CHAPTER VII

AMPHIBOLITES
Amphibolites are the common associates of charnockites, granites and gneisses of Sivasamudram area. They occur as small bands, patches, lenses etc, parallel to the general trend of the gneisses. As the amphibolites are older than the granitic gneisses, they possibly reveal the pre-metamorphic history of the rock types that were present prior to the formation of these granitic gneisses.

Amphibolites are the products of the pre-existing rocks, which underwent series of mineralogical and chemical changes due to metamorphism. They have diverse modes of origin, formed either from basic igneous rocks or from sediments and consequently these are termed as 'ortho' and 'para' amphibolites. The major exposures of amphibolites are found in the granitic gneisses as bands and patches of various shapes. The northern portion of the area where the gneisses are widespread, has numerous exposures of amphibolites but less in charnockites. They are well exposed in between Devapatna and Vasavalli, Bachanshelli and east of Chotalli.

Field characters

In the field it is observed that wherever amphibolites occur within the gneisses they always bear gradational contacts with the latter. Minute patches of amphibolites
display various shapes like the pinch and swell type of cincous, rectangular to oval shaped isolated patches. Their size varies from a few square centimeter to a few square meters. Development of minor faults and fractures caused by the rotational movements of the amphibolite patches are common. The quartzofeldspathic veins are invariably seen to traverse the amphibolites.

Megascopically we can distinguish amphibolites of two types, one with dark colour medium to fine grained hard and compact, the other being dark dense and fragile with abundant shining crystals of dark brown hornblende.

**Petrography**

The thin section study of the amphibolites reveal the presence of diopside, plagioclase and quartz in addition to hornblende together with accessories like apatite, zircon, magnetite, biotite and sphen. On the basis of texture and mineral assemblage these amphibolites have been classified into the following types.

a) Hornblende-plagioclase amphibolite
b) Hornblende-plagioclase-quartz amphibolite
c) Hornblende-diopside-plagioclase amphibolite
d) Hornblende-diopside-plagioclase-quartz amphibolite.
a) Hornblende-plagioclase amphibolite

This variety of amphibolite exhibits granulitic texture, composed of brownish green hornblende which occurs as subhedral prisms and plates often blebbed by quartz and plagioclase. Next in abundance to hornblende is plagioclase often twinned with an anorthite content of 35%. Quartz occurs as anhedral to rounded grains with wavy extinction and bimorph lamellae. Occasionally, brownish green biotite is seen in close association with hornblende. Apatite, zircon and granular magnetite are noticed as the accessory minerals.

b) Hornblende-plagioclase-quartz amphibolites

This type differs from previous in texture. It is schistose in which the elongated prisms of brownish green hornblende and twinned laths of plagioclase with anorthite content 30 to 32% show a linear parallelism. Anhedral quartz occurs as plates which exhibit wavy extinction and lamellar nature. Granular and opaque magnetite discrete grains of zircon are seen as inclusions.

c) Hornblende-diopside-plagioclase amphibolite

This exhibits granulitic, feebly schistose and granoblastic textures. Brown green and strongly pleochroic hornblende occurs predominantly as subhedral prisms and plates which are often blebbed by granular quartz and...
plagioclase. Granular magnetite and prismatic apatite occur as
accessories. Colourless to pale greenish yellow diopside
occurs in subordinate amounts.

d) Hornblende-diopside-plagioclase-quartz amphibolite

This type also exhibits granulitic and schistose
textures. In addition to hornblende, diopside occurs as
feebly pleochroic subhedral elongated prisms with pale
yellowish green in colour. Quartz occurs as plates with
wavy extinction. Plagioclase occurs as twinned laths in
minor amounts.

Mineralogy

Hornblende

It is the most abundant constituent of the amphi-
bolite with deep brown to brownish green in colour. It is
frequently seen as subhedral prismatic plates with sieved
nature. Blebs of quartz, small plates of plagioclase and
needles of apatite are often seen poikilitically enclosed
within the large plates of hornblende. The pleochroic
colours are $X =$ pale yellowish green, $Y =$ deep yellowish
green and $Z =$ deep brown. The optic axial angle $(2V)$ varies
from $62^\circ$ to $67^\circ$, $\Delta\alpha = 15^\circ$ to $20^\circ$; $(\gamma - \alpha)$ from 0.018 to
0.022 and $n_\beta = 1.615$. 

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Plagioclase

It occurs as euhedral laths both twinned and untwinned nature. The anorthite content varies from 25 to 35%. Twinning is mostly on carlsbad and albite-carlsbad laws, which indicates an igneous parentage (ortho amphibolites). Alteration of plagioclase to saussurite and epidote is often seen.

Quartz

Generally quartz occurs as plates which exhibit wavy extinction and lamellar nature, where the schistocity is prominent. The deformed (schistose) types also exhibit undulatory extinction more conspicuously than in the granulitic types. Therefore shearing and translation, gliding might have been responsible for the development of lamellar nature in quartz.

