

FELSIC AND INTERMEDIATE ROCKS

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6.1 INTRODUCTION

In the previous Unit 4, you have learnt the concept of magma, physical properties, and composition of magma, Bowen's reaction series, and the mechanisms of magmatic differentiation. Further in Unit 5, you have read about the unicomponent and bicomponent systems, application of phase rule and equilibrium crystallisation of magmatic systems. You have also read that the igneous rocks are grouped into four major subgroups, based on their composition, such as: ultramafic, mafic, intermediate and felsic rocks in Unit 1. These terms are used to indicate chemical composition of igneous rocks (Fig. 6.1), the silicate minerals that comprise them, and the magma types through which they were derived or formed.

Petrographic description of a rock provides detail about its mineralogical composition and texture, i.e. shape, size and inter-relationship of mineral constituents. The mineralogical composition studies cover both megascopic and microscopic observations. Megascopic description of rocks includes all the characters which are visible in hand specimens by unaided eyes. While, microscopic characters of rocks are studied using thin sections under the petrological microscope. You have read about petrological microscope in Unit 9 and diagnostic features of different minerals in thin section in Unit 10 of BGYCT-131 course. The textural relationship on the other hand is mostly observed under the microscope. Since the petrographic description and textural details of any rock contribute greatly to the understanding of the sequence of crystallisation of the various mineral constituents in a rock. This knowledge provides an idea about their genesis.

In this unit, we will discuss megascopic and petrographic description of the important felsic and intermediate rocks. The mafic and ultramafic rocks will be discussed in next unit.

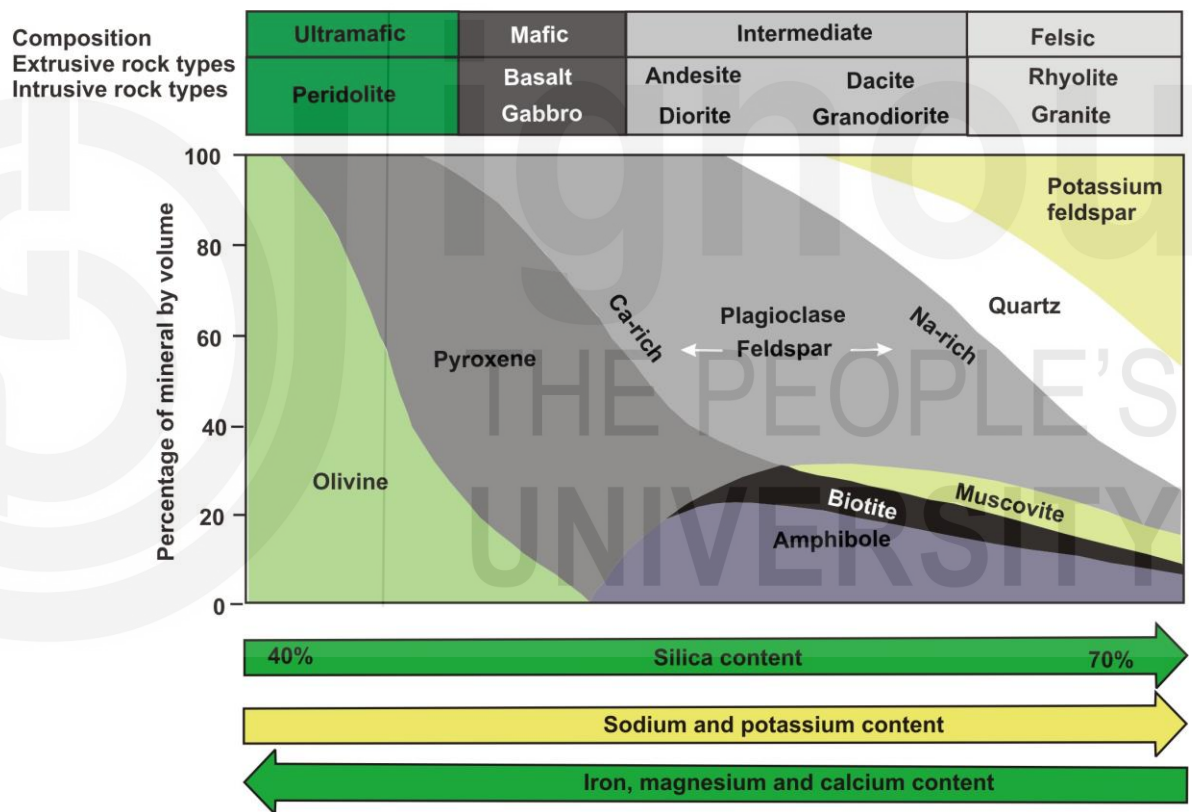


Fig. 6.1: Principal chemical and mineralogical characteristics of common igneous rock types.

Expected Learning Outcomes

After reading this unit, you should be able to:

- ❖ define felsic and intermediate igneous rocks;
- ❖ identify megascopic and microscopic characteristics of felsic rocks, e.g. granite and rhyolite; and

- ❖ learn and list megascopic and microscopic characteristics of intermediate rocks, e.g. granodiorite, diorite, syenite and phonolite.

6.2 WHAT ARE FELSIC ROCKS?

Let us discuss what are the felsic rocks.

The term **felsic**, i.e. FEL+SIC is a combination of the two words: **F**eldspar and **S**ilica. The igneous rocks which have more than 65% of silica content are called **felsic igneous rocks**. These rocks are usually enriched in sodium and potassium and depleted in iron, magnesium, and calcium than the mafic rocks. The important minerals in felsic rocks are quartz, feldspathoid, soda and potash feldspar and muscovite. Felsic rocks are usually light-coloured because the minerals that comprise felsic rocks are often light-coloured. In this unit we shall discuss the most common felsic rocks, i.e. granite and rhyolite. Before discussing the important felsic rocks, let us define the following:

- **Granitoid/ Granitic Rock:** In practice, a granitic rock is used commonly for a group of plutonic rocks which include (*sensu-stricto*) granites and is classified according to the percentage of quartz, alkali feldspar and plagioclase contents present in a QAPF diagram as you have read in Unit 3. In this unit we shall discuss medium to coarse-grained rocks that are mostly felsic with a few mafic minerals present (Fig. 6.2a). Please note that the granite (*sensu-stricto*) according to modern petrologists' convention, contains both plagioclase and alkali feldspar (orthoclase and microcline).
- **Rhyolite** is an extrusive rock and is closely related to granite in composition. It is cooled much more rapidly than the granite and gives a glassy appearance. Rhyolite has much finer crystals and commonly cannot be seen by the unaided eye (Fig. 6.2b). The minerals that make up rhyolite are quartz, feldspar, mica, and hornblende.
- **Pegmatite** is very coarse-grained felsic rocks that occur as dykes or pod like segregations both within granitic plutons which are intruded into the surrounding country rock. Compositionally, most of the pegmatites are similar to granite and are composed of quartz, alkali feldspar and mica. Pegmatites are formed during the final stage of magma crystallisation. They contain exceptionally large crystals and contain minerals that are rarely found in other types of rocks (Fig. 6.2c). Pegmatite is considered to be store house of gemstones.

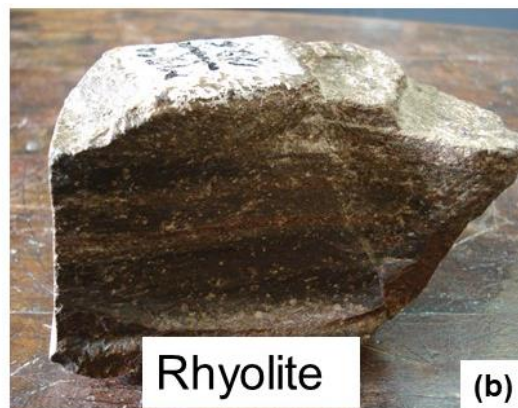




Fig. 6.2: a) Granite is intrusive/plutonic igneous rock; b) Rhyolite is extrusive/volcanic igneous rock, (Photo credit: Prof. Meenal Mishra); and c) Pegmatite with large crystals of tourmaline. (Source: www.gsi.gov.in)

You have studied the concept of essential and accessory minerals and also the igneous textures in Unit 2 and 3 of this course respectively. Let us recapitulate that texture is defined as the mutual relationship of different mineralogical constituents in a rock. It is determined by the size, shape and arrangement of these constituents (mineral and glass) within the rock. We shall discuss about mineralogical and microscopical characters of granite (a felsic plutonic rock) and rhyolite (a felsic volcanic rock) in the following sections.

