CHAPTER - II
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GEOLOGICAL SETTING AND PETROGRAPHY

2.1. INTRODUCTION

In this chapter the various field relationships between different rock types like contact relationships, foldings, fracturing, nature of shear deformation and sense of movement of rock types including mineral orientation like foliation, lineation etc., have been documented in exposures on the hills as well as in active quarries/road cuttings. The type of deformation, relative timing of intrusive igneous bodies and their deformation, has been studied. The field observation and interpretations is being followed, the suggestions and information provided in the recent text book on field geology (Passchier et al., 1990).

A study of fabric, which includes information on spatial and geometric configuration of all those component that make a rock significant. The term fabric covers information on texture, structure and crystallographic orientation as suggested by Hobbs et al., (1976). Apart from structural studies, micro-fabric study is important in unravelling deformation and metamorphic process in high-grade terranes. Micro-fabric elements include grain shape, grain boundaries, deformation lamellae, aggregates of grains with similar shapes, lattice preferred orientation. Detailed petrographic description, including micro-textural studies and mineral assemblages in different rock types is recorded in the area. Based on micro-textures, various mineral reactions occurred during high-grade metamorphism and textures related to exhumation of these rocks to upper crustal levels have been documented. Microfabric studies have been carried out following the recent text books (Passchier and Trouw, 1998 and references therein; David Shelley, 1993; Moorhouse, 1985).

In this chapter, the field relationship, micro-texture and mineral assemblages of different rock types from the massive/banded charnockitic granulites, retrogressed charnockite (blebby gneiss), basic granulites, gneisses, meta-pelites, syenites, granites, pegmatites and quartz veins have been presented under the following heads.
2.2. MASSIVE/BANDED CHARNOCKITIC GRANULITES

The massive/banded charnockitic granulites exposed in the area have been classified into enderbitic, charmo-enderbitic granulites and charnockitic granulites following the classification by Le Maitre (1989) (Fig.2.3). Form the QAP plot; it is clear that charmo-enderbitic granulite are the predominant rock types when compared to enderbites and charnockites. In the text, the term charmo-enderbitic granulites are being used. The charmo-enderbitic granulites are either massive or banded in nature in the field and hence the term MBC is used in the text. Incipient charnockitic granulites (IC), which are more common, the Archaean Dharwar craton have not been recognised in the area.

Two types of massive/banded charnockitic granulites (MBC) have been recognised in the area investigated viz., MBC-I and MBC-II, based on field relations, structure, mineral assemblages, geochemistry and radiogenic isotope age data. The charmo-enderbitic granulite occurring towards northern part of the area around Mettur (Fig.2.1 and Fig.2.2) forming part of the Biligiri Rangan Granulite, termed as MBC-I and southern part around Chennimalai, termed as MBC-II. Following are the characteristic features of MBC-I and MBC-II;

<table>
<thead>
<tr>
<th>MBC-I (Biligiri Rangan Granulite)</th>
<th>MBC-II (Chennimalai Granulite)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Innumerable enclaves of basic granulites occur</td>
<td>Basic granulate enclaves are scanty</td>
</tr>
<tr>
<td>2. Banding is defined by amphibole rich layers with minor biotites</td>
<td>Banding/foliation is defined mainly by biotite.</td>
</tr>
<tr>
<td>3. General trend is NS to N20-40°E</td>
<td>N50-80°E to E-W trends</td>
</tr>
<tr>
<td>4. Mainly charmo-enderbitic granulites in composition</td>
<td>Varies from enderbitic, charmo-enderbitic granulites and charnockite in composition</td>
</tr>
<tr>
<td>5. Tonalitic to trondhjemitic in bulk composition</td>
<td>Granodiorite to quartz monzonitic in bulk composition</td>
</tr>
<tr>
<td>6. Protoliths are ortho in nature</td>
<td>Protoliths are both para and ortho in nature</td>
</tr>
<tr>
<td>7. Early Archaean (&gt;3.1 Ga upto 3.3 Ga)</td>
<td>Late Archaean to early Proterozoic in ages (2.51 to 3.1 Ga ?)</td>
</tr>
</tbody>
</table>
Fig. 2.1. Geological Map of Southern India

4. Closepet granites 5. Region of shearing and retrograde metamorphism
8. Greenstone belts of Dharwar Group
9. Supracrustal rocks (Sargur-Sathyamangalam group of rocks)
Fig. 2.3. Q-A-P diagram for the classification of hypersthene bearing regional metamorphic rocks (after Streckeisen, 1974).

Fig. 2.4. Terminology of gabbroic rocks (Le Maitre, 1989).
2.2.1. Biligiri Rangan Granulites (BRG : MBC-I): The Biligiri Rangan granulites (BRG : MBC-I) is bounded by Dharmapuri-Mettur Shear Zone (DMSZ) in the east and the Moyar-Bhavani Shear Zone (MBSZ) in the south (Fig. 2.2). The greasy grey, medium to coarse grained, dark looking charno-enderbitic granulites are well exposed around northern part of the study area around Andiyur, Bargur, Kolatur, Chennatanda and north-western part of Mettur (Fig..2.2). These rocks are generally non garnetiferous. The foliation of charno-enderbitic granulites varies from N10°E to N40°E and dip amount also varies from exposure to exposure from 65°SE to 80°SE (Fig.2.2). The porphyroblast of feldspars are noticed, it varies in size from 1 to 2 cms in diameter, which doesn’t explain the movement in exposed region. Rarely the biotite are stretched along the foliation plane. Within the charno-enderbitic granulite, the mafic granulite enclaves occur as spherical to ellipsoidal shape with longer axes stretched along the foliation plane. They are of unmappable dimension commonly exposed around Mettur region.

The mafic enclaves are melanocratic, fine to medium grained with leucocratic plagioclase rich layers. As a result of intense deformation, some of these basic rocks have been stretched parallel to the foliation, resulting in the development of banded structures. All along these mafic enclave boundaries are noticed the bleached effect. It shows sharp contact with the host rock. Mafic enclaves measures 10 cms to one metre and show either dextral or sinistral sense of ductile deformation. Majority of mafic enclave have been rotated in an anticlockwise direction exhibiting sinistral sense of movement along the foliation plane, trending N30°E and dips 65°SE (Fig.2.5). Relict rootless fold of an asymmetrical mafic layer have been preserved in charno-enderbitic granulites.

Most of the mafic enclaves exposed around Mettur region are non-garnetiferous with the mineral assemblages of dark band consisting of clinopyroxene and hornblende and leucocratic layers consisting of feldspars. Numerous late dolerite dykes intruded along the foliation plane of charno-enderbitic granulites. Dolerite dyke range in width from 1 to 3 meters extending for a length of upto 100 meters. A set of late dolerite dykes trending N40°W occurs around Mettur.
Occurrence of fine grained, dark grey coloured, irregular patches of pseudotachylites observed around Mettur. These pseudotachylites have developed mainly along narrow zones with a trend of N40°W. Such zones have been noticed around Bargur and Mettur. The pseudotachylite occur as thin layers to thick bands measuring from few mm to 1 to 6 cms in thickness, extending with an irregular net-work for a length of upto 2 to 3 kms. Good exposures of pseudotachylites are seen in some of the active quarries around Kalipatti and Andipalyam (NE of Andiyur) and in some outcrops around Kolatur and Mettur (Fig.2.6).

