal Moraines. For detail refer “module 23 Glacial and Periglacial Landscapes”.

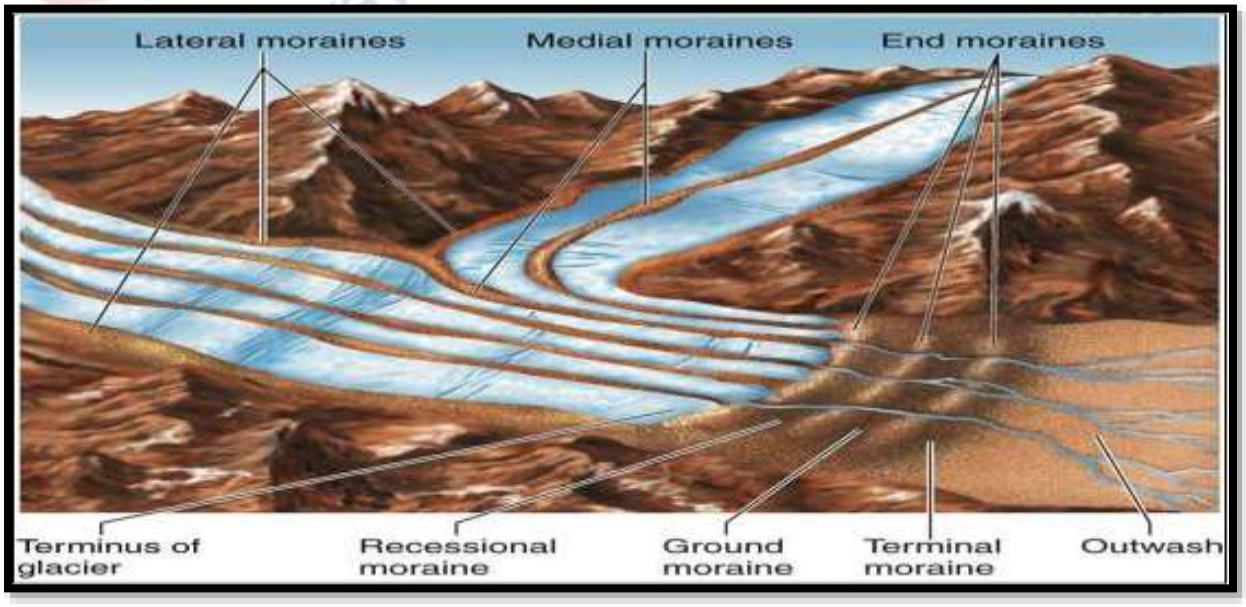

Figure 13: Types of Glacial Moraines

(C) METAMORPHIC ROCKS

Formation of Metamorphic Rocks and Metamorphism

Earth is an active and dynamic planet. Rocks once are buried at the great depth of the earth's surface, they may be deformed and their temperature may be changed as a consequence of burial or by the intrusion of hot magmas. After such changes in the surrounding condition of rocks, the characteristics of the rocks commonly become modified with undergoing metamorphism and finally transformed into metamorphic rocks. It is sure that changes in temperature and pressures the causes of rocks in metamorphism but they are not the only ones. Changes may be occurred as a result of changes in chemical composition. In this case, changes are most commonly associated with the movement of fluids combination like carbon dioxide (CO2) and water (H2O).

Metamorphism often progresses slowly from slight changes (low grade metamorphism) to substantial change (high grade metamorphism). For example, under low grade metamorphism, sedimentary rock like shale becomes the more compact metamorphic rock slate.

Agents of Metamorphism

There are some important influential factors which help rocks to be metamorphosed. The degree of metamorphism and the role of factors differ greatly from one environment to another.