6.3 GRANITE

Granite is one of the most common igneous rocks found on the Earth's surface and is commonly used as dimension/ building stones. Granite is a plutonic felsic rock. It is mostly light in colour and grains are large enough to be visible with the unaided eye. Let us discuss the megascopic and microscopic characteristics of granite in following subsections.

6.3.1 Megascopic Characters

Granite occurs as light coloured (leucocratic), medium to coarse-grained intrusive igneous rock (Fig. 6.3). It is essentially composed of quartz, alkali feldspar and plagioclase with minor amount of mica, amphiboles, and other accessory minerals. The predominance of alkali feldspar over plagioclase distinguishes it from granodiorite which is another felsic rock. It is important for you to note that granite is rich in alkali feldspars (orthoclase and microcline) as compared to plagioclase. Whereas granodiorite is rich in plagioclase as compared to alkali feldspars (orthoclase and microcline). You will learn about granite in section 6.6. The dominance of light-coloured minerals is responsible for its leucocratic nature of granite, although dark coloured mineral grains are visible and are dispersed throughout the rock. You may find different shades of granite such as grey, white, red or pink in colour (Fig. 6.3). These colours depend upon the bulk mineral composition of granite.

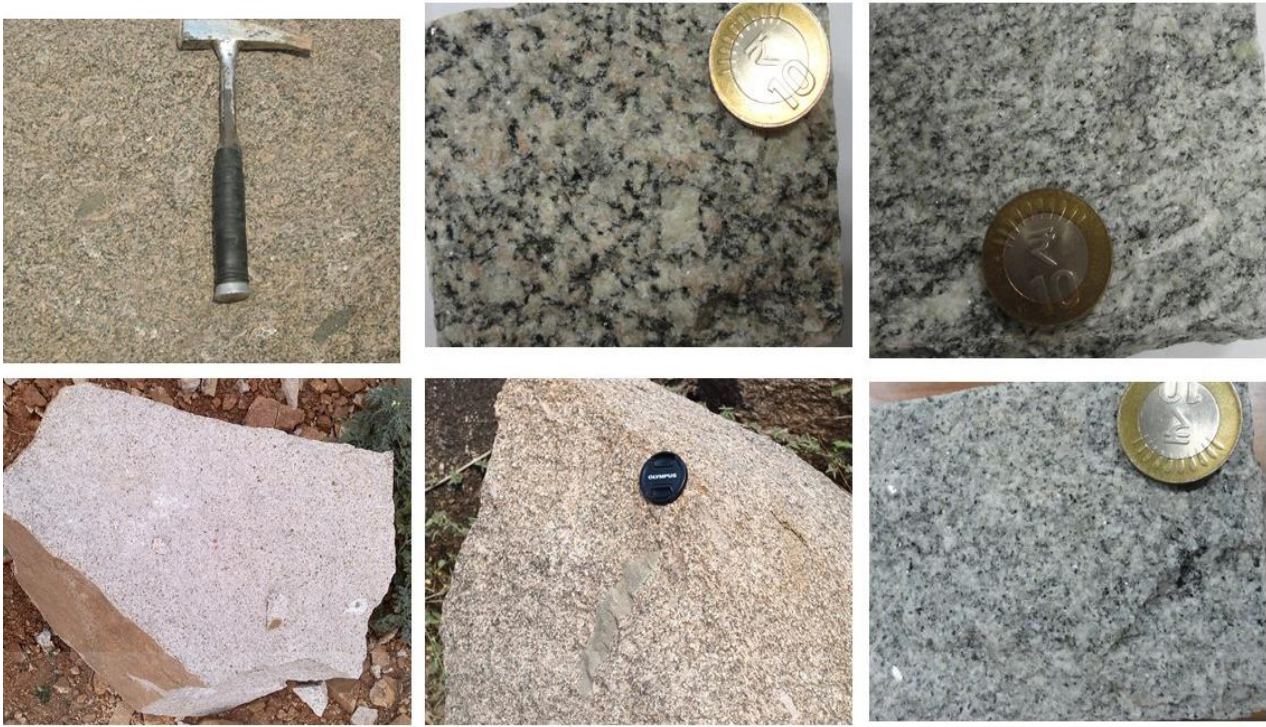


Fig. 6.3: Different colours of granite (grey, white or pink). (Photo credit: Prof. Meenal Mishra)

Granite contains more than 20% quartz, 50-80% alkali feldspars (orthoclase and/or microcline, perthite), plagioclase and mica (muscovite and biotite). In granite the amount of alkali feldspar (orthoclase and microcline) exceeds that of the plagioclase (Fig. 6.4). The mafic minerals are usually biotite, but amphibole may also occur. In a few types of granite, muscovite, garnet and cordierite are also present in variable amount.



Fig. 6.4: Field photograph showing medium-grained granite from Ladakh area. An aplitic dyke is cutting granite.

The megascopic characters of the rock are described below:

- i) **Colour:** Granite is light coloured (grey, white, pink or red) rock (Fig. 6.3). It is composed of light-coloured minerals therefore it is leucocratic rock, as you have read in Unit 3.
- ii) **Appearance:** It is medium-grained to coarse-grained grain size igneous rock.

- iii) **Mineralogical Composition:** The minerals which are found in these rocks as accessory, essential and secondary minerals are described below:
- **Essential Minerals:** Alkali feldspar (K-rich feldspar) > Na-rich plagioclase, perthite and antiperthite and quartz.
 - **Accessory Minerals:** Muscovite, biotite, hornblende, zircon, apatite, titanite (sphene), tourmaline, topaz, ilmenite and magnetite etc.
 - **Secondary minerals:** Sericite, chlorite and epidote.
- iv) **Texture:** The appearance, size and arrangement of different mineralogical constituents within the rock are as follows:
- **Physical appearance:** Granite consists of crystalline form and mostly show holocrystalline texture.
 - **Grain size:** It is generally medium to coarse-grained rock and exhibits equigranular or inequigranular (porphyritic) textures (Fig. 6.4).
 - **Mutual arrangement of the constituents/fabric:** The arrangement of the components is irregular and compact. Porphyritic texture is very commonly observed in granite. The feldspar phenocrysts (large crystals) are surrounded by fine quartz grains, feldspar and mica (Fig. 6.5).

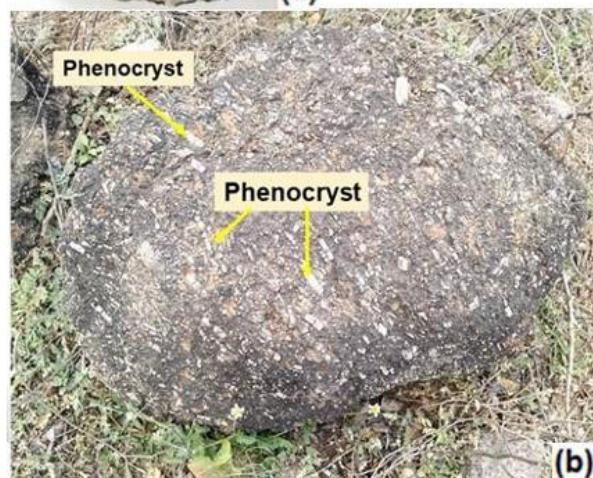
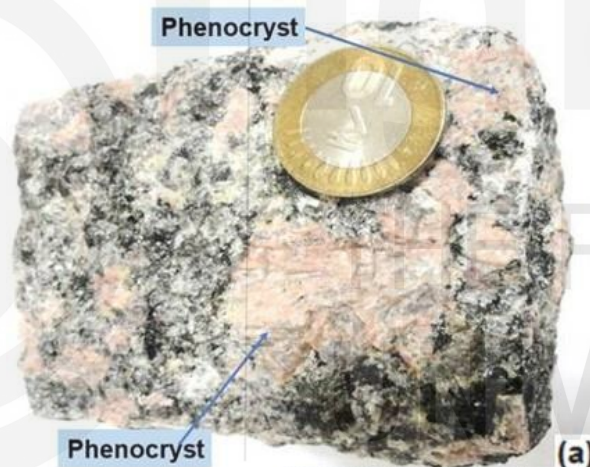


Fig. 6.5: a) Hand specimen of granite showing porphyritic texture. Phenocrysts (bigger crystals) of pink orthoclase are surrounded by smaller crystals (groundmass); and b) Boulder of porphyritic granite displaying phenocrysts of bigger crystals of lath shaped orthoclase (white) on the weathered surface. (Photo credit: Prof. Meenal Mishra)

- v) **Structure:** Granites commonly contain xenoliths (Fig. 6.6). Foliations are also rarely observed in a few granites.