An ultramylonite zone is developed (Fig.2.7) along N25°E trending planes, slightly offsetting the regional foliation. This further displaced by another ultramylonite zone trends E-W, this direction being parallel to the major ductile deformation in the Moyar Bhavani shear zone. ‘EYE’ shaped foliation exhibited by chamo-enderbitic granulites are seen within the E-W trending ultramylonite zone (near Molapariyur, NE of Bhavani).

The chamo-enderbitic granulites of MBC-I show equigranular to inequigranular, granulitic to granoblastic and polygonal to interlobate micro-texture. The major felsic minerals are quartz, plagioclase and potash feldspar. Three generations of quartz are present. The early quartz (Qtz I) occurs as an inclusions in garnet (Grt I), (not noticed in MBC-I), matrix quartz (Qtz II) are large, generally strained, fractured, showing wavy extinction. Some of the strained quartz grains show recovery and recrystallization features (Qtz III), which are smaller in size, strain free with embayed grain boundaries. However, the chamo-enderbitic granulite indicates the presence of micro-shears in quartz grains collected nearer to the major shear zones.

Plagioclase are tabular to subhedral, fresh to altered, exhibits multiple to polysynthetic twinning. Rarely feldspars show alteration to sericite. Strained plagioclase grains occur in chamo-enderbitic granulite often surrounded by microshears. The grain boundary of plagioclase feldspar bulge into the crystal with high dislocation density and form new, independent crystals. The porphyroblast of plagioclase feldspar with high dislocation density are replaced by new grains, smaller in size and re-orientation of grains and are called grain boundary migration recrystallization (Gottstein and Mecking 1985; Urai et al., 1986).
Fig. 2.5 Enclaves of two-pyroxene plagioclase in massive charno-enderbitic granulite (MBC-I). Note the presence of relict F1 folds within the basic granulites (Quarry 5 km NW of Mettur).

Fig. 2.6 Irregular net-work of Pseudotachylites within the charno-enderbitic granulite. Note the presence of isolated fragments of CEG within the dark grey pseudotachylite matrix (10 km SW of Mettur).
Potash feldspar are very rarely noticed in these charno-enderbitic granulites, which are medium grained with curved to embayed grain boundaries. Exsolution features are noticed in these charno-enderbitic granulites are perthitic feldspar, exhibits bent lamellae, indicating ductile deformation, post dating the perthites formation under deep seated conditions (Fig.2.8).

Euhedral orthopyroxene are hypersthene in composition, pleochroic from colourless, purplish pink to green. In deformed zones, hypersthene exhibits an inclined extinction (6°-8°) angle. Thin rim of exsolved magnetite around hypersthene which in turn surrounded by amphibole is observed in contact with plagioclase. Hypersthene shows alteration to either secondary amphibole (Hbl II) or yellowish red coloured secondary biotite (Bt II) (Fig.2.9). Some of the hypersthene grains indicate sinistral type of rotation along the foliation plane defined by biotite, which exhibits kink bands indicating deformation at high P-T conditions (Fig.2.10).

The flaky yellowish brown biotite occur in different orientation related to the foliation plane and fold pattern in the rocks. These biotite show ‘S’ and ‘Z’ shape rotations with both dextral and sinistral sense of deformation. Biotite shows crescent shaped deformation lamellae. Some of the micro-fractures cutting bent biotite flakes are filled by quartz grains. Rarely biotite shows alteration to colourless to light green colour chlorite.

Opaques are mainly magnetite, which are black in colour. They occur as thin films to tabular forms. The thin films/layers opaques are noticed all along the grain boundaries and cracks/fractures/cleavage planes of orthopyroxene.

Following are the mineral assemblages in the charno-enderbitic granulite around Mettur:

Qtz II + Pl + Kfs + Opx + Bt + Mag
Qtz II + Pl + Kfs + Opx + Hbl + Bt I, II + Mag
Qtz II, III + Pl + Kfs + Opx + Hbl + Bt I, II + Chl + Mag
Fig. 2.7 Exposure of ultramylonite with foliation trending N70°E, dips 60°S. Plagioclase porphyroclast showing ‘S’ type, dextral sense of movement, Molapariyur (NW of Bhavani).

Fig. 2.8 Perthites exhibits bent lamellae indicating ductile deformation of the MBC I Bargur forest area (NE of Andiyur).
Fig. 2.9 Thin rim of exsolved magnetite around hypersthene, which in turn surrounded by amphibole in contact with plagioclase.

Fig. 2.10 Dextral sense of rotation of hypersthene in CEG indicating deformation under deep seated granulite facies conditions. Hypersthene show deformation lamellae (Kolatur, N of Mettur).
2.2.2. Chennimalai Granulites (CG : MBC-II): The Chennimalai Granulites (CG) is bounded by MBSZ in the north (Fig. 2.2) and the Dharapuram shear zone (DSZ) in the south. The acid granulite in MBC-II varies from enderbites, chamo-enderbitic granulite to charnockites.

The charnockitic to enderbitic granulite of the Chennimalai granulites are massive to banded in appearance, medium to coarse grained, greasy grey looking rocks without any mafic enclaves. This is in contrast with the abundant mafic granulites enclosed within the Biligiri Rangan granulite (MBC-I) exposed around Mettur. These chamo-enderbitic granulites are generally non-garnetiferous.

The regional foliation of Chennimalai granulite is N60°E to E-W with steep dips (50-60°) towards south. Numerous tight, isoclinal folds are observed in these charno-enderbitic granulites (Fig.2.11). The isoclinal folds are defined by biotites. Local partial melting is noticed in these granulites with the formation of orthopyroxene neo-blasts, within the coarse grained quartz + plagioclase rich matrix, obliterating the foliation planes. These banded charno-enderbitic granulite exhibits felsic layers composed of quartz and plagioclase alternating with mafic layers composed of biotite. The acid granulites of MBC-II are mainly yellowish green in appearance, where the pinkish purple colour garnet grains are prominently observed whereas the non garnetiferous granulites are dark green to greenish black in colour. The foliation defined by biotite in most cases being continuous stylolitic. The foliation trend varies from place to place which are influenced by deformation. The deformation is mainly ductile with general trends varying from N50-80°E to E-W with dip of 50-60° towards NW.

In thin section, the charno-enderbitic granulites exhibit equigranular to inequigranular granulitic, polygonal to interlobate micro-textures.

Quartz (Qtz I) are noticed as inclusions in garnet (Grt I), which are small, 1-2mm in size, rounded and exhibits granulitic texture. Matrix Quartz (Qtz II) are anhedral, large-platy habit, shows undulose extinction, slightly strained with sutured grain boundaries. Quartz
shows recovery and recrystallization to give rise to smaller quartz grains (Qtz III). Plagioclase are tabular, fresh, not altered and exhibit polysynthetic twinning.

Hypersthene is pink in colour and rarely alters to yellowish red coloured biotites. Some orthopyroxene shows very strong pink-purplish pleochroism. Flaky, yellow to brown coloured biotite rarely shows deformational features like kink bands. Small tabular elongated serrated bordered yellow coloured biotites are also seen as inclusion in plagioclase. Biotite rarely alters to chlorite as thin films, which are colourless to green in colour and exhibits pleochroism.

Garnets are small, granular shape to large rounded in shape, most of them are free from inclusion but in some garnets, plagioclase and biotite occurs as inclusion. The size of the garnet varies from 0.1 mm to 3 to 4 mm in diameter. Opaques are magnetite.

