UNIT 15

CLASSIFICATION OF METAMORPHIC ROCKS

Structure

15.1 INTRODUCTION

You have learnt about factors, processes and products of metamorphism in Unit 12; types, grades, zones and facies of metamorphism in Unit 13; textures and structures of metamorphic rocks in Unit 14. Now in this unit we shall discuss the classification of metamorphic rocks. Metamorphic rocks can be classified on the basis of texture, structure, parent rock, grade and mineralogical composition or most importantly facies.

Expected Learning Outcomes

After reading this unit you should be able to:

- ❖ list the basis of classification of metamorphic rocks;
- ❖ discuss the classification of metamorphic rock based on parent rock, structure and texture, mineralogical composition, types and grade of metamorphism;
- ❖ differentiate between the foliated and non-foliated metamorphic rocks;
- ❖ describe the megascopic and petrographic characters of foliated rocks such as slate, phyllite, schist and gneiss; and
- ❖ explain the megascopic and petrographic characters of non-foliated rocks such as marble and quartzite.

15.2 CLASSIFICATION OF METAMORPHIC ROCKS

Metamorphic rocks can be classified on the basis of parent rock, texture, structure, mineralogical composition, metamorphic processes, grade and facies. Classification of metamorphic rocks have been summarised in Table 15.1.

15.2.1 Parent Rock

In the previous units the importance of temperature and pressure in determining the mineral assemblage in the metamorphic rocks has been emphasised. Try to recall!

In Unit 12 you have read that the composition of parent rock also plays an important role in determining the minerals formed during metamorphism. For example, it is not possible to form quartzite (composition silica oxide) from pure limestone (composition calcite). The metamorphic rocks can be classified on the basis of diverse origin of parent rock, viz. igneous, sedimentary or metamorphic.

- **Metamorphic rock of sedimentary origin**: These are the rocks metamorphosed from rocks of sedimentary origin and are also known as **parametamorphic** or **metasedimentary rocks**. For example, pelitic shale is metamorphosed to form slate; psammatic sandstone to quartzite; calcareous limestone to marble. Pelite is a term applied to metamorphic rocks derived from a fine-grained (<1/16 mm) largely clay bearing sedimentary protolith or parent rock. Psammite is a term applied to metamorphic rocks derived from an arenaceous (quartz-dominated) sedimentary protolith.
- **Metamorphic rock of igneous origin**: They are the rocks metamorphosed from rocks of igneous origin and are also known as orthometamorphic or metaigneous rocks. The parent igneous rock can be basic or acidic in nature. For example, dolerite, a basic igneous rock undergoes metamorphism to form amphibolite. Let us consider example of granite. It is acidic igneous rock that undergoes metamorphism to form granite gneiss.

- **Metamorphic rock of metamorphic origin**: The metamorphic rocks can also originate from a pre-existing metamorphic rock.

15.2.2 Structure and Texture

You have read in Unit 14 that metamorphic textures are studied under two categories based on the presence or absence of foliations viz. foliated and non-foliated. The term foliation refers to the texture caused by the parallel alignment of mineral grains. In textural classification, the rocks are classified on the basis of their physical appearance in hand specimen or outcrop, i.e. rocks may display slaty cleavage, schistosity or gneissosity. Therefore, the rock names slate, schist or gneiss are widely used. Rocks constituted of very sheet-like, tabular mineral grains that spilt into thin and even slabs are said to display slaty cleavage or foliation. The rocks which contain mineral grains that are large enough to be recognised in hand specimen, are well foliated and cleave into thin flakes are characterise schistose rocks. The large mineral grains in schistose rocks are called **porphyroblasts**. Gneissic rocks are generally coarse-grained that comprise alternating light and dark coloured bands of minerals arranged parallel to each other and may also show lenticular texture. Non-foliated rocks do not display foliation, and their massive and granular appearance resembles sedimentary rocks. Metamorphic rocks in which there is no visible orientation of mineral crystals have a non-foliated texture. For example, marble and quartzite are massive, medium to coarse grained and display granular texture with minerals visible to unaided eye.

We have discussed commonly found structures in metamorphic rocks in Unit 14. The metamorphic rocks have been classified on the basis of structures as follows:

- The phyllitic structure is characteristic of phyllite.
- The slaty structure is distinctive of slate.
- Schistose structure characterises schist displaying a preferred alignment of platy minerals, for example in mica schist, chlorite schist and hornblende schist.
- Gneissose structure is exclusively shown by the banded metamorphic rocks like gneisses, e.g. granitic gneiss.
- Granulose texture is characteristic of massive metamorphic rocks that exhibit welded interlocking mosaic of crystals, e.g. quartzite and marble.
- Migmatitic texture is observed in the metamorphic rocks like migmatite that displays alternating light and dark coloured bands, e.g., migmatite.

15.2.3 Mineralogical Composition

The metamorphic rocks can also be classified on the basis of mineralogical composition or facies. You have read about facies in Unit 13. Each facies comprise of a stable mineral assemblage depending on the combination of temperature, pressure and original composition. This classification depends on the ability of identifying critical or index minerals in a rock using microscope or other laboratory methods. The name of the rock is modified by the name of an index mineral placed as a prefix to the group name, e.g. garnet schist. The name of the index mineral indicates specific conditions of metamorphism and metamorphic rocks are classified according to mineral composition.

15.2.4 Types of Metamorphism

The metamorphic rocks can be classified on the basis of the types of metamorphism. You have learnt about types of metamorphism in Unit 13 in detail. Types of metamorphism have been categorised into the regional extent and local extent. The types of metamorphism such as regional (orogenic), ocean-floor, burial, subduction and collision metamorphism fall under regional extent. Whereas contact (igneous), cataclastic, hydrothermal, impact (shock), lightening and combustion metamorphism are of local extent.