Heat: High temperature is one of the obvious causes of rock metamorphism. It accelerates the chemical reaction that leads to the **recrystallization of existing minerals** and formation of new minerals. For example, limestone is recrystallized in the solid state but the rock is not melted however, only the mineral or textural changes take place that results into marble (CaCO3). In contrary to this, some rocks are not stable at higher temperatures because of containing so much water and break down to form new minerals, for instance, clay is transformed into mica. Pre-existing rocks experience an elevation in temperature when they are intruded by magma coming from below, is called contact or thermal metamorphism. The temperature increases with the depth of the earth's surface. So, the minerals of rock start becoming unstable which further leads to recrystallization into other minerals.

Pressure: Metamorphism is not purely thermal as pressure is another important factor in the process of metamorphism. Greater pressure in rocks consolidates mineral grains and produces a more compact rock with greater density. Bounding pressure at the greater depth may cause minerals to recrystallize into new minerals displaying more compact crystalline forms. In Mountain building process the differential stress deforms rocks.

Chemical: This become active when they are in contact with water. If it is hot water passing through rocks eat the greater depth of the surface then it is called hydro-thermal solutions which dissolve some materials and deposits in some other places. Such kind of solutions acts as accelerator to promote recrystallization by enhancing **ion migration from one chemical to another.** Chemical reaction is more advanced in hot environment where the solutions or fluid supply OH^{-2} (the hydroxyl ion) for the creation of certain key minerals like chloride and antinolite. For example, after being contact with water, asbestos forms serpentine.