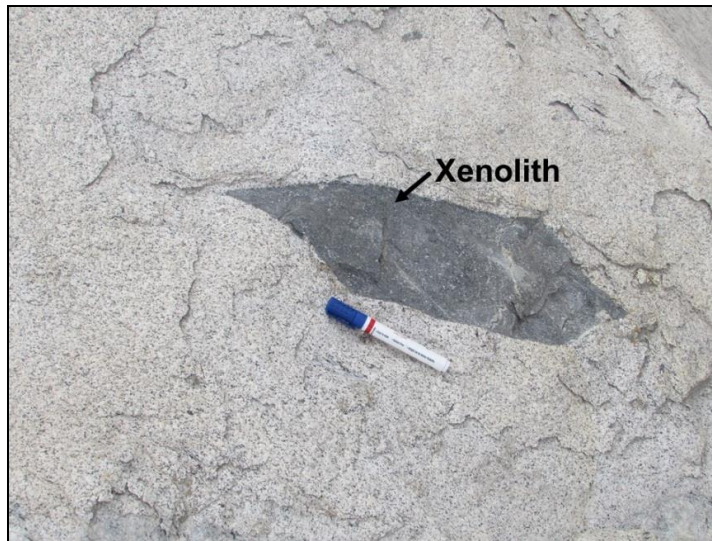


Fig. 6.6: Basaltic xenolith in granite. (Photo credit: Ihsan Ullah Lone)

6.3.2 Microscopic Characters

Microscopically granite contains mostly colourless minerals with very few coloured minerals under plane polarised light. It shows holocrystallinity. Most of the granite show equigranular texture, however a few types of granite contain coarse feldspar grains, surrounded by finer grains representing inequigranular texture. The microscopic characteristics of the granitic rock are described below:

- i) **Mineralogy:** Granite is essentially composed of quartz, alkali feldspar, plagioclase and mica in variable proportions (Fig. 6.7). The alkali feldspar is represented mostly by microcline and orthoclase and are always dominant over the plagioclase feldspar. While, studying thin sections of the granite under the microscope, you may also observe blebs or irregular lamellae of sodic feldspar within alkali feldspar. Such type of intimate intergrowth of sodic and potassic feldspars is called **perthite**. It results from subsolidus exsolution (unmixing of two minerals). You have read about exsolution texture (Fig. 6.8) in Unit 2. Let us recall. **Exsolution** textures represent chemical breakdown of an originally homogenous solid solution as it cools down. During cooling in solid state, the reverse process of solution, i.e. exsolution (unmixing) takes place and the intergrowth is produced.

Accessory minerals are those whose presence is not necessary which include: muscovite, biotite, hornblende, zircon, titanite (sphene), apatite, tourmaline and magnetite. Feldspar alters to sericite while hornblende alters to biotite and give rise to secondary chlorite. Epidote occurs rarely as secondary mineral in some of the granites.

- ii) **Texture:** The shape, size and mutual relationship between crystals are as follows:
- **Crystallinity:** The granite contains euhedral crystals of feldspar, mica, zircon, topaz and some other accessory minerals, while quartz occur in subhedral or anhedral forms. Hence, granite represents holocrystalline and hypidiomorphic texture.

- **Granularity:** Granite is medium to coarse-grained rock. It is usually granular with most of the grains of almost equal size (phaneritic), but porphyritic texture is also not rare. In case of porphyritic texture, phenocrysts of feldspar (usually euhedral or well-developed shape) are surrounded by smaller quartz and feldspar grains.
- **Mutual arrangement of the constituents/fabric:** In some granites **myrmekitic texture** is found. Myrmekite is the intergrowth of quartz in plagioclase. The intergrowths are microscopic in scale. These quartz-plagioclase (mostly sodic-albite or oligoclase) intergrowths are associated and commonly in contact with potassium feldspar texture (Fig. 6.8). In most of the granites, intergrowth of quartz and feldspar is observed giving rise to **graphic texture** (Fig. 6.9).

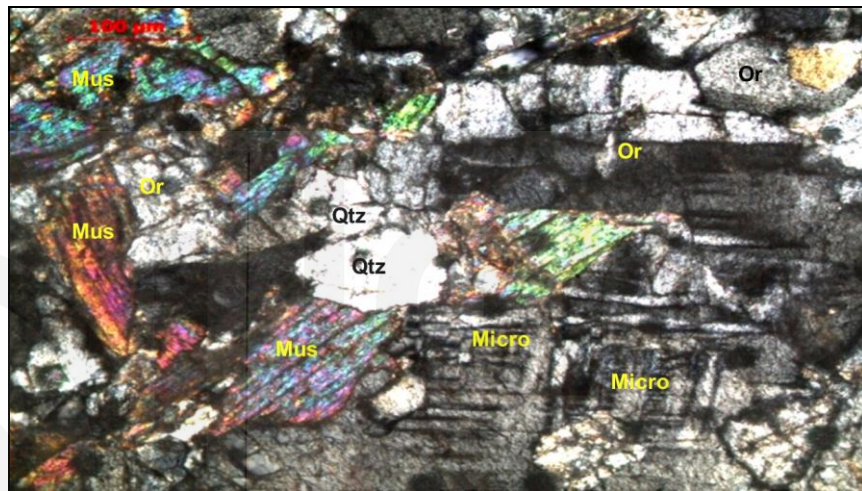


Fig. 6.7: Photomicrograph of granite showing typical mineralogy under cross nicol. Microcline (Micro) showing typical cross hatched twinning, orthoclase (Or) and quartz (Qtz) with first order grey interference colours and muscovite (Mus) with second and third order interference colours.

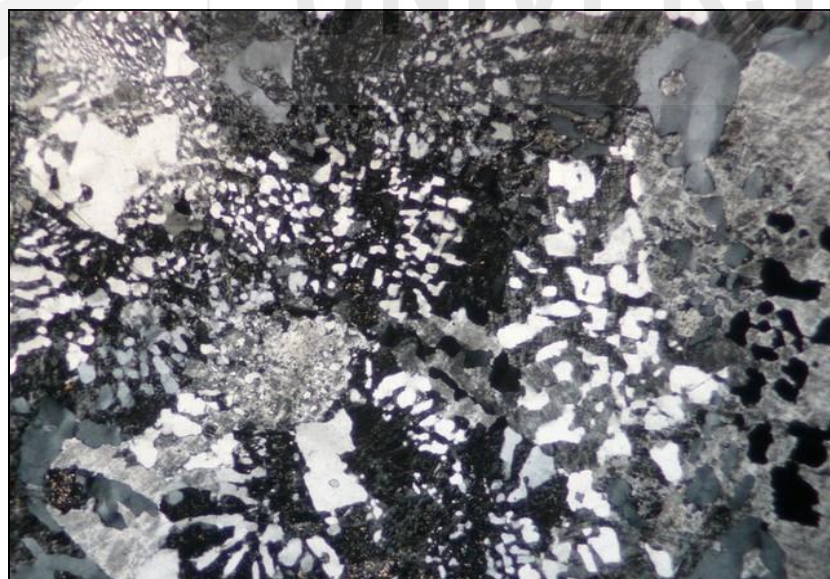


Fig. 6.8: Exsolution texture-myrmekitic texture. (Source: www.gsi.gov.in)

- iii) **Rock types:** The following types of granite are observed based on mineralogy:

- **Monzogranite:** Amount of alkali feldspar within the feldspar is 35-65% is called monzogranite. This is the most common granite type.
- **Syenogranite:** Within feldspars the alkali feldspar has an amount of 65-90%.
- **Alkali granite:** Amount of alkali feldspar within feldspar is >90%. The mafic minerals are alkali pyroxenes (aegirineaugite) and alkali amphibole.
- **Graphic granite:** Quartz and orthoclase show oriented intergrowth (Fig. 6.9) resulted from eutectic crystallisation.
- **Luxullianite (tourmaline-granite):** Tourmaline occurs in significant amount in such granites.