Table 15.1: Summary of classification of metamorphic rocks with different protoliths and their resultant metamorphic rocks and related textures.

Parent Rock	Texture	Rock Name	Type	Grade	Remarks
Mudstone	foliated	slate	regional	lower	Breaks into plates, slaty cleavage
Mudstone	foliated	phyllite	regional	moderate	More shiny and crenulated than slate
Mudstone	foliated	schist	regional	moderately high	Different schists recognised on the basis of mineral content
Mudstone	foliated	gneiss	regional	high	Well-developed light and dark colour banding
Granite	foliated	gneiss	regional	high	Well-developed light and dark colour banding
Quartz sandstone	non-foliated	quartzite	contact	low-high	Sugary texture composed of interlocking quartz grains, relatively hard, won’t fizz with acid
Limestone	non-foliated	marble	contact	low-high	Sugary texture composed of interlocking calcite grains, relatively hard, fizzes with acid
Basalt	non-foliated	metabasalt	contact	low	Greenish colour due to chlorite

15.2.5 Grades of Metamorphism

Grade of metamorphism is also used in classifying metamorphic rocks. You have learnt about grades in Unit 13 in detail. Grade of metamorphism has been categorized into low- and high grade. Low-grade metamorphism takes place at temperatures between about 200^{o}C to 320^{o}C, and relatively low pressure. Whereas, the high-grade metamorphism takes place at temperatures higher than 320ºC and relatively high pressure. As grade of metamorphism increases, hydrous minerals become less hydrous, by losing H_2O and non-hydrous minerals become more common.

There also exists agreement in naming a rock, for example, if a rock is monomineralic, it may be named after the dominant mineral such as- quartzite dominated by quartz. But most rocks contain 3 or more minerals, in that case the minerals are listed (with a hyphen between them) and placed in order of increasing modal amount before the group name, e.g. garnet-chlorite-hornblende schist, hornblende being in the maximum amount and garnet being the minimum. Some geologists also use the prefixes such as para- or ortho- which are used respectively for sedimentary and igneous protoliths (parent rock), for e.g. - para-gneiss and ortho-gneiss. If the original protolith is still recognizable the prefix meta- is added to the name of the rock, e.g. metabasalt, metagranite, etc.

Learners you have learned about the different classification schemes of metamorphic rocks in this section. Before discussing about the common metamorphic rocks, let us spend few minutes to perform an exercise to check your progress.

SAQ 1

a) What is granulose texture?

b) List the types of metamorphism of regional extent.

c) Quartz sandstone is metamorphosed to ______________.

d) Limestone is metamorphosed to ______________.

e) High grade metamorphism takes place at temperatures greater than ______________.

15.3 COMMON METAMORPHIC ROCKS

In this section the megascopic and microscopic characters of common metamorphic rocks will be discussed. This will also help you in identification of metamorphic rocks in hand specimen and under the microscope. On the basis of structure and mineralogy, the metamorphic rocks can be divided into foliated and non-foliated rocks.

1) **Foliated Metamorphic Rocks** have suffered a good amount of directed pressure during their genesis. The development of foliation surfaces or foliation planes takes place due to the pressure. The development of foliation planes takes place as the result of alignment of platy minerals. This eventually leads to the formation of weak planes and the rock becomes easily cleavable along these foliation surfaces. The sequence of foliated metamorphic rocks in accordance with their grade is: slate, phyllite, and gneiss.

2) **Non-Foliated Metamorphic Rocks** do not suffer any shear stress due to their formation near the surface. The development of foliation planes or surfaces does not take place in non-foliated rocks. Marble and quartzite are the types of metamorphic rocks which suffer a high stress but still don’t

develop foliated texture because of the absence of flaky/platy minerals in the rock. The absence of foliation surfaces and schistosity in the rock makes the rock hard and compact.

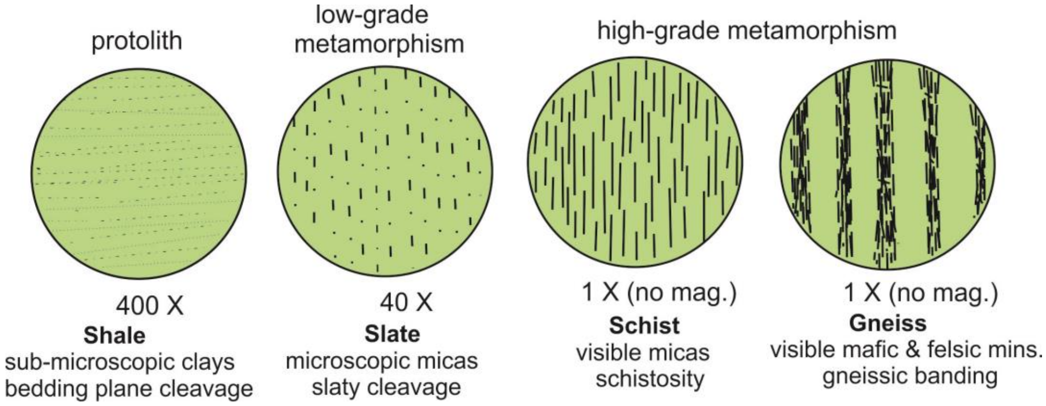

Fig. 15.1: Development of foliation planes with increase in grade in metamorphism resulting in different types of foliated metamorphic rocks.

Now we will discuss megascopic and petrographic characters of foliated rocks such as slate, phyllite, schist and gneiss.

15.3.1 Slate

Slate generally displays close resemblance to shale. Slate is a fine-grained foliated metamorphic rock formed by low-grade regional metamorphism of shale or mudstone. Aluminum rich minerals in shale are metamorphosed to micaceous minerals in slate. The parallel alignment of these flaky/ platy minerals gives rise to foliation in slate which causes the slate to break along these foliation planes easily. Slate exhibits slaty cleavage or excellent rock cleavage, i.e. tendency to break into thin and flat slabs or sheets (Fig. 15.2).

