UNIT 14

Texture and Structure of Metamorphic Rocks

Structure

14.1 INTRODUCTION

You have learnt about factors affecting metamorphism, products and processes of metamorphism in Unit 12 and types, grades, zones of metamorphism and metamorphic facies in Unit 13. Now in this unit we will learn about textures and structures found in metamorphic rocks. Metamorphic rocks are generally associated with lots of frameworks which may range from microscopic scale to the very large scale such as tens of kilometres.

These constructions within the rocks may be induced structurally or mineralogically. The induction of such structures depends on kinematic as well as thermodynamic adjustments in the protolith rocks or the rocks undergoing metamorphism. These structures and textures provide important clues to the crustal dynamics and evolution.

While studying the textures and structures of igneous and sedimentary rocks you have been introduced to the terms such as texture and structure in Unit 2 and Units 9 and 10 of this course. Let us recall, ‘texture’ is used to describe the size, shape, and arrangement of grains within a rock. Mostly igneous and many sedimentary rocks consist of mineral grains that have a random orientation. However, metamorphic rocks contain platy minerals and/or elongated minerals such as micas and amphiboles, which display some kind of preferred orientation in which the mineral grains exhibit a parallel to subparallel alignment. Structures in metamorphic rocks are a product of unbalanced directive forces and various interrelated textures are present in the rock unit. The term structure includes features on a large scale or on outcrop scale or on the hand specimen scale, or even at a regional scale. On the contrary the term **texture** is used for features at small scale, viz. from microscopic to hand specimen scale. Mutual agreement and arrangement of minerals in the rock unit, their shape, size and growth are the responsible factors for the development of a certain texture. Metamorphic rocks are rich in different type of structures and textures which are simply modifications brought about in the fabric and mineralogy of the metamorphic rocks with the changing physicochemical conditions. You have read about these physicochemical conditions while discussing factors of metamorphism in Unit 12.

Expected Learning Outcomes

After reading this unit you should be able to:

- acquaint with the factors affecting metamorphic textures;
- discuss palimpsest, typomorphic, reaction and intergrowth textures in metamorphic rocks; and
- explain the structures, viz. foliation and lineation, slaty cleavage, schistose and gneissose structures in metamorphic rocks.

14.2 FACTORS AFFECTING TEXTURES IN METAMORPHIC ROCKS

Before studying the textures in metamorphic rocks, let us examine the factors controlling the metamorphic mineral content, textures and structures. They depend on the following factors:

1. Composition of the parent rock
2. Temperature during metamorphism
3. Pressure during metamorphism
4. Effects of tectonic forces
5. Effects of chemically active fluids.
6. Time

Let us discuss about them briefly.

1. **Composition of the parent rock** is very significantly reflected in the resulting metamorphic rock as usually no new elements (other than water) are added to parent rock/protolith. The mineral makeup of the parent rock also largely determines the degree to which each metamorphic factor/agent brings about change. For example, when the magma forces its way into surrounding rock, high temperatures and hot fluids may alter the host rock. If the host rock is composed of minerals that are comparatively not reactive, such as quartz grains in sandstone, then the alterations or changes that may occur will be confined to a narrow zone next to the pluton. However, when the host rock is a limestone, which is highly reactive, the zone of metamorphism may extend to a larger distance from the intrusion. Most metamorphic rocks have the same overall chemical composition as their protolith/ parent rock. However, it is possible that the loss or acquisition of volatiles such as water (H_2O) and carbon dioxide (CO_2) may take place. Therefore, when we try to find out or ascertain the parent material from which metamorphic rocks were derived, the most important clue comes from the chemical composition of the parent rock.
2. **Temperature during metamorphism** is controlled primarily by the outward flow of heat from Earth's deep interior, as we have discussed in the previous unit while discussing factors affecting metamorphism. It is important for you to understand that all the minerals are stable over finite temperature range. The new minerals formed are stable under different temperature conditions. But if temperature gets high enough, melting will occur and this would lead to the formation of an igneous rock.
3. **Pressure during metamorphism** typically increases 1 kilobar per 3.3 km of burial within the crust. The pressure is generally proportional to the depth of burial within the Earth. We have discussed that the confining pressure is the pressure applied equally in all directions. The minerals formed under high-pressure have a more compact structure that results in a higher density.
4. **Tectonic forces** often lead to forces that are not equally distributed in all directions, known as **differential stress**. The compressive stress causes flattening perpendicular to the stress and the shearing stress causes flattening through sliding parallel to the stress. The planar rock texture of aligned minerals produced by differential stress is known as foliation which increases with pressure and time.
5. **Chemically active fluids** have a catalysing role to play during metamorphism. The rising temperature causes water to be released from unstable minerals. The hot water (as vapour) being very reactive is most important and acts as rapid transport agent for mobile ions.
6. **Time** is an extremely important factor controlling metamorphism. The formation of metamorphic minerals and textures may take thousands to millions of years. The longer time period allows newly formed stable minerals to grow larger and the development of more clearly defined foliation. It involves processes like recrystallisation, phase change, metamorphic reaction, pressure solution and plastic deformation. These processes sometimes occur alone and sometimes together.

14.3 HOW DO METAMORPHIC TEXTURES FORM?

The formation of metamorphic minerals and textures takes place slowly; it may take thousands to millions of years. The most common processes are:

- **Recrystallisation** changes the shape and size of grains without changing the identity of the minerals constituting the grains. For example, during recrystallisation of limestone and formation of marble, a tightly fitted mosaic of large crystals of calcite may replace a cluster of small and rounded grains of calcite cement together.
- **Phase change** transforms one mineral into another mineral with the same composition but with a different crystal structure. For example, the transformation of quartz into a denser mineral called coesite represents a phase change. Both the minerals have the same formulae (SiO_2) but different crystal structures. Phase change involves a rearrangement of atoms.
- **Metamorphic reaction** or **neocrystallisation** (from the Greek *neos,* for new) which results in the growth of new mineral crystals that differ from those of the protolith. During neocrystallisation, chemical reactions digest minerals of the protolith to produce new minerals of the metamorphic rock. For this process to take place, atoms migrate (diffuse) through solid crystals that is a very slow process, and/or dissolve and reprecipitate at grain boundaries.
- **Pressure solution** takes place when a wet rock is squeezed more strongly in one direction producing ions that migrate through the water to precipitate elsewhere. Precipitation may take place on faces where the grains are squeezed together less strongly. Thus, pressure solution causes grains to become shorter in one direction and elongated in another.
- **Plastic deformation** takes place when a rock is squeezed or sheared at elevated temperatures and pressures. Under such conditions minerals behave like soft plastic and change shape without breaking. Such deformation can take place together with the metamorphic reactions.

14.4 TEXTURES IN METAMORPHIC ROCKS

Now let us learn about the textures found in metamorphic rocks. Metamorphic textures demonstrate a great diversity in the size, shape, orientation and spatial arrangement of crystals which results from variable P-T (pressure and temperature) conditions during the metamorphism. Metamorphic textures could be categorised into four groups:

1. Palimpsest Texture
2. Typomorphic Texture
3. Reaction Textures
4. Corona Texture
5. Intergrowth Texture

14.4.1 Palimpsest Texture

The primary texture of the original rock is sometimes found to exist which is known as palimpsest texture. We use the term 'blastic' or 'blast' as suffix to represent the resembling metamorphic equivalents of igneous textures. Palimpsest texture is also known as **relict texture** because it is the texture which has survived metamorphism and shows the inheritance of protolith rock textures even after the metamorphism. Low-grade metamorphic rocks show good preservation of relict textures and are formed in such a way that deformation gets limited to let the preservation happen. Examples of palimpsest (relict) texture includes: basto-ophitic, blastoporphyritic, blasto-intergranular texture, and others.

