This chapter deals with petrographical features of the various lithologic units exposed in the area under study. The order of description is according to their decreasing abundance in the field:

**DYKE PHASE**
- Rhyolite, olivine dolerite and microgranite.

**INTRUSIVE PHASE**
- Biotite hornblende granite, biotite granite, alkali granite. Olivine gabbro.

**EXTRUSIVE PHASE**
- Basalt.

### 3.1 INTRUSIVE PHASE

**Biotite hornblende granite:** It is porphyritic, massive, hard, compact and pink in colour. It contains phenocrysts of pink orthoclase and quartz.

Under microscope the rock is coarse grained, hypidiomorphic in texture (Plate 7.1). The minerals present are alkali feldspars (perthite and orthoclase), quartz, biotite, plagioclase, hornblende and the accessories are magnetite, zircon, fluorite, apatite and tourmaline. In a few sections (Js 14 and Js 16) fayalite is also observed.
Alkali feldspars include perthite and orthoclase. Perthite occurs as large phenocrysts which are subhedral to anhedral in form (Plate 7.2). It shows grills and patches of albite in potash feldspars giving rise to perthitic texture (Plate 7.2) and shows reaction relationship with quartz and orthoclase. Orthoclase occurs as turbid cloudy anhedral and subhedral phenocrysts. It shows twinning according to Carlsbad law (Plate 7.1). Inclusions of quartz, biotite specks and hornblende prisms are common in both perthite as well as orthoclase. Orthoclase is commonly altered to sericite (Plate 7.3). Intergrowth of alkali feldspars with quartz gives rise to granophyric texture (Plate 7.2).

Quartz occurs as subhedral and anhedral phenocrysts. The margins of the quartz crystals are invariably sutured (Plate 7.4). It shows characteristic wavy extinction.

Plagioclase occurs as subhedral phenocrysts intergrown with potash feldspars and quartz. Polysynthetic twinning is the most characteristic feature (Plate 7.1). Unlike potash feldspars it is clear and contains inclusions of
quartz and biotite. In certain cases it is seen altered to kaolinite (Plate 7.3).

Biotite occurs as large flakes. It shows one direction cleavage and usually parallel extinction (X ≈ c = 3°±) (Plate 7.4). Pleochroism is X = pale yellow, Y = Z = dark brown to reddish brown. The margins of the larger flakes are altered to chlorite (Plate 7.5). It is seen intergrown with hornblende. Inclusions of zircon and magnetite are fairly common in biotite (Plate 7.5).

Hornblende occurs as prismatic crystals (length 3 mm and width 1.5 mm). It is seen intergrown with biotite (Plate 7.6). It shows pleochroism (X = yellowish green, Y = green, Z = dark green). Extinction angle (Z ∠ c) varies from 14° to 20° and cleavage is two directional at 56°-124° angle (Plate 7.6).

Fayalite occurs as subhedral phenocryst associated with hornblende and biotite. It is highly fractured and shows high interference colours (Plate 8.1). The significance of this mineral has been discussed in the Chapter 7.

Accessories magnetite occurs as dark anhedral grains in biotite and hornblende (Plate 7.5, 7.6). Other accessory minerals are zircon, apatite, and tourmaline.
Biotite granite: It is massive, hard, compact and white in colour. It contains phenocrysts of orthoclase, albite and quartz.

Under microscope it is coarse grained and shows hypidiomorphic texture (Plate 8.2). The minerals present are alkali feldspars, quartz, biotite and plagioclase. Accessories include magnetite, zircon and fluorite.

Alkali feldspar - include perthite and orthoclase and occurs as subhedral phenocrysts (Plate 8.2). Orthoclase predominates over perthite and shows twinning according to Carlsbad law, whereas perthite displays perthitic texture. Orthoclase in white biotite granite is less altered as compared to pink biotite hornblende granite. Inclusions of biotite are common in orthoclase (Plate 8.2).

Quartz occurs as subhedral and anhedral phenocrysts. The boundaries of the quartz grains are sutured (Plate 8.2). It is interstitial between larger phenocrysts of feldspars and biotites. It is intergrown with alkali feldspars (Plate 8.2).

Biotite occurs as subhedral flakes. Irregular larger
flakes are commonly interstitial to quartz and potash feldspars, whereas the small specks and streaks are seen interleaved between the larger quartz and potash feldspar crystals. It usually shows parallel extinction \((X^\perp c = 3^\circ \pm)\) and pleochroism is \(X = \) pale yellow; \(Y = Z = \) dark brown to reddish brown. Pleochroic haloes are also displayed (Plate 8.2).