Following are the mineral assemblages in MBC-II:

- Qtz II + Pl + Kfs + Opx + Bt + Mag
- Qtz II, III + Pl + Kfs + Opx + Hbl + Bt + Mag
- Qtz I, II, III + Pl + Kfs + Opx + Hbl + Bt I, II + Grt + Chl + Mag

2.2.2.1. Banded Magnetite Quartzite (BMQ): Good exposure of BMQ are seen in and around Chennimalai occupying the hillock, flanked by hornblende biotite gneiss. The BMQ is a typical landmark, exposed in the elevated region of about 534 mts (above MSL) around the Chennimalai town, with low lying undulating terrane of 200 to 300 mts. The BMQ’s consisting of thin alternating bands of quartz and magnetite with the regional E-W direction. Numerous green coloured sulphide mineralizations are noticed along micro-fractures.

In thin section, magnetite grains show stretching with recrystallised grains of quartz. Pyroxenes are mainly orthopyroxene with few clinopyroxenes exhibiting green to purplish colour. Following are the mineral assemblages in BMQ:

- Mag + Qtz II and III
- Mag + Opx ± Cpx + Qtz II and III ± Pl
2.3. SHEAR ZONES
The charno-enderbitic granulites of the MBC-I and MBC-II have been dissected by a set of shear zones along which the high-grade metamorphic rocks have been transformed into lower-grade metamorphic rocks. It is along these shear zones, the deeply buried rocks like the granulite facies lithologies have been exhumed. The study of rocks in shear zones is important in understanding nature of shear deformation, type of retrograde alteration and fluid flow in shear zones.

The granulite blocks of MBC-I and MBC-II are cut by a set of shear zones which are considered to be a part of the crustal scale Palghat-Cauvery Shear System (PCSS) (Drury et al., 1984; Meissner et al., 2002). Detailed field studies in the area have helped to identify and characterize the following shear zones.

1. The E-W trending Moyar Bhavani Shear Zone (MBSZ), separating the MBC-I from MBC-II.
2. The NNE-SSW trending Dharmapuri Mettur Shear Zone (DMSZ).
3. The NE-SW to E-W trending Chennimalai Shear Zone (CSZ).

2.3.1. Moyar-Bhavani Shear Zone (MBSZ): The Moyar Bhavani Shear Zone in the study area is approximately 40 to 60 kms wide and extending for a length of about 120 kms from Sathyamangalam in the west to Sankaridurg in the east (Fig. 2.2). Within the MBSZ more complex lithologies exhibiting various types of deformational features have been noticed.

The following three distinct litho-units have been recorded in the MBSZ:

a) Numerous dismembered garnetiferous meta-gabbros and meta-anorthositic gabbros, forming part of the Bhavani layered igneous complex, confined to northern margins of the MBSZ.

b) A group of meta-sedimentary rocks (Sathyamangalam Group of supracrustal rocks) interbanded with retrogressed charnockitic granulitic and fissile biotite bearing Bhavani gneisses in the central, eastern and southern part of the MBSZ.

c) Numerous, irregular patches of medium to coarse grained pink coloured Sankari–Tiruchengodu granites in the central and eastern part of the MBSZ.

2.3.1.1. Meta-gabbros (Bhavani layered complex): Both garnetiferous and non-garnetiferous basic granulites are noticed within the MBSZ. Only one sample is non-garnetiferous pyroxenite collected from Menakattupalyam (SW of Andiyur). Based on the
mineralogy the basic granulite are classified into the gabbro-norite and pyroxene hornblendites after the diagram of Le Maitre 1989 (Fig.2.4). The gabbroic rocks are medium to coarse grained, melanocratic garnetiferous gabros occur as concordant lenses, sheets and also occur as small mounts within the planes in the shear zones consisting mainly of blebby and biotite gneiss. These basic granulite are well exposed around Andiyur, Bhavani and Erode (Fig.2.2). These exposures are found on small hillocks, whose peak height varies from 260 meters above MSL around Andiyur and upto 434 meters above MSL around Bhavani.

The basic granulite occurring around northern margin of Moyar Bhavani shear zone (MBSZ) appears as a huge hillock but in the southern margin of MBSZ appears to be as huge enclaves within the fissile biotite gneiss. These basic granulite exhibits minor penetrative deformation and their coarse grained gabbroic texture, despite the thorough metamorphic recrystallization at granulite grade, is still preserved. Small bodies of pyroxene hornblende gabbroic norite are more intensely deformed and the original gabbroic texture has been stretched and flattened. The mafic layers and leucocratic layers are defined by hornblende-pyroxene grains and plagioclase feldspar grains respectively. The reddish brown coloured porphyroblastic garnet and dirty green coloured pyroxenes and hornblende are very conspicuous in the field. Gabros are studded with reddish garnet measures from few millimetres and upto 3 cms in diameter. Gabroic rocks occur conformable to the regional foliation from N60-70°E to E-W with steep dip, at an angle 80°SE direction. Tight minor isoclinal folds have been observed within these garnetiferous gabros. Ductile deformation of basic granulite exhibit an broad fold trending NS, dipping towards N, steep plunging lineation 45°E defined by hornblende. These ductile deformation implies that in these pyroxene hornblende gabbroic norite have undergone regional folding before high grade metamorphism, which exhibits both melanocratic and leucocratic layers. These garnetiferous gabros exhibit strong mylonitic to ultramylonitic deformational features with cumulus plagioclase rich layers are parallel to each other. Due to intense deformation and mineral segregation, the gabbroic rocks exhibit banded structures with alternating leucocratic (Pl+Hbl) and melanocratic bands (Cpx+Hbl+Grt) (Fig.2.12).
Fig. 2.11 Tight, isoclinal folds in charno-enderbitic granulites (MBC II) exposed around Chennimalai. The CEG are interbanded with calc-silicate and banded magnetite quartzites.

Fig. 2.12 Basic granulites showing broad folds with axial planes trending NS, with fold axis plunging towards north within the MBSZ. Kulichipalyam (South of Andiyur).
Quartz veins are noticed very frequently all along these basic granulites, which are evident for the extensional type of tectonic. They are emplaced along N-S direction. It varies in thickness from few millimetres up to 15 cms, length varies from 2 to 5 mts. Quartz veins with inclusions of garnet also traverse these basic granulites filling the brittle fractures, which also show the ductile deformation. Along these planes sinistral sense of brittle deformation is noticed, which measures 0.5 to 1.5 cms in diameter.

Syntectonic spiral (snow ball) garnet showing apparent dextral rotations as deduced from the inclusion patterns of opaque minerals in basic granulite are noticed. The plagioclase feldspar and pyroxenes are stretched and elongated along the mafic bands, where porphyroblastic garnets are noticed, which indicates that they are recrystallised under high differential stress. This implies the plastic deformation, bent around relatively hard metamorphic mineral garnet surrounds the highly stressed plagioclase and pyroxene grains (Fig.2.13).

Four types of shears are noticed in these basic granulites they are:

i) The early E-W trending ductile shears showing dextral sense of movements.
ii) The second generation of ductile shears trending N40°W, showing dextral sense of movement, displacing the early E-W shears.
iii) N-S trending brittle shears (with dextral sense of movement) filled with quartz veins with relict garnet.
iv) N50°E trending brittle shears (with sinistral sense of movement) displacing the banded metagabbros.

