4-1. METHOD OF STUDY:

The samples chosen for chemical analysis were selected from rock samples collected during the systematic mapping of the area. While collecting the samples emphasis was given on the mode of occurrence and the texture of the rocks. Bulky samples were chosen for rocks with coarse, porphyroblastic texture and with segregation bands. Further selection was also made on the basis that the rock must show indication of transformation, if any.

The samples selected for chemical analyses were first crushed to pass through 90-100 mesh sieve. Each of the powdered sample was coned and quartered and a portion was taken for chemical analysis. The samples were analysed in terms of SiO$_2$, TiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, FeO, MgO, MnO, CaO, Na$_2$O, K$_2$O, P$_2$O$_5$, H$_2$O$^+$, with the help of rapid analytical methods of Shapric and Brannock (1962). In most cases, the total of the p.c. of the oxides differs (often as much as 13), from 100. For comparison of the analyses, the average composition of similar rocks occurring at other areas are shown along with the average of the analysed rocks.

In order to enhance the utility of the analyses to the genetic interpretation through representative diagrams,
the Niggli values, and C.P.I.W. norms were calculated from the analyses. It was also attempted to establish the relationship, if any, between metasediments like mica schist, banded quartz magnetite rock, Q.F.G. and granodiorite, calculating the composition into standard unit cell of Barth (1952, pt. 82-83).

An attempt has also been made to analyse the degree of metamorphisms attained by the rocks. For this purpose, the phase diagrams were prepared (A.C.P. diagram of Eskola, Turner, 1968, pp. 172-177), from the chemical analyses for placing the metamorphic mineral assemblages in their proper facies (chapter 6).

4-2. METASEDIMENTS:

4-2A. Biotite-sillimanite-cordierite gneiss: The analysis of the rock is shown in the tabular form (table 12). For comparison and ready reference, the analyses A and B (table 12) are given from Devaraju and Sadashivaiah (1971, p.9) and Verma (1968, p. 91) respectively of biotite-sillimanite-cordierite gneiss. The analysed sample shows higher proportion of SiO₂ and alumina. The MgO is also slightly in excess over CaO. The plot of the analysis falls in the pelitic field (Fig. 24) in Heier's diagram (1962, p. 160).
4-2B. Mica schist: Two samples were analysed from the rock (table 13). The average composition of mica schists given by Poldervaart (1955, p. 36) and of greywacke by Pettijohn (1949, p. 250) shows a slight excess of alumina. This is reflected by the availability of normative corundum. The plot of the analyses falls on the dolomitic field close to the pelitic boundary (Fig. 24) in the Heier's diagram (op. cit.). The plot of these points also falls on the clays and shales field in the diagram of Nookolds (1954) and Ronov and Khelbnikova (1957, see Winkler, 1967, p. 56, Fig. 10) where clays and shales contain carbonate of about 35%. The proportion of Na is higher than K in both the samples. The excess of CaO and MgO is also obvious. The average proportion of all the oxides shows close affinity to greywacke.

4-2C. Banded quartz-magnetite rock: Three samples of the analysed rock show higher proportion of Fe and lower proportion of silica and negligible amount of alumina (table 14). The chemical analysis of this rock shows a close affinity to the analyses given by Govett (1966, pp. 1191-1212). The plots of SiO₂-Al₂O₃-Fe₂O₃ of the rock (Fig. 22a) fall in and on the boundary of the compositional fields of Govett (op. cit.) for the average of 136 analyses of Pre-Cambrian iron formation of North America. The rock is also chemically comparable to the iron ores of Kanjamalai, Salem dist., Madras state (Saravanan, 1969).
pp. 236-244). The plots of Fe$_{304}$– Fe$_{203}$– FeO$_{tio2}$ fall on the sedimentary field (Fig. 22 b) (after Balsley and Buddington, 1958, pp. 777-805).

4-2D. Calc-silicate rock: Only one sample of the rock has been analysed. The bulk composition of the rock is comparable with the average chemical composition, of the other calc-silicate rocks (table 15). The higher proportion of the alumina in the rocks indicates that the original sediment was an aluminous clay mixture. The plot of the analysis falls on the calcareous field (Fig. 24) of Heier (1962, op. cit.). The analysis also gives Niggli values of + qz, high c, and low fm and low alk.

