CHAPTER - VIII

METAMORPHISM

INTRODUCTION

Metamorphically, the rocks of Ambamata are more varied and interesting than visualised by the earlier workers. In fact, the details of the metamorphic characters have not been adequately studied by any one. Fairly less intense metamorphic conditions were visualised by Heron (1953) who found a number of anomalies in mineral assemblages that somehow did not provide a real metamorphic picture. He has invoked 'metamorphism of Intermediate zone' for the Delhi rocks, and has given more importance to the contact and metasomatic effects of Erinpura granite. More recently, The sequence of metamorphic events, as worked out by the present author is as under :

Event 1 (M_1) : Regional (progressive) metamorphism that synchronised with F_1 and F_2 foldings. It was during this period that the lower portions of the pelitic sediments were transformed into gneisses, and the oceanic (basaltic) basement changed over to ortho-amphibolites.

Event 2 (M_2) : Contact metamorphism due to the emplacement of Erinpura granite.

REGIONAL METAMORPHISM (M_1)

This metamorphic event was obviously an integral part of the Delhi upheaval, during which the oldest oceanic crust along with the overlying Ajabgarh sediments were involved in the earliest foldings, and were transformed into metamorphic assemblages typical of amphibolite facies. This is clearly revealed from the ACF diagram (Fig. VIII.1), the A, C & F values being calculated from the chemical data given in Chapter VII. Allowing for the effects of contact metamorphism the various mineral assemblages related to M_1, have been found as under :