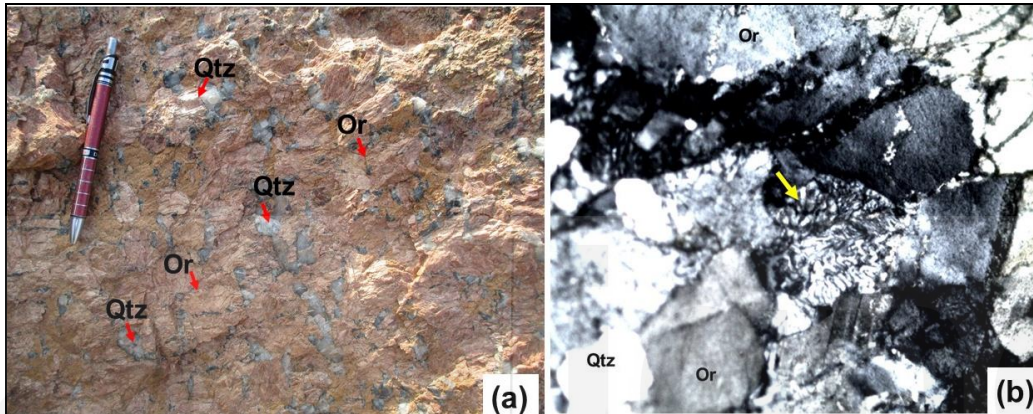


Fig. 6.9: Typical graphic texture seen in granite: a) Hand specimen of granite showing graphic intergrowth between grey quartz and pink orthoclase (Photo credit: Dr. Suresh Kumar); and b) Photomicrograph of granite showing graphic texture (marked by yellow arrow).

- iv) **Classification:** Granite is classified as felsic plutonic igneous rock.
- v) **Occurrence:** Granite is an intrusive igneous rock which is very hard and crystalline. It most commonly occurs in the form of stocks, bosses and batholiths.



Watch the following videos to know more about texture of granite.

- **Igneous Textures, Processes and Pathways: An Overview**
Link: <https://www.youtube.com/watch?v=9NU3SL7HWF4>
- **Igneous Textures, Processes and Pathways: Phaneritic Textures**
Link: https://www.youtube.com/watch?v=tw7vVvp6R_U
- **Igneous Textures, Processes and Pathways: Homogenous Textures**
Link: <https://www.youtube.com/watch?v=Zx6wQG0qiG4>
- **Rapakivi Texture**
Link: <https://youtu.be/voXGUT4HSxY>

6.4 RHYOLITE

In the above section you have read about megascopic and microscopic characteristics of granite. Now, let us discuss about another felsic rock, rhyolite. Rhyolite is a volcanic rock of felsic composition (Fig. 6.2b). It is a light-coloured

rock with high silica content (>68%). Alkali ($\text{Na}_2\text{O}+\text{K}_2\text{O}$) content reaches upto 5%. You have already read that rhyolite is extrusive equivalent of granite. These rocks are formed by acidic lavas which erupt at low temperatures (700 to 850°C) as compared to basalt and are much more viscous.

Let us now discuss the megascopic and microscopic characteristics of rhyolite in the following sections.

6.4.1 Megascopic Characters

Rhyolite is a light coloured, fine-grained igneous rock, dominated by quartz (>20%), alkali feldspar (>35%) and biotite. It is often porphyritic with feldspar (sanidine) and rarely quartz and plagioclase phenocrysts within the fine-grained or glassy groundmass. In case, quartz phenocrysts are not present, it is often difficult to identify rhyolites without chemical analysis due to their glassy groundmass. Many rhyolites consist of mainly glass, and are termed as **obsidian**, or are partially devitrified, and termed as **pitchstones**. Most of the rhyolites are banded due to small differences in composition in the glass.

You may find rhyolite with grey, bluish grey or pink in colour. Banding is quite commonly observed. It is normally related to the difference in the vesicles and crystallites in the glassy groundmass. The megascopic characters of rhyolite are:

- i) **Colour:** Generally, rhyolite (Fig. 6.10) is light coloured, such as pink, grey, bluish grey, but red rhyolites are also observed.
- ii) **Appearance:** The appearance of rhyolite is fine-grained and often banded.

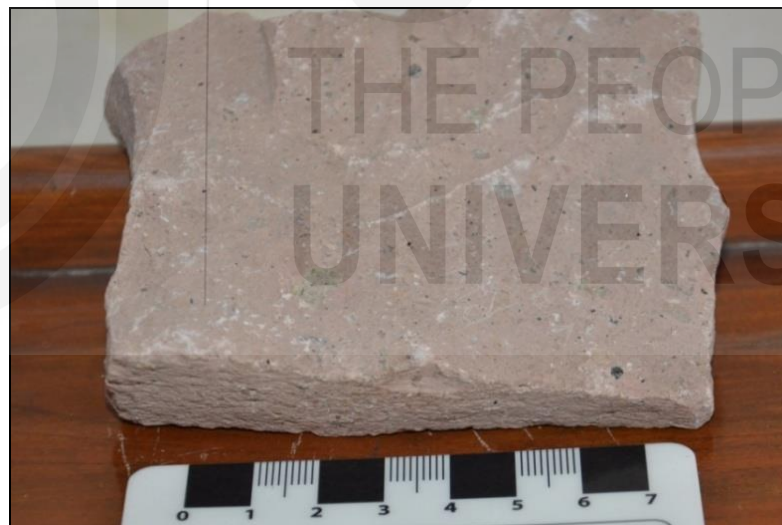


Fig. 6.10: Rhyolite with some minute vesicles.

iii) **Mineralogical Composition:** The rock is mostly fine-grained with few crystals visible by unaided eyes. The essential, accessory and secondary minerals are described below:

- **Essential Minerals:** K-feldspar (sanidine) > Na-rich plagioclase, quartz, biotite.
- **Accessory Minerals:** Zircon, apatite, magnetite, ilmenite, pyroxene, amphibole.
- **Secondary Minerals:** Sericite, chlorite.

iv) **Texture:** The appearance and grain size present in rhyolite are discussed below:

- **Physical appearance:** The texture of rhyolite varies from glassy, aphanitic to porphyritic. The orientation of small crystals in the rock reflects the lava flow direction. Frequently, rhyolite shows altering layers that differ slightly in granularity or colour.
- **Grain size:** It is fine-grained, mostly aphanitic, but a few euhedral to subhedral crystals may also be present in the finer matrix.
- **Mutual arrangement of the constituents/fabric:** Commonly rhyolite is equigranular and fine grained but sometimes it may exhibit porphyritic texture in hand specimen.

v) **Structure:** Rhyolite rock may have vesicular (Fig. 6.10) or amygdaloidal structure. It may contain spherulites that are spherical bodies, comprising of radial aggregates of needles, usually of quartz and feldspar. You have read about these structures in Unit 3 of this course. Rhyolitic magma flows very slowly and commonly develop a flow banding in the matrix. This is due to high viscosity and low capacity of the rhyolitic lava flow. You can observe flow banding both at megascopic and microscopic levels. In the field you may observe rhyolite occurring in the form of volcanic plate and lava basin with relatively large thickness and small propagation. Flow structure (Fig. 6.11a) and columnar joints (Fig. 6.11b) are commonly found in rhyolite. You have read about flow structures and columnar joints in Unit 3 of this course.

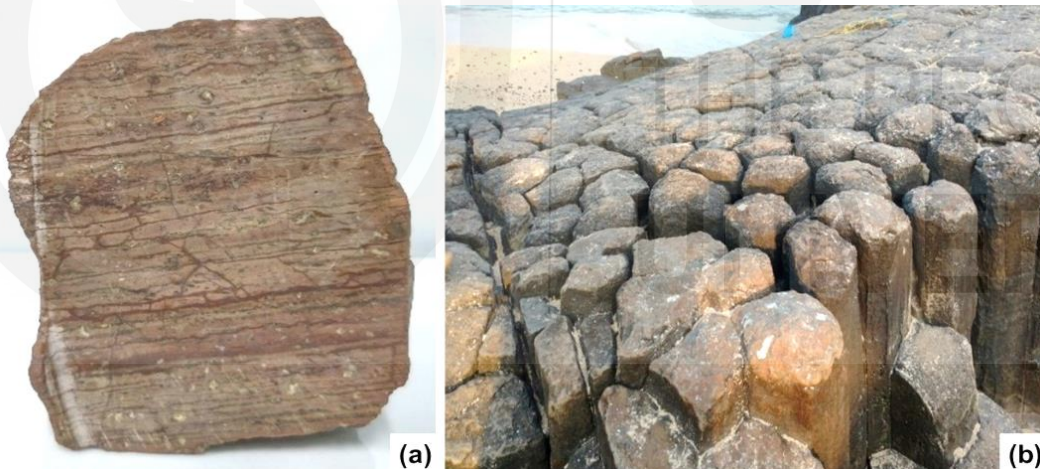


Fig. 6.11: a) Flow structures in rhyolite. Notice the dark and light bands marking flows (Photo credit: Dr. Amit Kumar); **and b) Columnar joints in rhyolite.**
(Source: www.gsi.gov.in)