4-3. METABASICS:

4-3A. Amphibolite: Five samples of amphibolite were chemically analysed and presented in table 16. These indicate that the amphibolites are chemically similar to the basic igneous rocks.

Variation trends in amphibolites can be represented by plotting of Niggli numbers particularly al-alk against c (Fig. 26 b); K against mg (Fig. 25 c, 26 a); al, fm, c, alk, k, mg and ti against Si (Fig. 25 a) and mg against fm (Fig. 27).
The plots of $\text{al}$, $\text{fm}$, $\text{c}$, $\text{k}$, $\text{mg}$, $\text{ti}$, vs $\text{si}$ (Fig. 25a) roughly correspond with the trend of the Karroodolerite (Walker and Poldervaart, 1949, pp. 591-706) and with the conmemara striped amphibolites (Evans and Leake, 1960, p. 1435). The $\text{fm}$ and $\text{mg}$ show a decrease and $\text{al}$, $\text{alk}$, $\text{k}$ and $\text{ti}$ show an increase with the increase of $\text{si}$ (Fig. 25a), but the trend shown by $\text{c}$ vs $\text{si}$ is not very conspicuous, still, the plots do not lie apart from the Karroodolerite trend (Fig. 25a). That the trend roughly corresponds with the Karroodolerite might be due to the inadequate number of analysed samples. The plot of $\text{c/fm}$ in the diagram of Niggli (Johannsen, 1939, p. 106, Fig. 24) falls on the eruptive field. The $\text{Fe}^{++}$+$\text{Fe}^{++}$, $\text{Mg}$ and ($\text{Na}+\text{K}$) $\text{K}$, $\text{Ca}$, and $\text{Na}$, in the diagram after Nockolds and Allen (1953, p. 106) (Fig. 23) show similar trend shown by the tholeiitic and plateau basalts. The plot of $(\text{al-alk})$ vs $\text{c}$ (Fig. 26b) shows a close grouping of points within the field of Karroo dolerites and indicates the middle to late stage of magmatic differentiation (cf. Walker and Poldervaart, 1949; Evans and Leake, 1960). The plot of $\text{a}$ against $\text{mg}$ is of value in separating the trend of a basic igneous suite from the trend shown by mixtures of palite and limestone or dolomite, as the two trends are approximately at right angles to each other (Leake, 1964). The $\text{c}$ vs $\text{mg}$ plot (Fig. 26a) for the present amphibolites shows a disposition comparable within an igneous origin. The scattering in the $\text{K}$-$\text{mg}$ plots (Fig. 25c) may be
due to K-metasomatism. However, the alk-mg trend (Fig. 25 b) is comparable with that for a dolerite suite. The plot mg vs fm (Fig. 27) shows a gradual rise of mg with increase of fm conforms the trend of basic igneous rocks. Fig. 24 is an ACF plot after Heier (op. cit.) where the area within the circle is the area of basic igneous rocks. All the plots of the analysed amphibolites fall within this basic igneous rock field. So, also is the case with Nockolds and Allen (Winkler, 1967, p.56, Fig. 10).

It is also seen that the average composition of the analysed amphibolites (table 17) corresponds almost closely to the average composition of the plateau basalts given by Daly (1933) and to the average composition of the Pauni amphibolites of Sahu and Venkatachalam (1969, p.57) and with close affinity to the Karroo dolerite (Nockolds, 1954). For further comparison, the average composition of pelite (Shaw, 1956, p. 928) and clay-dolomite mixture (Niggli, 1954, p.27) have also been tabulated.

4-4. QUARTZO-FELDSPATHIC GNEISS:

Six samples of quartzo-feldspathic gneiss from different localities (table 17) were chemically analysed. The results show the dominance of Na$_2$O over K$_2$O, a characteristic of the autochthonous granites of Read (1949, p.148). It also shows an affinity to the trondhjemites (Turner and
Verhoogen, 1960, p. 343). The average composition of the gneisses is not only similar to that of average composition of epidote-amphibolite facies acid gneisses (Ramberg, 1951), but also to the average composition of the epidote-amphibolite facies acid gneisses of the area north west of Loch Tollie (Bowes and Bhattacharjee, 1967, p. 33, table 3): but differs somewhat from that of an average composition of quartzo-feldspathic gneiss given by Poldervaart (1958).