Plagioclase occurs as subhedral phenocrysts. It is intergrown with orthoclase and quartz. Polysynthetic twinning is the characteristic feature. As compared to orthoclase plagioclase grains are less altered.

Alkali granite: It is hard, massive, compact and bluish in colour. Blue colour is due to the presence of arfvedsonite, aegirine and riebeckite. This granite has been reported for the first time in this area.

Under microscope the granite is coarse grained hypidiomorphic (Plate 8.3) in texture. The minerals present are: alkali feldspar (perthite and orthoclase), quartz, arfvedsonite, aegirine, kataphorite and biotite. Accessories include magnetite, apatite, zircon, fluorite and riebeckite.
Alkali feldspars include perthite and orthoclase and occasional microcline. Perthite is clear and occurs as large phenocrysts which are subhedral to anhedral in form. It shows perthite texture (Plate 8.4). Orthoclase is turbid and cloudy. It shows twinning according to Carlsbad law (Plate 8.4). Inclusions of arfvedsonite, aegirine, kataphorite and biotite specks are common in alkali feldspar (Plate 8.5 and 8.6).

Quartz occurs in subhedral and anhedral forms. It shows undulatory extinction. It is seen intergrown with orthoclase and perthite. At places quartz crystals are seen enclosed piokilitically between larger potash feldspar grains and also as inclusions in the alkali amphiboles (Plate 8.5).

Arfvedsonite occurs as prismatic crystals (Plate 8.3). It shows pleochroism (X = dark bluish, Y = bluish green, Z = yellowish green). Extinction angle (X\(\wedge c\)) varies between 12° to 15°. It is seen intergrown with kataphorite and aegirine (Plate 8.5). Small crystals of arfvedsonite occur as inclusion in feldspar. Arfvedsonite shows reaction relationship with the kataphorite (Plate 8.5).
Aegirine occurs as small prismatic crystals. It is intergrown with arfvedsonite and kataphorite (Plate 8.6 and 8.3). It is pleochroic (X = dark green, Y = light green, Z = yellowish green). Extinction angle (X\(\wedge c\)) varies between 4° to 7°.

Kataphorite occurs as prismatic crystals, (Plate 8.5) and is also frequently intergrown with aegirine and arfvedsonite (Plate 8.5). It is pleochroic (X = pale yellow, Y = green brown, Z = green brown). Extinction angle (Z\(\wedge c\)) varies between 20° to 55°. It shows reaction relationship with arfvedsonite and aegirine. Composition zoning is common and kataphorite commonly forms cores rimmed by aegirine and arfvedsonite (Plate 8.3, 8.5 and 8.6). It is usually mistaken for hornblende and can be distinguished from the latter on the basis of pleochroism and higher extinction angle. The mineral has been confirmed by the chemical analysis done on electron microprobe (Plate 8a). Table 3.1 gives the chemical analysis and the structural formula.

Most natural kataphorites are Fe\(^{2+}\) rich and a complete solid solution exists between Na(NaCa)Fe\(^{2+}\)\Fe^{3+}\ (Si_{7}Al)O_{22}(OH)_{2} and the magnesian analog Na(NaCa)
TABLE 3.1: MICROPROBE ANALYSIS OF KATAPHORITE

<table>
<thead>
<tr>
<th>Wt% of oxides</th>
<th>Mol. prop. of oxides</th>
<th>Atom. prop. of oxygen from each molecule</th>
<th>No. of anions on basis of 23(O), i.e. col(3)x9.244</th>
<th>Nos. of ions in formula</th>
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<td>0.367</td>
<td>3.392 Fe 3.39 Fe 3.39</td>
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<tr>
<td>MnO</td>
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<td>0.010</td>
<td>0.092 Mn 0.09 Mn 0.09 5.50</td>
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<td>MgO</td>
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<td>0.144</td>
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<td>0.176</td>
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<td>0.035</td>
<td>0.323 Na 0.64 Na 0.64 2.44</td>
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<td>2.488</td>
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</table>

= \frac{23}{2.488} = 9.244

Formula: \((\text{Na} \quad \text{Ca} \quad \text{K}) \ (\text{Fe} \quad \text{Mg} \quad \text{Ti}) \ (\text{Al} \quad \text{Si} \quad \text{O} \ (\text{OH})
   \quad 0.64 \quad 1.62 \quad 0.18 \quad 3.39 \quad 1.13 \quad 0.21 \quad 1.44 \quad 6.77 \quad 22 \quad 2\)
$\text{Mg}_4\text{Fe}^{3+}(\text{Si}_7\text{Al})_2\text{O}_{22}(\text{OH})_2$ (magnesio-kataphorite). The kataphorite series contains more Al and Ca than the arfvedsonite.