Ortho-amphibolites

1. Hornblende + plagioclase + quartz + sphene
2. Hornblende + plagioclase + quartz + epidote

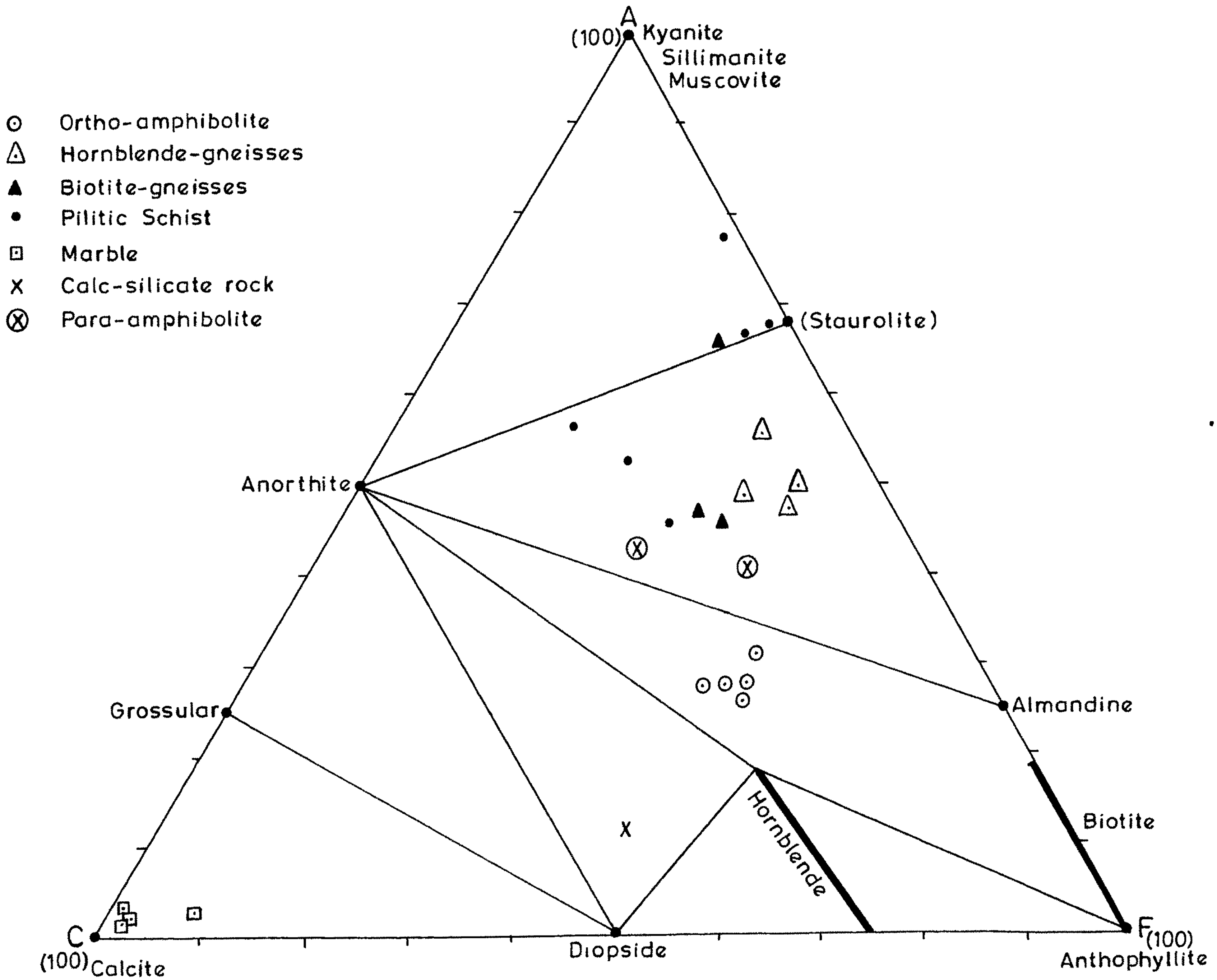


Fig. VIII.1. ACF DIAGRAM FOR THE MEDIUM-PRESSURE AMPHIBOLITE FACIES SERIES
(After Miyashiro, 1973)

TABLE VIII.1

A, C & F VALUES FOR ORTHO-AMPHIBOLITES AND METASEDIMENTARIES

Sample No.	Name of the rock	A (Al_2O_3+ Fe_2O_3)	C (CaO)	F (MfO+FeO)
1	Ortho-amphibolite	27.30	23.13	49.57
2	Ortho-amphibolite	30.90	22.26	46.84
3	Ortho-amphibolite	27.04	24.77	48.19
4.	Ortho-amphibolite	27.92	25.85	46.23
5.	Ortho-amphibolite	27.40	26.55	46.05
6.	Hornblende gneiss	47.53	9.79	42.68
7.	Hornblende gneiss	49.11	14.36	36.53
8.	Hornblende gneiss	49.86	7.95	42.19
9.	Hornblende gneiss	55.97	8.65	35.38
10	Biotite gneiss	45.86	17.19	36.95
11	Biotite gneiss	46.64	18.21	35.15
12	Biotite gneiss	65.62	9.43	24.95
13	Pelitic schist	67.35	4.63	28.02
14	Pelitic schist	56.89	28.01	15.10
15	Pelitic schist	52.56	22.84	24.60
16	Pelitic schist	77.97	2.01	20.02
17	Pelitic schist	67.33	5.08	27.59
18	Pelitic schist (qtz. schist)	67.59	2.28	30.13
19	Pelitic schist	45.84	21.68	32.48
31	Marble	0.54	97.73	1.73
32	Marble	2.85	89.01	8.14
33	Marble	0.19	98.06	1.73
34	Marble	0.83	97.20	1.97
35	Marble	3.07	95.87	1.06
36	Calk silicate rock	43.22	16.70	40.08
37	Para-amphibolite	55.83	12.15	32.02
38	Para-amphibolite	60.82	10.62	28.56

3. Hornblende + plagioclase + quartz + epidote + biotite

4. Hornblende + plagioclase + quartz + garnet

5. Hornblende + plagioclase + quartz + garnet + epidote

Pelitic rocks

Hornblende gneisses (Transitional)

1. Hornblende + plagioclase + quartz + potash felspar

2. Hornblende + plagioclase + quartz + potash felspar + sphene

3. Hornblende + plagioclase + quartz + potash felspar + sphene + epidote.

Biotite gneisses

4. Plagioclase + potash felspar + quartz + biotite

5. Plagioclase + potash felspar + quartz + garnet

Granulites

6. Quartz + felspars + garnet + sillimanite + cordierite

Schists and associated rocks

7. Quartz + biotite

8. Quartz + plagioclase + microcline + biotite

9. Quartz + plagioclase + microcline + biotite+ muscovite

Mineralised zone

10. Quartz + tremolite

11. Quartz + tremolite + spinel

12. Quartz + biotite + anthophyllite

13. Anthophyllite + spinel

Calcareous rocks

Marble + Calc schist and Calc silicate gneisses

1. Calcite
2. Calcite + quartz
3. Calcite + tremolite
4. Calcite + tremolite + quartz
5. Calcite + tremolite + quartz + diopside
6. Calcite + forsterite
7. Calcite + forsterite + phlogopite
8. Calcite + quartz + plagioclase + actinolite

Para-amphibolites

9. Actinolite + plagioclase + quartz
10. Actinolite + plagioclase + quartz + diopside

Nature of the biotite - and hornblende gneisses

These foliated rocks were considered by Heron to comprise an early phase of Erinpura granite, involved in the Delhi folding. Also, some foliated varieties have been referred to as comprising composite gneisses with sheets of granite interbedded with pelites and amphibolites. But the present study has adequately established that the gneisses are in no way connected with Erinpura granite, but are older rocks. It is most significant to observe that the typical intrusive masses of non-foliated granite show very sharp contacts with the gneisses, and they occur all over in other metasediments also. Mineralogically, it is found that while a typical Erinpura granite contains substantial muscovite, the gneisses are devoid of this mica. Secondly, the occasional presence of garnet in gneisses also points to their derivation from a metapelite.