The field of composition of the analysed quartzo-feldspathic gneiss is shown by the plots of normative Q-Ab-Or and Ab-Or-An (Fig. 28 a,b). All the plots fall apart from the minimum melting point composition towards the Q-Ab side line and then show a marked difference from those of the H.S. Washington's 571 analysed plutonic granitic rock (Bowen and Tuttle, 1958, Fig. 42) containing 80% or more of normative Q-Ab-Or. The normative An-Ab-Or plots of the analysed gneisses also show little relation to the low temperature trough in the Q-An-Or system (cf. A.W. Kleemann, 1965, Fig. 2, and 4 a). However, the similarity between both the average composition of the analysed samples of the area and the weighted bulk composition of these gneisses, and the average composition of the amphibolite facies gneisses given by H. Ramberg (1951, op.cit.) is shown by their respective Q-Ab-Or and Or-Ab-An proportions. The plots of the analyses of the present gneiss fall on the quartzo-feldspathic field (Fig. 24) of Heier (op.cit.).
A comparison with the Connemara orthogneisses (Benjamin, 1968, pp. 456-470, Fig. 6 & 7) has been attempted. The plots of the alk vs si and c vs mg bear no relation to the trend of the Connemara orthogneiss (Fig. 30 a, b). Hence, the quartzo-feldspathic gneiss of the present area are not comparable to the orthogneiss.

4-5. GRANODIORITE:

The average composition of the six analysed samples (table 18) shows a dominance of Na₂O over K₂O, which characterised the affinity of these rocks to the granodiorites belonging to the autochthonous granites of Read (1949, p. 148). The average composition of these rocks also compares well with the composition of the grey granite of Shirahatti area (Murthy and Sadashivaiah, 1961, p. 178); the average composition of Woodson Mt. type, southern California Batholiths (Turner and Verhoogen, 1961, p. 344), and the average composition of the Taubeneck’s granodiorite. But the average composition of 47 samples of Pre-Cambrian granite (Daly, 1933, from Mahadevan Volume, 1961) which falls on the plutonic field of Tuttle and Bowen (1958, Fig. 42) shows little relation to the present rocks.
The plots of normative Q-Ab-Or (Fig. 29 a) lie towards the Q-Ab-side line and show little relation to the plutonic rock field of 571 analyses given by H.S. Washington (1917) containing 80% or more of normative Q-Ab-Or (cf. Tuttle and Bowen, op. cit.). The normative An-Ab-Or (Fig. 29 b). Proportion also bears little relation to the low temperature trough in the SiO₂-An-Ab-Or system (cf. Kleemann, 1965, Fig. 2 and 4 a).

The plots of Fe⁺⁺⁺Fe⁺⁺, Mg and (Na⁺K) in the diagram (Fig. 30 d) after Nockolds and Allen (1953, p. 106) show no trend comparable to the trend shown by the plutonic rock series of southern California batholiths and to the Pre-Cambrian diorite-granite plutonic series from Pembrokeshire, Wales (Thorpe, 1970, pp. 491-499, Fig. 1) which show the trend of igneous rocks.

4-6. CHEMICAL VARIATION BETWEEN MICA SCHIST, QUARTZOFELDSPATHIC GNEISS AND GRANODIORITE:

The variation of different oxides in all the rock types is quite clear. Silica is high in Q.F.G. soda and potash are high in Q.F.G. and granodiorite. The content of alumina is higher in mica schist. Other oxides also show similar variation from mica schist to granodiorite.

The plots of the proportion of FeO +Fe₂O₃+Mgo against Na₂O +K₂O, both recalculated to 100, shows a linear
variation from mica schist to granodiorite (Fig. 31 a) with overlap between the field of Q.F.O. and granodiorite. The plot of CaO against MgO, both recalculated to 100, shows a linear variation from mica schist to granodiorite with some overlap (Fig. 31 a). Again, weight percentage of Na2O against that of Si of the mica schist, Q.F.O. and granodiorite, shows a linear variation (Fig. 30 c).

In general, it is seen that potassium content is greater in the granodiorite and Q.F.G. than in the mica schist. This might be due to the development of potash feldspar in the granodiorite and Q.F.G. and muscovite in both the rocks as replacement mineral, and segregated bodies consisting of biotite associated with the Q.F.G.