Textural studies in meta-gabbros exhibit granulitic to granoblastic micro-texture. Two types of garnets have been recorded in the basic granulites viz.,

1. Porphyroblast garnet (Grt I)
2. Coronitic garnet (Grt II)

1. Porphyroblast garnet: Porphyroblastic garnet are larger, euhedral to irregular in shape and size varies from 1.4 μm up to 6 μm. They commonly contain mineral inclusions of mainly clinopyroxene, plagioclase and quartz. The inclusion of clinopyroxene (Cpx I) grain in garnet varies from 1 to 2 μm in diameter. Diopside in the matrix show equilibrium texture with good grain boundary contact with Grt I. In deformed zones garnet show cataclastic texture. The micro-fractures even cross cut the clinopyroxene inclusions in Grt I. Some of these fractures are often filled with retrograde minerals like greenish yellow coloured
chlorite with or without quartz. Often a set of parallel fractures developed in diopside grains which are filled with chlorite, gives an appearance of multiple twinning. Many of the micro-fractures traversing diopside, plagioclase and garnet grains are coated with reddish brown coloured iron oxide indicating fluid activity (Fig.2.14). The porphyroblastic garnet contains inclusions of diopside and in between these grain boundaries, one can observe a thin rim of recrystallised quartz, which defines the low energy grain boundaries. The alteration reaction of garnets is as follow:

\[
\text{Grt + H}_2\text{O} \rightarrow \text{Chl} + \text{Qtz} \quad \text{--------- 1}
\]

In few sections studied around Bhavani, the porphyroblastic garnet (Grt I) show symplectic rims of plagioclase III and clinopyroxene III indicating the garnet breakdown reaction (Fig.2.16). The lamellar symplectite varies in size from 0.2 to 0.9 mm and the globular symplectites are upto 0.7 mm in length 0.1 mm in width. The symplectites grow from the outside to inwards and those large grains with irregular shape, completely surrounded by newly formed Pl III and Cpx III. Both the globular and lamellar symplectites have been identified in the basic granulites. These symplectites have been formed through grain boundary area reduction of the original grain (Grt I) during high grade metamorphism (Passchier and Trouw, 1998). Following reaction has been proposed based on the micro-texture.

\[
\text{Grt I + Qtz I} \rightarrow \text{Pl III + Cpx III (ITD)} \quad \text{--------- 2}
\]

2. Coronitic garnet: Coronitic garnet (Grt II) developed at the contact between matrix plagioclase (Pl I) and matrix clinopyroxene (Cpx II) grains. Rarely plagioclase show bent lamellae and zoning. Coronitic garnet is developed all along the deformed plagioclase grain in contact with diopside, suggesting that the formation of Grt II outlasted thrust tectonics in the area.

\[
\text{Cpx II + Pl I} \rightarrow \text{Grt II + Qtz (IBC)} \quad \text{--------- 3}
\]

In basic granulites of Andiyur area the corona of garnet separates plagioclase from clinopyroxene and hornblende in the matrix forms coronitic garnet around plagioclase
Fig. 2.13 Syntectonic (snow ball) garnet in mafic granulites, showing apparent dextral rotation as deduced from the inclusion patterns of opaque minerals in basic granulites within the MBSZ. The foliation trend is N80°E. Kulichipalyam (South of Andiyur).

Fig. 2.14 Porphyroblastic garnet (Grt I) with inclusions of clinopyroxene (Cpx I) in basic granulite. Note greenish blue coloured amphibole rimming Cpx I indicating retrograde alteration. Cpx II in the matrix show thin films of exsolved iron oxide related retrograde metamorphism.
and such monomineralic coronas are also known as MOATS (Passchier and Trouw, 1998) (Fig.2.15).

Following are the mineral assemblages recorded in basic granulites:

Cpx I,II + Pl I,II+ Grt I + Hbl + Qtz + Ilm +Mag
Cpx I,II + Grt I + Hbl + Pl I,II + Qtz + Chl + Ilm + Mag
Grt I + Cpx I,II + Hbl + Pl I,II + Opx + Qtz + Ilm + Mag
Grt I, Cpx I,II,III + Hbl + Pl I,II,III + Qtz + Chl + Ilm + Mag
Cpx I,II + Pl I,II + Grt II + Qtz + Hbl + Ilm + Mag

Clinopyroxene: Based on micro-textures the following three generation of clinopyroxenes is recorded in basic granulites:

1. Clinopyroxene (Cpx I) as an inclusion in porphyroblast garnet (Grt I).
2. Larger clinopyroxene (Cpx II) grains in the matrix occur as stable phase with garnet (Grt I).
3. Smaller, symplectitic diopside (Cpx III) with plagioclase around porphyroblastic garnet (Grt I).

The clinopyroxene (Cpx I) occurring as inclusion in garnet (Grt I) are pale green in colour. A thin rim of bluish green amphibole surrounds the diopside indicating retrograde alteration. The clinopyroxene are irregular to rounded in shape measuring 0.8mm to 1.4mm in diameter (Fig.2.17).

Larger clinopyroxene (Cpx II) grains occur in the matrix and exhibits sharp contact with garnet and plagioclase as a stable phase. Cpx II are pale green in colour, exhibits parallel cleavages. Rarely inclusion of smaller grains of quartz is seen. It is pleochroic from light green, purple to dark green colour. Reddish brown coloured haematite and circular to thin films of magnetite is noticed along cleavage planes.

Smaller, Cpx III symplectitically intergrown with plagioclase after garnet (Grt I) is seen in mafic granulites. Cpx III grains are pale green/dark green to bluish green in colour varying in size from 0.2mm to 0.8 mm. Symplectites are affected by grain boundary area reduction (GBAR), which are either lamellar type or globular types. The lamellar symplectite that are not affected by GBAR and in which lamellae’s are elongated with parallel boundaries are known as lamellar symplectites. Rarely symplectite occurs between garnet and
Fig. 2.15 Plagioclase (PlIII) and clinopyroxene (Cpx III) symplectites pseudomorphing porphyroblastic garnet (Grt I) in basic granulite within MBSZ with the reaction Grt I + Qtz $\rightarrow$ Cpx III + Pl III + Hbl II (Harley 1989; ITD).

Fig. 2.16 Formation of coronitic garnet (Grt II) at the contact of clinopyroxene and plagioclase in the basic granulite within MBSZ indicating isobaric cooling.
clinopyroxene giving rise to bluish green coloured Mg-rich hornblende and plagioclase (Fig.2.18).

**Orthopyroxene:** Orthopyroxene in basic granulites are irregular in shape with size varying from 0.4mm to 0.6mm and occur as a stable phase with matrix plagioclase and quartz. Orthopyroxene are pink in colour, pleochroism varies from green to purplish pink colour. Orthopyroxene, wherever in contact with plagioclase show alteration to anthophyllite. They are colourless; coronitic over orthopyroxene with size varies from 0.03 to 0.05mm. The rim of anthophyllite is surrounded by greenish coloured hornblende. This type of texture is called double corona texture (Fig.2.19). However, when orthopyroxene in contact with quartz show no such growth of new mineral.

The corona texture indicates the following retrograde reactions with addition of water.

\[
\begin{align*}
\text{Opx} + \text{H}_2\text{O} & \rightarrow \text{Anthophyllite} \\
\text{Opx} + \text{Pl} + \text{H}_2\text{O} & \rightarrow \text{Amphibole}
\end{align*}
\]

Some of the orthopyroxene also show alteration to yellow coloured biotite and quartz are noticed.

**Plagioclase:** Plagioclase (Pl I) occur as inclusion in garnet, they are euahedral to subhedral plagioclase laths show polysynthetic twinning in observed. The larger grains of plagioclase are deformed ductily. These plagioclase shows growth of coronitic garnet. Plane of contact of plagioclase and Grt II show bleached effect is noticed without the perfect twining, but the same grain show perfect twinning in the core. The core composition of plagioclase is anorthite rich and the rim is albite in nature (Fig.2.16). Such similar zoning has been documented in high pressure retrogression of granulites, Uganda Orogen, Canada (St-Onge and Ijewliw, 1996).