Biotite occurs as small flakes and is characterised by one directional cleavage and parallel extinction ($Xac = 3^\circ \pm$). It occurs with arfvedsonite and kataphorite (Plate 8.3). In alkali granite, biotite is less altered as compared to biotite hornblende granite and biotite granite. It shows pleochroism $X =$ pale yellow, $Y = Z =$ dark brown to reddish brown.

Accessories Magnetite occurs as anhedral black isotropic grains scattered hapazardly in the groundmass. It also occurs as inclusions in kataphorite and arfvedsonite (Plate 8.5 and 8.6). Also small euhedral zircon, apatite and flourite occur as accessory minerals.

According to the petrographical features discussed, pink biotite hornblende granite and white biotite granite of the Jalor area correspond to subsolvus granites whereas alkali granite correspond to hypersolvus granites of Tuttle and Bowen (1958). Subsolvus granites are characterised by discrete grains of plagioclase in addition to K-feldspars and quartzs,
and the hypersolvus granites are characterised by the absence of albitic plagioclase except as a component of perthite.

Table 3.2, gives the modal estimates of the biotite hornblende granite, biotite granite (subsolvus) and alkali granite (hypersolvus) of the Jalor Fort area. The recalculated modal volume percentage of the Jalor granites when plotted on the QAP diagram (after Streckeisen, 1967) straddle the true granite as well as alkali granite fields. The biotite hornblende granite, biotite granite (subsolvus) fall in the granite field whereas the alkali granite (hypersolvus) cluster in the alkali granite field. It has been observed that the granites in which biotites exceed the hornblende are subsolvus, whereas the granites in which arfvedsonite, aegirine, and kataphorite exceed the biotites are hypersolvus. Further extending the scope of Streckeisen (1967), Lameyre and Bowden (1982) distinguished different plutonic series and their fractionates. The diagram has the ability to clearly display granitoid composition representing various tholeiitic, calco-
### TABLE 3.2: MODAL ANALYSES OF JALOR GRANITES

**Biotite hornblendegranite, biotite granite**  (Subsolvus)  

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<td>25.87</td>
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<td>22.46</td>
<td>23.33</td>
<td>30.81</td>
<td>30.26</td>
<td>23.52</td>
<td>26.60</td>
<td>26.96</td>
<td>36.16</td>
<td>27.82</td>
<td>33.04</td>
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<td>2.00</td>
<td>0.92</td>
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<td>2.69</td>
<td>2.97</td>
<td>0.99</td>
<td>1.32</td>
<td>2.24</td>
<td>1.63</td>
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**Alkali granite**  (Hypersolvus)
alkaline and alkaline series. The Lameyre and Bowden plot has been superimposed on Streckeisen plot and a perusal of the diagram (Fig. 3.1) shows that the biotite hornblende granite, biotite granite (subsolvus) of the Jalor area plot in the fields of aluminous granitoids found in alkaline provinces formed by crustal fusion and show affinity to A-type granites of the Lachlan fold belt, (Australia) (Collins et al., 1982), whereas the alkali granite (hypersolvus) fall in the alkaline and peralkaline fields of the Nigerian younger granites which are related with granitoids associated with continental rifting.

Olivine gabbro: The rock is massive, compact, hard and black in colour.

Under microscope the rock is coarse grained. Euhedral, disoriented plagioclase 'laths' are enclosed in extensive 'plates' of augite resulting in ophitic texture (Plate 9.1). The minerals present are; plagioclase, augite, olivine, chlorite and accessories include quartz, iron oxides, rutile and green spinel.

Plagioclase occurs as equidimensional lath shaped crystals, invariably well twinned according to the
Tholeiitic
Calc-alkaline trondhyemitic (low K)
Calc-alkaline-granodioritic (medium K)
Calc-alkaline monzonitic (high K)
Aluminous granitoids found in alkaline provinces
Alkaline and peralkaline
Overlapping field of granitoids formed by crustal fusion

Fig. 3.1 Quartz - Alkali feldspar - Plagioclase diagram showing the composition of Jalor granites; (+) biotite hornblende granite, biotite granite (subsolvus), (X) alkali granite (hypersolvus), (x) Nigerian Younger Granites and (0) A-type granites of Australia, relative to the important fields of various global granitoid series as defined by Lameyre and Bowden (1972).
albite and pericline laws (Plate 9.1). Larger plagioclase laths enclose small olivine crystals poikilitically (Plate 9.2). Tiny inclusions of alteration products such as saussurite, sericite are encountered in the plagioclase but mostly plagioclase is water clear and unaltered.