You have read about all these textures in Unit 2 of this course where textures found in igneous rocks have been addressed. We will discuss them as relict textures in metamorphic rocks.

1. **Blasto-ophitic texture**: Plagioclase laths are seen suspended in a pyroxene matrix (sometimes olivine). Plagioclase laths may be seen fully surrounded in the matrix (ophitic) or they may be partially surrounded (sub-ophitic). This type of texture at a microscopic level if found intact even after deformation in a metamorphic rock is said to be a relict texture (Fig. 14.1).

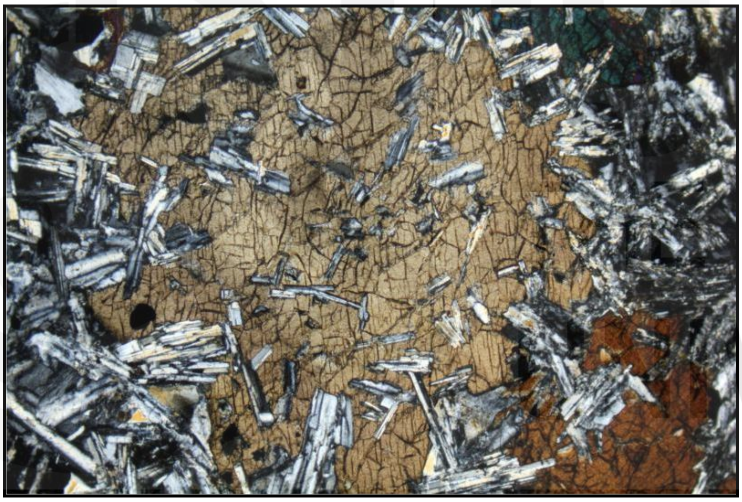

Fig. 14.1: Photomicrograph showing plagioclase laths, as inclusion within big augite crystal indicative of blasto-ophitic texture, under XP. Note few plagioclase laths on the margin are partially enclosed. (Field of View = 2mm; Source: www.alexstrekeisen.it)

2. **Blasto-intergranular texture**: The igneous relict textures in metamorphic rocks that show occupancy of interstices formed between plagioclase crystals by ferromagnesium minerals (such as pyroxene, olivine etc.) The interstices are generally formed between two large crystals and are angular (Fig. 14.2).

3. **Blasto-porphyritic texture**: Larger grains or crystals are surrounded by the fine-grained matrix or glassy groundmass (Fig. 14.3). They are more common in extrusive igneous rocks but may occur in medium- to coarse-grained igneous rocks. Their presence in a metamorphic rock is considered to be of a relict of the texture existing in the parent rock.

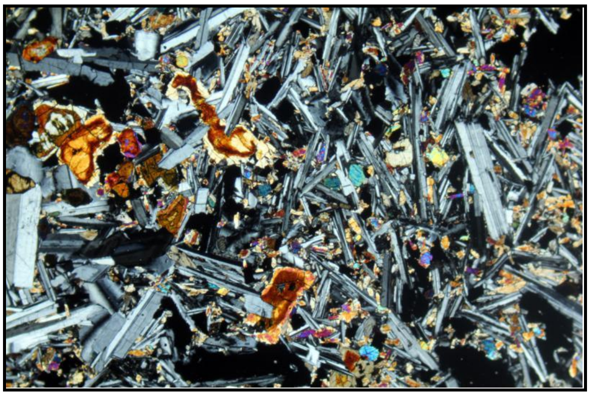

Fig. 14.2: Photomicrograph showing coarse-grained blasto-intergranular texture in a metamorphic rock under XP. Angular interstices between the plagioclase laths are occupied by pyroxene mineral (orange brown). This is indicative of basalt as a protolith. (Source: www.alexstrekeisen.it)

Fig. 14.3: Photomicrograph showing larger crystals of plagioclase, biotite and clinopyroxene clustered and surrounded by fine grained groundmass depicting blasto-porphyritic texture. (Source: www.alexstrekeisen.it)

4. **Blasto-cumulate texture**: Early formed crystals with high density settle down giving rise to cumulate texture. This texture survives metamorphism and is preserved as relict texture in metamorphic rocks.

14.4.2 Typomorphic Texture

These textures are characteristic and are developed in metamorphic rocks either by the dynamic forces or by the effect of thermal action or crystallisation.

A) **Textures Based on Dynamic Forces**

Textures based on the dynamic forces can be categorised into:

- Porphyroclastic texture
- Mylonitic texture

1) **Porphyroclastic Texture**: Due to deformation in the metamorphic rock, the softer minerals get crushed and form groundmass while the resistant minerals get fragmented and appear to be larger than the surrounding minerals. Two distinct grain size distributions of the same mineral, viz. coarser grained porphyroclasts and finer grained fragments are produced. The larger grain is known as the porphyroclast and resulting texture is called as porphyroclastic texture (Fig. 14.4).

Fig. 14.4: Photomicrograph of porphyroclast grain consisting of quartz (rounded grain) surrounded by softer minerals in groundmass exhibiting porphyroclastic texture under XP. (Field of View = 2mm; Source: www.alexstrekeisen.it)

2) **Mylonitic Texture**: The development of foliation planes or oriented minerals in the metamorphic rocks is such that it forms the platy minerals or quartz (ribbon quartz) to orient in a particular direction (Fig. 14.5). Ductile deformation due to cataclastic metamorphism is thought to be the prime cause for such a textural development in metamorphic rocks. Based on the development of foliation mylonitic texture may categorised as:

- **Protomylonitic**: When development of foliation mylonitic texture is incipient or preserves initiation of mylonitisation;
- **Orthomylonitic**: When the rocks develop a well - defined foliation. Quartz grains get oriented in a ribbon-like fashion;
- **Ultramylonitic**: It is most advanced stage of cataclastic metamorphism and results in the recrystallisation of the highly strained crystals into smaller ones to develop a granoblastic polygonal texture.