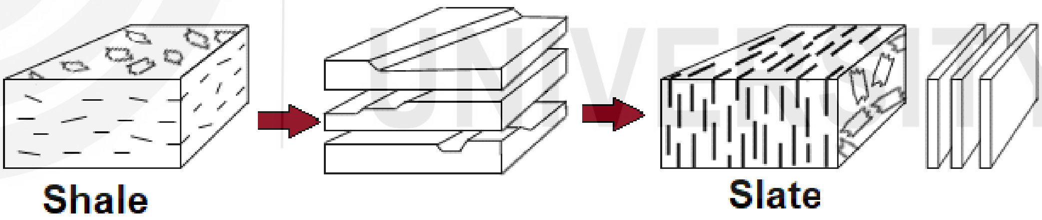

Fig. 15.2: Metamorphism of shale protolith to slate and evolution of shale fissility to foliation in slate.

a) **Megascopic characters**: In hand specimen foliation can be seen at the millimeter scale with fine grains and variable colours with shades of black, grey (Fig. 15.4a) and green etc. While in thin section the textural association could be identified with new mica growing in a direction perpendicular to the direction of stress. Slate is most often formed by the low-grade metamorphism of shale, mudstone, or siltstone. Slate's colour depends on its mineral constituents. Often black (carbonaceous/graphitic) slate contains organic material; red slate gets its colour from iron oxide; and green slate usually contains chlorite. The original shale bedding (relict bedding) is sometimes preserved as colour contrasts in a slate. In most cases the slate's fracture cleavage lies at some angle to the original bedding plane. Slate displays perfect slaty cleavage with smooth surface and breaks easily along the planes parallel to the sheet silicates, causing a slaty cleavage. Essential minerals are biotite, chlorite, muscovite and accessory minerals are apatite, graphite, magnetite, tourmaline or zircon.

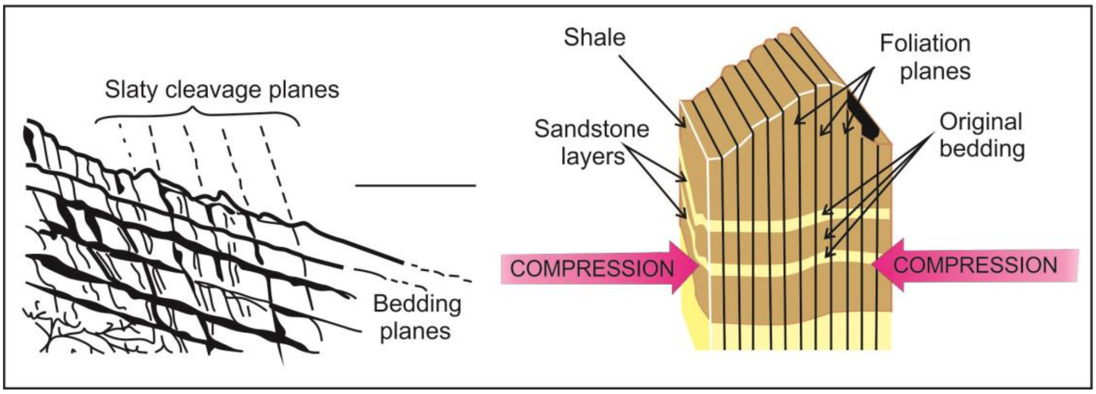

Fig. 15.3: Relation between foliation and bedding plane.

b) **Petrographic characters**: At microscopic level the fine texture of the rock doesn't let the identification of micas easy (Fig. 15.4b). Texturally, slate is very fine-grained, well foliated with parallel foliation or layering of fine-grained platy minerals such as chlorite. Crenulation cleavage may be present. The slate is formed due to metamorphism of mudstone/ siltstone / shale.

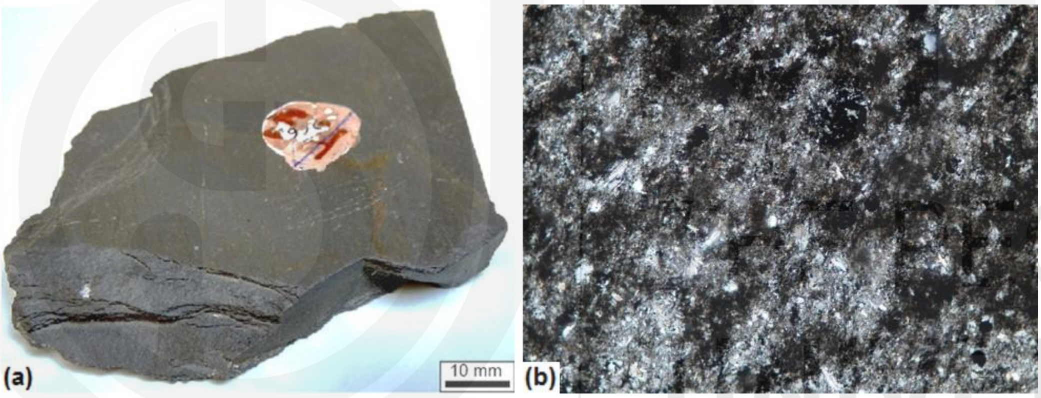

Fig. 15.4: a) Hand specimen of slate; and b) Photomicrograph of indiscernible mica crystals in slate (XP image, 10x).

15.3.2 Phyllite

You have read about the slate. Now let us read about the phyllite.

Phyllite is a fine-grained foliated metamorphic rock formed by the metamorphism of slate. The foliation is caused by preferred orientation of very fine-grained mica. It represents a gradation in the degree of metamorphism between slate and schist. Its constituent platy minerals are larger than those in slate but not yet large enough to be readily identifiable with the unaided eye. Although phyllite appears similar to a slate, it can be easily distinguished from slate by its glossy lustre and its wavy surface. Phyllite usually exhibits rock cleavage and is composed mainly of very fine crystals of either muscovite or chlorite, or both.