Augite is the most dominant mafic mineral in the olivine gabbros of the Jalor Fort area. It occurs as 'plates' (Plate 9.3), subhedral and rarely euhedral in form. The augite plates enclose the plagioclase laths giving rise to ophitic texture (Plate 9.1). Cleavage is perfect, two directional nearly at 90° and the extinction angle (Z\(\neq c\)) varies between 36°-42°. Inclusions of iron oxides are common in augite. Plates of augite which enclose labradorite (plagioclase) indicate plagioclase crystallising earlier than pyroxenes and subsequently both crystallised simultaneously as is evidenced by ophitic relationship by the two.

Olivine occurs as euhedral and subhedral crystals. It is seen intergrown with clinopyroxene - augite and also occurs as rounded poikilitic crystals enclosed by either plagioclase or augite (Plate 9.4 and 9.3). It is highly
fractured (Plate 9.5) and shows high order interference colours.

Chlorite occurs as anhedral crystals interstitial between augite and plagioclase crystals (Plate 9.5). It is feebly pleochroic (light green to yellowish green).

Biotite occurs as anhedral flakes and is seen intergrown with augite and chlorite. It is in most of the cases replaced by iron oxides (Plate 9.5 and 9.6).

Minor amount of quartzs occurs as subhedral clear interstitial grain, either between plagioclase crystals or the outer margins of plagioclase grain boundaries associated with granular olivine and minor alkali feldspar. It is characterised by undulatory extinction.

Accessories are magnetite and ilmenite, associated with augite or biotite (Plate 9.6). Rutile and green spinel are scattered throughout the groundmass.

Table (3.3) gives the modal analyses of the olivine gabbros. The re-calculated modal volume percentage of these rocks when plotted on plagioclase, pyroxene and olivine diagram (Fig. 3.2) (Streckeisen, 1967) fall in the gabbroid and olivine gabbro norite fields.
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Fig. 3.2 Plagioclase - Pyroxene - Olivine diagram showing fields of olivine gabbro (▼).
3.2 DYKE PHASE

Rhyolite: The rock is hard, massive and compact. Both porphyritic and non-porphyritic varieties occur. It is pink, yellowish pink and brownish blue in colour. Phenocrysts of quartz and feldspars in the porphyritic variety can be distinguished in the hand specimen.

Under microscope, the porphyritic varieties show porphyritic and microcrystalline texture (Plate 10.1). The non-porphyritic variety shows flow structure (Plate 10.2) and spherulitic texture. Occasionally porphyritic varieties also exhibit spherulitic texture (Plate 10.3). Minerals present are: alkali feldspars, quartz, hornblende, biotite, aegirine and reibeckite. The accessories are zircon, fluorite, apatite and iron oxides.

Alkali feldspars (Perthite, orthoclase and microcline): These occur as euhedral and subhedral phenocrysts embedded in cryptocrystalline quartzo-feldspatic groundmass (Plate 10.1). Perthite shows exsolved albite lamelles and microcline cross-hatched twinning. Orthoclase is altered to sericite and kaolinite (Plate 10.6). Inclusions of quartz grains in alkali feldspar.
Plagioclase occurs as small tabular crystals (Plate 10.1). It is intergrown with alkali feldspars. The crystals show twinning according to albite law. Plagioclase is comparatively less altered than orthoclase.

Quartz occurs as subhedral phenocrysts (Plate 10.4). It is clear and sometimes broken or embayed (Plate 10.4). The embayments are filled with quartzo-feldspathic groundmass. When intergrown with alkali feldspars it shows granophyric texture (Plate 10.4).

Biotite occurs as subhedral flakes embedded in the cryptocrystalline quartzo-feldspathic groundmass (Plate 10.5). It shows parallel extinction (X∥c = 3°±) and brown colour. Pleochroism is X = pale yellow, Y = Z = dark brown to reddish brown. The margins of biotite crystals are altered to chlorite and inclusions of opaques are fairly common (Plate 10.5).

Hornblende occurs as small discrete, altered prisms within the cryptocrystalline groundmass. It is sometimes found intergrown with biotite.