6.4.2 Microscopic Characters

Rhyolite is composed of quartz, sanidine, plagioclase with minor amount of biotite, anorthoclase and magnetite when observed under the microscope. Glass is present in a variable amount. At places, the glassy portions are devitrified. Rock textures vary from holohyaline to hemicrystalline. The common texture in rhyolite is porphyritic.

i) **Mineralogy:** In general, the fine-grained groundmass is mostly made up of quartz, sanidine and plagioclase with lesser amount of orthoclase, biotite, amphibole, pyroxene and glass. Some phenocrysts of sanidine, plagioclase and

quartz are also recognised along with the amphibole and/or biotite. Quartz is more than 20% and the amount of alkali feldspars (sanidine/orthoclase) exceeds with that of the plagioclase. The mafic minerals are usually biotite and/or amphibole. Microscopically, you may find that some of the rhyolites contain equigranular quartz and feldspar and show uniform and homogenous nature. Presence of idiomorphic phenocrysts of quartz, sanidine and plagioclase set in a nearly aphanitic matrix consisting of quartz, sanidine/orthoclase, plagioclase, biotite and hornblende can be very well recognised in the porphyritic rhyolites (Fig. 6.12). One or more minerals out of zircon, apatite, xenotime, pyroxene, amphibole, magnetite, ilmenite, rutile and leucoxene may be present in rhyolites as accessory minerals. Sericitisation and chloritisation is commonly observed in rhyolite.

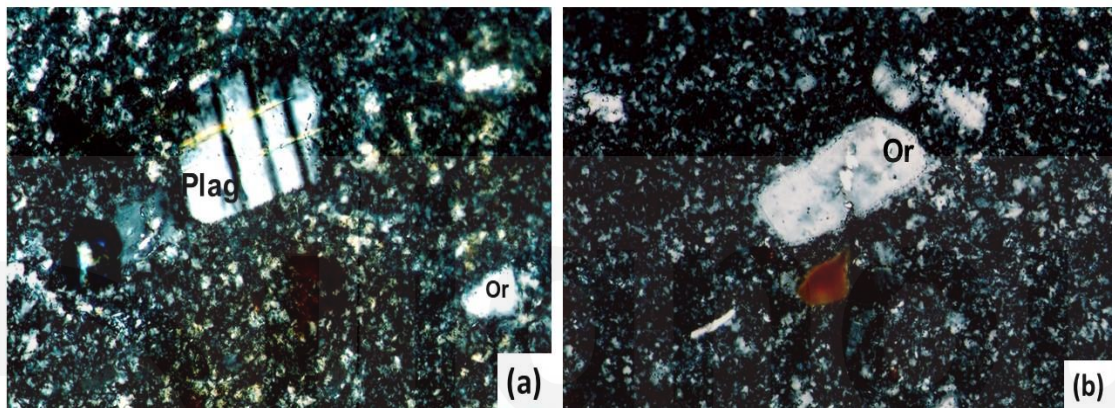


Fig. 6.12: Photomicrograph of porphyritic rhyolite showing fine grained vitrophyric matrix and phenocryst of euhedral grains of a) Plagioclase (Plag), b) Clouded orthoclase (Or) shows resorption at the margins. (Photo credit: Prof. Meenal Mishra)

- ii) **Texture:** Microscopically, the texture of rhyolite varies from cryptocrystalline to microcrystalline felsitic type to porphyritic type in accordance with their megascopic features. Spherulitic texture is also observed in devitrified glass portions. Holohyaline and hypocrySTALLINE textures characterise obsidian and pumice which contain volcanic glass.
- **Crystallinity:** Rhyolite is mesocrystalline or hemicrystalline, very fine grained and partly glassy.
 - **Granularity:** Grain size is very fine and/or partly glassy.
 - **Mutual arrangement of the constituents/fabric:** In thin section rhyolite appears very fine-grained. It may be glassy with holohyaline texture. Rhyolite can exhibit porphyritic texture with phenocrysts of quartz, plagioclase (Fig. 6.12a) and orthoclase/ sanidine (Fig. 6.12b). Quartz phenocrysts are bipyramidal in shape. The groundmass may be fine-grained or vitrophyric. Devitrification is commonly observed in thin section. The margins of phenocrysts often show resorption.
- iii) **Rock types:** Based on mineralogy and texture following rock types are observed in rhyolite:
- **Obsidian:** Rhyolitic glass with 1-2% water content, usually black, or rarely red in colour, having cusped fracture is called obsidian.

- **Perlite:** Rhyolitic glass with 3-5% water content, characterised by cusped fractures and globular appearance are called perlite.
- **Pumice:** It is highly vesicular glassy rhyolite (solidified magma foam) originating mostly during explosive volcanic eruption.

iv) **Classification:** Rhyolite rocks are classified as felsic volcanic rocks.

v) **Occurrence:** Rhyolites are more common and voluminous on the continents than in the oceans. They range from small domes and lava flows to much larger centres that have erupted volumes measured in hundreds of km³. Due to high silica content rhyolite melts are highly polymerised and form highly viscous lava. They also occur as breccia or volcanic plugs and dykes. Rhyolite occurs mostly at areas where thick crust is developed. It is commonly present along the subduction zones, but can also be observed in the extensional regions and in large magmatic provinces associated with the flood basalts. In India, rhyolite is extensively present within the Malani Igneous suit in Rajasthan.



Watch the following videos to know more about texture of rhyolite.

- **Igneous Textures, Processes and Pathways: An Overview**
Link: <https://www.youtube.com/watch?v=9NU3SL7HWF4>
- **Igneous Textures, Processes and Pathways: Aphanitic Textures**
Link: <https://www.youtube.com/watch?v=pboabkaFzWY&t=5s>
- **Igneous Textures, Processes and Pathways: Volcaniclastics**
Link:

In the previous sections we have studied about the megascopic and microscopic characters of felsic rocks like granite and rhyolite. Before going to the next section spend 5 minutes to check how you are progressing.

SAQ 1

- Name at least one plutonic and volcanic felsic igneous rock.
- Name the volcanic equivalent of granite?
- What are the essential minerals present in granite and rhyolite?
- Name important textures associated with granite.

6.5 WHAT ARE INTERMEDIATE ROCKS?

In the above sections you have read about felsic rocks. Now let us discuss, what are intermediate rocks?

Intermediate rocks are those igneous rocks which contain silica between 52 - 65%. Intermediate rocks are roughly even mixtures of felsic and mafic minerals that have chemical composition between those of basic and acid rocks. The most common felsic mineral in these rocks is plagioclase, while the most common mafic minerals in these rocks are hornblende, augite and/or biotite. There is little or no quartz

present in these rocks. Most common intermediate rocks are granodiorite, diorite, syenite, andesite and phonolite.

Now in the following subsections we will discuss about megascopic and microscopic characteristics of some common intermediate rocks such as granodiorite, diorite, syenite and phonolite.

6.6 Granodiorite

Granodiorite like granite is another most commonly found igneous rock on the surface of the Earth. It is also a plutonic felsic rock. It is mostly light coloured with grains large enough to be visible with the unaided eye.

You have read in the introduction part of this unit that granodiorite is a part of the granitic clan of rocks. It has some similarity with the granite. It differs from granite in having dominance of plagioclase over alkali feldspars and having low quartz and low SiO₂ contents.

6.6.1 Megascopic Characters

Granodiorite is usually medium-grained to coarse-grained and medium to light coloured intrusive felsic rock (Fig. 6.13). The large phaneritic crystal in this rock is due to slow cooling. Mineralogically, it is composed of quartz (10-30%), feldspar (plagioclase, alkali feldspar) and minor amount of biotite and amphibole. Out of the total feldspar present in the granodiorite, the Na rich plagioclase is more than K-feldspar (orthoclase). The mafic minerals are represented by amphibole, pyroxene and biotite.

