CHAPTER VI

DYKE ROCKS
INTRODUCTION

The occurrence of the numerous basic dykes in the Precambrian terrain is surprisingly a common feature but has remained as an unsolved problem. However it can be surmised that the occurrence of basic dykes in such terrains is possibly connected with the basic igneous activity in the early times after the formation of the crust and the upper mantle. Had the erosion in such shield areas continued to a greater degree than what is seen today, it can be visualised that the basic igneous rocks which have given rise to the dyke phase of basic igneous activity in the Precambrian terrains and which now lie hidden in the lower part of the upper mantle would have been exposed. In the absence of the radiometric age data, it is difficult to decide whether all the dykes are of the same age or of different ages. However the author of the thesis believes that all the basic dykes of the Koppal area are of the same age and Comagmatic. On this presumption the dykes of the Koppal area are described in the following account.

Koppal area is not an exception in containing good number of basic dykes which are represented by olivine dolerite, olivine-bronizite dolerite, poikilitic dolerite, basaltic dykes, quartz dolerite and meladiabase. This
chapter deals with the petrographic, mineralogical, petrochemical and magmatic evolution of the dyke rocks of Koppal area.

**DOLERITE DYKES**

It is found that all the basic dykes of the Koppal area, except the meladiabse (which is also a variety of dolerite but extremely rich in ferromagnesian minerals), are represented by dolerite dykes of various petrographic types. These are more or less scattered throughout the area, intruding all the major rock types, namely granites, gneisses and pyroxene syenite.

**DISTRIBUTION AND FIELD CHARACTERS**

The distribution of the dolerite dykes is shown on the geological map (Map I) of the area. Its perusal reveals that there exist two sets of dykes trending E-W and NE-SW with local variations here and there. Among these two sets, the one striking EW occurs more prominently in most parts of the area whereas the other set trending NE-SW is less prominent and occurs here and there. Field observations suggest that the frequency of the occurrence of dolerite dykes in granites and gneisses is more than in the pyroxene syenite. Most of the dolerite dykes commonly consist of a jumbled array of more or less rounded
boulders along their strike, forming low mounds without rising much above the plains, while a few of them form conspicuous mounds and ridges 2 to 5 metres high and consist of large rectangular slabs or jointed boulders (plate XXIV a, b, c). Mounds and ridges formed by these dykes are located i) 0.5 Km. north of Lebigeri ii) 0.2 Km. south of Basapur iii) 0.5 Km. north of Kidadalu iv) 1.5 Kms. north east of Kunikeri.

They vary greatly in their thickness from a minimum of 0.5 metre as seen in the basaltic dyke, 200 metres north east of Muddaballi, to about 50 metres as seen in the dolerite 0.5 Km. north of Lebigeri. Only small dykes which are less than 10 metres in length show regularity in their thickness while in the large dykes considerable variation in thickness is noticed. They are traced along the strike from a few metres to nearly 3.0 Kms. when they peter out or disappear below the soil cover. However dykes traced along the strike for more than one kilometre are less in number and are located i) 0.5 Km. north of Lebigeri ii) 2.0 Kms. NW of Koppal iii) 0.2 Km. south of Basapur and iv) 1.5 Kms. north of Kunikeri.

Though the intersection of the dykes is noticed 1.0 Km. north east of Lebigeri, it is not possible to know the relative age of the intersecting dykes due to the
lack of any chilling effect of one against the other and also due to the badly exposed nature of the contacts. While most of the dykes are vertical and run straight along their course, a few show a sinuous nature along the strike.

Though the dykes are undoubtedly younger and intrusive into the granites, gneisses and pyroxene syenite of the area, they rarely contain xenolithic masses of the surrounding rocks. Besides there are no signs of any forceful injection, dismemberment and digestion of the rocks in which they have intruded. Presence of the chilled margins noticed in some of the dykes suggest a long interval of time between the formation of the country rocks and the intrusion of the dykes. It is also evident that the former were sufficiently cool when the dykes intruded.

CLASSIFICATION

On the basis of the mineral assemblage and texture, the dolerite dykes of the Koppal area have been classified into the following petrographic types (The figures given in the parantheses indicate the number of each type of dyke recorded in the area).

1. Quartz dolerite (38)
2. Basaltic dyke (5)
3. Olivine dolerite (2)
4. Olivine-bronzite dolerite (1)
5. Poikilitic olivine-bronzite dolerite (1)

The terminology employed for the different types of dolerite is based on the following characters.

The name quartz dolerite is here applied to the dykes mainly showing ophitic and subophitic textures and chiefly containing plagioclase, clinopyroxene and subordinate but characteristic micropegmatite with or without free quartz. Micropegmatitic texture is not due to the intergrowth between alkali feldspar and quartz but between labradorite and quartz.

The name basaltic dyke is employed for the dykes exhibiting a typical basaltic texture, namely intergranular and intersertal and invariably consisting of clinopyroxene and plagioclase with interstitial glassy matter.