The condition of formation of phyllite requires the P-T conditions similar to the low-grade metamorphism of regional type. Phyllite is characterised by silky sheen due to the presence of fine-grained mica minerals that is called the phyllitic luster commonly observed at the cleavage surfaces. The fissile property of the protolith doesn’t fade off and is retained in phyllite.

a) **Megascopic characters**: In hand specimen phyllite resembles slate since it is fine grained, hard with foliations of millimeter scale (Fig. 15.5a). Phyllite displays less compaction with tints of grey and phyllitic lustre. Phyllite is variable in colour with shades of grey with sheen. It is fine to medium grained, hard but less compact. Phyllite is foliated on mm scale with well-developed foliations. Surface of the phyllite is typically lustrous and sometimes wrinkled. Presence of mica (biotite and muscovite) flakes give rise to a satin luster to phyllite and it displays phyllitic structure. Essential minerals are muscovite, biotite, quartz and plagioclase. Sericitic mica, graphite and chlorite are accessory phases. Phyllite is a low grade (higher than the slate) metamorphic rock. Shale or mudstone is protoliths of phyllite.

b) **Petrographic characters**: The textural characters of phyllite are similar to the slate but the most perceptive character is the prominence of foliation planes due to mica growth (Fig. 15.5b). Phyllite is fine to medium grained (0.1-1.00 mm particle size), foliated (mm scale) and quite commonly wrinkled or wavy. The foliations are well-developed. Flaky minerals are aligned perpendicular to c axis giving rise to lineation. Essential mineral are muscovite, biotite, quartz and plagioclase. Accessory minerals are sericitic mica, graphite and chlorite.

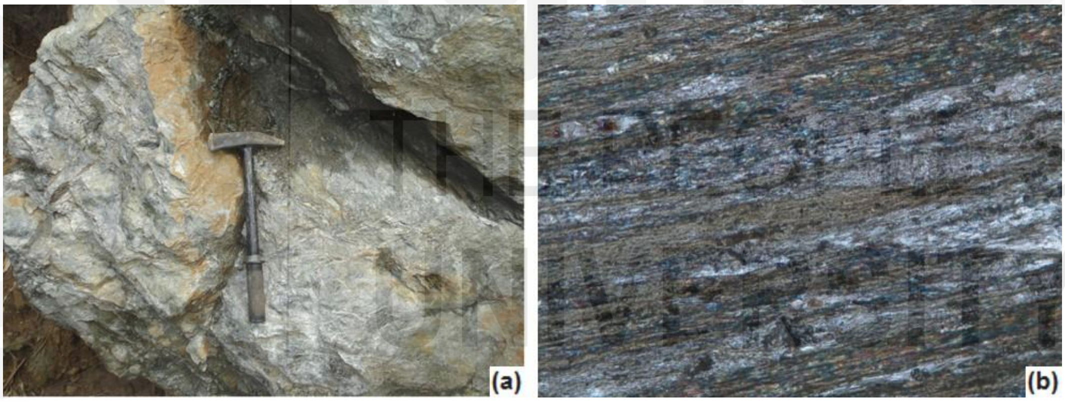

Fig. 15.5: a) Silvery phyllite with phyllitic shine due to the presence of white mica; and b) Discernible mica crystals in Phyllite under XP, (magnification 10x).

15.3.3 Schist

Schist is a strongly foliated medium grained metamorphic rock in general. It is formed on the continental side of a convergent plate boundary by the metamorphism of rocks at higher metamorphic grade than slate. Schist is a medium to coarse-grained metamorphic rock possessing foliation known as schistosity. Schist is composed of flaky/platy mineral grains that are large enough to be discerned with naked eye. The alignment of these flaky/platy minerals leads to the formation of foliation surfaces. The foliation surfaces so formed are quite distinct and coarse due to higher degree of crystallisation in micaceous minerals. Apart from describing texture, the term schist describes rocks having a wide variety of chemical compositions. In order to indicate the variation in composition, mineral names are prefixed to the rock name ‘schist’.

For example, schists composed primarily of muscovite and biotite is called mica schist. Many metamorphic rocks comprise some common accessory minerals like garnet and staurolite which occur as porphyroblasts. In that case the rock is called garnet-mica schist, hornblende-schist, and staurolite-mica schist depending on the dominance of minerals occurring as porphyroblasts.

a) **Megascopic characters**: Hand specimen identification could be done with the help of prominent schistosity planes which range from millimeter to centimeter scale. The rock has suffered high directional stress and has thus become hard and compact and the growth of mineral grains make it somewhat coarse-grained rock (Fig. 15.6a). Schist is fine to medium grained and often crystals can be seen by unaided eyes. Quartz and feldspar grains show no preferred orientation. Schist is smooth and rough in touch. The flaky minerals in schist form roughly parallel layers. The rock breaks easily when hammered due to the presence of mica. It displays schistose structure. Essential minerals are mica, quartz, and plagioclase. Quartz, feldspars, kyanite, chlorite, garnet, staurolite and sillimanite may be present as accessory minerals. Schist is intermediate/medium metamorphic grade between phyllite and gneiss.

b) **Petrographic characters**: Microscopically the schist can be identified by the continuous foliation planes and coarse texture (Fig. 15.6b). The foliation is in the form of banding in which flakes of micaceous minerals could be seen oriented in a particular direction. Parallel orientation of mica flakes give rise to schistose structure. Essential minerals are muscovite, quartz and plagioclase. Porphyroblasts of garnet are common. Quartz, feldspars, kyanite, chlorite, garnet, staurolite and sillimanite are accessory minerals.