Aegirine and riebeckite occurs as small, anhedral specks
and needles. These are interwoven within cryptocrystalline groundmass. Aegirine shows pleochroism ($I = \text{dark green}, \ Y = \text{light green}, \ Z = \text{yellowish green}$) and extinction angle ($X \cdot a \cdot c$) is between $4^\circ-8^\circ$ (Plate 10.6). Riebeckite is identified by its blue colour, extinction angle ($X \cdot a \cdot c$) is between $3^\circ$ to $5^\circ$. Pleochroism is $X = \text{light blue}, \ Y = \text{blue}, \ Z = \text{dark blue}$.

Olivine dolerite: It is hard, compact, massive and greenish black in colour.

Under microscope, the rock is medium grained. The plagioclase crystals penetrate into, but are not enclosed in the pyroxenes resulting in subophitic texture (Plate 11.1). The minerals present are: plagioclase, augite, olivine and the accessories include, chlorite, opaques, zircon and apatite.

Plagioclase occurs as subhedral laths embedded in the groundmass of augite plates (Plate 11.1). Twinning is according to albite law. At places, large laths of plagioclase enclose poikilitically small olivine grains (Plate 11.2).

Augite: It occurs as subhedral patchy aggregates.
Plagioclase laths are seen embedded in the groundmass of augite giving rise to subophitic texture (Plate 11.1). Its extinction angle ($\alpha_{ac}$) varies between 40° to 45° and cleavage is perfect two directional at 90°. It contains opaques (ilmenite and magnetite) as inclusions. At places it is seen altered to sericite and chlorite (Plate 11.3).

Olivine occurs as subhedral grains, enclosed between labradorite laths and augite crystals (Plate 11.2). It shows high relief and high order interference colours. It is also intergrown with augite and is highly fractured.

Microgranite: It is hard and compact, medium to fine grained and pinkish brown in colour.

  Under microscope, the rock is microcrystalline and contains alkali feldspars, quartz, plagioclase, biotite and accessory opaques.

Alkali feldspars (Perthite and orthoclase): These occur as small subhedral phenocrysts in microcrystalline groundmass (Plate 11.4). Perthite shows perthitic texture, whereas orthoclase is cloudy and shows Carlsbad twinning. It is generally intergrown with small anhedral
Quartz giving rise to micrographical texture (Plate 11.4).

Quartz occurs as subhedral to anhedral crystals. The boundaries of the larger phenocrysts are sutured. It shows wavy extinction and micrographical texture with alkali feldspars (Plate 11.4).

Plagioclase occurs as subhedral crystals in microcrystalline groundmass. These show twinning according to albite law and are intergrown with alkali feldspars.

Biotite occurs as short, anhedral flakes scattered in the microcrystalline groundmass. It shows parallel extinction ($X \cap c = 3^\circ \pm$) and is pleochroic: $X =$ pale brown, $Y = Z =$ dark brown to reddish brown. It is seen intergrown with small prismatic hornblende. Tiny inclusions of iron-oxide are common.

Hornblende occurs as small, prismatic, subhedral phenocrysts. It is seen intergrown with minute biotite specks. Extinction angles ($Z \cap c$) varies between $17^\circ$ to $25^\circ$ and pleochroism ($X =$ light green, $Y =$ green, $Z =$ dark green).
3.3 EXTRUSIVE PHASE

Basalt: The basalt flows are altered, weathered and friable and vary in colour from olive green to greenish black.

Under microscope these are fine grained and exhibit discrete subophitic texture and glomeroporphyritic texture (Plate 11.5). Minerals present are plagioclase, augite, chlorite, and minor calcite and epidote.

Plagioclase occurs as microlites and laths scattered throughout the finer altered groundmass of augite giving rise to glomeroporphyritic texture (Plate 11.5). It exhibits polysynthetic twinning. It is mostly saussuritised (Plate 11.5) resulting in the release of calcite and epidote. In some cases, plagioclase is seen embedded in altered augite plates giving rise to discrete ophitic texture.

Augite occurs as anhedral crystals, which is highly altered to chlorite and sericite (Plate 11.6). It shows extinction angle ($Z \perp c$) between 40° to 45°.

Chlorite occurs as pelted mass (Plate 11.6) which appear
to have formed after the replacement of volcanic glass and as an alteration product of augite and biotite (Plate 11.6). It is feebly pleochroic from light brownish green to light green. Inclusion of opaques are predominant in chlorite and augite.