The matrix plagioclase (Pl II) occurs as a stable phase with Cpx II and Grt I. The microfracturing of the plagioclase are very common and are perpendicular to twin lamellae along which dislocation slips have been observed. The grains show clockwise rotation along these fractures. These dislocation slips or movements in petrographical studies are considered as minor slips at very high temperature conditions (Kruhl 1987). Plagioclase
Fig. 2.17 Porphyroblastic garnet (Grt I) with clinopyroxene inclusions (Cpx I) showing smooth grain boundary (low energy) contacts in basic granulite within MBSZ. Numerous brittle fractures cross cut the Grt I developed during ductile/brittle deformation in the shear zone. Most of these fractures are filled by light green coloured chlorite with minor amount of quartz.

Fig. 2.18 Porphyroblastic garnet (Grt I) breaking down to plagioclase (Pl II) + bluish green amphibole symplectites, exhibiting Isothermal decompression path.
feldspar also occurs as an inclusion in garnet (Grt I). The plagioclase shows alteration to epidote (Fig.2.20).

The plagioclase (Pl III), occurs as a vermicular type intergrown with Cpx III as a symplectic texture after porphyroblast garnet. Plagioclase does not show any twinning and size varies from 0.05 to 0.2mm.

**Amphibole**: Amphiboles, occurs as irregular shape, tabular to vermicular with size varying from 0.2mm to 1.0mm, yellowish green to pale/dark brownish green in colour. Perfect diamond shaped cleavages are seen in amphibole. The brownish green amphibole in the matrix is stable with garnet, clinopyroxene, orthopyroxene and plagioclase. The amphiboles also exhibits a thin film of reddish brown haematite grains along cracks/fractures/cleavage planes. Another type of hornblende occurs around the margins of clinopyroxene (Cpx II), without any distinct cleavage plane, pale yellowish green in colour. These hornblende occurs as symplectitic product with quartz after orthopyroxene.

**Biotite**: Rarely specs of yellowish brown coloured titanium rich serrated borders biotite are noticed. The biotitization after orthopyroxene is also noticed.

**Opaques**: The blackish coloured opaques are noticed alongwith the garnet, clinopyroxene, amphibole and orthopyroxene are identified as magnetite. Rarely reddish brown coloured irregular films of haematite are noticed along the grain boundaries of clinopyroxene. Sphenes rimming opaques is noticed rarely as a coronitic texture.

**2.3.1.2 Retrogressed charnockite (MBC-I Blobby Gneiss)**: Medium to coarse grained, pale grey coloured tonalitic to dioritic gneisses occurs within the MBSZ and also in DMSZ. In MBSZ, this retrogression taken place in the southern region of BRG and of basic granulites. These retrogressed charnockite are mainly observed around Andipalayam (around SE Andiyur) in the MBSZ.
In retrogressed charnockites, development of colourless anthophyllite at the contact of hypersthene and plagioclase and then to bluish green amphibole indicating retrograde alteration. Note that such reactions are absent, when hypersthene is in contact with quartz grains.

\[ \text{Opx} + \text{H}_2\text{O} \rightarrow \text{Anthophyllite} \]

\[ \text{Opx} + \text{Pl} \rightarrow \text{Amphibole} \]

Fig. 2.20 Plagioclase feldspar altering to epidote in retrogressed basic granulite in MBSZ.
The charno-enderbitic granulites of the MBC I show evidence of retrogression giving rise to gneiss with relic orthopyroxene. Such type of gneiss with relic orthopyroxene is termed as blebby gneiss. The blebby gneiss are recognised in the field by their nebulitic, homogenised appearance, pale grey colour with darker patches and these rocks generally do not show any marked foliation. They are homogenous with 'blebbly' mineral texture (McGregor et al., 1986), where irregular dark patches with relict orthopyroxene is set in a light coloured quartz-plagioclase matrix. But the feldspar and pyroxene also occurs as a porphyroclastic in the hand specimen.

It is difficult to demarcate the boundary between the blebby gneiss and other rock types like fissile biotite gneiss and meta-pelites in the shear zone. However, one can observe this blebby gneiss in well exposed quarries around Andipalyam (NE of Andiyur). It measures for few meters to several kms as per sketches (Fig.2.2). The trend of blebby gneiss varies from place to place, foliation trends N45°E to N70°E to E-W and dips at an angle 45°-80°NW. But also observed the sinistral sense of brittle shears trending N20°W dipping 50°SW to vertically (Fig.2.21). These brittle fractures are often filled by Quartz vein. Along this plane numerous pseudotachylite are observed trending N25°W dipping 70°-80°SW.

The intrusion of pegmatite and quartz vein are noticed in the field rarely and they trend almost in same direction as N10-20°W dipping 60°NW. In some of the places, orthopyroxenes show alteration to irregular net-work of reddish coloured iron-oxide (Fig.2.22). It has been shown that such patches may represent pseudomorphs after pyroxenes (Beach, 1974). In high strained zones, these rock exhibit foliation defined by biotite with relic orthopyroxene. Thin, greenish coloured epidote veins with leucocratic margin is the characteristic feature of these retrogressed charnockites, when compared to biotite gneiss. In some region it measures for few mm to a cm and it trends N70°E, along which bleaching effect is prominently noticed. These epidote veins are intruded along foliation plane (N70°E dipping 60°SW).
Fig. 2.21 Banded hornblende gneiss with foliation trending N50°E, dipping 70°SE. This is cut by brittle shears exhibiting sinistral sense of movement along N20°W. Redipalyam (NE of Andiyur) within MBSZ.

Fig. 2.22 Yellowish brown coloured, relict orthopyroxene grains, partially altered to anthophyllite in blebbly gneiss.
The microscopical characteristics of retrogressed charmockite are quite distinct. Equigranular to inequigranular, polygonal textures with straight to curved grain boundaries are noticed between quartz, plagioclase, biotites and altered pyroxenes.

Quartz are anhedral, shows undulose extinction. Larger grain of quartz shows recovery and recrystallization. Plagioclase are tabular, lath shaped polysynthetic twining, highly irregular micro fracture are prominently observed. Some of these micro fractures are filled by ferruginous material. Some of the grain shows bent lamellae and they are dirty brownish colour and exhibits kaolinisation. In the micro fracture the sericitization is noticed rarely.

Biotite are of two generation, the early greenish yellow long, elongated, tabular with some inclusions of quartz grain and alters to pale green to colourless chlorite. All along the margins of biotite, opaques are seen as a result of retrogression. Some of the biotites show alteration to chlorite. Many of the biotites are altered products of hypersthene with the following reaction:

\[ \text{Opx} + \text{Kfs} + \text{H}_2\text{O} \rightarrow \text{Bt} + \text{Qtz} \]  

Relic euhedral orthopyroxene are observed in retrogressed rocks which is light pink to colourless, pleochroic from pink to light green. Many of the orthopyroxenes show partial to complete alteration to green coloured amphibole or biotites with exsolved phases of Fe-Ti oxides. In highly altered zones orthopyroxene is completely pseudomorphed by anthophyllite.