The average composition of the mica schist is different from the average composition of the Q.F.G. and from the average composition of the granodiorite (table 13.17, 18). This well observed from the following, mainly in the major chemical constituents which are expressed in terms of the differences in the (average) cation percentages of these rocks (cf. Barth, 1962, pp. 345-349). The composition of the standard cell of mica schist, Q.F.G. and granodiorite are given below:

1. Mica schist: K$_2$.1 Na$_4$.2 Ca$_2$.7 Mg$_3$.3 Fe$_5$.2 Al$_{18}$.0
   Ti$_{0}$.4 Si$_{63}$.6 (O$_{159}$.2 (OH)$_{0}$.8 )$_{160}$.0
2. Q.F.G. : K1.7 Na5.6 Ca2.0 Fe1.4 Al15.2 Si72.0
   Ti0.1 (0159.4 (OH)0.6) 160.0

3. Granodiorite : K2.1 Na8.1 Ca1.8 Mg0.6 Fe1.7 Al16.3
   Ti0.1 Si68.7 P0.1 (0159.0 (OH)1.0) 160.0

Thus, relative to the mica schist, the Q.F.G. shows the following excess and deficiency of cations per 100.

<table>
<thead>
<tr>
<th>Excess</th>
<th>Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4 Na</td>
<td>.4 K</td>
</tr>
<tr>
<td>8.6 Si</td>
<td>.7 Ca</td>
</tr>
<tr>
<td><strong>Total</strong> 10.0 cations</td>
<td><strong>1.9 Mg</strong></td>
</tr>
</tbody>
</table>

Representing 35.8 valancies

| 3.8 Fe   | 2.8 Al |
| .4 Ti    | .2 H   |

**Total** 10.2 cations

Representing 28.4 valancies.

Similarly, the average composition of the granodiorite shows, relative to that of the Q.F.G., the following excess and deficiency of cations per 100.
The average composition of the mica schist can also be directly compared with that of the granodiorite and thus the latter shows, relative to the former the following cation (Per 100) excess and deficiency.

<table>
<thead>
<tr>
<th>Excess</th>
<th>Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8 Na</td>
<td>0.9 Ca</td>
</tr>
<tr>
<td>5.1 Si</td>
<td>2.7 Mg</td>
</tr>
<tr>
<td>Total 8.9 cations</td>
<td>2.5 Fe</td>
</tr>
<tr>
<td></td>
<td>1.7 Al</td>
</tr>
<tr>
<td></td>
<td>0.3 Ti</td>
</tr>
<tr>
<td></td>
<td>0.1 P</td>
</tr>
<tr>
<td>Total 8.12 cations</td>
<td></td>
</tr>
</tbody>
</table>

Representing 24.2 valancies

Representing 22.3 valancies.
The excess or deficiency of the cation percentages in the three rock types are well noticeable. This might be mainly due to the higher percentage of silica in the quartzofeldspathic gneiss and also comparatively higher in the granodiorite.

Quartzofeldspathic gneiss shows excess of Na and Si and deficiency of K, Ca, Mg, Al, Fe, Ti and H in comparison with mica schist. Granodiorite shows excess of Ca, Mg, and Si and deficiency of K, Na, Al, Fe, P and H in comparison with Q.F.G. Similarly, granodiorite shows excess of Si and Na and deficiency of Ca, Mg, Fe, Al, Ti and P in comparison with mica schist.

4-7. INTERPRETATION ON THE GEOCHEMISTRY OF THE ROCK TYPE:

Although, it is difficult to make any definite conclusion, with these limited number of chemical analyses, yet the field occupied by these analyses in the standard diagram mentioned above is quite conclusive. Hence, this study of the geochemistry of the rock indicates the following.

1. that the metasediments - mica schist, biotite-
sillimanite-cordierite gneiss, calc-silicate rock, banded quartz-magnetite rock show close affinity to pelitic (containing 35% carbonate), pelitic, calc-aluminous and iron sediments, respectively.
2. that the amphibolites of the present area maintain an igneous trend comparable to orthoamphibolites.

3. that the quartzo-feldspathic gneiss shows close similarity to gneisses derived from pelitic sediments.

4. that the granodiorites of the present area is dominated by Na$_2$O over K$_2$O and shows no trend close similarity with igneous trend.

5. that the chemical variation is continuous from mica schist to quartzo-feldspathic gneiss and then to granodiorite.