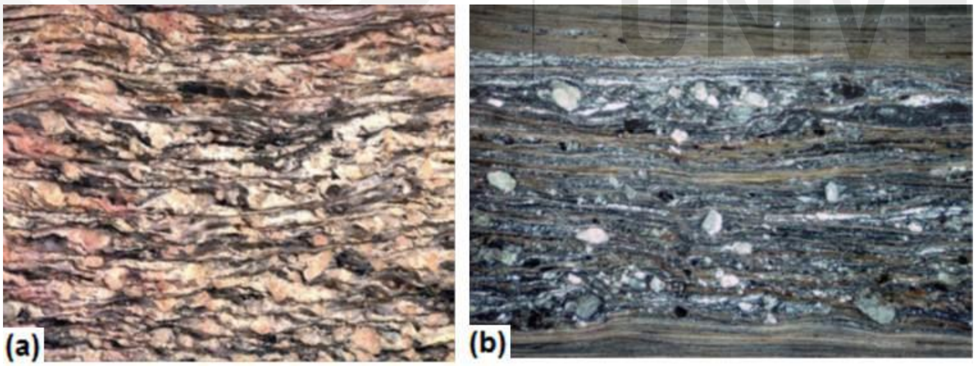

Fig. 14.5: a) Mylonite on an outcrop scale. (Source: www.alexstrekeisen.it)**; b) Photomicrograph of mylonite between two ultramylonite bands under XP.** (Field of view = 5mm; Source: Wiersma et al., 2009)

B) Textures Based on Thermal Effect

We have discussed the typomorphic texture produced due to the dynamic effect. Now we shall discuss typomorphic textures based on thermal effect. When thermal metamorphism is not associated with any deformation, the mineral grains show a randomly oriented texture, unarranged and scrambled giving rise to either granoblastic or hornfelsic textures. However, the development of granoblastic texture may occur in regionally metamorphosed rocks too. Textures based on thermal effect can be:

- Nodular texture
- Granoblastic texture

1) **Nodular Texture**: When the growth of oval-shaped porphyroblasts of minerals such as cordierite or scapolite takes place in association with randomly distributed quartz and other minerals, then the texture so developed is called a~~s~~ nodular texture in the metamorphic rocks (Fig. 14.6).

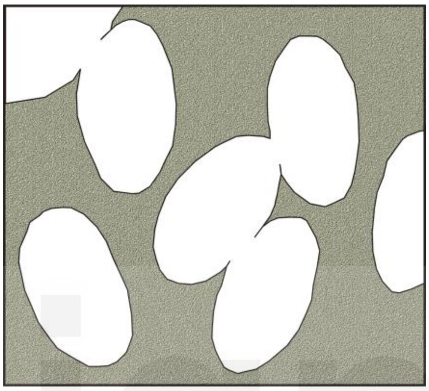

Fig. 14.6: Nodular texture: diagrammatic representation in a thermally metamorphosed rock. (Source: Spry, 1969)

2) **Granoblastic Texture**: This is a characteristic texture developed in a non-foliated metamorphic rock such as marble or quartzite. The grains are equigranular to nearly equigranular and form a welded mosaic of recrystallised mineral grains. The development of porphyroblastic grains is not seen.

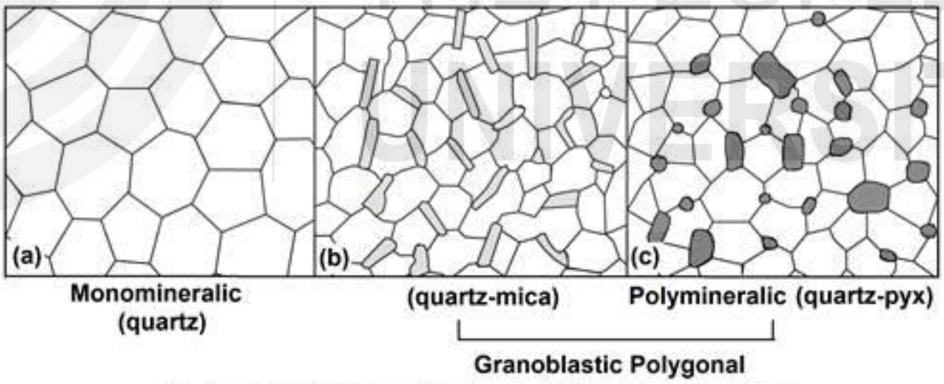

Fig. 14.7: Diagrammatic representation showing different possible polygonal granoblastic textures in a non-foliated metamorphic rock: a) Monomineralic quartz in quartzite; b) and c) Polymineralic quartz-mica and quartz-pyroxene. (Source: Spry, 1969)

The granoblastic texture may vary from equidimensional grains having straight grain boundaries and well-developed crystal faces, as in polygonal granoblastic texture (Fig. 14.7) to irregular grain boundaries (as in interlobate granoblastic texture). There may also be a situation where along with the grain irregularity the minerals are anhedral too (as in amoeboid granoblastic texture). When mineral grains are interlocked, randomly oriented and prismatic or elongated in habit with common triple junctions then such a granoblastic texture is called a **decussate granoblastic texture** (Fig. 14.8).

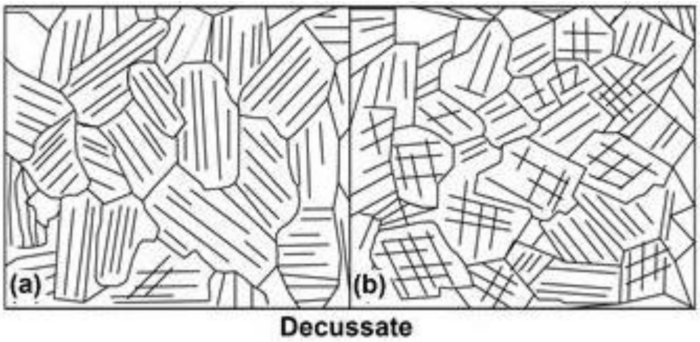

Fig. 14.8: a) and b) Diagrammatic representations show decussate granoblastic texture in non-foliated metamorphic rock. (Source: Spry, 1969)

C) Crystallisation Textures

Apart from textures based on dynamic and thermal effect, crystallisation textures also fall in the typomorphic type of metamorphic textures in which coarse-grained metamorphic textures develop. Some of the crystallisation textures are:

- Porphyroblastic texture
- Poikiloblastic texture

1) **Porphyroblastic texture**: When coarse-grained minerals are seen to occur in a fine-grained ground mass or are surrounded by fine-grained minerals then such a texture is called as **porphyroblastic texture** and the large mineral grain is called a **porphyroblast**. The metamorphic minerals like garnet and staurolite tend to recrystallise and form large, individual crystals while other minerals such as mica and biotite tend to form masses composed of small interlocked grains. Rock will typically contain large crystals of one mineral embedded in a matrix of small crystals of the other, e.g. large garnets are often found embedded in a mass of fine-grained muscovite or biotite (Fig. 14.9). Porphyroblastic texture in metamorphic rocks is quite similar in appearance to the porphyritic texture found in igneous rock.

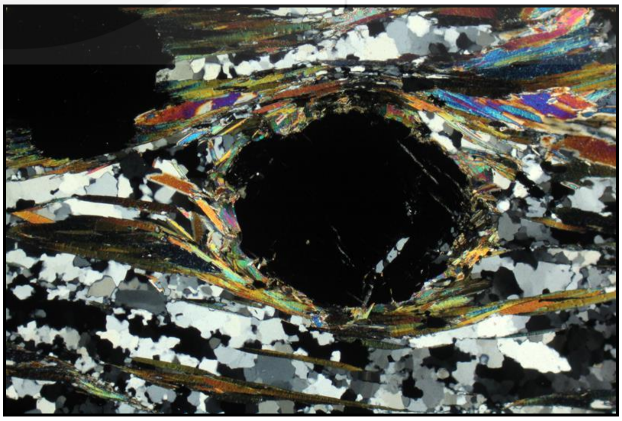

Fig. 14.9: Photomicrograph showing porphyroblastic texture with garnet as a porphyroblast under XP. (Field of view = 2mm; Source: www.alexstrekeisen.it)

2) **Poikiloblastic texture**: This type of texture is marked with the addition of several fine-grained inclusions within the porphyroblast grain. The orientation of the mineral grains occurring as inclusions may be random, helictic or spiral or seem to be rotated (Fig. 14.10).