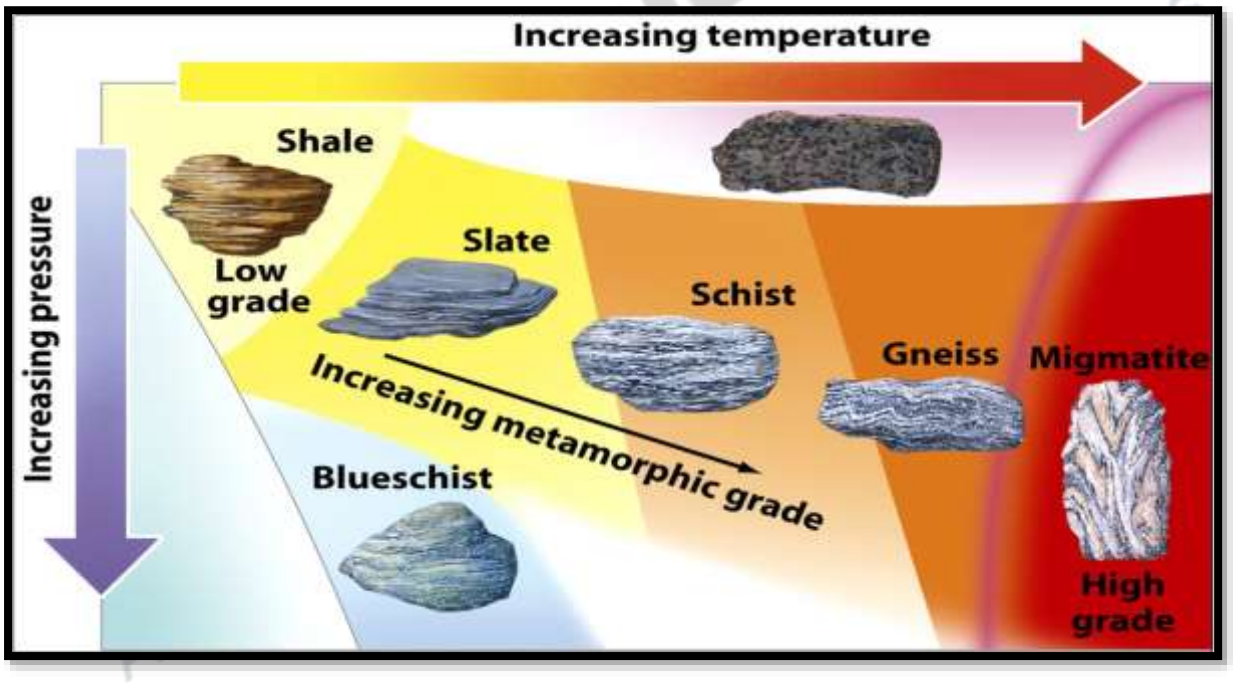

Figure 14: Grades of metamorphism

Types of Metamorphic Rocks

1. Classification on the basis of place of occurrence

1.1. Contact Metamorphism

Such metamorphism happens when the mineral composition of surrounding rocks is altered due to high temperature of ascending magma. It is also known as thermal metamorphism. The best example is limestone which is altered to marble because of contact metamorphism. The area between the altered rocks and intruded magma is called **aureoles.**

1.2. Regional Metamorphism

When pressure is dominant to change the forms of rock in extensive area, the process is known as regional metamorphism. This process is also known as dynamic metamorphism. Apart from pressure, temperature is also active in changing the forms of rocks. Both pressure and heat change the original form of sedimentary rock leading to folding during mountain building. Consequently, rocks are crystallized and crystallized can be further recrystallized by greater pressure and heat.

