Metamorphic rocks

Metamorphic rocks are created by changes induced at high temperature (up to about 600°C) and/or high pressure (around 500 Mpa at 20 km depth). These changes (metamorphism) take place in the solid state.

The type of metamorphic rock produced depends on the original rock material that was metaporphosed and the temperature and pressure conditions which were imposed.

Agents of metamorphism

The agents which bring about metamorphism of rocks are as follows:

- **Physical agents:** Heat, uniform pressure, and directed pressure.
- **Chemical agents:** Chemically active water and gases.

Types of metamorphism

Depending upon the dominance of one or the other of the above agents, the metamorphism has been classified as follows

1. Thermal metamorphism
2. Dynamothermal metamorphism
3. Cataclastic metamorphism
4. Metamorphism
5. Regressive metamorphism

Thermal metamorphism

In thermal metamorphism the changes brought about in rocks are mainly due to heat, but heated magmatic waters or vapours carrying mineral matter in solution also play important part. When the thermal metamorphism occurs in the immediate vicinity of igneous intrusions, it is called "*contact metamorphism",* and when it occurs on a regional scale at depth, it is called *"plutonic metamorphism".*

By thermal metamorphism clays and shales may change into porcellanite, hornfelse, even mica-schist, while sandstone and limestone may form quartzite and marbles.

Dynamothermal metamorphism

This type of metamorphism is also called *"regional metamorphism".* It is caused when both directed pressure and heat act together. It leads to more or less complete Recrystallisation of rocks combined with the production of new structures.

The directed pressure involved movement and shearing, and therefore, it is the main factor in forming *foliated, banded* and *cleavable* rocks. The new minerals are muscovite, biotite chlorite, talc, amphiboles, kyanite etc. The foliated rocks include slates, phyllites, schist, and gneisses. Dynamothermal metamorphism takes place in fold mountain regions.

Cataclastic metamorphism

In this type of metamorphism mainly directed pressure of stress predominates. The stress produces shearing movements in the rocks and causes crushing, granulation, and powdering. Therefore, the cataclastic rocks show mainly mechanical breaking with little new minerals formation. Cataclastic metamorphism occurs in the higher levels of the earth's crust where rocks are mostly and brittle. Examples of cataclastic rocks are mylonites and fault breccia.

Metasomatism

The metasomatism replacement of rocks is brought about by deposition from hydrothermal solutions (hot magmatic waters). The replacement takes place molecule by molecule so that as new mineral is added, the old is removed and the volume of the rock remains unchanged. The new rock frequently produces all the textural details of the original rock. The metasomatism replacement is often accompanied by deposition of metallic ores.

Metasomatism replacement is commonly found associated with carbonate rocks as limestones and dolomite which are easily dissolved and replaced by silica, iron ore, or other minerals.

Regressive metamorphism

By orogenic movements, an intensely metamorphosed rock such as schist may be transferred from a region of plutonic metamorphism (ketazone) to epizone, where normally low grade metamorphic rocks (like slates and phyllites) are formed. In due course of time the schist may change its characters appropriate to its new environments, and may convert itself into phyllite. This process is called *"regressive metamorphism".*

Metamorphic zones

The degree or intensity of metamorphism generally increases with depth because as the depth increases temperature and pressure also increase. From the earth's surface downwards there are three metamorphic zones

i) Epizone or upper zone
ii) Mesozone or intermediate zone
iii) Katazone or lower zone

Epizone

The epizone lies near the earth's crust surface where temperature is low (300°C) and directed pressure is high. In this zone cataclastic metamorphism takes place. The alteration in rocks is weak and phylliytes are the typical rocks.

Mesozone

It is an intermediate zone where temperature is of the order of 300°C to 500°C. The directed pressure is also high and therefore, dynamothermal metamorphism takes place. Schists are the typical rocks of mesozone.

Ketazone

It is the bottom zone where directed pressure is absent, uniform pressure is high, and temperature is also high (500°C to 800°C). In the ketazone plutonic metamorphism predominated which produces even grained rocks.

Grade of metamorphism

The grade of metamorphism varies directly with the amount of heat and pressure to which the rocks have been subjected. For example, slate and phyllite which show a low grade of metamorphism, are formed away from the intrusive igneous body, while a high grade metamorphic rock like gneiss, is formed near its margin. The increase in the grade of metamorphism is also accompanied by an increase in grain size. For example, slate and phyllites are fine grained, while schists and gneisses are coarse grained.

Metamorphic minerals

The which occur in metamorphic rocks are divided into two groups

i) Stress minerals
ii) Anti-stress minerals

The stress minerals which are usually flat, tabular, elongated, or flaky in nature, are formed during regional metamorphism (directed pressure). Examples of such minerals are micas, chlorite, talc, albite, amphiboles, kyanite, and staurolite. The anti-stress minerals develop during thermal metamorphism (uniform pressure). These are often Equidimensional in form. Examples of such minerals are potash feldspars, pyroxenes, olivine, andalusite, sillimanite, cordierite, and spinel.

Structures of metamorphic rocks

The main structures of the metamorphic rocks are

i) Schistose structure
ii) Gneissose structure
iii) Granulose structure
iv) Slaty structure

Schistose structure

It is formed by parallel arrangement of flat, tabular, elongated, bladed or flaky minerals such as muscovite, biotite, chlorite, talc, and hornblende. The rocks having schistose structure have a tendency to split readily into flakes, leaves, or thin slabs parallel to the schistosity.

Gneisses structure

A rock possessing gneissose structure exhibits a pronounced banded appearance in which light and dark coloured bands alternate. The light coloured bands are composed of quartz and feldspars, while dark bands contain ferromagnesian minerals. In gneissose rocks the planes of shictosity are poorly defined.

Granulose structure

Granulose (even grained) structure is produced due to predominance of Equidimensional minerals such as quartz, feldspar, pyroxenes, and calcite. The flaky minerals are either absent or present only in small amounts. On breaking a granulose rock produces a rough fracture surface.

Slaty structure

The slaty structure is also called "slaty cleavage". The rock possessing slaty cleavage has a unique property of splitting into thin smooth sheets. The slaty cleavage may form at any angle to the old bedding planes of the shale from which the slaty rock has been derived.

Description of metamorphic rocks

Phyllite

Phyllite is a low grade metamorphic rock which has a glossy and shining luster. The shining luster is due to the presence of large amount of fine flakes or mica (sericite). Phyllites are composed of sericite and quartz. Phyllites gradually pass into slates which are the first stage in the metamorphism of shales.

Schist

A rock having well developed schistose structure is known as a schist. Schists are largely composed of flaky minerals such as muscovite, biotite, hornblende, chlorite, talc etc. Depending upon the type of flaky mineral present, the schists are described as muscovite-schist, biotite-schist, hornblende-schist, chlorite-schist, talc-schist, talc-schist etc.

Gneiss

A rock having gneissose structure is called a gneiss. It is composed of feldspars, quartz, and some mafic minerals. Gneisses are distinguished by the minerals that are present in comparatively large amount, such as biotite-gneiss, hornblende-gneiss, etc

Marble

Marbles are produced by the metamorphism of limestones and dolomites. They contain interlocking grains of calcite or dolomite minerals and hence their structure is said to be granulose.

Quartzite

Metamorphosed sandstones having granulose structure are called quartzites. They are mainly composed of quartz with a small amount of mica, tourmaline, graphite or iron-minerals.

Slate

Slates are produced by the metamorphism of shale. They are fine grained rocks having slaty structure due to which they split into thin smooth plates. They are composed of very fine grained mixture of quartz, chlorite, sericite, and feldspars.