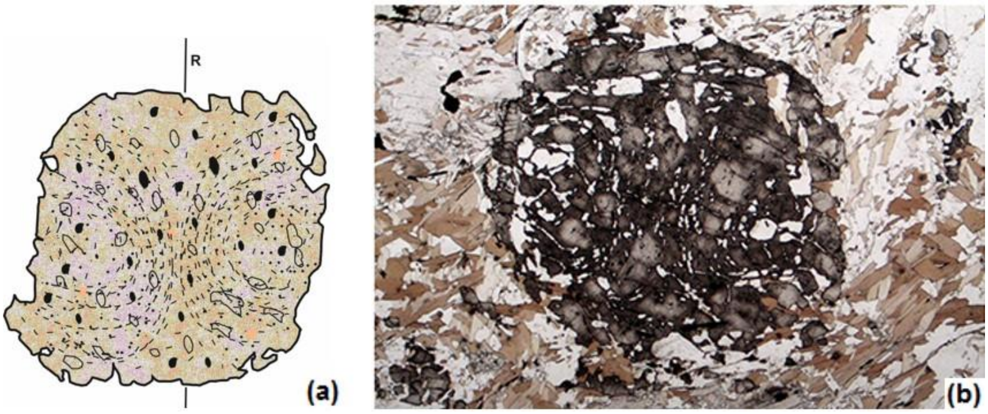

Fig. 14.10: Poikiloblastic texture showing inclusions with helictic orientation within the porphyroblast, 'R' = Rotation axis. (Source: Bard, 1980)

14.4.3 Reaction Texture

You have learnt about palimpsest (relict) and typomorphic textures in the previous sections. Now let us study the reaction texture.

When a new mineral formation takes place either by the replacement of older mineral or by the reaction between two phases or sequential reactions; the formation of new minerals take place in the form of concentric rings around a pre-existing grain. This texture is known as reaction texture. Some of the important reaction textures are:

- Reaction-Rim texture
- Kelyphitic texture

1) **Reaction-Rim texture**: When replacement of an older phase (mineral) takes place along the rim of the mineral then a new mineral is formed. The rim becomes irregular and forms a contact between the two mineral phases indicating some reaction taking place between both the phases (Fig. 14.11).

2) **Kelyphitic texture**: In this texture also, replacement takes place but by the intergrowth of two or more minerals. The resultant texture is such that the new minerals completely encircle the replaced mineral (Fig. 14.12). This type of texture generally develops in retrogressive metamorphic rock. It is also called as a **replacement texture**.

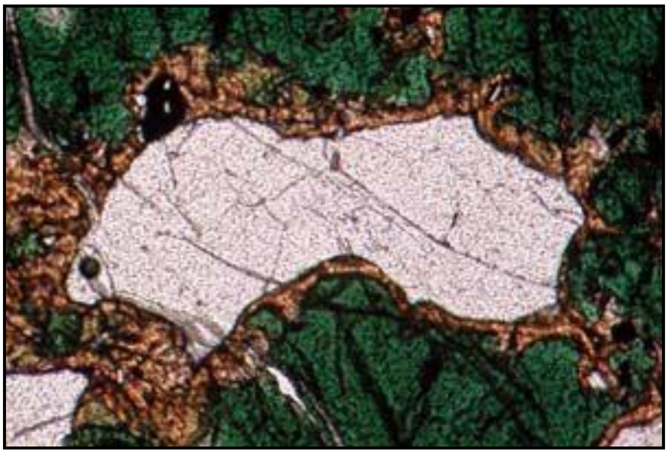

Fig. 14.11: Reaction- Rim of garnet between plagioclase and hornblende. (Source: www.academic.brooklyn.cuny.edu)

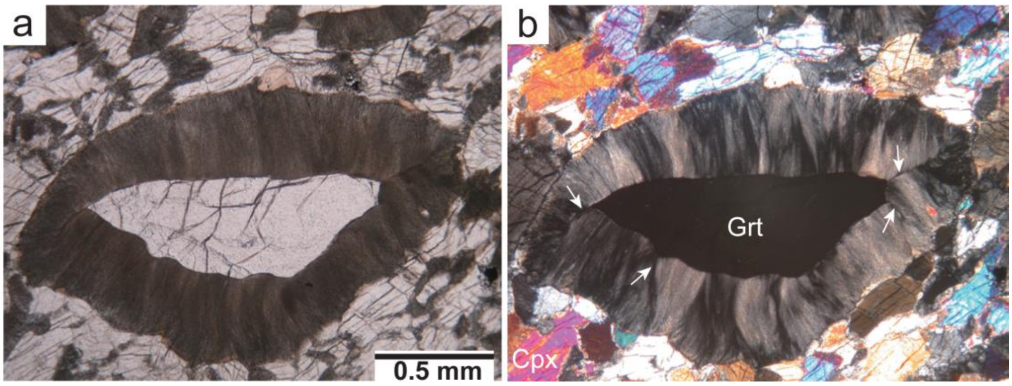

Fig. 14.12: Kelyphitic texture showing garnet-clinopyroxenite; a) PPL; and b) XP. (Source: Obata, 2007)

14.4.4 Corona Texture

This type of texture may develop in both prograde and retrograde phase of metamorphism. One or more minerals form a complete rim around the older phase present in the centre or core of the texture such that the geometry resembles a corona (Fig. 14.13). The rim layers formed may range from one to five in numbers depending upon the number of reactions that have taken place.

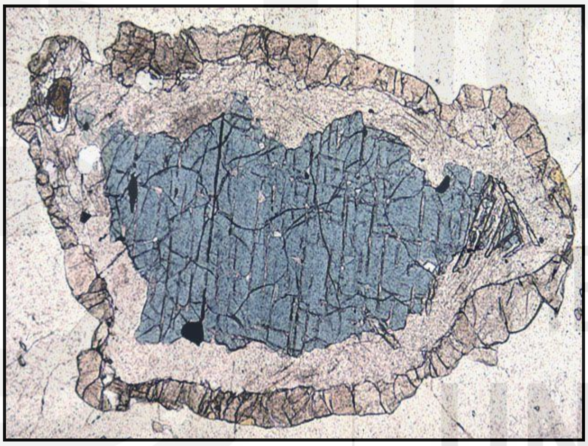

Fig. 14.13: Photomicrograph showing orthopyroxene in the outer rim – sillimanite (middle layer) corona on sapphirine (blue). (Source: Sandiford, 1985)

14.4.5 Intergrowth Texture

Symplectite texture is represented by worm-like appearance of minerals formed along the boundary of the older minerals which are reacting. Fig. 14.14 shows symplectite intergrowth of orthopyroxene– garnet–cordierite. It is also called a reaction textures in which fine-grained mineral intergrow irregularly due to some reaction taking place at the rim of the previously formed mineral.