Olivine dolerite is characterised by the ophitic and subophitic textures with subordinate but characteristic presence of olivine in addition to the essential minerals, plagioclase and clinopyroxene.

Olivine-bronzite dolerite is characterised by the ophitic and subophitic textures with subordinate but characteristic presence of olivine in addition to the essential minerals plagioclase, bronzite and augite.
The name poikilitic olivine dolerite is employed for an olivine bronzite bearing dyke showing a typical poikilitic texture, which is due to the occurrence of numerous pyroxene crystals in large plagioclase laths and plates. In mineral assemblage this type is similar to olivine bronzite dolerite.

**PETROLOGY**

**Quartz Dolerite**

It is the common type and occurs almost scattered throughout the area. The exposures of quartz dolerites generally form prominent mounds and ridges and vary greatly in their size. Good exposure of these dykes are located i) 0.2 Km. north of Lebigeri ii) 2.0 Kms. NW of Koppal iii) 1.0 Km. north of Kidadalu iv) 0.2 Km. south of Basapur and v) 3.0 Kms. north of Kunikeri.

Megascopically the quartz dolerites are medium to coarse grained, dark grey or brownish black coloured rocks and contain whitish or brownish laths of plagioclase and blackish brown lustrous plates of pyroxene.

In thin section it is medium to coarse grained, inequigranular rock and commonly exhibits ophitic and subophitic textures (plate XXV a). Glomeroporphyritic texture is occasionally seen. Small amount of modal
quartz invariably in the form of micropegmatitic intergrowth associated with apatite needles and skeletal iron ore grains is locally present. The chief mineral components are plagioclase (45.0 to 62.0% An) and clinopyroxene (augite and pigeonitic-augite). Apatite, iron ore, biotite and chlorite constitute the secondary and accessory components.

The quartz dolerite, showing ophitic and subophitic textures, exhibits variation in the grain size. It is particularly so in the size of plagioclase laths that occur enclosed in the pyroxene and those present in their interstices. The former are almost distinctly smaller than the latter.

The pyroxene of the quartz dolerite is colourless and has $2V_r = 37$ to $44^\circ$, $Z^C = 36$ to $46^\circ$, $(\gamma - \alpha) = 0.025$ and $N_B = 1.698$, whereas the plagioclase varies from andesine to labradorite with an anorthite percentage varying from 45 to 62. It is invariably twinned after albite, carlsbad and albite-ala laws. Colourless quartz, invariably in the form of a micropegmatitic intergrowth, occurs as pegs, triangular and rectangular plates in the interstices of plagioclase and often replacing it. Quartz dolerite shows considerable deuteric alteration evidenced by the presence of biotite, uralite and chlorite in notable amounts.
Basaltic Dykes

Basaltic dykes are next in abundance to quartz dolerite dykes and are located i) 0.2 Km. NE of Muddaballi ii) 0.8 Km. S 20°E Horatattanahalu iii) 0.2 Km. S 70° W of Gavimath iv) 1.0 Km. north of Chilavadigi and v) 0.2 Km. north of Bhadarabhanda. They generally run for a distance of a few metres and disappear below the soil cover, showing regularity in their thickness which commonly does not exceed more than a metre. They are fine grained rocks and exhibit a metalloidal lustre with the specific gravity varying from 3.0 to 3.12.

In thin section it is fine to medium grained rock and exhibits typical intergranular and intersertal textures. Sometimes the dyke shows textural variations from the centre to the margins. Such a variation is typically present in the basaltic dyke (A/217a) located 0.2 Km. NE of Muddaballi. In this dyke the central portion is characterised by intergranular and intersertal textures (plate XXV b), whereas the margins exhibit a vitrophyric texture where phenocrysts of both plagioclase and pyroxene are enclosed in an aphanitic ground mass (plate XXV c).

The basaltic dyke consists chiefly of pyroxene and plagioclase, which are almost identical in mineral composition to the pyroxene and plagioclase occurring in the quartz
dolerite, except for an occasional presence of micro-pegmatic texture. It is comparatively more fresh without any marked deuteric alterations.

Olivine dolerite

This type is represented by two dykes located

i) 2.0 Kms. N 60° E of Naregallu
ii) 1.6 Kms. N 45° E of Chilavadigi. Olivine dolerites are restricted in their length and breadth and are seen at the surface without forming any mounds and ridges. They do not exceed more than 10.0 metres along their strike with the thickness varying from 0.2 to 1.0 metre.

In hand specimen it is remarkably fresh and lustrous. It is medium to coarse grained and consists of greyish white laths of plagioclase and dark brown pyroxene. Sp.Gr. varies from 3.0 to 3.16.