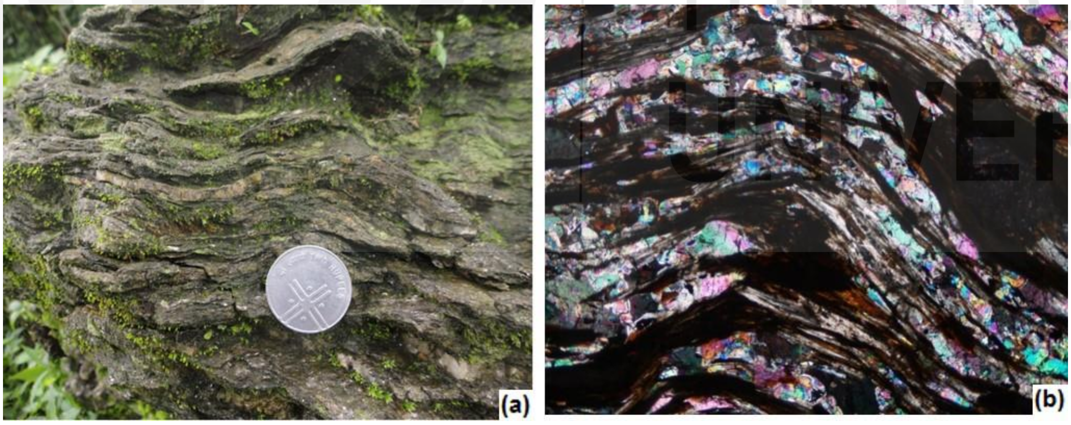

Fig.15.6: a) Biotite Schist showing folded schistosity; and b) Schistose bandings showing fold in schist (XPL image, 2x).

15.3.4 Gneiss

Gneiss is a compositionally layered metamorphic rock; typically composed of alternating dark-coloured and light-coloured layers with variable thickness. Gneiss is a medium to coarse grained rock that shows much similarity with schist rocks as they both show light and dark coloured bands of felsic and mafic minerals respectively. Most of the gneisses are felsic in composition and are derived from high grade metamorphism of granite or often from shale. During high-grade metamorphism the light and dark components separate, giving gneisses their characteristic banded or layered appearance. Gneisses can also comprise primarily of dark minerals. For example, an amphibole-rich rock that exhibits a gneissic texture is called amphibolite. Gneiss is formed by regional metamorphism from a variety of protoliths. These banded gneisses often exhibit evidence of deformation, including folds and sometimes faults.

a) **Megascopic characters**: Gneisses are metamorphic rocks in which granular and elongated (as opposed to flaky/platy) minerals predominate. It is characterised by alternate light and dark coloured bands comprising minerals of respective colours which is responsible for the compositional and/or structural variation. The banding is not continuous unlike schist. Foliation is distinct but the rock does not cleave along the foliation planes like slate and schist. Colour is variable with alternate dark and light bands. Gneiss exhibits gneissose structure. Quartz, feldspars, mica and amphiboles with alternate light and dark coloured bands give rise to the gneissic bands in the rock. Light and dark bands of felsic (such as feldspar and quartz) and mafic minerals (biotite, pyroxene, amphibole, garnet etc) characterise gneiss.

b) **Petrographic characters**: In thin section petrography of the gneiss is differentiated form the schist by the foliated bands which are discontinuous and wane off in gneisses. This is due to the inactivity of slip planes with increase of temperature. Also, the grains are relatively bigger in size than schist due to static recrystallisation. Quartz, feldspars, mica and amphibole grains alternate as light and dark coloured bands giving the rock a gneissic banding. Light band comprise felsic minerals such as feldspar and quartz while the dark bands comprise mafic minerals such as biotite, pyroxene, and amphibole.

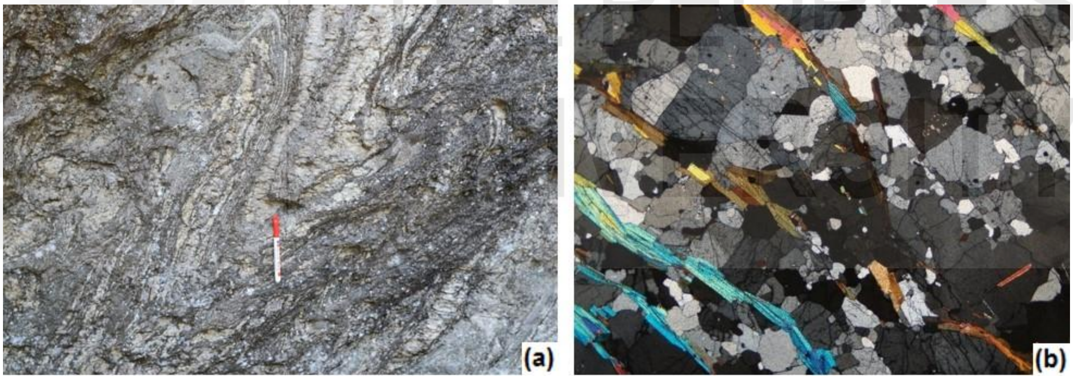

Fig. 15.7: a) Folded gneiss; and b) Coarse grains with discontinuous foliation bandings in gneiss (XPL image, 2x).