Myrmekitic texture is one such example wherein vermicular, or wormy quartz intergrows plagioclase (Fig. 14.15). This type of texture is commonly seen in high-temperature metamorphic rocks.

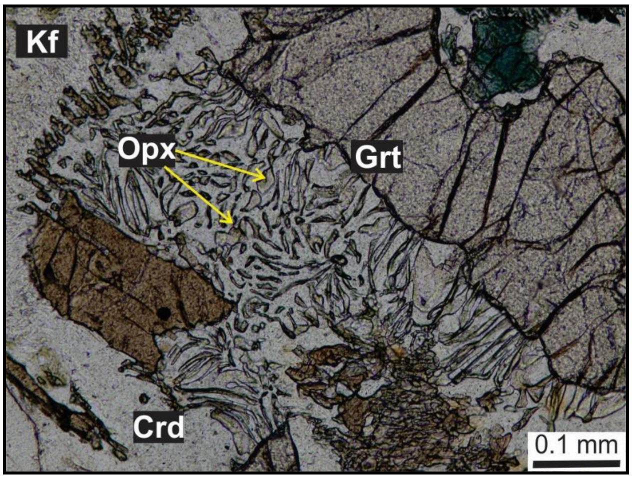

Fig. 14.14: Photomicrograph showing symplectite intergrowth of orthopyroxene (Opx) – garnet (Grt) – cordierite (Crd) under XP. (Source: Prakash et al. 2017)

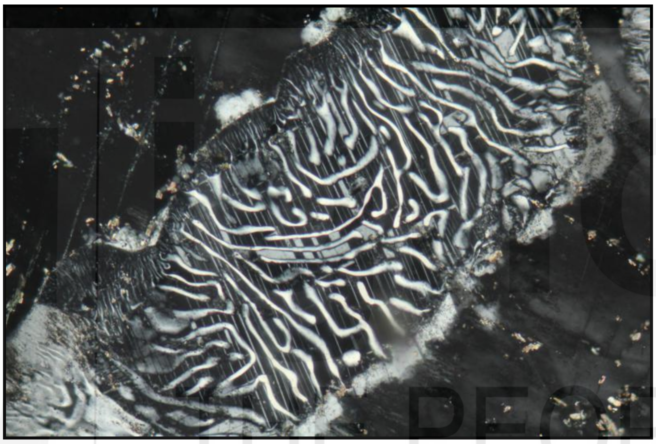

Fig. 14.15: Photomicrograph showing myrmekite texture in plagioclase. Note wormy quartz in plagioclase. (Field of view = 2mm; Source: www.alexstrekeisen.it)

So, you have learnt about the textures found in metamorphic rocks. Before discussing about the structures in metamorphic rocks, please spend few minutes to perform an exercise to check your progress.

SAQ 1

a) What is recrystallisation?

b) What are the denser polymorphs of quartz?

c) What is pressure solution?

d) Why is palimpsest texture known as relict texture?

e) What is porphyroblastic texture?

f) What is kelyphitic texture?

14.5 STRUCTURES IN METAMORPHIC ROCKS

We have discussed the textures found in metamorphic rocks in the above section. Let us now study structures commonly found in the metamorphic rocks. Some of the common structures related to the metamorphic rocks are:

14.5.1 Foliation and Lineation

Foliation indicates a texture displayed by metamorphic rocks in which mineral grains exhibit a preferred, directional orientation. The alignment of platy minerals or alternating layers of light (felsic) and dark (mafic) minerals is seen in foliated metamorphic rocks. The layering within metamorphic rocks is called foliation. It is derived from the Latin word *folia*, meaning "leaves”. Penetrative surfaces which are nearly or fully parallel defining the planar fabric elements are called **foliation** and the penetrative sets comprising of parallel or nearly parallel lines forming a linear fabric element are termed **lineation** (Fig. 14.16)**.** The term penetrative structures occur virtually all over the rock body even at the microscopic level. However, structures penetrative in one domain may not be penetrative in other domain/s.

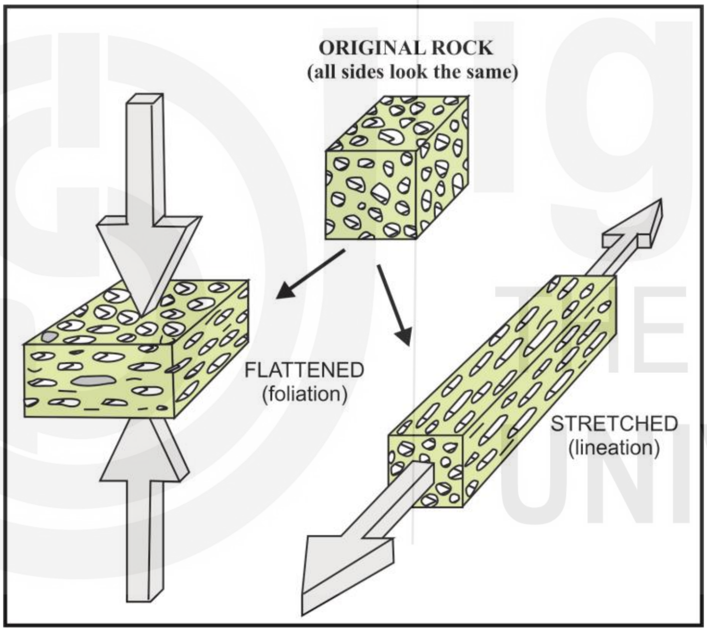

Fig. 14.16: Representation of the processes involved and type of morphology developed in foliation and lineation. (Source: www.usgs.gov)

Foliation is a planar feature whereas lineation is a linear feature. Foliations could be seen on all sides of the rocks as lines and lineations are viewed as circular to irregular specks or dots on at least one surface of the rock. The development of planar and linear features takes place in a plane perpendicular to the maximum principal stress applied on parallelly arranged flaky minerals (mica, chlorite) as evident from the foliations. Cleavage is the tendency of a rock to break along surfaces of a specific orientation. All cleavages are foliations, and the two terms are often used to describe the same structure. Foliation is a more general term than cleavage because it includes planar geometric features that might not result in a cleavage.

Foliations and lineations could be morphologically classified (Twiss and Moore, 2007) as given in Table 14.1 and 14.2. Foliations are distinguished by differences in preferred orientation of mineral grains in structure or in composition. Foliations defined by a spacing of 10 μm or more are known as spaced foliations. Continuous foliations exhibit finer structure or in other words are closely spaced. **Spaced foliations** are categorised into three categories: compositional, disjunctive, and crenulation foliations. **Compositional foliations** are marked by layers, or laminae, of different mineralogical composition. **Disjunctive foliations** are characterised by thin cleavage domains or seams, marked by concentrations of oxides and/ or strongly aligned platy minerals. **Crenulation foliations** are formed by harmonic wrinkles or chevron folds that develop in a pre-existing foliation. **Continuous foliations** are defined either by domains with spacing less than 10 μm and they are divisible by grain size into **fine** and **coarse** continuous foliations. Slate and schists have fine and coarse continuous foliation respectively. Some of the most common rock types showing foliation are the phyllites, schists and gneisses. Feldspars commonly show lineation and foliation in granites.

Table 14.1: Morphological classification scheme for foliation.