In thin section it is a coarse grained inequigranular rock and exhibit both ophitic and subophitic textures (plate XXV d). It essentially consists of well twinned plagioclase of labradorite (52 to 72% An) composition and colourless or pale pink, subhedral prismatic prisms and plates of clinopyroxene having $2V_T = 42$ to $44^\circ$, $Z = 39$ to $42^\circ$, $(\tau - \alpha) = 0.026$ and $N_\beta = 1.695$. Granular colourless, olivine often forming aggregates has $2V_\alpha = 81$ to $82^\circ$,.
(γ - α) = 0.036 to 0.038 and $N_{55} = 1.715$ to 1.720.
Olivine is often surrounded by thin rim of iron ore.
Olivine dolerite is more fresh than the quartz dolerite and basaltic dyke.

Olivine-bronzite dolerite

It is represented by a solitary dyke located 3.0 Kms. north of Koppal town. It runs for about 0.5 Km. along the strike $N 40^\circ W$, having an average thickness of 10.0 metres and is exposed at the surface without forming any mounds and ridges.

In hand specimen it is remarkably fresh and lustrous. It is medium to coarse grained and consists of greyish white plagioclase, greenish or brownish black pyroxene. It is hard and compact with a Sp.Gr. 2.99.

In thin section it exhibits typical ophitic and subophitic textures and consists essentially of plagioclase and pigeonitic-augite. Bronzite and olivine form the subordinate constituent minerals, whereas apatite and iron ore occur as the common accessory ones. Plagioclase occurs as subhedral laths with an anorthite content ranging from 55 to 72%. It is always twinned after albite, carlsbad, albite-ala and albite-carlsbad laws. Clinopyroxene occurs as subhedral plates and prismatic laths
with $2V_r = 48^\circ$, $Z \land c = 36$ to $40^\circ$, $(\gamma - \alpha) = 0.029$. These optical properties coincide fairly with those of pigeonitic-augite. Colourless to pale pink bronzite always occurs as large rectangular plates, associated with clinopyroxene. It has $2V_\alpha = 78^\circ$, $N_\beta = 1.673$ and $(\gamma - \alpha) = 0.0168$. Olivine occurs as granular aggregates, which is invariably studied with iron dust. It has $2V_\alpha = 81$ to $83^\circ$, $(\gamma - \alpha) = 0.045$ and $N_\beta = 1.720$ to $1.725$. Olivine-bronzite dolerite is remarkably fresh and does not show any dueteric alteration which is commonly seen in other types.

Poikilitic Olivine-Bronzite dolerite

It is also represented by a single dyke located 2.5 Kms. S 75° W of Gunnahalli. It is a narrow thin dyke, measuring 5 metres in length and a metre in width. Poikilitic olivine-bronzite dolerite differs from normal olivine dolerite and olivine bronzite dolerite by its lustre mottling which is due to the occurrence of numerous small pyroxene crystals included in large plates of plagioclase. It is also hard and compact with a specific gravity 3.18.

In thin section it is coarse grained and exhibits a poikilitic texture (plate XXVI a). Plagioclase though less abundant when compared with pyroxene, always forms large well twinned laths and plates. Pyroxene (chiefly pigeonitic-augite and occasionally bronzite) varying in its shape and
size, forms euhedral equant grains and invariably occurs as inclusions inside the plagioclase. Olivine occurs as granular aggregates, associated with iron ore grains. It has optical properties similar to those present in olivine dolerite and olivine-bronzite dolerite.

MINERALOGY

Plagioclase

It is the abundant mineral in most of the dolerite dykes of the area. It occurs as subhedral tabular and prismatic plates and laths of various sizes, enclosed partially or completely in pyroxene to form subophitic and ophitic textures in quartz and olivine dolerites. In the case of basaltic dykes prismatic laths form intergranular and intersertal textures, whereas in poikilitic dolerite it occurs as large plates containing inclusions of numerous tablets and granules of pyroxene.

It constitutes 42 to 45% of the mode in quartz dolerite and almost equal to that of pyroxene. In olivine bronzite dolerite and poikilitic dolerite it varies from 31 to 47.0% of the mode and always subordinate to pyroxene in basaltic dykes. The anorthite content of the plagioclase varies from 52 to 64.0%, while in olivine dolerite the anorthite percentage is slightly higher (52 to 72%). It is
invariably characterised by the polysynthetic twinning and is commonly twinned after the albite and carlsbad laws and less commonly after those of albite-carlsbad and maneback-ala. Twinning after the baveno law is scarcely present and is only restricted to the plagioclase feldspars of quartz dolerite. 2Y of plagioclase feldspar ranges from 82 to 87°. Anorthite contents, optic axial angle and twin laws of plagioclase feldspar present in various types of dolerites are given in table XXXV.

Generally plagioclase feldspar, except in quartz dolerite, is more fresh and clear, whereas in quartz dolerite it commonly shows the effect of ducteric alteration.

The micropegmatitic texture present in the quartz dolerite of the area is a characteristic feature and is rarely recorded in geological literature. A brief account about it is given below.