Diopside

It occurs as granules and plates with pale yellow to dirty green in colour, faintly pleochroic with $X$ = pale green $Y$ = grey and $Z$ = yellow; $N_y = 52^\circ$ to $55^\circ$, $Z \neq C = 46^\circ$, $N_{\beta} = 1.70$ and $(Y - \beta) = 0.023$ to 0.030. Alteration of diopside to hornblende is quite common and the relict pyroxene is seen in and around the hornblende. Some sections exhibit granulitic texture with subnematic prisms of hornblende.
possessing pyroxene cleavages. Biotite is not common and discrete grains of apatite, magnetite, and sphene are occasionally seen. Zircon is rarely observed in Sivasamudra amphibolites.

Petrochemistry

To know the chemical changes involved during the transformation of the original rocks to amphibolites, a systematic sampling and the chemical analyses are necessary. Unfortunately in the areas like the present one such a detailed study has not been possible because the original rocks which have given rise to amphibolites are no longer seen. The chemical analysis of the amphibolite (for both major and minor elements) will throw some light regarding the parentage and the nature of metamorphism.

Chemical analyses together with the mode and calculated CIPW norm are presented in Table XXI. The chemical data are interpreted by using Niggli values as suggested by Leake (1964). All the three analyses of the amphibolites when plotted in the various petrochemical diagrams of Leake (op. cit) place the rocks in the igneous field. The plots in the Niggli mg/c diagram are very close to the trend line of Harroo dolerites. Also the plotted points of the ortho amphibolites of Langoy area fall in the middle stage differentiates. Evans and Leake (1960) have also observed that
low Niggli K values (0.5) and high TiO₂ content (1 percent) are indicative of ortho amphibolites.

**Trace elements**

Loeke (1969) considered that a correlation of Cr and Ni values with Niggli mg could be a better conclusive factor for deciphering the ortho and para nature of the amphibolite. A good correlation to these values is seen from the data given below:

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>119</th>
<th>32</th>
<th>167A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr (ppm)</td>
<td>150</td>
<td>130</td>
<td>120</td>
</tr>
<tr>
<td>Ni (&quot; )</td>
<td>250</td>
<td>220</td>
<td>200</td>
</tr>
<tr>
<td>Mg (&quot; )</td>
<td>0.50</td>
<td>0.48</td>
<td>0.46</td>
</tr>
</tbody>
</table>

The trace elements like Cu, Co, Ni, Cr and Zn when compared with those from the amphibolites of Eseryville and Colton area (Engel et al. 1964) the Sivasamudram amphibolites are more richer in these elements. The higher concentration of these elements are generally seen in the basic igneous rocks.
Several investigators from the Karnataka University, while carrying out detailed, field, petrographic and petrochemical investigations on the various rock types of the gneissic complex of Karnataka have reported the occurrence of amphibolites from a number of localities. Their detailed study of these rocks indicate that the amphibolites associated with the gneisses and granites are of the ortho type. They are derived from the metamorphism of basic igneous rocks. The petrochemical data published in literature on the metabasalts of Archaean age also indicate that these rocks are comparable with oceanic tholeiites. But archaean metabasalts are considerably lower in alumina and potash than the recent oceanic tholeiites, as indicated by Glikson (1971).

A summary of the relevant salient features which indicate the formation of Sivasamudram amphibolites from the metamorphism of basic igneous rocks are given below.

1) They occur as small dyke like bodies, lenses and patches within the gneisses aligned parallel to the regional trend.

2) Decrease in the frequency of abundance and distribution of amphibolite patches from the gneisses to granite, which suggest that the amphibolites are resedites after granitisation process.
3) Presence of ophitic and sub-ophitic textures with relict clinopyroxenes in the amphibolites indicate their derivation from basic igneous rocks.

4) Variation in texture from granulitic to schistose texture and sloved nature of the ferro-magnesian minerals indicate the effects of metamorphism on the pre-existing rocks.

5) Absence of genetic relation is seen between pelites and amphibolites by the field evidence and chemical investigations.

6) Transformation of pyroxenes to amphibolites is clear, and some times the amphiboles show pyroxenic cleavages.

7) The petrochemical investigation indicates that these amphibolites belong to 'ortho' type.

Based on these evidences the author of the thesis concludes that the amphibolites of the present investigation are ortho type. The major elemental study of the amphibolites alone will not be able to give the correct genetic picture and a perusal of the trace element data of the schistose and the igneous looking hornblendic rocks shows that amongst the key elements, V, Cr and Ni are appreciably higher in the rocks of igneous parentage. In fact as
observed by Leake (1964), many basic igneous rocks which do not have higher content of chromium and nickel, these elements will not be of much value. The parent basic igneous rocks, after having undergone series of mineralogical and chemical changes, have given rise to these amphibolites occurring both in the gneissic and metasedimentary terrains. Though it has not been possible to decide the exact nature of the pre-existing basic igneous rocks which have given rise to the amphibolites, it is surmised that they are probably basic dykes of pre cambrian age.