Foliation and Cleavage	Spaced	Compositional
		Disjunctive
		Crenulation
	Continuous	Fine
		Coarse

Lineation may be structural or mineralogical. **Structural lineation** is marked by the selective preference of orientation of linear structures in the rock whereas the **mineral lineation** is formed by alignment of minerals parallelly (Fig. 14.17). The mineral orientation is seen associated either with elongated (amphiboles) mineral grains, acicular (sillimanite) **mineral grains** or elongate **polycrystalline** aggregates. Structural lineation can be categorised as: **discrete** and **constructed**. Discrete lineations are formed by the orientation of discrete objects such as ooids, pebbles and fossils. Constructed lineations are formed from planar features such as intersection of two foliations, crenulation hinge lines, boudin lines, structural slickenlines, and mullions. You have read about this in Block 3 of BGYCT-131 course.

Table 14.2: Morphological classification scheme for lineation.

Lineations	Structural	Discrete
		Constructed
	Mineral	Polycrystalline
		Mineral grain

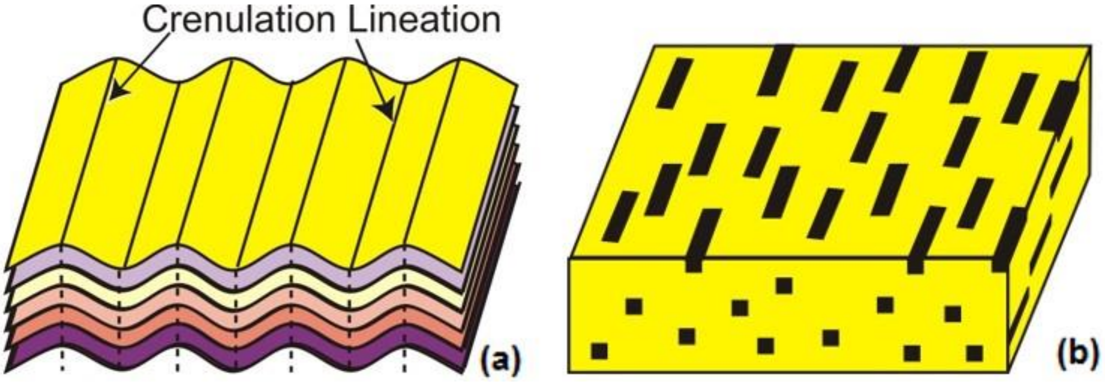

Fig. 14.17: a) Crenulation lineation; and b) Mineral lineation.

14.5.2 Slaty Cleavage

Slaty structure has a strong parallelism in the foliation of fine-grained clay minerals and platy minerals such as micas impart a strong slaty cleavage. Parallel alignment or layering of fine-grained platy minerals (Fig. 14.18) in a certain direction falling perpendicular to the stress maximum gives a plane parallel to bedding called as slaty cleavage. This kind of planar feature develops in fine-grained rocks such as slate and phyllite. Here when the protolith undergoes metamorphism then clay minerals get converted to chlorite. The other platy minerals could be micaceous type. Such a structure (texture) forms under low-grade metamorphic conditions that wane off with increasing grade in metamorphism. The slaty cleavage develops when compression causes clay flakes to reorient and regrow into an orientation perpendicular to the direction of compression. The plane so formed is a foliation plane of weakness along which the rock splits very easily into thin plates or layers (Fig. 14.19). This cleavage allows it to split into thin sheets that make excellent roofing shingles.

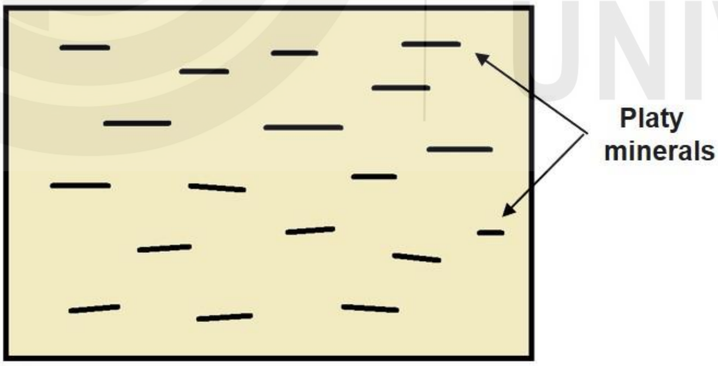

Fig. 14.18: Development of slaty cleavage in a sedimentary protolith. Note the alignment of platy minerals.

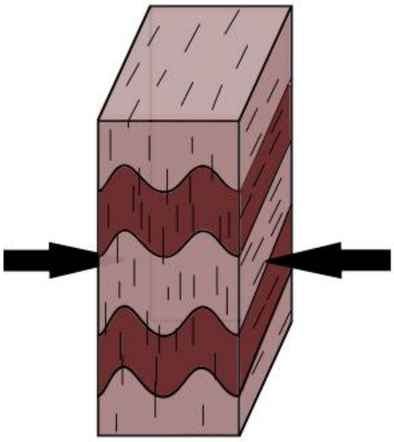

Fig. 14.19: Schematic representation of continuous foliation indicating formation of slaty cleavage.

14.5.3 Schistose Structure /Texture

Schistose structure or schistosity is strongly foliated texture produced by the growth of minerals. Schist has a foliation or mineral alignment of medium to coarse-grained minerals. Schistosity is defined by the preferred orientation of large mica flakes. This texture is found in mica schist, chlorite schist and hornblende schist.

Schistosity is the layering developed due to the parallel arrangement of micaceous minerals or platy minerals developed as the result of metamorphism under directed pressure in low to medium grade coarse-grained metamorphic rocks. Grain size increases and the grains could be easily identified even with the unaided eye (Fig. 14.20). The structure so developed is again a planar feature forming a foliation plane. The mineral content and the grain size in schistosity are different from that in the slaty cleavage. In schistose structure chlorite breaks to form minerals such as feldspar, mica and quartz etc. The newly developed minerals align themselves in such a manner that their longer axis is oriented parallel to the directed maximum stress (Fig. 14.21). The rocks having such a texture are called as **schists**. The other minerals, viz. kyanite, sillimanite, staurolite etc. are also part of the foliation plane. Along the foliation plane, the rock having schistosity is weak and could be cleaved with some difficulty.