After casual observation the micropegmatitic texture appears to have resulted from the intergrowth between plagioclase of labradorite (52 to 62% An) composition and quartz. The interstices between the laths of labradorite show triangular and rectangular plates of quartz inside labradorite and simultaneously extinguishes over some area,
<table>
<thead>
<tr>
<th>Q</th>
<th>An%</th>
<th>$2V _\gamma</th>
<th>No. of grains</th>
<th>Albite</th>
<th>Carlsbad</th>
<th>Albite-carlsbad</th>
<th>Albite-ala</th>
<th>Manebach-Baveno-ala</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz dolerite</td>
<td>50-65</td>
<td>82-87°</td>
<td>97</td>
<td>38</td>
<td>33</td>
<td>12</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Olivine dolerite</td>
<td>52-72</td>
<td>81-86°</td>
<td>21</td>
<td>4</td>
<td>13</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Olivine bronzite dolerite</td>
<td>55-72</td>
<td>84-86°</td>
<td>14</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poikilitic olivine dolerite</td>
<td>45-50</td>
<td>81-84°</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Basaltic dykes</td>
<td>54-62</td>
<td>81-87°</td>
<td>27</td>
<td>6</td>
<td>13</td>
<td>6</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td></td>
<td></td>
<td>66</td>
<td>65</td>
<td>24</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>
which under crossed nicols simulates the intergrowth texture of an eutectic origin. On careful examination it is found that twinned labradorite, enclosing pegs and plates of quartz, in some places is optically continuous over a large area, thereby indicating that the twinned labradorite had formed earlier and was later replaced by quartz which is also optically continuous (plate XXVII a). Such a texture may have resulted either from dueteric action or solid diffusion or an assimilation of psammitic sediments. It is clear from the field evidences that quartz dolerites are free from xenoliths of rocks in which they have intruded. The author of the thesis believes that the micropegmatitic texture has originated by dueteric action; silica of the silica rich residuum of the basic magma replacing the earlier formed plagioclase. This conclusion is supported by the occurrence of micropegmatitic textures confined to areas which show local enrichment of volatiles evidenced by the presence of numerous apatite needles and skeletal grains of iron ore around the micropegmatite.

Though there are numerous occurrences of quartz alkali feldspar intergrowths, termed as micropegmatite, from many dolerites and diabases, micropegmatite of a replacement origin where labradorite has been replaced by
quartz is rarely recorded. Naik and Sadashivaiah (1965) and Moore (1966) have reported similar micropegmatitic textures from dolerites of Molakalmuru, Mysore State, India and Trankei, South Africa respectively. Drecher-Kaden (1948) and Sugi (1931) have also recorded micropegmatite of replacement origin, where oligoclase is replaced by quartz.

Quartz

It occurs only in quartz dolerites and constitutes 3.6 to 5.17% of the mode. It is seen more commonly as angular pegs, plates, patches and small veins, invariably replacing plagioclase and forming a micropegmatitic texture and less commonly as discrete grains.

Clinopyroxene

Monoclinic pyroxene, present in various types of dolerite, is represented by pigeonitic-augite (MacDonold and Kuno 1950).

It is colourless to pale brown and occurs as prisms and subhedral to euhedral plates. Optical properties of the pyroxene present in the various types of dolerites are given in table XXXVI. A perusal of the table reveals that there is no appreciable variation in the optical properties of pyroxenes of different types of dolerite.
### Table XXXVI.

**Optical Properties of Clinopyroxene (Augite) from the Dolerite Dykes of Koppal Area**

<table>
<thead>
<tr>
<th></th>
<th>2(V_{\gamma})</th>
<th>2(A_{\alpha})</th>
<th>((\gamma - \alpha))</th>
<th>((\gamma - \beta))</th>
<th>((\beta - \alpha))</th>
<th>Colour and Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz dolerite</td>
<td>35-45°</td>
<td>1.698-1.702</td>
<td>35-46°</td>
<td>0.023 to 0.026</td>
<td>0.020 to 0.022</td>
<td>0.0035 to 0.0039</td>
</tr>
<tr>
<td>Olivine dolerite</td>
<td>42-44°</td>
<td>1.695</td>
<td>39-42°</td>
<td>0.023</td>
<td>0.020</td>
<td>0.0035</td>
</tr>
<tr>
<td>Olivine bronzite dolerite</td>
<td>46°</td>
<td>1.712</td>
<td>36-40°</td>
<td>0.028</td>
<td>0.025</td>
<td>0.0035</td>
</tr>
<tr>
<td>Poikilitic dolerite</td>
<td>44°</td>
<td>1.715</td>
<td>39°</td>
<td>0.028</td>
<td>0.024</td>
<td>0.0043</td>
</tr>
<tr>
<td>Basaltic dykes</td>
<td>44°</td>
<td>-</td>
<td>31-32°</td>
<td>0.024</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Optic axial angle, $2V_\perp$ varies from 35 to 45° with the exception of clinopyroxene in olivine-bronzite dolerite where it is 48°. $Z\wedge c$ varies from 35 to 46° and $N_B$ from 1.690 to 1.720. These optical properties fairly coincide with those of pigeonitic-augite (MacDonold and Kuno op cit). Twinning on (001) is occasionally present. Pyroxene is fresh and clear, particularly in olivine dolerite whereas in quartz dolerite it is slightly altered to hornblende.