The following mineral reactions have been documented based on micro-textural studies during retrograde metamorphism of charno-enderbitic granulite in the shear zones.

\[ \text{Opx} + \text{Pl} + \text{H}_2\text{O} \rightarrow \text{Bt II} + \text{Qtz} \]  
\[ \text{Opx} + \text{H}_2\text{O} \rightarrow \text{Ath} \]  
\[ \text{Opx} + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Ath} + \text{Mag} \]  
\[ \text{Opx} \rightarrow \text{Ath} \rightarrow \text{Bt} \]  
\[ \text{Opx} + \text{Qtz} + \text{H}_2\text{O} \rightarrow \text{Ath} \text{ (Winkler 1979)} \]
2.3.1.3. Fissile-Biotite Gneiss (Bhavani Gneiss): The term Bhavani gneiss is used for the highly deformed fissile hornblende/biotite gneiss in the MBSZ (Gopalakrishnan 1994, map published by GSI 1995). The fissile biotite gneiss are most dominant rock type in the study area, which have been exposed as a distinct litho unit in and around Bhavani, Erode and Sankari. They exhibit gneissic banding defined by alternating melanocratic biotite rich bands with leucocratic quartz and plagioclase rich bands. The rock is felsic with distinct penetrative foliation. It is medium to coarse grained leucocratic gneiss with foliation defined by biotite. The foliation varies in some regions and it shows smooth, continuous and straight to curved foliation. The rocks exhibit a regional foliation trending E-W. Preserve of relict isoclinal rootless folds and eyed (sheath folds) fold patterns indicates that the gneisses have suffered different stages of deformation. The gneissic rocks show complex fold pattern as indicated by changing foliation from E-W, N20°E to N10°W. Presence of ‘S’ shaped trials indicates dextral sense of ductile deformation. The late N40-60°W trending ductile shears with dextral sense of movement are filled by pegmatites. High grade ductile deformation is noticed in this terrane, which are deformed both melanocratic and leucocratic layer in a zigzag manner. This broad fold of ductile deformed layers trends N20°E, plunges 70°NE. Rootless fold of a leucocratic layer in a fissile biotite gneiss noticed around Erode, implies the strongly deformed nature under retrograde metamorphic conditions. Relict ‘EYE’ shaped folds are alternating with leuco and melanocratic layers, which are symmetric in nature at an axial plane (Fig.2.23). The lineation in fissile biotite gneiss are defined northerly plunging, sub vertical (45°) hornblende grains.

The mineral assemblages present in Bhavani gneiss are Qtz + Pl + Kfs + perthites + biotite + opaque, but the biotite gneiss show gradation to biotite + sillimanite/kyanite bearing gneiss, suggesting that the fissile Bhavani gneiss represent metamorphosed arenaceous to arkosic sediment associated with psammo-pelitic sediments of the Sathyamangalam Group. Numerous quartz veins in the gneiss show ptygmatic folding. Foliation varies in Temple hill of Bhavani from N25°W to N75°W and at places E-W trending. In the Moyar-Bhavani shear zone (MBSZ), the plagioclase feldspar clot enclosed in elongated, quartz and feldspar grains stretching lineation to the foliation plane. Lenses of
recrystallised quartz and feldspars define the mylonite foliation. The foliation wraps around feldspar porphyroclasts. Micro-shears are also noticed paralleling the foliation plane.

The mineral textures in the Bhavani gneisses are metamorphic with equidimensional grains and common triple point junctions. It is an equigranular polygonal texture with straight to gently curved grain boundaries. Most of the plagioclase grain shows perthitic textures. The mineral assemblages of Bhavani Gneiss are

Qtz + Pl + Kfs + Bt + Opq
Qtz + Pl + Kfs + Bt + Sil + Opq.

The Bhavani Gneiss exhibits well developed granoblastic texture quartz, which constitutes about more than 60% of the rock occurs as anhedral grains, shows undulose extinction. Characteristic feature of quartz grains in these Bhavani Gneiss are large, single crystal of equigranular-interlobate almost equidimensional, porphyroblastic strongly flattened-platy habit. The triple point junctions, three slightly curved boundaries meet with dihedral angles of approximately 120° (David Shelly, 1993). Quartz-plagioclase grains do not show any stretching indicates high grade metamorphism outlasted deformation. The triple junctions between the grains indicating re-equilibrium under high P-T conditions of metamorphism. This implies that strain, stress and temperature have a vital influence in the movement of existing grain boundaries or the development of new grain boundaries. In this process strain involving plastic deformation stores dislocation energy which drives recrystallization.

Plagioclase are lath shaped, polysynthetic twinning and often shows zoning. Plagioclase exhibits the myrmikitic texture and antiperthitic texture. The antiperthitic exsolutions, potash feldspar are strings, peg like and also rod shaped in plagioclase grains suggesting subsolidus phenomena during high grade metamorphism. Plagioclase shows alteration to sericite.

Potash feldspar are euhedral to subhedral, medium relief, cross hatch twinning is prominently observed. K-Feldspars alter to sericite along the grain boundaries. Potash
feldspar exhibits micro-kink bands. Biotites are long, elongated, yellowish brown in colour. Some grains measures width more than the length.

2.3.1.4. Meta–Pelites: The meta-pelites well exposed around Sankari (Fig.2.2). Meta-pelites are composed of garnet-kyanite/sillimanite-plagioclase-biotite and is associated with marbles and calc-silicates rocks. These meta-sedimentary units are classified as Sathyamangalam Group of supracrustal rock (Gopalakrishnan, 1994). The pelites show regional foliation trending E-W, dipping 80°S. In meta-pelites, leucocratic plagioclase + quartz rich layers alternate with, needle shaped, bluish green coloured kyanite. Often kyanite measure as big as 1.5 cms in length. Kyanite is associated with 0.2 to 2 cms sized, whitish needles of sillimanite.

Cement grade marbles interbanded with calc-silicate rocks are being mined around Sankari. These meta-pelites are medium to coarse grained, biotite rich layers defines the foliation plane.

In highly deformed zones, both leucocratic and melanocratic layers show stretching parallel to regional fabric with flattened quartz + plagioclase grains indicating mylonitic fabric. Ataxial vein of quartz in meta-pelites show ‘C’ type shear bands where porphyroclast quartz indicates dextral sense of movement along the foliation plane (Fig.2.24). The grain size in the mylonite is smaller than the wall rock except that isolated lenses/pods of quartz grain are noticed.

In thin section, the meta-pelites show inequigranular, polygonal to porphyroblastic textures. Quartz are tabular to platy in habit with undulose extinction. Tiny quartz grains occur as inclusions in porphyroblastic garnet. Plagioclase of oligoclase in composition (An28) shows polysynthetic twinning.

Porphyroblastic garnet occurs with numerous mineral inclusions and exhibit compositional zoning. The core is pinkish in colour with pinkish brown colour along the rims. Based on trails of quartz grains in garnet, a syn-tectonic origin of porphyroblast garnet is indicated.
Fig. 2.23 ‘EYE’ shaped fold patterns in Bhavani gneiss (6 kms to N Erode).

Fig. 2.24 Ataxial vein of quartz in kyanite/sillimanite bearing meta-pelites with ‘C’ type shear bands in porphyroblast quartz indicating dextral shear sense in meta-pelites. 5 kms south of Sankari village (near TV tower).
Inclusion patterns are curved and continuous with the fabric, ‘S’ shaped sense of movement is noticed of dextrally ductile deformation. These movements are also influenced by the adjacent matrix biotite grains.