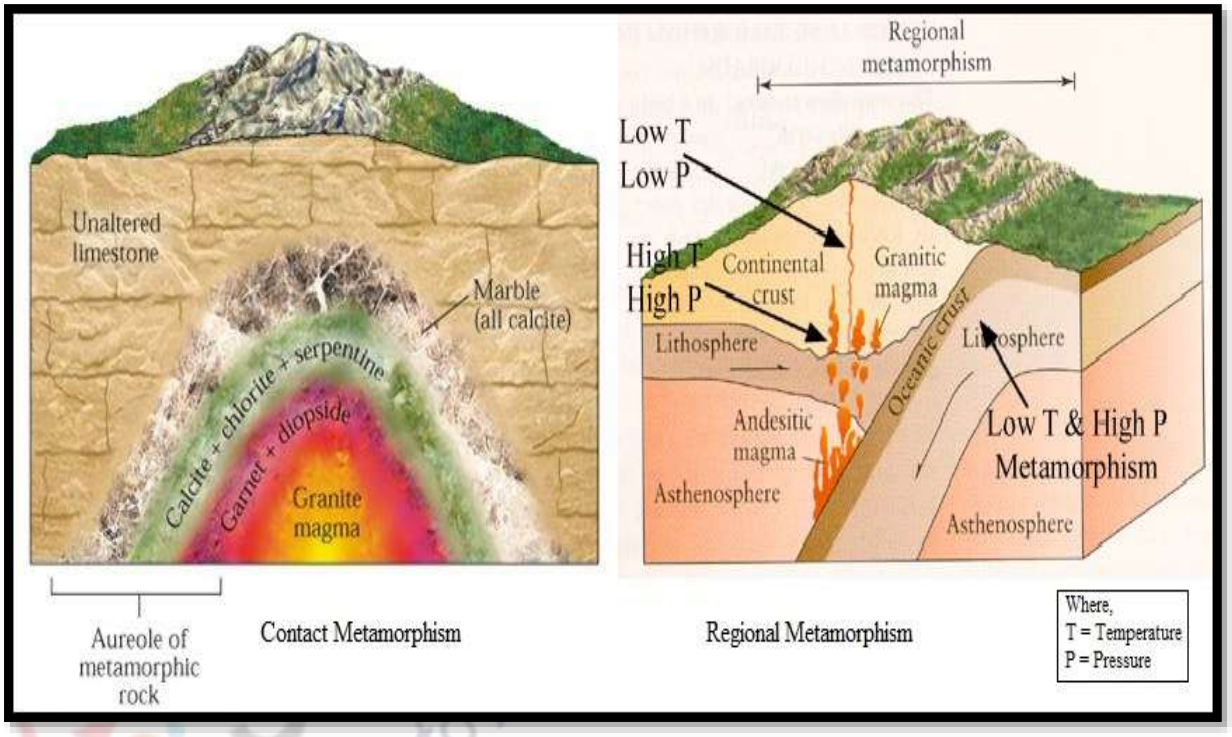

Figure 15: Contact Metamorphism and Regional Metamorphism

2. Classification on the basis of foliation or structure

2.1. Foliated Rocks

The term foliation comes from the Latin word ‘leaf’ (as the parallel leaves or pages of a book) thereby characterises as the nearby flat arrangement of minerals in a rock. Foliation may develop in both igneous and sedimentary rocks. Granite among igneous rocks can be metamorphosed in the similar foliation process to become granitic gneiss.

2.1.1. Slate:

It is composed of very fine grained **mica flakes** which are too small to be visible. Under the higher temperature, some of the clay minerals become unstable and break down to form new phyllosilicates. The most important characteristic is that it has excellent rock cleavage that

can be broken down into flat slabs. Slate is produced by the low grade metamorphism of shale.

2.1.2. Schist:

Schists are platy that split into thin flakes or slabs very easily while this process is called schistosity or schistose structure. Coarse grained minerals like Muscovite and biotite are the composition of mica schist.

2.1.3. Gneiss:

This rock is composed of medium and coarse grain minerals in which there may be a limited or partial development of schistose structure that often give rise to a layered or lenticular structure. The most predominant minerals of gneiss are feldspar, quartzite, muscovite, biotite and hornblende.

Figure 16: Different types of foliated rocks

2.2. Non Foliated Rocks

Unlike foliated rocks, non foliated rocks form under constant pressure but a minimum deformation takes place and the parent rocks are composed of mineral crystals like quartzite or calcite. For example, when a limestone composed of fine grained calcite is heated by the intrusion of magma, the fine grains recrystallize to form larger interlocking crystals producing marble with large equidimentional grains which are actually randomly oriented.

2.2.1. Marble:

It is characterized by coarse grained crystalline rock which originates from limestone. It is discussed earlier that marble is made of large interlocking calcite crystal that was in the form of smaller size in limestone. Marble is useful as building stone due to its colour and relative softness. For example, Taj Mahal in India and Lincoln Memorial in Washington D.C. are the important exhibition of white marble.

2.2.2. Quartzite:

This rock is composed of more than 80 per cent of quartz because the parent rock is quartz sandstone. The another important characteristic of this rock is that this is very hard metamorphic rock due to the high grade of metamorphism in which quartzite grains in parent rock blend. The colour of pure quartzite is white while iron oxide may exhibit reddish or pinkish marks and grey colour is because of dark minerals.

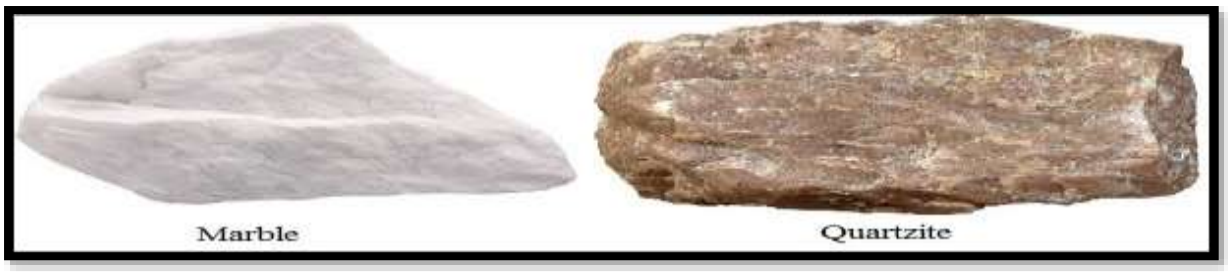

Figure 17: Different types of non-foliated rocks

(D) Rock Cycle

The cycle starts with molten materials like magma which comes from below the earth's surface and reaches to it subsequently. Magma occasionally erupts with the help of weak surface or fracture and high pressure of interior. Eruption results lava after cooling and solidifying of magma. This process is called crystallization that can occur both beneath the earth's surface and over the earth's surface. The resultant rocks are called igneous rocks.