As regards the hornblendic gneisses, they very clearly reveal their derivation from original (? perhaps striped amphibolites. The mineral composition of the various layers of these gneissic rocks point to the addition of granitic constituents from the overlying biotite gneisses. The author does not envisage any granitisation of amphibolites by Erinpura granite.

Nature of the so called "Schistose Quartz porphyry"

Sharma (1931) considered these rocks to comprise an igneous porphyry. Heron and Ghosh (1938) however, were doubtful about this nomenclature and they thought these rocks could be of sedimentary origin. But they did not adequately explain their true nature. Merh (1950) also doubted their igneous origin and suggested that they could be due to the metamorphism of the original arkosic sediments.

The present study has adequately shown that :

1. these rocks are not 'porphyries' but represent metamorphosed sediments of graywacke to subgraywacke nature.

2. the bigger grains of quartz are at most places, original pebbles.

3. the so called 'phenocrysts' of plagioclase and microcline are infact porphyroblasts, having grown metasomatically by the appropriate emanations from the granitised portions below. In other words, these larger felspars and some quartz grains, are the fore-runners of the granitising process which operated more intensely at deeper levels.

The original sediments showing considerable compositional variation, were metamorphosed to the existing finegrained mass of variable mineralogy, at places schistose, in which were embedded pebbles of quartz. In this mass, subsequently porphyroblasts of felspar were metasomatically developed.

The narrow band of tremolite, anthophyllite and talc bearing rocks (associated with the mineralised zone) obviously constitute a minor zone of calc-magnesian sediments within the pelites. These rocks have provided fairly conclusive evidence of amphibolite facies metamorphism.

<u>Metamorphic conditions</u>

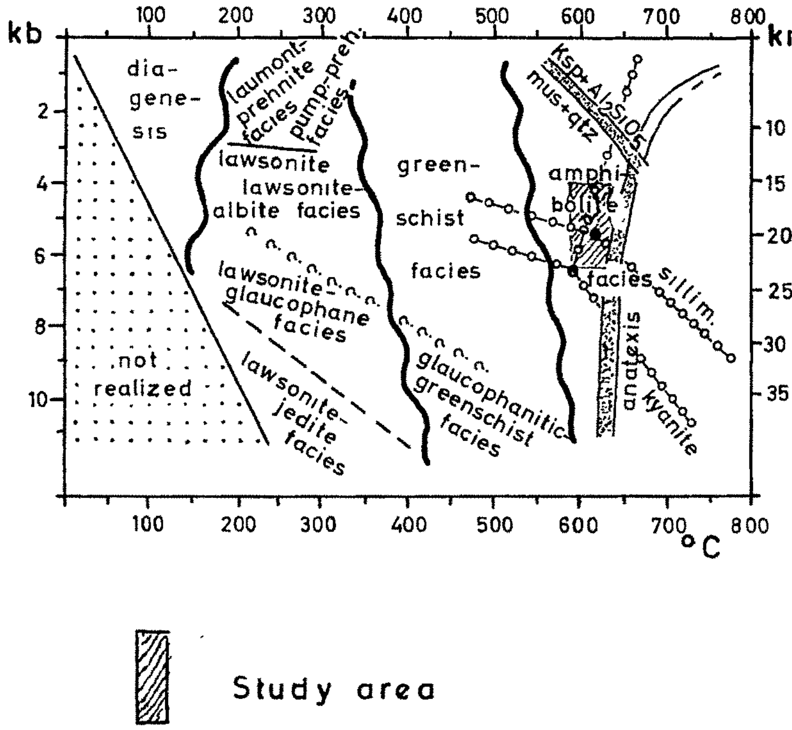
An interesting feature of the mineral assemblages of the rocks of Ambamata area, is the diversity of metamorphic grades shown in different parts. At one end, the pelitic and semi-pelitic assemblages are typically gneissic pointing to a high metamorphic grade, while at the other end the biotite schists and micaceous quartzites indicate (considerably) lower grade, so much so that the rocks have partly preserved their original sedimentary nature. Obviously, the rocks in the neighbourhood of Mala, Amli Mal, Ghoda Tankni, north and northwest of Ambamata represent biotite and almandine zones of medium pressure metapelites of Miyashiro (1973). The overall scarcity of almandine appears to be due to the original composition of the metasediments, which must have been rich in quartzo-felspathic constituents and poor in argillaceous and aluminous materials. The essential phases of the typical assemblage are quartz-plagioclase-biotite-muscovite-epidote (Turner, 1968, p. 306). In such cases, with the absence of almandine, the actual isograd separating biotite zone from almandine zone is difficult to demarcate. However, the appearance of hornblende at the expense of actinolite is an indication of almandine isograd.