**Bronzite**

It is only present in two types, namely olivine-bronzite dolerite and poikilitic olivine-bronzite dolerite. It is colourless and commonly occurs as large subhedral, plates, elongated parallel to 'c' axis and invariably encloses thin rods and ovoidal bodies of pigeonitic-augite (plate XXVII b), arranged parallel to the (100) cleavages. It constitutes 10.20% of the mode in poikilitic dolerite and 7.16% in olivine-bronzite dolerite. Optical properties of bronzite are given in table XXXVII. Though most of the grains are fresh, at some places there is marginal alteration either to hornblende or to biotite.

**Olivine**

Olivine is one of the important minerals present in three varieties of dolerites, namely olivine dolerite,
### OPTICAL PROPERTIES OF BRONZITE FROM DOLERITE DYKES OF KOPPAI AREA.

<table>
<thead>
<tr>
<th></th>
<th>2V&lt;sub&gt;⊥&lt;/sub&gt;</th>
<th>W&lt;sub&gt;β&lt;/sub&gt;</th>
<th>(γ-⊥)</th>
<th>(γ-β)</th>
<th>(β-⊥)</th>
<th>Colour and Pleochroism</th>
<th>Mol.% of MgSiO&lt;sub&gt;3&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivine bronzite</td>
<td>78°</td>
<td>1.673</td>
<td>0.0168</td>
<td>0.0095</td>
<td>0.0073</td>
<td>pale pink, feebly pleochroic in shades of pale pink</td>
<td>12</td>
</tr>
<tr>
<td>Foikilitic olivine bronzite dolerite</td>
<td>88°</td>
<td>1.698</td>
<td>0.0148</td>
<td>0.007</td>
<td>0.0078</td>
<td>pale pink, feebly pleochroic in shades of pale pink</td>
<td>18</td>
</tr>
</tbody>
</table>
olivine-bronzite dolerite and poikilitic olivine-bronzite dolerite. It varies in modal percentage from 3.50 to 9.67.

It occurs in crystals which are equant or slightly elongated parallel to 'c' axis and sometimes the granular variety forms aggregates. It is frequently surrounded by black opaque dust of iron ore. It is generally colourless but grains studded with iron dust exhibit pale brown colour. It has $2V_\alpha = 81$ to $83^\circ$, $(\gamma-\alpha) = 0.036$ to $0.044$ and $N_\beta = 1.71$ to $1.72$. Optical properties of olivine, present in the different types, are given in table XXXVIII and they indicate that it is hyalosiderite with $65\% \text{Mg}_2 \text{SiO}_4$ (Poldervaart 1950). It is occasionally traversed by minute fractures filled with iron dust.

Iron ore

It is the most common accessory mineral in all the types of dolerites and appears to be a mixture of magnetite and ilmenite. It forms irregular skeletal crystals which are commonly associated with olivine, pyroxene and micropegmatite. It is comparatively more present in quartz dolerites than in basaltic dykes and olivine dolerites. Alteration of iron ore to leucoxene is observed in some sections.
<table>
<thead>
<tr>
<th></th>
<th>2(\gamma)</th>
<th>(N/\beta)</th>
<th>((\gamma-\alpha))</th>
<th>((\gamma-\beta))</th>
<th>((\beta-\alpha))</th>
<th>Colour and Pleochroism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivine dolerite</td>
<td>81-83°</td>
<td>1.715</td>
<td>0.036</td>
<td>0.022</td>
<td>0.014</td>
<td>Pale grey, Nonpleochroic</td>
</tr>
<tr>
<td>Poikilitic olivine</td>
<td></td>
<td></td>
<td>0.0395</td>
<td></td>
<td></td>
<td>Pale brown, Feebly pleochroic, X=pale sand brown, Y=pale brown, Z=pale buff brown</td>
</tr>
<tr>
<td>Bronzite dolerite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pale brown, Nonpleochroic</td>
</tr>
<tr>
<td>Olivine bronzite</td>
<td>81-83°</td>
<td>1.720</td>
<td>0.0447</td>
<td></td>
<td></td>
<td>Pale brown, Nonpleochroic</td>
</tr>
</tbody>
</table>
Apatite is seen as needles intimately associated with micropegmatite patches and also as stumpy granular inclusions in plagioclase. Hornblende is bluish green to green in colour and occurs more commonly along the margins of pyroxene of quartz dolerites. It sometimes forms rims around pyroxene. Biotite is pale yellow to brownish yellow in colour and occurs as flakes and patches along the cleavages of pyroxene.