15.3.5 Marble

Marble is a non-foliated, high temperature and pressure, thermal and regionally metamorphosed rock generally formed by metamorphism of limestone or dolostone. Marble comprising dolomite (18 mole% of Mg + limestone) is called a dolomarble. Pure marble is white and composed essentially of the mineral calcite. During the formation of marble, calcite comprising the protolith recrystallises so the fossil shells, pore spaces and distinction between grains and cement disappears. On metamorphism the calcite crystals are reconstituted in a denser and equigranular form of calcite crystals (Fig. 15.8) rendering the rock compact even though the calcite has a hardness of only 3 on the Moh's hardness scale. Marble usually forms in convergent tectonic setting or due to the heating of limestone or dolomite by the ascending magma. Unlike quartzite, marble could be scratched with a metal blade. Marble is easy to cut and shape because of its low hardness. White marble is particularly prized as a stone from which monuments and statues are made developed, such as the Taj Mahal in India. Unfortunately, marble's composition of calcium carbonate causes it to weather when exposed to acid rain. Marble formed from limestone interbedded with shale appears banded and exhibits visible foliation. On their deformation, these banded marbles develop highly contorted mica-rich folds that give the rock a rather artistic design. These decorative marbles have been used as a building stone ever since human civilisation.

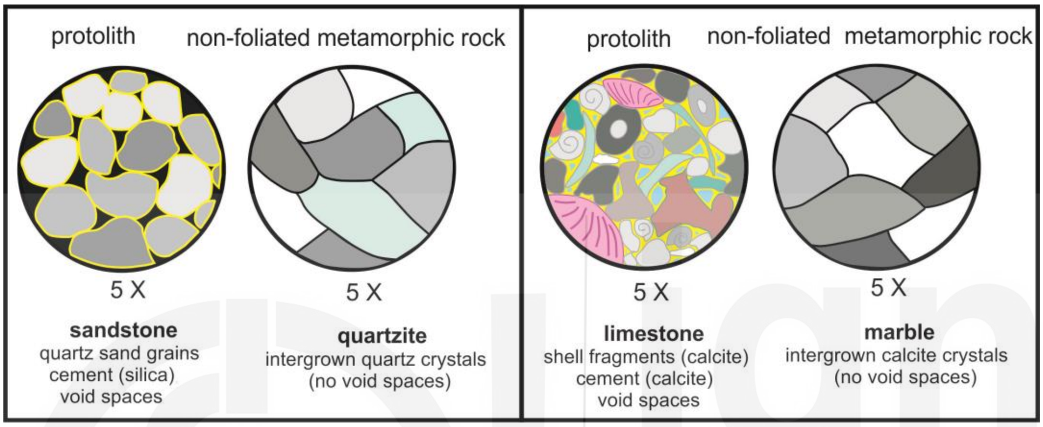

Fig. 15.8: Protolith and grain differentiation between quartzite and marble. (Source: https://bostoncollege.instructure.com/courses/1325378 /pages/vl1b-metamorphic-rocks)

a) **Megascopic characters**: Marble is medium to coarse grained, crystalline, equigranular, hard and compact. Marble displays granular and saccharoidal (sugary) texture. It typically consists of fairly uniform mass of interlocking calcite crystals. The marble can be of pink, grey, green, or even black colour which is due to the impurities inherited from parent rock or protolith. Pure marble is white, whereas, marble with traces of iron is reddish or pink. As primarily the marble is composed of calcium carbonate it reacts with dilute acid.

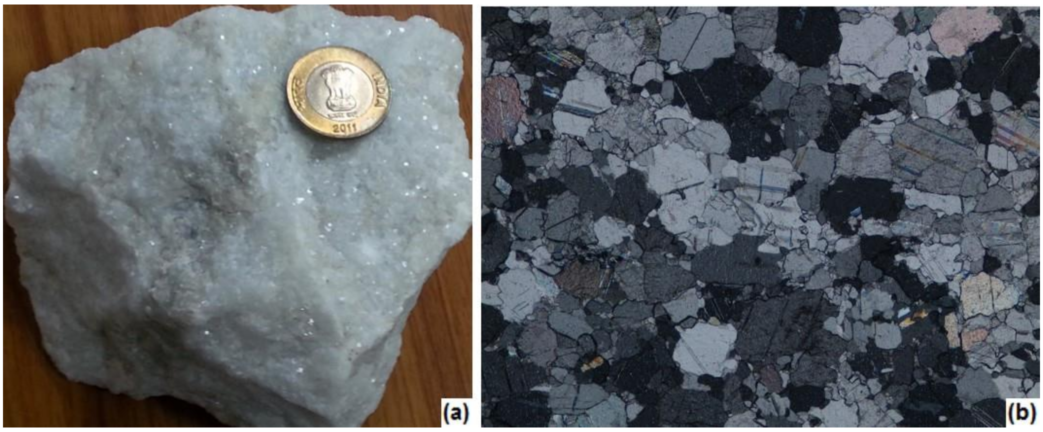

Fig. 15.9: a) Hand specimen of Marble; and b) Coarse grains with sugary texture in marble (XPL image, 4x).

b) **Petrographic characters**: Marble is medium to coarse grained and displays crystalline, granular and sugary texture with interlocking grains. Three sets of calcitic rhombohedral cleavage are present in marble at microscopic level. This cleavage pattern becomes more prominent when there is presence of dolomite in marble. Though, marble is very much confused with quartzite still mineralogical composition and compactness of marble makes the distinction easy. Its mineral composition is dominantly calcite or dolomite. Clay minerals, micas, quartz, pyrite, iron oxide, and graphite may also be present.

15.3.6 Quartzite

Quartzite is a non-foliated hard metamorphic rock. It is formed by the metamorphism of pure quartz sandstone. Alteration of quartz rich (>90% quartz) sandstone takes place due to the pressure, heat and chemical activity during the metamorphism. During metamorphism, the pre-existing quartz grains recrystallise, giving rise to the new larger grains. Under moderate- to high-grade metamorphism, the quartz grains in sandstone fuse together and make the rock denser, equigranular and hard. In the process, the distinction between cement and grains as also open pore spaces disappear and grains become interlocking. The recrystallisation is often so complete that when broken, quartzite will split through or across the quartz grains rather than along their curved boundaries. It is formed along the convergent plate boundaries and along the orogens. Quartzite is a common metamorphic rock as its protolith sandstone too is common.

a) **Megascopic characters**: Pure quartzite is white, but iron oxide may produce reddish or pinkish stains due to presence of ferrous mineral. It is sometimes green also (fuchsite quartzite). Quartzite looks glassier than sandstone and does not have the grainy, sandpaper like surface characteristics of sandstone. It is medium grained, equigranular comprising interlocking grains of quartz giving a sugary appearance. It is hard and compact and shows granulose texture and structure. Unlike marble, quartzite cannot be scratched with a metal blade due to the predominance of quartz which gives the rock hardness corresponding to 7 on Moh's hardness scale. Quartzite is dominantly composed of quartz but some mineral impurities such as hematite may be present. Minerals like micas, feldspars, garnets and some amphiboles may also be present.