At the other end are the pelitic gneisses (biotite gneiss) that represent granitised metasediments, the transformation having been brought about metamorphically under medium pressures and some what high temperatures. The ortho-amphibolites that underlie the gneisses, also show assemblages that point to the upper limits of the amphibolite facies. According to Miyashiro (1973, p. 235) the epidote and biotite are stable mineral phases under intermediate pressure amphibolite facies. It may be mentioned that in this area, the epidote in calcareous rocks is however, a product of contact metamorphism

This metamorphic variation within the amphibolite facies is most significant. According to Turner and Verhoogen (1961), the amphibolite facies metamorphism is characterised by a temperature range of 550° to 750°C with pressures varying between 2 to 8 kilobars. Obviously the rocks of the study area (Fig.VIII.2) having originated under medium pressure (? constant) conditions, exhibit a temperature range from biotite isograde to as much as the upper limits of the amphibolite facies.

An interesting aspect of this progressive metamorphism related to the early folding, is reflected in the higher grade mineral assemblage encountered in the extreme northwest near Surpagla. Here, the medium grade amphibolitic rocks come in abrupt contact with the high grade granulitic rocks containing fibrolite, cordierite and garnet of low pressure to the west. As already stated, this contact has been described by Desai et al. (1978) as an unconformity, while Sychanthavong (personal communication) has considered this abrupt change due to the presence of minor subduction zone. The metamorphic change is most obvious and the author also tends to agree with Sychanthavong and is inclined to take these high grade granulitic rocks also to be originally Delhis. This aspect has been further discussed in Chapter - X.

PT DIAGRAM INDICATING THE POSITION OF THE ROCKS OF THE STUDY AREA (after Winkler, 1975)



CONTACT METAMORPHISM (M_2)

The contact metamorphic changes are related to the Erinpura Granite, which forms very distinct intrusive bodies cutting the various metasediments. The Erinpura granite has been responsible for the development of skarns in calcareous rocks, and hydrothermal changes in pelites, and meta-dolerites etc. The contact effects of granites can be grouped into the following categories :

Effects on calcareous rocks

Wherever the limestones have either come in contact or have been included as xenoliths in granite, a number of skarn minerals have developed. Profuse development of grossular garnet (Plate VII.1) and epidote is observed near the contact of granite both in the Rasanio (Δ 737) and Minagarh (Δ 921) ridges. The ocasional presence of wollastonite in various calcareous rocks, also could be due to the effect of granite.

Effects on pelitic schists

The effects of granite on the pelitic rocks are more or less of hydrothermal nature. These changes ideally seen in the area north and northwest of Ambamata comprise following :

PLATE VIII.1

Garnet porphyroblasts in Calc-silicate Skarns. Loc. Northeastern spur of Rasanio hill.

1. Biotite to chlorite
2. Tremolite to talc
3. Anthophyllite to talc
4. Occasional growth of clusters of quartz and microcline in pelitic schists.

It was on account of these retrograde changes and near total absence of garnet, these have misled the earlier workers in assigning the proper metamorphic grade to these rocks of Ambamata. The author would like to emphasize that the overall metamorphic nature is revealed on considering the calcareous and amphibolitic rocks, and it was on that basis that a considerably higher grade metamorphism has been visualised. The granite has obscured the various evidences imparting a 'greenschist facies' appearance to the metapelites.

(In the extreme northwest corner of the study area, granulitic rocks across the tectonic junction, also show hydrothermal effects of granite. Here, the mineralogical changes consist of the development of biotite at the expense of garnet, and pinitization of cordierite).

Effects on basic rocks

The hydrothermal changes brought about in basic sills of dolerites by the granite, are as under :

1. Saussuritization and sericitization of plagioclase
2. Uralitization and chloritization of pyroxene
3. Occasional development of veins and patches of fine quartz aggregate and microcline

OVERALL METAMORPHIC PICTURE

The picture of the metamorphic evolution of the area associated with the various phases of Delhi orogeny, presents some interesting details. Within the limits of a relatively small area, almost all major events of the Delhi orogeny and their main characteristics are recorded.

The main event of metamorphism that synchronised with early co-axial foldings, was characterised by medium pressure but showed much variation in temperature change. This is adequately reflected in the grade of metamorphism from north to south. The effect of granite, bringing about numerous hydrothermal changes in various rocks, has been responsible for considerable modification of the nature of pre-existing rocks. A proper evaluation of the metamorphic and hydrothermal changes together with the correct understanding of the structure of the area, has in turn, provided a correct metamorphic picture which explains quite a few geological anomalies of this part of Delhis.