**Modal Analyses**

Though the modes of various minerals present in different types of dolerites are already referred to in the previous section dealing with mineralogy, it is tabulated in Table XXXIX for comparison and ready reference.

Modal composition and their relationships between the different types of dolerites is shown on a trilinear diagram (Fig. 20) having as its co-ordinates late minerals (consisting micropegmatite, iron ore, apatite etc.), plagioclase and pyroxene. It is seen from the figure that the plotted points of the olivine-bronzite dolerite, olivine dolerite, basaltic dykes and quartz dolerite fall close to each other thereby suggesting that they are comagmatic and derived from a parent magma of calcalkaline composition by fractional crystallization in depth.
LATE MINERALS

PIS. 20: VARIATION IN I®DAI COMPOSITION OF DOLERITE DYKES FROM KOPPAL AREA, SHOWING DIFFERENTIATION TREND.

1, 2, 3 and 4 quartz dolerites, 5 basaltic dolerite, 6 olivine dolerite, 7 olivine bronzite dolerite and 8 poikilitic olivine bronzite dolerite.

FIG. 20: VARIATION IN MODAL COMPOSITION OF DOLERITE DYKES FROM KOPPAL AREA, SHOWING DIFFERENTIATION TREND.

1, 2, 3 and 4 quartz dolerites, 5 basaltic dolerite, 6 olivine dolerite, 7 olivine bronzite dolerite and 8 poikilitic olivine bronzite dolerite.
PETROCHEMISTRY

Nine fresh samples of dykes, four of quartz dolerites, two of basaltic dykes and one each of olivine dolerite, olivine-bronzite dolerite and poikilitic dolerite have been chemically analysed and the results along with the calculated C.I.P.W. norms, mafic indices, Niggli values and Niggli bases are given in table XXXX. The table reveals the following characters which are exhibited by the various types of dolerite dykes.

i. Variation in the percentage of SiO₂ with a minimum of 46.0 in olivine dolerite and a maximum of 51.0 in quartz dolerite is not appreciable. The small variation in SiO₂ indicates that the magma which gave rise to the various types of dolerites did not undergo any extensive differentiation and that most of the dykes are more or less representative of the composition of the magma itself.

ii. Al₂O₃ also exhibits a small variation of 3.0%, with a minimum of 12.09% in quartz dolerite and a maximum of 15.49% in olivine dolerite.

iii. TiO₂, FeO and Fe₂O₃ generally show a progressive increase from olivine dolerite to quartz dolerite.
vi. Contents of MnO and CaO are fairly uniform and no appreciable variation is observed, whereas MgO progressively increases from quartz dolerite to olivine dolerite. A maximum of 10.5% MgO is present in olivine dolerite with a minimum of 2.58% recorded in quartz dolerite.

v. Among the alkalies Na₂O does not exhibit any appreciable variation and it is always in excess of K₂O which progressively increases from olivine dolerite to quartz dolerite. The minimum of 0.50% K₂O is recorded in olivine dolerite whereas the maximum 1.30% is present in quartz dolerite.

Observed chemical variations in different types of dolerite dykes are reflected in the calculated C.I.P.W. norms, Niggli values and Niggli bases. Comparatively normative quartz, orthoclase and magnetite are more present in the quartz dolerites than in the olivine dolerite. Formation of a small amount of normative quartz in two of the three olivine bearing dolerites is a characteristic feature, which indicates that the magma from which different the types of dolerites were derived was almost saturated and the small amount of olivine present in the mode appears to be due to the earlier formed olivine having escaped reaction with the magma.
Calculated Niggli values show an increase in 'Si', 'alk' and 'k' values and decrease in 'mg' values from olivine dolerite to quartz dolerite. Similarly increase in 'Kp', 'Ne' and 'Cs' values and decrease in 'Fo' and 'Fa' values of Niggli bases from olivine dolerite to quartz dolerite is observed.

A petrochemical study based on the lines of McDougall (1962), Burri and Niggli (1945), Wager and Deer (1939) and Walker and Poldervaart (1949) was undertaken so as to know the trend of the differentiation and magmatic affinities of the dykes and it is discussed below.

Variation diagram of McDougall

\[
\text{Mafic index} = \frac{\text{FeO} + \text{Fe}_{2}\text{O}_3}{\text{FeO} + \text{Fe}_{2}\text{O}_3 + \text{MgO}} \times 100
\]

dykes is given in table XXXX. The crystallization history of the dolerite dykes of the Koppal area can be divided into two stages on the basis of the mafic index. Olivine-bronzite and olivine dolerites which approximate the composition of the parent magma having a mafic index of less than 60, form the early stage of fractional crystallization whereas basaltic and quartz dolerite dykes having mafic index more than 60 represent late stage derivations. The oxide percentages plotted against mafic index provides the convenient way of demonstrating the variations in the
FIG. 21 VARIATION DIAGRAM OF DIFFERENT OXIDES OF DOLESITE DIES OF KOPPAL AREA, PLOTTED AGAINST MAFIC INDEX.
composition of the magma as the fractionation proceeds. The trends of variation of the various oxides (Fig. 21) especially of MgO, FeO, K₂O and SiO₂ clearly indicate that the different types of dolerites have resulted due to the fractional crystallization of common parental magma of Calc alkaline composition and fairly coincide with the similar variation diagrams drawn for Karroo and Guina dolerites (1949).