Fig. 14.20: Rock cutting polished surface showing schistosity or schistose structure. (Source : https://flexiblelearning.auckland.ac.nz/rocks_minerals/rocks/schist.html)

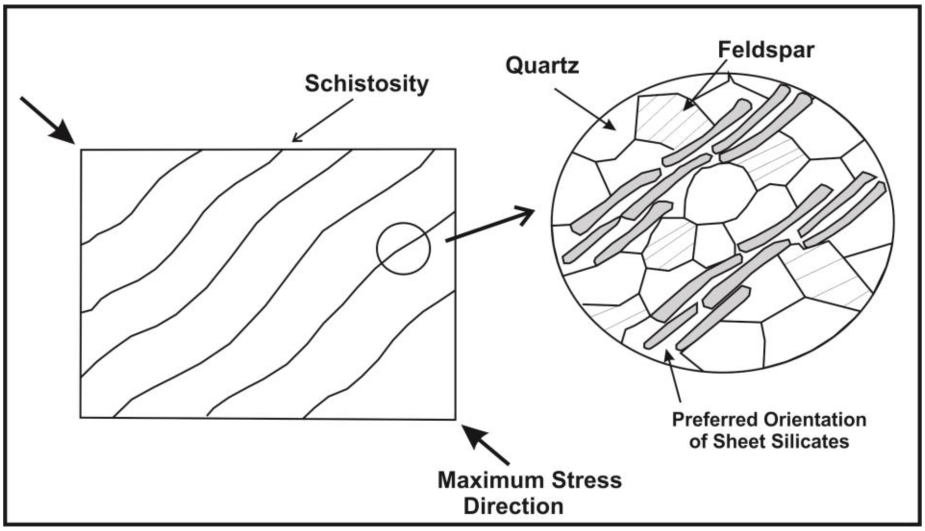

Fig. 14.21: Schistosity development and stress direction forcing minerals to align perpendicular to the latter forming foliation plane.

14.5.4 Gneissose Structure/Texture

Gneissose structure shows discontinuous banding of light-coloured medium to coarse-grained minerals such as quartz and feldspar and dark-coloured minerals such as. pyroxene and hornblende with granulose texture. Thus, the light and dark bands of different compositions are arranged alternately. These bands are produced by the segregation of minerals. This compositional layering or gneissic banding gives the gneiss a characteristic striped appearance. The banded structure is formed due to metamorphic differentiation and alteration of schistose rocks when the latter is exposed to very high grade of regional metamorphism. The bands so formed are of two types - the dark bands and the light bands, and the arrangement is such that they appear to alternate (Fig. 14.22). The lighter bands are composed of felsic minerals and the dark bands comprise of mafic minerals (Fig. 14.23). The difference between the aforementioned bands may just not be limited to colour and mineralogy but also in the texture of the bands. Such megascopic display is exclusive of the rocks known as gneiss. The fabric of gneisses is comparably weaker than the schistosity and continues to get weaker with the lessening of mica content in the rock (Fig. 14.24). Once the partial melting starts the process of migmatisation commences with eventually the unmelted parts comprising the darker layers and the melted parts comprise the light-coloured layers.

Fig. 14.22: Gneissose banding in hand specimen.

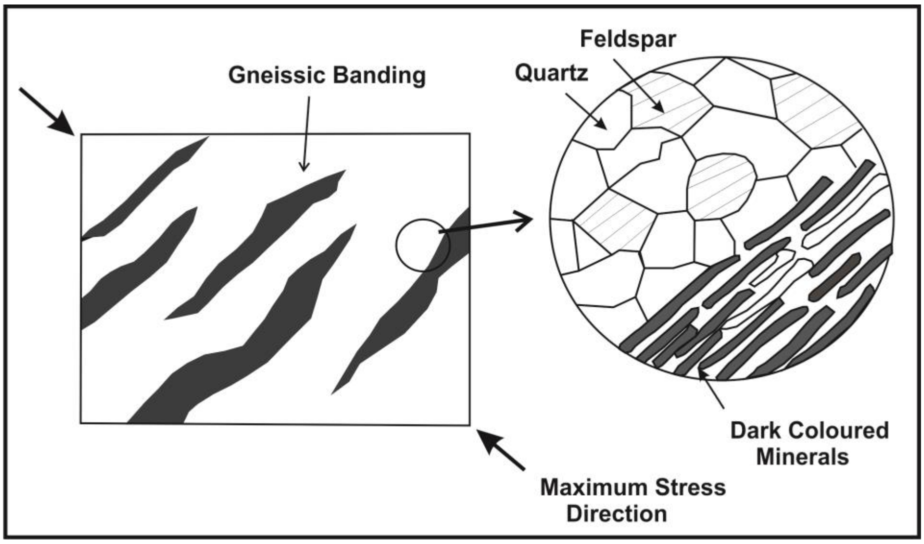

Fig. 14.23: Stress alignment and processes leading to the formation of bands in gneiss. Note that the bands in gneiss are discontinuous.

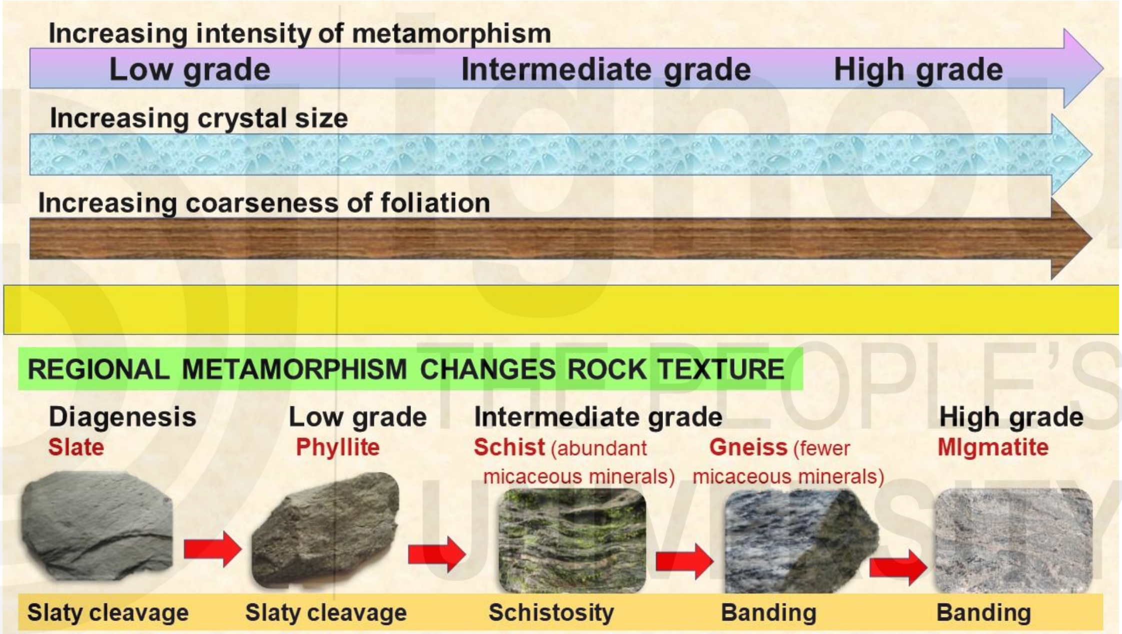

Fig: 14.24: Foliated rocks are classified by metamorphic grade, grain size, type of foliation and banding. As the intensity of metamorphism increases crystal size and coarseness of foliation increases.

14.5.5 Cataclastic Structure

The cataclastic structure is a tectonically developed structure. The stress plays its role in the absence of high temperature and fragments the rock due to intense shearing. They are produced against the directed pressure acting along a fault zone where two rock units after faulting slide past each other. The softer minerals in the rock due to shearing get powdered while the resistant minerals, which overcome the crushing force to some extent, get shattered and crushed forming crushed breccias (Fig. 14.25). The pulverisation of minerals is essentially due to the sliding action but no crystallisation of new minerals occurs. The resultant texture due to such a stand out of minerals finds similarity with the porphyritic texture and is thus called as the **porphyroclastic** or **pseudoporphyritic** structure. When the shear stress is high enough along with the reasonably raised temperatures the mylonitic structure develops (Fig. 14.26).