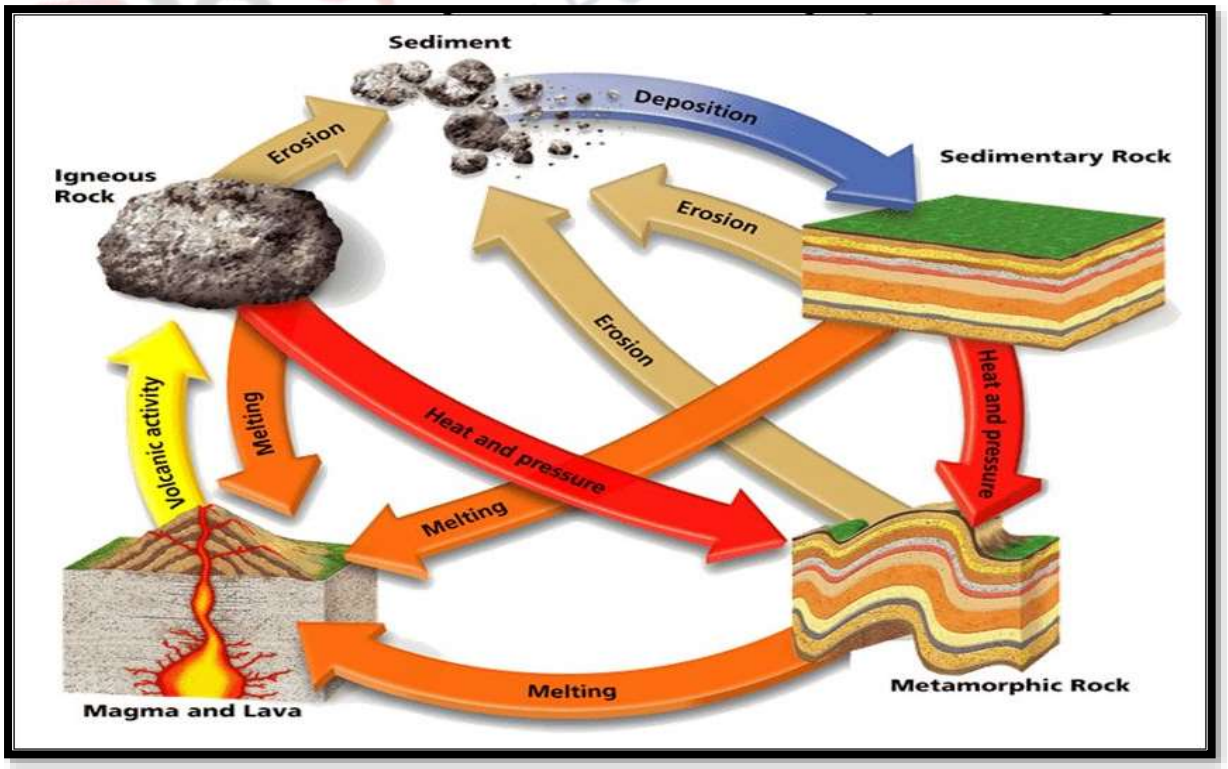

Figure 18: Rock Cycle

These rocks begin to be eroded when they are influenced by erosional agents like water, wind, glacier etc. and subsequently, hard rocks are decomposed and disintegrated slowly. The loose particles move downslope from one place to another with the help of erosional agents and deposited depressions including oceans, river flood plains, swamps, desert basins etc. Sediments become sedimentary rocks under lithification process. If sedimentary rocks are being involved in mountain building, these rocks have to face great pressure and heat resulting metamorphic rocks. The resultant rocks may face either more heat or erosional agents that can produce magma or sediments respectively and automatically, the cycle can start again.