2alk - 100-2al - 2(al-alk) diagram of Burri and Niggli

When 2alk - 100-al - 2(al-alk) values of the analysed dolerites of the Koppal area are plotted on the trilinear diagram (Fig. 22) it is seen that there is an enrichment of the ferromagnesian minerals with the concomitant impoverishment of feldspar in olivine-bronzite dolerite and olivine dolerite, and an impoverishment of ferric constituent with constant feldspar in basaltic and quartz dolerites.

Mgo - FeO - (Na₂O + K₂O) and CaO - MgO - (Na₂O + K₂O) diagrams of Wager and Deer

These diagrams (Figs. 23 and 24) illustrate the part played by refractory constituents during the crystallization of the basic magma. For comparison and ready reference the plots of the analyses of Skaergaard, Breven and
PLOTS OF THE ANALYZED DOLERITE DYKES FROM KOPPAL AREA SHOW DIFFERENTIATION TRENDS.

DIGRAM OF BURR I AND NIGGLI (1945)

DIAGRAM OF

$FeO - K_2O + Na_2O - MgO$ DIAGRAM OF

DOLERITE DYKES OF KOPPAL

$CaO - MgO - K_2O + Na_2O$ DIAGRAM OF DOLERITE DYKES OF KOPPAL
Hallefors dykes, Daly's average basalts, andesite, dacite rhyolite and trends of Central Victoria rocks are also shown in the diagrams. In the MgO - FeO - (Na₂O + K₂O) diagram (Fig. 23) MgO, the significant constituent of the more refractory mineral is at one corner, while FeO, the significant constituent of medium refractory minerals is at another corner and total alkalies (Na₂O + K₂O), the significant constituents of less refractory minerals, are at the third one. The plotted points of the analysed dolerite dykes of the Koppal area indicate a course of crystallization and differentiation which is almost similar to those of Breven and Hallefors dykes. Likewise Devaraju (1966), Mahabaleshwar (1970) and Govindrajulu (1971) have obtained similar trends for the dolerite dykes from different parts of Mysore State namely, Halgur-Satanur, Shivasamudram and Jamakhandi areas respectively.

CaO - MgO - (Na₂O + K₂O) diagram (Fig. 24) of Wager and Deer (op cit) also suggests the same course of differentiation as those indicated by normative minerals (Fig. 22) of Burri and Niggli (op cit) and FeO - MgO - (Na₂O + K₂O) diagram (Fig. 23).

It is clear from the figs. 22, 23 and 24 that different varieties of dolerite dykes of the Koppal area bear a
comagmatic relationship and they have been formed by a differentiation from a parent magma of possibly an olivine-bronzite dolerite composition.

**MacDonald and Katsura's diagram**

Plots of $\text{Na}_2 + \text{K}_2\text{O}$ values against $\text{SiO}_2$ values of various types of dolerite dykes of Koppal area fall in the tholeiitic field (Fig. 25).

**K - $\text{Mg}$ diagram of Burri and Niggli**

$K - \text{Mg}$ values for different types of dolerite dykes of the Koppal area are plotted in the diagram (Fig. 26), from which it is seen that all the plotted points, except for two, fall within the field of the Pacific Suite which in turn suggests that the magma from which the dolerites were derived resembles that suite.

A general petrochemical study of the dolerite dykes of the area suggests that they belong to the Pacific Suite of igneous rocks and that their parent magma is calc-alkaline in composition, being akin to olivine-bronzite dolerite, from which basaltic and quartz dolerites have been formed by fractional crystallization.

**GENESIS OF DOLERITE DYKES**

It is here attempted to find out whether the various
FIG. 25. MACDONALD AND KATSURA'S DIAGRAM (1964).

Plots of analysed dolerite dykes from Koppal area are confined to tholeitic field.