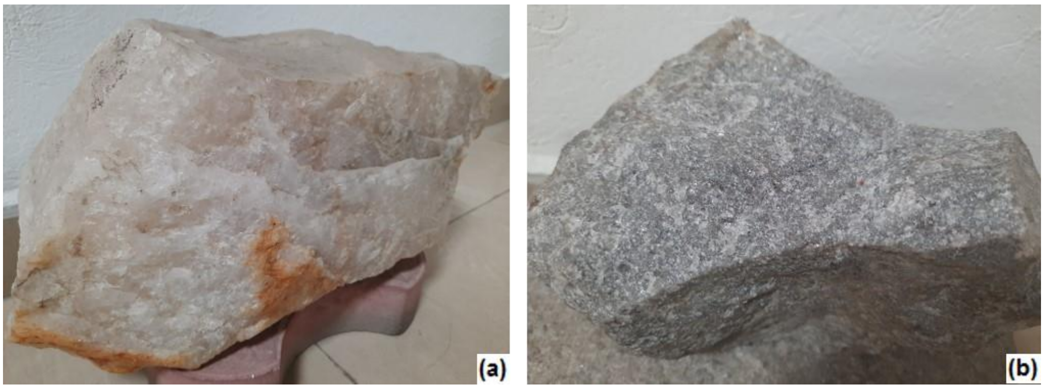

Fig. 15.10: Quartzite samples from IGNOU Headquarters: a) Quartzose quartzite; and b) Ferruginous quartzite.

b) **Petrographic characters**: Quartzite in thin section is medium grained, equigranular, with interlocking grains of quartz with appreciable compactness. It shows granular, sugary texture. Apart from quartz other minerals if present are considered to be impurities (hematite etc.). Other mineral like hematite, mica, feldspar, garnet and some amphibole may be present.

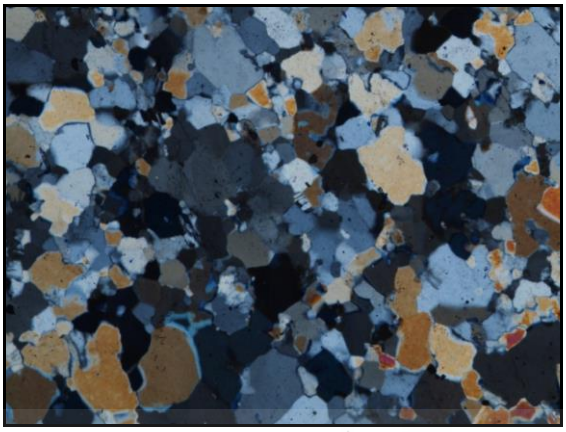

Fig. 15.11: Coarse grains with sugary texture in marble (XPL image, 4x).

Table 15.2: Characteristics of some of the common metamorphic rocks.

Non-foliated			
Parent Rock	**Metamorphic Rock**	**Dominant Minerals**	**Distinguishing Characteristics**
Limestone, Dolomite	Marble Dolomitic marble	Calcite or dolomite	Coarse, interlocking grains with rhombohedral cleavage, effervesces to drop of acid
Quartz sandstone	Quartzite	Quartz	Interlocking grains of granular quartz, hard, scratches glass
Shale, Basalt	Hornfels	Fine-grained mica	Fine-grained dark rock, may have some coarser minerals present, usually scratches glass
Foliated			
Parent Rock	Metamorphic rock	Dominant minerals	Characteristics
Shale	Slate	Clay minerals, micas	Fine grained, splits easily, slaty cleavage
Shale	Phyllite	Micas	Fine-grained rock with silky lustre, usually splits along wavy surfaces

Learners, you have learnt about the common metamorphic rocks in this section. Before progressing further, let us spend a few minutes to perform an exercise to check your progress.

SAQ 2

a) Differentiate between foliated and non-foliated metamorphic rocks.

b) Mention two examples each of foliated and non-foliated rocks.

c) Gneiss exhibits________________ structure.

d) Marble displays granular and ____________ texture.

15.4 SUMMARY

Let us summarise what we have learnt in this unit:

- Metamorphic rocks can be classified on the basis of parent rock, texture, structure, mineralogical composition, metamorphic processes and grade.
- Metamorphic rock can be of sedimentary, igneous or metamorphic origin.
- Metamorphic rocks have been classified as phyllitic structure, slaty structure, schistose structure, gneissose structure, granulose texture and migmatitic texture.
- The metamorphic rocks can also be classified on the basis of mineralogical composition or facies.
- Types of metamorphism has been categorised into regional extent and local extent. The types of metamorphism such as regional (orogenic), ocean-floor, burial, subduction and collision metamorphism fall under regional extent. Whereas contact (igneous), cataclastic, hydrothermal, impact (shock), lightening and combustion metamorphism are of local extent.
- Grade of metamorphism has been categorized into low- and high grade.
- On the basis of structure and mineralogy, the metamorphic rocks can be divided into foliated and non-foliated rocks.
- The foliated metamorphic rocks in accordance with their grade are: slate, phyllite, and gneiss.
- Marble and quartzite are non-foliated rocks having granular and equidimensional texture.