Kyanite exhibits bladed to tabular habit and comparatively larger in size. They are colourless to light blue in colour, show 32° inclined extinction. Biotites are medium to coarse grained, which occurs as inclusion in garnet. They also occur in the matrix as larger grains. They often show bending along foliation plane. Sillimanite are fibrous to needle shaped, colourless to dirty brown in colour, shows parallel extinction. Sillimanite is seen generally growing after kyanite (Fig.2.25) and is post kinematic in origin.

Following are the mineral assemblages in meta-pelites:
Qtz I, II and III + Pi + Kfs + Ky + Sil + Grt + Bt + Mag

2.3.2. Dharmapuri-Mettur Shear Zone (DMSZ): The charno-enderbitic granulites exposed around Mettur is dissected by NNE-SSW trending ductile to ductile-brittle shear zones termed as the DMSZ. This shear zone represents a major deep seated fracture, which is seismically active (Grady, 1971). The width of the DMSZ is about 10-50 kms extending for a length of about 200-250 kms (Fig.2.2). This shear zone is cut by late E-W trending Moyar-Bhavani shear zone (MBSZ) towards north of Bhavani. The DMSZ is also referred to as Dharmapuri suture rift zone by Gopalakrishnan (1994).

The present investigation from Vellar to Kumarapalyam (N of Bhavani) has shown that the charno-enderbitic granulites of Mettur area has been dissected by ductile to brittle shears where the granulites show evidence of retrograde metamorphism. The ductile shears with dextral sense of movement (Fig. 2.26) trending N10-40°E and with gentle to steep dips (40 to 80°SE), cross cut the charno-enderbitic granulites. Perpendicular to shear planes, lineation defined by hypersthene plunging 60-70°southwards is noticed. As a result of retrogression, orthopyroxene show alteration to biotite and amphiboles, plagioclase alters to epidote and sericite. In the field retrogression is seen as a bleached zone, where the greasy colour of the charno-enderbitic granulite changes to whitish coloured gneiss rocks. The end product of
Fig. 2.25. Sillimanite is growing after kyanite, post kinematic in origin.

Fig. 2.26. Charno-enderbitic granulites of the MBC I cut by N65°E trending ductile shears in the MBSZ, exposure along the road cutting, 4 km east of Mettur. The sense of movement is dextral.
retrograde metamorphism is a biotite bearing gneiss occasionally showing presence of relic orthopyroxene occurring as dark looking patches, which generally termed as blebby gneiss. Some of the feldspar grains are stretched along the foliation plane and shear plane, such process is commonly seen around Mettur, Vellar and Kumarapalyam.

Numerous, thin epidote veins are observed cross cutting the foliation plane in the gneisses. Some of these epidote veins trends N70°E dipping 35°NW. Pseudotachylite veins and films like layers are continuous and in some region it is discontinuous trending at N30°W. Numerous inclusions of feldspars and quartz grains of country rock are enclosed within the pseudotachylite. Such types of pseudotachylites are noticed around Vellar and Mettur region (NE of Bhavani).

In thin section retrogressed charnockites show inequigranular, interlobate polygonal/ granoblastic micro-textures with gently curved grain boundaries between the mineral assemblages such as quartz, plagioclase, orthopyroxene, amphiboles, opaques and biotites.

Quartz are anhedral, inequigranular, interlobate, large-platy some what strain free and numerous micro fracture zone are noticed frequently in almost all the regions. The micro fractures are filled by some of the tiny retrogressed minerals which are not recognisable. Some of the micro fractures of 1mm thick are filled by smaller quartz veins.

Tabular plagioclase shows alteration and exhibit polysynthetic twining. Small specks of sericite grains are observed in almost all the grain of plagioclase, which fill almost all micro fracture/cracks. But these fractures are also filled by irregular network of dark films/layers of opaque minerals, indicating circulations of fluids along the fractures zones.

The hypersthenes are tabular, pink in colour and almost all the grains are fractured and shows alteration to light bluish green coloured amphibole at the borders of the grain. Along with the cleavage plane some micro fractures/cracks are noticed in orthopyroxene, which are filled by opaques during the process of retrogression. These opaques are magnetite and are bordered by a brownish coloured haematite.
Biotites show kink bands. In some section the orthopyroxene show alteration to honey yellow coloured biotite.

23.2.1. Epidote-Hornblende-Biotite Gneiss: The epidote hornblende biotite gneiss are medium to coarse grained, pale green coloured rocks exposed around Vellar (Fig.2.27) which extends further north upto the Dharmapuri and Harur in Tamil Nadu (Fig.2.1). This rock is granodiorite to quartz dioritic composition. Presence of bluish quartz in gneisses, a typical mineral in the charnockite granulites, indicates that these rocks represent original charno-endebritic granulites. As a result of retrogression, few irregular patches of charnockitic granulites are noticed in these gneisses. Few metagabbros occur as enclaves. The general foliation of these gneisses are N40°E to S40°W, dipping 60°NW or 80°SE. The foliation is defined by hornblende, trending N20°E, with lineation plunging at 5° southwards. A late E-W trending, brittle shear cross cut these gneisses.

Numerous yellowish green coloured, millimetres to a centimetres wide, epidote bearing veins transect the gneiss, filling the brittle fractures trending N70°E dip at an angle of 35°NW. Some of the epidote veins also fill a set of conjugate fractures.

Numerous thin quartz veins with reddish brown flakes of ankerite are also seen along the brittle fracture. Some of the quartz veins contain sulphide minerals like chalcopyrite and pyrite. These veins show wall rock alteration showing silicification and epidotisation with the development of sericite, chlorite and carbonate. Irregular network of pseudotachylites with a general trend of N-S with steep dips are seen near the Vellar.

In thin sections, quartz grains are anhedral, inequigranular, interlobate, large-platy in habit. Plagioclase grains are highly altered and show saussuritization and sericitization. They appear cloudy and exhibits buff white colour. Numerous micro fractures /cracks/shears are noticed in quartz and plagioclase grains in the gneiss. Some of the microshears cross cut the different minerals which are continuous, straight to curve but some are perpendicular to each other. Step like, sinistral sense of brittle fractures is recorded in few sections. All along these
micro fractures, quartz grains show recovery and recrystallization features under low
temperature conditions.

Relic pyroxene is observed in few sections with alteration haloes consisting of bluish green
hornblende and yellowish biotite. Euhedral, colourless epidote grains occur as clusters
within plagioclase grains. Light green to colourless chlorites occur within plagioclase and
hornblende.

Following are the mineral assemblages in epidote-hornblende-biotite gneiss:

Qtz II + Pl + Hbl + Bt + Mag ± Ep
Qtz II, III +Pl + Kfs + Hbl + Bt +Mag + Ep ± Opx + Chl

2.3.3. Chennimalai Shear Zone (CSZ): Chennimalai shear zone (CSZ), is a narrow,
generally E-W trending shear zone of 2-6 kms wide extending around 80 kms. All along
these shear zones, the charno-enderbitic granulites of the MBC-II show evidence of
retrograde metamorphism. Both ductile and ductile/brittle shears are recorded in the CSZ,
which are either parallel to sub parallel to the foliation. The E-W trending Noyil River
occupies this shear zones. The main rock types within this CSZ is hornblende-biotite
gneiss which encloses irregular patches of charno-enderbitic granulites, calc granulites,
banded magnetite quartzite, pyroxenites, syenites and granites. These rock types are
intruded by quartz veins.