- i) **Colour:** Granodiorite is of variable colours, but typically light coloured like grey, orange, pink and white. Some darker granodiorite types also occur in shades of greyish black (Fig. 6.13).
- ii) **Appearance:** It appears as holocrystalline, medium-grained to coarse-grained and light in colour.
- iii) **Mineral content:** The essential, accessory and secondary minerals are described below:
 - **Essential minerals:** Na-rich plagioclase, K-feldspar (orthoclase), quartz, biotite and amphibole. Quartz is generally colourless to smoky and identified by its glassiness, hardness, lack of cleavage, and conchoidal fracture. Feldspar dominates the granodiorite composition and is easily recognised by its appearance, colour and cleavages. Biotite is flaky, black and silver in appearance and hornblende is black/dark-green and prismatic in nature.
 - **Accessory minerals:** Muscovite, apatite, magnetite, zircon.
 - **Secondary minerals:** Sericite, chlorite, epidote.
- iv) **Texture:** The appearance, size and arrangement of different mineralogical constituents within the rock are as follows:
 - **Physical appearance:** Granodiorite consists of crystalline form and hence it shows holocrystalline texture (Fig. 6.13) with large phaneritic crystals.
 - **Grain size:** It is generally medium-grained to coarse-grained rock. They may show both equigranular and inequigranular (porphyritic) textures.

- **Mutual arrangement of the constituents/fabric:** The arrangement of the components is irregular and compact.
- v) **Structure:** The layered structure commonly occurs in many granodiorite plutons. Foliations are rarely observed in some granodiorites.

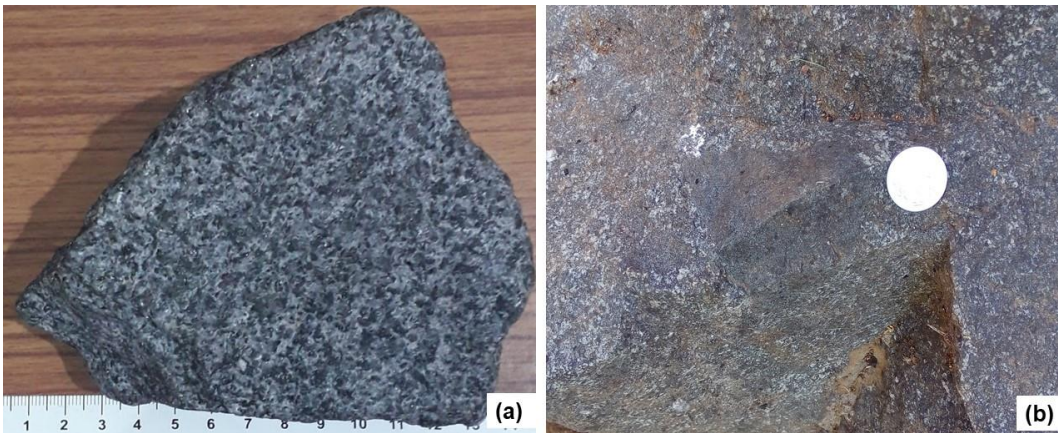


Fig. 6.13: Granodiorite showing uniform holocrystalline texture: a) Coarse-grained; and b) Medium-grained.

6.6.2 Microscopic Characters

Thin sections of the granodiorite show phaneritic texture. Under polarised light it contains many colourless minerals like plagioclase, alkali feldspar, quartz etc. with a few coloured minerals like biotite and hornblende. The microscopic characteristics of the rock are described below:

- i) **Mineralogy:** In order of abundance, it is composed essentially of plagioclase feldspar, alkali feldspar, quartz, biotite and hornblende in variable amount. Plagioclase is almost $2/3^{\text{rd}}$ of the total feldspar present in the rock. As it is a felsic rock, the light-coloured felsic minerals (quartz and feldspar) dominate over the mafic and dark minerals like biotite, hornblende and pyroxene (Fig. 6.14a). Minor amount of muscovite and pyroxene is also present in thin section. Quartz is typically anhedral (ill-formed crystals), and occurs as fillings within the interstices between the other minerals masking its own characteristic crystal shape. Quartz sometimes shows undulose/wavy extinction. The plagioclase typically shows lamellar twinning under cross nicols. Green hornblende with typical two sets of cleavages and pleochroism and brown biotite with one set of cleavage and pleochroism are commonly seen in these rocks. You have already read the optical properties of these minerals in BGYCT-133 and BGYCL-134 courses. Some of the minerals which may occur as accessory minerals are muscovite, zircon, titanite (sphene), apatite, tourmaline, magnetite etc. In some of the rocks, feldspars have undergone alteration to sericite, while hornblende and biotite may alter into secondary chlorite. Epidote also occur rarely as secondary mineral in some of the granodiorite.
- ii) **Texture:** The shape and size of the crystals are as follows:
- **Crystallinity:** Granodiorite is mostly granular in nature. Anhedral and subhedral minerals such as quartz, biotite and feldspar are present. You may get some euhedral grains of hornblende, zircon, sphene and plagioclase in some of the thin sections of granodiorites. The texture of granodiorite is hypidiomorphic.

- **Granularity:** The rock is mostly medium-grained to coarse-grained. It is usually granular with most of the grains are of almost equal in size (phaneritic), but porphyritic texture is also not rare (Fig. 6.14a and b). In case of porphyritic texture, feldspar phenocrysts (usually euhedral or well-developed) surrounded by smaller grains of quartz, feldspar and biotite. Zoned feldspar can also be seen in some of the granodiorite.
- **Mutual arrangement of the constituents/fabric:** Intergrowth texture is commonly observed in granodiorite. Like granite, graphic and myrmekitic textures are also observed in the granodiorite.

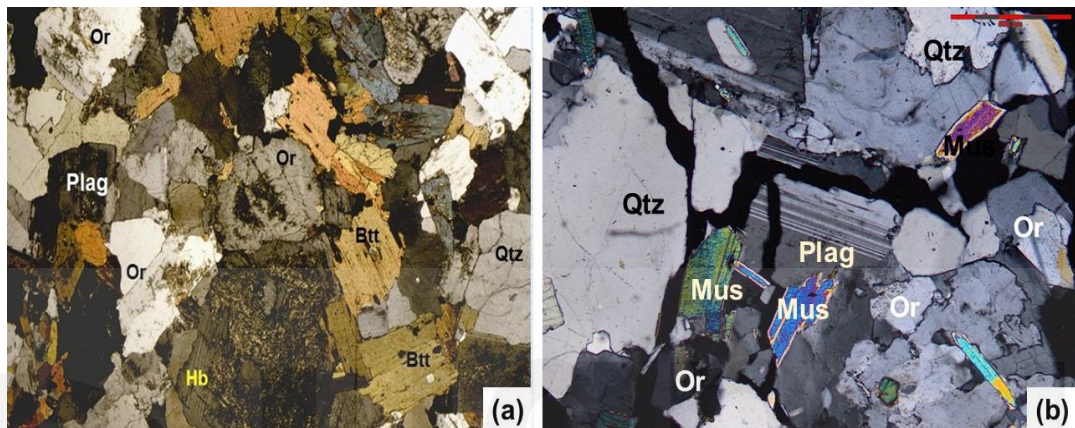


Fig. 6.14: Photomicrographs of granodiorite consisting of: a) Anhedral quartz (Qtz), orthoclase (Or), plagioclase (Plag), hornblende (Hb) and biotite (Btt); and b) Quartz, plagioclase, orthoclase and muscovite. (Photo credit: Prof. J. P. Shrivastava)

iii) **Rock types:** The following rock type is observed:

- **Tonalite:** It is usually coarse-grained rock with lesser amount of quartz and feldspars. They are represented almost exclusively by Na-rich plagioclase with no or very little alkali feldspar.

iv) **Classification:** Granodiorite is classified as felsic plutonic igneous rock.

v) **Occurrence:** Granodiorite is an intrusive rock. It is formed mostly in subduction zones (active continental margins) and collisional settings. It also occurs in small volume, shallow intrusive bodies of andesitic to dacitic volcanoes. The rock is very hard, crystalline and is visibly homogeneous in texture.



Watch the following video to know more about granodiorite.

- **Igneous Textures, Processes and Pathways: Homogenous Textures**

Link: <https://www.youtube.com/watch?v=Zx6wQG0qiG4>

6.7 DIORITE

In the above section you have read about megascopic and microscopic characteristics of granodiorite. Now, let us discuss about another intermediate rock, diorite. Diorite is a plutonic igneous rock with intermediate composition. It is crystalline in nature and usually shows granular texture. Its appearance may vary widely, but usually it is found consisting roughly of equal size crystals. Its volcanic equivalent is andesite. Diorite in wider sense may include other varieties such as

quartz diorite, quartz monzodiorite, monzodiorite etc. In strict sense of its definition based on QAPF diagram of IUGS classification, it consists of feldspar out of which more than 90% is plagioclase and less than 5% is quartz. Due to its mineralogical composition, it commonly appears as speckled black and white and hence is often referred to as "salt and pepper" rock.