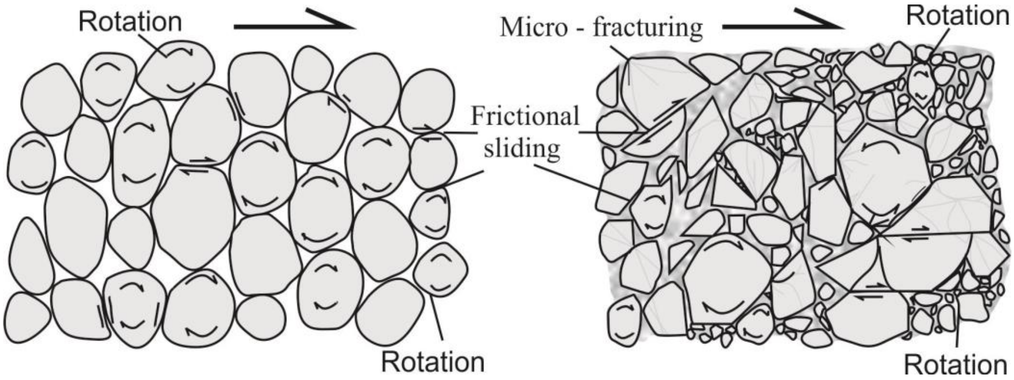

Fig. 14.25: Diagrammatic representation of processes involved in cataclastic metamorphism: a) Granular flow-rock fabric pre-deformation; b) Post-deformed whole rock showing cataclastic structure. (Source: Haakon Fossen, 2010)

Fig. 14.26: Microstructure of a mylonite texture. (Source: Lapworth, 1899)

14.5.7 Pseudotachylite

A dark coloured, very fine-grained rock developed due to devitrification of glass and occurring as veins is called as pseudotachylite (Fig. 14.27). The name has a prefix of pseudo- so as to indicate its resemblance to the basaltic glass (tachylite). The complete devitrification of glass is in response to frictional melting that takes place as a consequence of either seismic faulting (due to rapid movement of fault) or impacting (melt produced due to heat emanation by shock) or during landslides (melt produced due to heating as a consequence of large blocks moving during landslides).

Fig. 14.27: Injection vein of pseudotachylite. (Source: http://www.lpl.arizona.edu/~rlorenz/pseud.html)

Pseudotachylites formed in seismic faulting may occur as injected vein type (vein injection in walls) or fault vein type (along the fault surfaces) or they may occur as pseudotachylite breccia (matrix in tectonic breccias). Pseudotachylites are taken as palaeoseismic (earthquake) indicators.

Learners, you have now learnt the details of structures found in the metamorphic rocks. Before going to the next section, please spend a few minutes to perform an exercise to check your progress.

SAQ 2

a) What is slaty cleavage?

b) Define schitosity.

c) Define gneissose structure.

d) Mention a cataclastic structure.

e) What is pseudotachylite?

f) What is mineral lineation?

14.12 SUMMARY

Let us summarise what we have learnt in this unit:

- Structure includes features on large scale or outcrop scale or hand specimen scale or they may be at a regional scale also. On the contrary the term texture is used for features at small scale, i.e. from the microscopic to the hand specimen scale.
- The factors controlling the metamorphic mineral content, textures and structures depend on: (1) composition of the parent rock; (2) temperature; (3) pressure; (4) effects of tectonic forces and chemically active fluids; and (5) time.
- The most common processes responsible for formation of textures are: recrystallisation, phase change, metamorphic reaction or neocrystallisation, pressure solution and plastic deformation.

- Metamorphic textures could be categorised into: (1) palimpsest textures; (2) typomorphic textures; (3) reaction textures; (4) corona texture; and (5) intergrowth textures.
- Palimpsest texture is also known as relict texture because it is the texture which is inherited from the protolith rock textures that is preserved even after the metamorphism.
- Typomorphic textures are developed in metamorphic rocks either by the dynamic forces or by the effect of thermal action or by crystallisation.
- The development of reaction texture takes place either by the replacement of the older mineral or by the reaction between the two phases. Corona texture develops in both the prograde and retrograde phase of metamorphism.
- Foliation is a planar feature whereas lineation is a linear feature. The development of planar and linear features takes place in a plane perpendicular to maximum principal stress applied on parallelly arranged flaky minerals (mica, chlorite).
- The slaty cleavage develops when compression causes clay flakes to reorient and regrow into an orientation perpendicular to the direction of compression.
- Schistosity is the layering developed due to the parallel arrangement of micaceous minerals or platy minerals developed as the result of metamorphism in low to medium grade coarse-grained metamorphic rocks.
- Gneissose structure shows discontinuous banding of light-coloured medium to coarse-grained minerals.
- The cataclastic structure is a tectonically developed structure. Dark coloured, very fine-grained rock developed due to devitrification of glass and occurring as veins within the sheared country rocks are called pseudotachylite.

14.12 ACTIVITY

- Make a list of textures and structures you have studied and draw their sketches.
- Try to look for the structures that you studied in the slabs used in the kitchen and on the floors.

14.13 TERMINAL QUESTIONS

1. Discuss the factors affecting textures in the metamorphic rocks.
2. Describe palimpsest textures present in the metamorphic rocks.
3. Describe typomorphic textures found in the metamorphic rocks.
4. What is foliation and lineation? Discuss their morphological classification.

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14.15 FURTHER/SUGGESTED READINGS

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14.16 ANSWERS

Self Assessment Question

1 a) Recrystallisation changes the shape and size of grains without changing the identity of the minerals constituting the grains.

b) Coesite, stishovite.

c) Pressure solution, takes place when a wet rock is squeezed more strongly in one direction producing ions that migrate through the water to precipitate elsewhere.

d) Palimpsest texture is also known as relict texture because it is the texture which has survived metamorphism and shows the inheritance of protolith rock textures even after the metamorphism.

e) When coarse-grained minerals are seen to occur in a fine-grained ground mass or are surrounded by fine-grained minerals then such a texture is called as porphyroblastic texture and the large mineral grain is called a porphyroblast.

f) In this texture also, replacement takes place but by the intergrowth of two or more minerals.

2 a) Parallel alignment or layering of fine-grained platy minerals (Fig. 14.16) in a certain direction perpendicular to the stress maximum defined by parallel alignment of micas and/or kaolinite is called as slaty cleavage.

b) Schistosity is the layering developed due to the parallel arrangement of micaceous minerals or platy minerals developed as the result of metamorphism under directed stresses in low to medium grade coarse-grained metamorphic rocks.

c) Gneissose structure shows discontinuous banding of alternating bands of light-coloured medium to coarse-grained minerals such as quartz and feldspar and the bands comprising dark-coloured minerals.

d) Porphyroclastic or pseudoporphyritic structure.

e) A dark coloured, very fine-grained rock developed due to devitrification of glass and occurring as veins is called as pseudotachylite.

f) Mineral lineation is formed by parallel alignment of minerals.

Terminal Questions

1. Please refer to section 14.1.
2. Please refer to subsection 14.4.1.
3. Please refer to subsection 14.4.2.
4. Please refer to subsection 14.5.1, Tables 14.1 and 14.2.