Plots of analysed dolerites from Koppal area are Pacific suite of igneous rock.
associated dolerite dykes which differ in their texture, mineralogy and chemical composition, the detailed account of which is given in the previous sections of this chapter, have been derived from the differentiation of a common parent magma and, if so, what was its probable mode. In order to visualise this problem, different evidences enumerated in earlier sections have been recapitulated here for ready reference and discussion.

i. The dolerite dykes of the Koppal area, which have intruded into the granites gneisses and the pyroxene syenite generally occur as small mounds and ridges and are occasionally exposed at the surface exhibiting considerable variations in their dimensions.

ii. They are free from xenoliths and evidences of forceful injection and dismemberment of associated rocks.

iii. Chilled margins noticed in a few dykes indicate that the country rocks, in which dykes have intruded, were sufficiently cool and support the existence of a long interval of time between the formation of the country rocks and the intrusion of the dykes.
iv. They are represented both by the undersaturated types like olivine and olivine-bronzite dolerite and the saturated ones like basaltic and quartz dolerite dykes.

v. They vary in mineralogical composition and textures. In some dolerites typical ophitic and subophitic textures are prominent, while others are characterised by basaltic, vitrophyric and poikilitic textures.

vi. Among the different types of dykes, quartz dolerites constitute more than 90.0%.

vii. Micropegmatitic texture is believed to have been formed from the replacement of plagioclase feldspar (mostly labradorite) by quartz.

viii. Anorthite content of plagioclase feldspar in quartz dolerite and basaltic dykes varies from 54 to 62%, whereas in olivine dolerite it varies from 54 to 72%.

ix. Plotting of the modes of various dolerites on a trilinear diagram suggests that they bear a comagmatic relationship, supporting the assumption that they have been derived from a common parent magma.
x. Petrochemical study of dolerite indicates that the different varieties of dolerites bear a comagmatic relationship and have been derived from the basic magma of calc-alkaline composition, akin to olivine-bronzite dolerite.

xi. Differentiation trends of the dolerite dykes of the Koppal area fairly coincide with the dolerites reported from Karroo, Halgur-Satanur, Shivasamudram and Jamakhandi area.

On the basis of these field and laboratory evidences, it can be presumed that the dolerite dykes of the Koppal area have been derived from a basic magma, probably of calc-alkaline composition. The author feels, on the strength of various variation diagrams of dolerite dykes, that the different types of dolerites namely olivine-bronzite dolerite, olivine dolerite, basaltic dyke and quartz dolerite have been derived from the same parent magma, consequent on fractional crystallization and differentiation. It is evident that their intrusion was guided by the ancient fracture planes present in granites, gneisses and pyroxene syenite, along which the intrusion of these dykes have taken place and there was a long interval of time between the formation of the country rocks and intrusion of the dykes.
Johannsen (1957) gave the name meladiabase for diabases rich in ferromagnesian minerals. A solitary exposure (plate XXIV), located 1.0 Km. south of Horatattanalu, striking NNW, 20.0 metres in length and 20 to 50 cms. in width is classified as meladiabase owing to its extreme abundance of pyroxene. Meladiabase from the Koppal area differs from that of Johannsen in the following respects: i. strong porphyritic and penidiomorphic texture ii. extreme richness of pyroxene to the almost exclusion of plagioclase iii. absence of olivine either in the mode or in the norm.

Though meladiabase dykes are reported from many parts of the crystalline complex of Mysore by investigators like Devaraju and Sadashivaiah (1966), Jamakhandi and Sadashivaiah (1968) and Sadashivaiah and Tadakod (1968) their occurrences are too few as compared with the other basic dykes of the area.

In hand specimen, meladiabase of Koppal is fine grained, blackish grey, compact and porphyritic containing abundant glistening tablets of pyroxene in fine grained matrix. Sp. Gr. of meladiabase is 3.19.
In thin section it exhibits porphyritic, glomeroporphyritic and panidiomorphic textures (plate XXVI b) and is composed of abundant phenocrysts of colourless pyroxenes which often form aggregates in a fine grained matrix consisting small euhedral to anhedral pyroxene, numerous needles of iron ore, microlites of plagioclase and isotropic interstitial glass.

Pyroxene generally occurs as euhedral to anhedral crystals, seen as both phenocryst (28.8%) and also as ground mass constituent (56.20%). Phenocryst pyroxenes often form aggregates and occasionally twinned on (100). It is colourless and has $2V = 38$ to $42^\circ$, $Z\wedge c = 37$ to $38^\circ$ and $N_e = 1.685$. Optical properties classify (McDonold 1950) the pyroxene as pigeonitic-augite. It is often altered to chlorite. Small prismatic needles of iron ore (8.32% of mode) confined only to ground mass occur, along with the microlites of plagioclase and interstitial glassy matter (6.60%).

A fresh specimen of meladiabase has been chemically analysed and the results along with the calculated C.I.P.W. norm, Niggli values and Niggli bases are given in table XXXX. It is interesting to note from this analysis of meladiabase which is extremely rich in pyroxene that it is
almost similar to the quartz dolerite except for the low per cent of alumina. Similarly C.I.P.W. norm, Niggli values and Niggli bases are comparable with those of quartz dolerite. Presence of 10.0% normative quartz in the meladiabase which is extremely rich in mafic constituents suggest that it also contains good amount of felsic component in an occult form.

It is therefore concluded that the meladiabase and quartz dolerites of the area, having almost the same chemical composition with variation in mineral assemblage are believed to be derived from the same magma but crystallized under different conditions of cooling.