6.7.1 Megascope Characters

The megascopic characters of the rocks are described below:

- i) **Colour:** Diorite is dark to medium in colour, typical speckled black and white.
- ii) **Appearance:** Due to its mineralogical composition, it commonly appears as speckled black and white, hence it is often referred to as "salt and pepper" rock (Fig.6.15). It is a medium-grained to coarse-grained holocrystalline intrusive igneous rock.



Fig. 6.15: Diorite showing uniform salt and pepper appearance.

- iii) **Mineralogical Composition:** The essential, accessory and secondary minerals are described below:
 - **Essential Minerals:** Ca-Na plagioclase, amphibole, less biotite and pyroxene (clino- and/or orthopyroxene). Among the mafic minerals, the amphibole predominates. The feldspar in diorite is generally white. The dark minerals in diorite are primarily biotite and amphibole.
 - **Accessory Minerals:** Minor amount of quartz, alkali-feldspar, apatite, magnetite and garnet. Olivine and feldspathoids may also be seen in some diorites.
 - **Secondary minerals:** Chlorite, sericite, epidote.
- iv) **Texture:** The appearance and grain size present in diorite are as follows:
 - **Physical appearance:** Diorite is medium to dark in colour with typical equal sized black (mostly hornblende and minor pyroxenes) and white (plagioclase) crystals, holocrystalline rock.
 - **Grain size:** The grain size of diorite is medium-grained to coarse-grained.

- **Mutual arrangement of the constituents/fabric:** The mafic minerals are commonly present in good quantity along with the light coloured feldspathic minerals. The arrangement of the components is irregular and compact.

6.7.2 Microscopic Characters

Microscopically, diorite is a coarse-grained rock, consisting of Ca-Na plagioclase and one or more of the mafic minerals such as clino- and ortho-pyroxenes, hornblende and biotite. Minor amount of quartz and K-feldspar may also be present. Olivine may also be seen in some of the diorites. If quartz is more, the rock is termed as **quartzdiorite**.

- i) **Mineralogy:** The minerals present in diorite are similar to those of the gabbro except that the anorthite content of plagioclase is usually 50% and presence of minor amount of quartz. Main minerals present in this rock are plagioclase (oligoclase, andesine) and amphiboles (mainly hornblende) (Fig. 6.16). Plagioclase usually dominates over the hornblende and other mafic minerals. It frequently contains minor amount of quartz, pyroxene (usually augite, but some orthopyroxene may also be present) and biotite. In some of the diorite, olivine is also seen in smaller amount. Magnetite, apatite, sphene (titanite), ilmenite, zircon etc. are the main accessory minerals present in varying amount in diorite

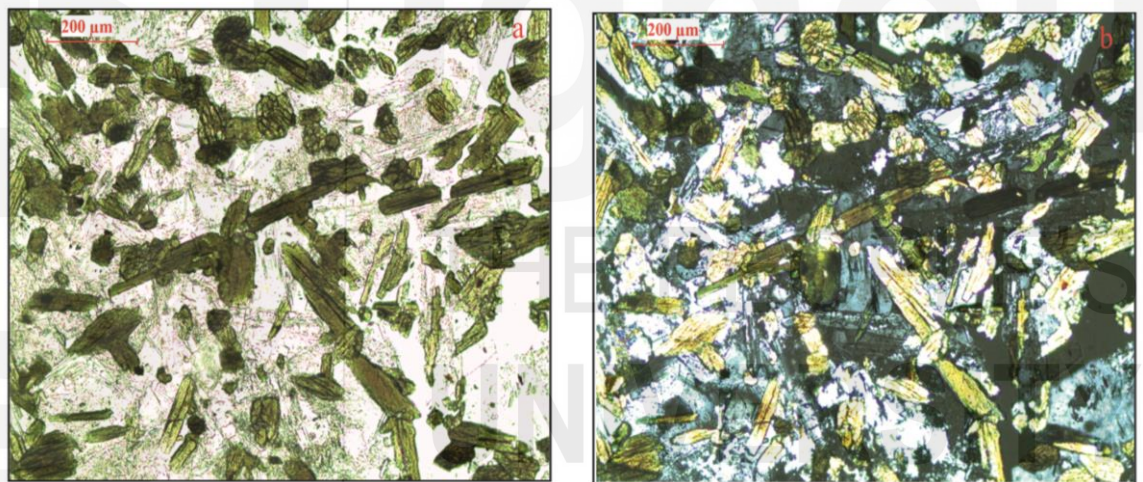


Fig. 6.16: Photomicrograph of diorite showing plagioclase and hornblende under PPL (left side) and XP (right side).

Under the microscope, the diorite contains laths of plagioclase feldspar with lamellar twinning and minor amount of subhedral quartz. The other important minerals mafic minerals are dominated by high relief hornblende and augite with their characteristic cleavage, and common biotite which exhibits some pleochroic haloes caused by zircon inclusions. Biotite occurs as pale brown to dark brown pleochroic subhedral crystals. Some of the clinopyroxenes can be easily recognised by their second order interference colours of blue and purple. The orthopyroxenes are pleochroic and show first order interference colours. In many of the diorite thin sections, you may also observe cloudy nature of plagioclase due to its alteration.

- ii) **Texture:** Microscopically the texture of diorite are as follows:
- **Crystallinity:** It is holocrystalline and hypidiomorphic. The hornblende and augite grains are subhedral. Biotite and feldspar are present as subhedral to euhedral in shape.

- **Granularity:** The texture is phaneritic and crystals are of medium size (1-2mm).
- **Mutual arrangement of the constituents/fabric:** Diorite contains phaneritic grains, often speckled represents texture of a coarse-grained rock and is occasionally porphyritic.

iii) **Rock types:** Following rock types are observed in diorite.

- **Quartzdiorite:** It is a variety of diorite containing quartz (>5%) and alkali feldspar.
- **Monzodiorite:** It is a variety of diorite containing olivine and feldspathoids.
- **Alkali diorite:** In alkali diorite it is observed that Ca-Na plagioclase > orthoclase-microcline, nepheline, sodalite, alkali amphibole, alkali pyroxene and biotite are present.

iv) **Classification:** Diorite is classified as plutonic intermediate igneous rock.

v) **Occurrence:** Diorite is usually associated with the subduction zones. Diorite may form larger plutons, but usually present in the form of sills, dykes and stocks. It occurs in both continental and oceanic crust and is not a rare rock type, but it is significantly less common than granitoids.

6.8 SYENITE

Syenite is an intrusive plutonic rock. It belongs to the alkali series of intermediate igneous rock with >65% SiO₂. The term “syenite” in a wider sense involves similar rock types like quartz syenite, alkali feldspar syenite, foid syenite and foid monzosyenite. A true syenite (*sensu stricto*), however, is having alkali feldspar (orthoclase and /or microcline) as a major mineral component with total feldspar content is >65%. Quartz is typically lacking in syenite. Compositionally, it resembles to granite with absence or very low quantity of quartz. It occurs in a wide variety of colours. Trachyte and phonolite are the two volcanic equivalents of syenite. Nepheline syenite of Kishangarh in Rajasthan is one of the exposures of a such rock type.

6.8.1 Megascopic Characters

- Colour:** Syenite is found in varied colours, but mostly it is leucocratic.
- Appearance:** Syenite is medium-grained to coarse-grained intrusive leucocratic rock, where alkali feldspar predominates (Fig. 6.17). The mafic minerals are represented by small amount of pyroxenes (usually aegirine-augite and aegirine), amphibole and biotite. Plagioclase occurs also in a small amount. Quartz or feldspathoid could be found in a minor amount. It is the intrusive equivalent of trachyte and phonolite. It is formed mostly in continental rift zones.
- Mineralogical Composition:** The essential, accessory and secondary minerals present in syenite are as follows:
 - **Essential Minerals:** Alkali feldspar, plagioclase, amphibole, biotite, pyroxene.
 - **Accessory Minerals:** Quartz or feldspathoid, ilmenite, apatite, magnetite and zircon. Foid syenites contain significant amount of relatively rare feldspathoid

minerals which are called foids in a simplified manner. Syenitic rock that contains quartz cannot contain feldspathoids and vice versa.

- **Secondary minerals:** Chlorite and sericite.

iv) **Texture:** Microscopically the texture of syenite is as follows.