6. that the study of the unit cell suggests a close relation between, metasediments, quartzo-feldspathic gneiss and granodiorites.

and 7. that the variation of Fe$_t$, MgO and Na$_2$O +K$_2$O (Fig. 30 d) of the present granodiorite does not correspond with the variation trend of plutonic rocks.
Fig. 22 a. Variation in $\text{Al}_2\text{O}_3 : \text{SiO}_2 : \text{Fe}_2\text{O}_3$ of banded quartz-magnetite rock of the Hahim area. Closed area represents the compositional field of Pre-Cambrian iron formation of Govett (1966, pp.1191-1212).

b. Composition diagram of Banded quartz-magnetite rock of the Hahim area (after Balsley and Buddington, 1958).
FIG. 22.

COMPOSITIONAL FIELD OF PRE-CAMBRIAN IRON FORMATION
PRESENT SAMPLES.

1 = SEGREGATIONS WITH GRANITE PEGMATITE
2 = HYDROTHERMAL REPLACEMENT VEIN ORES
3 = MAGMATIC SEGREGATIONS
O = PRESENT SAMPLES
● = AVERAGE OF THE PRESENT SAMPLES.
Δ = KANJAMALAI IRON ORE.
Fig. 23. Mg : Fe"+ Fe"" : Na+ K & Ca : K : Na plots (cation proportions) of the Hahim amphibolites. The possible magmatic trend lines are after Nockolds and Allen (1954).

A = Average of Pauni amphibolites (Sahu and Venkatachalam, 1969)
B = Average of all basalts (Daly, 1933)
C = Average of clay dolomite mixture (Niggli, 1954).
D = Average of tholeiite basalts and dolerite (Nockolds, 1954).

Fig. 23.

Fig. 24.
Fig. 25 a. Plots of al, fm, c, alk, k, mg and ti against Si of the Hahim amphibolites.

b. Plot of alk against mg of the Hahim amphibolite.

c. Plot of K against mg of the Hahim amphibolite.
Fig. 25.
Fig. 26 a. mg against c (Niggli values) in the diagram 
(after Leake, 1964) showing regions of 
pelites and carbonates. The curved line 
with arrow indicates the trend of karroo 
dolerites.

b. Niggli values al-alk against c plot of the 
Hahim amphibolites, in the diagram (after 
Leake, 1964) showing fields of pelites, 
igneous and karroo dolerite.
Fig. 26.
Fig. 27. Variation of mg against fm in the amphibolite of the Mahim area.
Fig. 28 a. Plots of normative $\text{An}:\text{Ab}$ proportions of quartzo-feldspathic gneiss.

A = Average of the present samples

B = Average of the Lewisian rocks (Bowes and Bhattacharjee, 1967)

C = Trondhjemite (Goldsmith, 1916)

D = Average composition of epidote and amphibolite facies gneiss (Ramberg, 1951)

E = Average of 250 quartzo-feldspathic gneiss (Poldervaart, 1955).

b. Plots of normative $Q:\text{Ab}$ proportions for the present Q.F.G. The diagram shows a line representing the variation in water vapour pressure from 500 to 10,000 bars (After Tuttle and Bowen, 1958).
Fig. 28.
Fig. 29 a. Plots of normative Ab$ or Q$ proportions of the granodiorite.

A = Average of the present samples
B = Average of Woodson Mt. type (Turner and Verhoogen, 1961)
C = Grey granite from Shirahatti area, (Murthy and Sadashivaiah, 1961)
D = Average of Pre-Cambrian granite (Daly, 1933)
E = Granodiorite from Bald Mt. (Taubenack, 1957).

b. Plots of An : Ab: or proportions of the present granodiorite.
Fig. 29.

\[ \text{Fig. 29.} \]
Fig. 30a. Variation of alk against Si of the present Q. F. G. The dotted line indicates the trend of connemara orthogneiss.

b. Variation of e against mg of the Q. F. G.

c. Variation of Na₂O + K₂O against Si of mica schist, Q. F. G. and granodiorite of the present area.

d. Plot of Na₂O + K₂O : Mgo : Fe₂+ of the present granodiorite (after Nockolds and Allen).
Fig. 30
Fig. 31 a. Chemical correlation between Cao and Meo 
(both recalculated to 100) mica schists, 
Q.F.G. and granodiorite of the Hahim area. 
b. Chemical correlation between potash + soda 
and iron oxides + magnesia in mica schists, 
Q.F.G. and granodiorites of the Hahim area.
Fig. 31.