15.5 TERMINAL QUESTIONS

1. How are metamorphic rocks classified on the basis of parent rock?
2. Discuss the megascopic and petrographic characters of slate.
3. Describe the megascopic and petrographic characters of schist.
4. Explain the megascopic and petrographic characters of quartzite.

15.7 REFERENCES

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15.9 ANSWERS

Self Assessment Questions

1 a) Granulose texture is found in massive metamorphic rocks exhibiting welded interlocking mosaic of crystals, e.g. quartzite and marble.

b) The types of metamorphism such as regional (orogenic), ocean-floor, burial, subduction and collision metamorphism fall under regional extent.

c) Quartzite

d) Marble

e) 320^{o}C

2 a) Foliated metamorphic rocks have suffered a good amount of directed pressure during their genesis. The development of foliation surfaces or foliation planes takes place due to the pressure. Whereas non-foliated metamorphic rocks do not suffer any shear stresses due to their formation near the surface. The development of foliation planes or surfaces does not take place in non-foliated rocks.

b) Foliated-schist and gneiss; non-foliated-marble and quartzite

c) Gneissose

d) Saccharoidal

Terminal Questions

1. Please refer to subsection 15.2.1.

2. Please refer to subsection 15.3.1.
3. Please refer to subsection 15.3.3.
4. Please refer to subsection 15.3.6.

GLOSSARY

Apparent fibers : Cross sections of serpentine plates that look fibrous in thin section.

Augen structure : It refers to a larger, stronger crystals (like feldspar, quartz, garnet) embedded in a metamorphic matrix and sheared into an asymmetrical eye-shaped crystal.

Aureole : A zone of contact metamorphism that surrounds an intrusion.

Background alteration : Alteration has pervasively affected the entire rock and is not primarily bound to veins or foliation planes

Banded structure : Term used for prominent layering or banding in veins or nodules. These types of structures are formed due to successive deposition or replacement of pre-existing rocks such as granite gneiss.

Banded vein : Vein with rhythmic layering parallel to the vein walls.

Bastite : Serpentine texture after chain and layer silicates preserving important textures of the protolith (e.g., plastic deformation) and pre-serpentine alteration assemblages.

Black smokers : The mineral laden water emerging from the seafloor through hydrothermal vents. It is named after the dark-colored precipitates produced when the hot vent water meets cold seawater.

Burial metamorphism : It occurs when rocks are deeply buried, at depths of more than 2000 meters. Burial metamorphism commonly occurs in sedimentary basins, where rocks are buried deeply by overlying sediments.

Cataclasite : A type of breccia that forms in a brittle way within fault zones.

Chrysotile : White asbestiform serpentine, usually in veins with magnetite.

Composite vein : Compositionally zoned vein containing different mineral assemblages that may or may not represent different generations.

Confining pressure	:	It has equal pressure on all sides and is responsible for causing chemical reactions to occur just like heat.
Contact metamorphism	:	It occurs in rock exposed to high temperature and low pressure when hot magma intrudes into or lava flows over pre-existing country rocks.
Cross-fiber vein	:	Asbestiform or pseudofibrous vein in which the fibers (or apparent fibers) are oriented perpendicular to the vein walls.
Directed stress	:	An unequal balance of forces on a rock in one or more directions. It is also called differential or tectonic stress. These stresses are generated by the movement of lithospheric plates.
Fibrous	:	Single crystals resembling organic fibers or crystalline aggregates that look like they are composed of fibers.
Foliation	:	This term describes minerals lined up in planes. Minerals most notably the mica group, are mostly thin and planar.
Geothermal gradient	:	The average change in temperature that is experienced as material moves into the Earth. Near the surface, this rate is about 25°C/km.
Glaucophane	:	This mineral has a distinctive blue color, is an index mineral found in blueschist facies, associated with converging plate boundary.
Gneissic banding	:	Metamorphic foliation in which visible silicate minerals separate into dark and light bands or lineation. These grains tend to be coarse and often folded.
Gondite	:	Metamorphic rock comprising spessartine variety of garnet.
Hornfels	:	Non-foliated rock which is identified by its dense, fine grained, hard, blocky or splintery texture composed of several silicate minerals.
Hydrothermal metamorphism	:	Metamorphism which occurs with hot fluids going within rocks, altering and changing the rocks.
Index minerals	:	They form at certain temperatures and pressures to identify metamorphic grade and provide important

		clues to a rock's protolith and metamorphic conditions.
Khondalite	:	Khondalite is quartz–manganese-rich garnet–rhodonite schist. It may also contain sillimanite and graphite. It is found in the Eastern Ghats between Vijayawada and Cuttack in India.
Metamorphic facies	:	Group of minerals called facies assemblages. They provide information about the metamorphic processes that have affected the rocks and are useful in interpreting the history of a metamorphic rock.
Metamorphic texture	:	This term is used for the description of the shape and orientation of mineral grains in a metamorphic rock.
Migmatite	:	Since gneisses form at the highest temperatures and pressures, some partial melting may occur. This partially melted rock is a transition between metamorphic and igneous rocks. Migmatites appear as dark and light banded gneiss.
Mylonites	:	Metamorphic rocks created by dynamic recrystallisation, generally resulting in a reduction of grain size.
Non-foliated	:	This type of texture does not exhibit lineation, foliation, or other alignments of mineral grains. Non-foliated metamorphic rocks are typically composed of just one mineral, and usually show the effects of metamorphism with recrystallisation in which crystals grow together but have no preferred direction.
Phase diagram	:	Chart that show the stability of different phases of a substance at different conditions.
Regional metamorphism	:	It occurs when parent rock is subjected to increase temperature and pressure over a large area.
Subduction zone metamorphism	:	It is a type of regional metamorphism that occurs when a slab of oceanic crust is subducted under the continental crust.