- **Physical appearance:** Syenite is leucocratic, granular, holocrystalline rock.
- **Grain size:** It is medium-grained to coarse-grained rock.
- **Mutual arrangement of the constituents/fabric:** It is also granular in nature like granite and show phaneritic texture.



Fig. 6.17: Hand specimen of syenite showing pink and white orthoclase. (Source: www.gsi.gov.in)

6.8.2 Microscopic Characters

- Mineralogy:** Microscopically, the syenite is identified by the dominance of alkali feldspar, (Fig 6.18) lesser to minor amount of plagioclase (<10%) and with little or no quartz. If the quartz is present in the rock, it cannot exceed more than 5%. The alkali feldspar present in the rock may include orthoclase and perthites or very rarely microcline. Perthites are also commonly observed in syenite. Minor amount of mica, augite and hornblende may also be present. Biotite is rarely found. Common accessory minerals are apatite, ilmenite, magnetite and sulphides. Alkali syenites are rich in alkali minerals such as feldspathoids (nepheline, sodalite and leucite), alkali amphibole (riebeckite and arfvedsonite), alkali pyroxene (aegirine and aegirine-augite) and K- feldspars. It is poor/no plagioclase and quartz.
- Texture:** Microscopically the texture of syenite is as follows:
 - **Crystallinity:** The rock contains both euhedral and subhedral crystals, hence show pandiomorphic (euhedral crystals of same size) and hypidiomorphic (subhedral crystals of equal size) texture.
 - **Granularity:** It shows phaneritic texture (medium-grained to coarse-grained).
- Mutual arrangement of the constituents/fabric:** Perthitic textures are commonly observed.
- Rock types:** Following rock types are observed in syenite:

- **Quartz syenite:** It is called quartz syenite when the occurrence of quartz (Si-saturated variety) is more.
- **Nepheline syenite:** Presence of nepheline (feldspathoids) in a Si-under-saturated variety is called nepheline syenite.

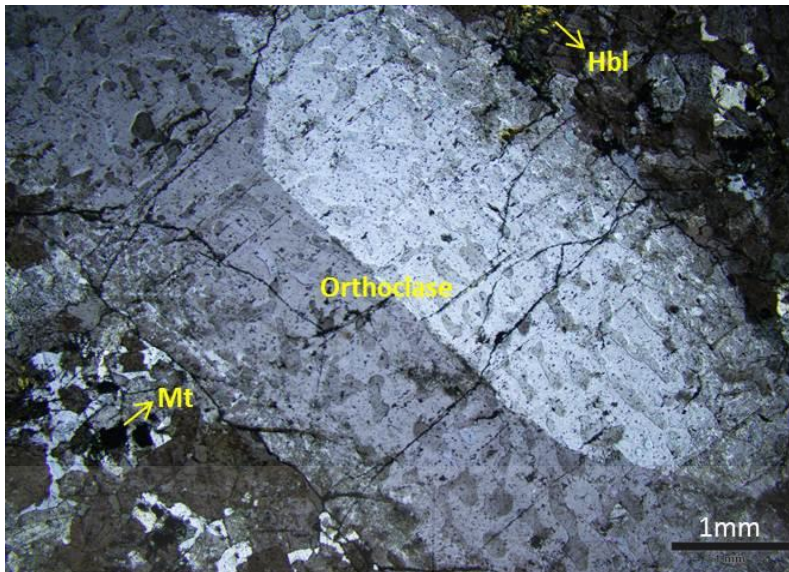


Fig 6.18: Photomicrograph of syenite showing porphyritic texture with orthoclase as phenocryst. Abbreviation: Mt- magnetite, Hbl-hornblend. (Photo credit: Mageswarii. G)

- v) **Classification:** Syenite is classified as intrusive plutonic intermediate rock.
- vi) **Occurrence:** Syenitic rocks are usually associated with other plutonic rocks. They form relatively small intrusive bodies or parts of larger intrusions. Syenitic rocks are produced by alkaline igneous activities typically resulted from partial melting of lower crust. Syenites are formed in continental rift zones and thick continental crustal areas or subduction zones.

In the previous sections we have studied about the megascopic and microscopic characters of intermediate rocks like diorite, syenite and granodiorite. Before going to the next section spend 5 minutes to check how you are progressing.

SAQ 2

- a) Name two plutonic and one volcanic intermediate rock.
- b) What are the essential minerals of granodiorite?
- c) Which rock is referred to as “salt and paper” rock?
- d) Give mineralogy of syenite.

6.9 SUMMARY

In this unit, we have discussed megascopic and petrographic characteristics of some of the important felsic and intermediate rocks. Let us summarise now.

- Granite and granodiorite are the most abundant igneous rocks present on the Earth's crust.

- Granite and granodiorite both contain quartz and feldspar as essential minerals. Granite will have more alkali feldspar than plagioclase while granodiorite will have more plagioclase than alkali feldspar.
- Rhyolite has similar mineralogy as of granite, but it is volcanic rock, hence it is fine grained.
- Diorite is a plutonic rock having dominantly plagioclase (oligoclase, andesine) and amphiboles (mainly hornblende) with a minor amount of augite, quartz and biotite.
- Syenite is an intrusive plutonic igneous rock of intermediate composition. It has high percentage of alkali feldspar (orthoclase and perthite) with little or no quartz/ feldspathoid.

6.10 ACTIVITY

Try to find out any building where granite is used either as wall tile/ floor tile or in pillar or as kitchen platform. Try to identify its minerals and name it as per its mineralogical classification. Note that granite, granodiorite, diorite, syenite, gabbro and andesite are being sold under the commercial name “Granite”.

6.11 TERMINAL QUESTIONS

1. How will you differentiate following rocks in the field?
 - a) Granite and granodiorite
 - b) Granodiorite and diorite
 - c) Granite and syenite
2. Discuss petrography of granite.
3. Describe mineralogy and textures present in the following rocks as observed under the petrological microscope.
 - a) Granodiorite
 - b) Rhyolite
 - c) Syenite
 - d) Diorite
4. Describe microscopic characteristics of a felsic composition of any volcanic rock giving suitable sketches.

Audio/Video Material Based Questions:

- Explain how felty texture is seen under the polarising microscope.
- Draw diagram of banded rhyolite as seen under the microscope.
- Discuss the texture of granodiorite as seen under the microscope.
- Mention the common texture found in aplite.
- What is alkali granite?
- Write about myrmekitic texture.

6.12 REFERENCES

- Best, M G. (1986) Igneous and Metamorphic petrology, CBS Publications. ISBN 81-239-0984-5.
- Winter, John D. (2001). An Introduction to Igneous and Metamorphic Petrology, 1st Edn. Prentice-Hall Inc., New Jersey. ISBN: 0132403420, 978- 0132403429.
- www.gsi.gov.in

(Website accessed between 20th March to 3rd April 2020)

6.13 FURTHER/SUGGESTED READINGS

- Best, M G. (1986) Igneous and Metamorphic petrology, CBS Publications.
- Ehlers, Ernest G., & Blatt, H. (1999). Petrology: Igneous, Sedimentary, and Metamorphic, 1stEdn. CBS Publications.
- McBirney, Alexander R. (2006). Igneous Petrology, 3rd Edn. Jones and Bartlett Publishers.
- Winter, John D. (2001). An Introduction to Igneous and Metamorphic Petrology, 1st Edn. Prentice-Hall Inc., New Jersey.

6.14 ANSWERS

Self Assessment Questions

- a) Granite and rhyolite.
 - b) Rhyolite.
 - c) Quartz and feldspar (alkali feldspar > plagioclase).
 - d) Equigranular, Porphyritic, Graphic.
- a) Diorite, Syenite and phonolite.
 - b) Quartz, Plagioclase and mica.
 - c) Diorite.
 - d) Essential Minerals: Alkali feldspar, plagioclase, amphibole, biotite, pyroxene.
Accessory Minerals: Quartz or feldspathoid, ilmenite, apatite, magnetite, zircon.
Secondary minerals: Chlorite and sericite.

Terminal Questions

- a) Please refer to introduction of subsections 6.3.1 and 6.6.1.
 - b) Please refer to introduction of subsection 6.6.1 and 6.7.1.
 - c) Please refer to introduction of subsections 6.3.1 and 6.8.1.
2. Please refer to introduction of subsection 6.3.2.
3.
 - a) Please refer to subsection 6.6.3.
 - b) Please refer to subsection 6.4.2.

- c) Please refer to subsection 6.8.2.
 - d) Please refer to subsection 6.7.2.
4. You may describe rhyolite rock, refer to subsection 6.4.2



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