The effect of bleaching, retrograde alteration and development of retrograde minerals like
amphiboles, biotite, epidote and chlorite from the original granulite facies mineral
assemblages is much similar to the one recorded within the Moyar-Bhavani Shear zone.
However, the process of retrogression of charno-enderbitic granulites is less intensive in
CSZ, when compare to similar process observed in the MBSZ. In CSZ, it is ferro-
hypersthene, which shows alteration to low grade mineral assemblages. Tabular plagioclase
shows bent lamellae along with the recrystallised quartz in the shear plane (Fig.2.28).
Myrmikitic texture and antiperthites are also common in the retrogressed rocks.
Fig. 2.27 Retrogressed CEG (MBC I) with relict hypersthene grains along Dharmapuri-Mettur Shear Zone (DMSZ), Vellar.

Fig. 2.28 Deformed plagioclase grains with bent lamellae in charnockite granulites (MBC-II). Note the recovery and recrystallization of quartz I grains in the matrix, where ever micro-shears traverse the rock.
2.3.3.1. Hornblende-Biotite Gneiss: The hornblende-biotite gneiss are most dominant rock type in the southern granulite terrain, occupying a large aerial extent. The rock is dirty white to pale green in colour, fine to medium grained with a very distinct penetrative foliation. The main foliation trend is E-W except some minor local variation. The foliation planes are smooth, continuous with straight to curved foliation plane. The leucosomes are normally observed which are coarse grained consisting of quartz and feldspar but the melanosomes are finer in grain size consisting of hornblende, biotite and opaques. The hornblende-biotite gneiss show sharp contact with other major rock types. Several sets of shears transect the gneiss trending E-W, which dips at 50° towards south.

In thin section the gneiss exhibit granoblastic texture with inequigranular, interlobate grain boundaries. Grains are sutured and strained with secondary mineralization along sutures. Equilibrium textures are predominant with few disequilibrium textures like myrmikitic and perthitic textures. Early quartz are large, stretched, sutured and exhibits wavy extinction. The late quartz are small, strain free and mainly observed in fracture/shear planes and grain boundaries. Plagioclase shows effect of strain, such as twin lamellae. Potash feldspar are inequigranular, sutured, stretching and exhibits patchy/undulose extinction. Potash feldspars alters to sericite along micro-fractures. Perthites are mainly rod to vermicular type. Hornblende are euhedral to subhedral prismatic grains. They show retrogression process to biotite and chlorite. Following are the mineral assemblages in hornblende-biotite gneiss:

\[
\text{Qtz II} + \text{Pl} + \text{Or} + \text{Hbl} + \text{Bt} + \text{Mag} \\
\text{Qtz I, II and III} + \text{Pl} + \text{Or} + \text{Mc} + \text{Hbl} + \text{Bt} + \text{Chl} + \text{Mag}
\]

Opaques grains are irregular in shape and occur as exsolved phase from hornblende accumulating all along the grain boundaries. Some of the biotites show alteration to pale green coloured chlorite.

2.4. INTRUSIVES

2.4.1 Syenites: Within the Dharmapuri-Mettur shear zone (DMSZ) numerous alkali syenites and carbonatite plutons of oval to round shaped ring complexes have been reported as for examples around Jalakandpuram, Nangavalli and Taramangalam (Fig.2.2).
Numerous medium to coarse grained leucocratic syenites shows sharp contact with epidote-hornblende-biotite gneiss near Vellar (Fig.2.29) and the igneous body show a general trend of N20°W cross cutting the foliation (N10-20°E) of epidote-hornblende-biotite gneiss. The alkaline complexes show well preserved igneous mineralogical layering defined by hornblende and clinopyroxene. These syenites are undeformed igneous rocks, represent post-kinematic intrusives into the Dharmapuri-Mettur shear zone, intruded during an extensional tectonic regime. Development of epidote-hornblende-biotite gneiss along northern part of the Dharmapuri-Mettur shear zone, where syenites are more common which indicates an extensive fluid activity synchronous with the emplacement of syenites in the shear zone. Younger quartz reef cut across all the above mentioned rock types along NNE-SSW direction.

The NNE-SSW trending pikili-ijolite nepheline syenite complex occurring along the western margin of Dharmapuri suture rift zone appears to be an earlier intrusion (Gopalakrishnan, 1994). The syenites lying to the north of Sankari some of the southern most alkali pluton although minor bands of syenites and lamprophyre are observed in Sankari dome. The felsic igneous activity and their characteristics by the emplacement of post-orogenic, A-type magmas generated in rift related environments of high heat flow and abundant volatile activity correlative with an extensional tectonic regime (Nedelec et al., 1995, Rajesh et al., 1996) and probably including melts generated from both upper mantle and lower crustal sources are inferred. The alkali syenites carbonatite plutonism is the youngest phase of igneous activity of the tensional regime, as the rocks preserve undeformed igneous textures. The thin section study of syenites show inequigranular, hypidiomorphic textures with anhedral to subhedral potash feldspar as the dominant mineral constituent and often found as megacryst. The cross hatched twinning, without any perthitic texture and recrystallised small grain of microcline feldspar is also noticed along the grain boundaries. Leucocratic layers of feldspar are alternating with segregated mafic minerals like hornblende are a typical features in thin sections. Orthoclase are subhedral, no inclusions are observed, but the zoning effect is noticed. Plagioclase occurs in lesser amounts. Hornblende are altering to brownish red coloured biotite with releasing reddish coloured haematite and the rest of the opaques are mainly magnetite.
2.4.2. Sankari-Tiruchengodu Granite: The numerous intrusives of granitic rocks around Sankari, Tiruchengodu and Idapaḍdi representing an extensive granitic activity in the Moyar-Bhavani shear zone. The intrusive rocks of Sankari-Tiruchengodu granite are seen as a huge hillock or an Inselberg within the eroded plains of the MBSZ, which implies the erosional activity. In Sankari-Tiruchengodu, the granitic intrusions are sheet like, which varies in thickness from few meters upto 10 to 20 meters. Network of granitic intrusion is seen enclosed in the meta-pelites and fissile biotite gneiss with latest igneous activity of quartz, feldspathic vein in the granitic layers (Fig.2.30).

The granitic intrusion is exposed at different elevated region varying from 330 metres above MSL upto highest peak in Sankari at 715 metres above MSL, whereas granites around Tiruchengodu occur at a height of 358 metres upto 501 metres above MSL.

The southern part of the dome is emplaced by more of pegmatite and quartz veins, which trends EW dipping 80°S. The structural style observed in the gneisses (host) and in the supracrustal rocks is very well reflected in the foliation seen within the granite, suggesting that the pink foliated granites are representing synkinematic emplacements. The Sankari and Tiruchengodu granites are pink in colour with medium to coarse grained.

Petrographic studies of different varieties of granite identified in the study area indicate no significant variation in their mineralogy. Textures of Sankari and Tiruchengodu granites are inequigranular, granoblastic and interlobe grains with embayed grain boundaries.

Quartz are anhedral, platy-fractured and shows undulose extinction, strain free bigger in size. But rarely in some particular grains of bigger quartz (Qtz II) grains are surrounded by neoblasts of smaller grains of quartz (Qtz III), which are fresh (comparatively) bluish coloured recrystallised quartz are also noticed.

Microcline feldspar are of two generation one is larger, tabular to irregular in shape, cross hatched twinning. Inclusions mainly quartz, biotite and plagioclase are noticed. Most of them prominently show perthitic texture, the plagioclase grains are vermicular type, strings
Fig.2.29 Layered syenite cutting the epidote – hornblende gneiss, Vellar

Fig.2.30 Network of fine to medium grained pink Sankari granites intruding into meta-Pelites, Sankari.
to rod shaped grains. But overall the microcline feldspars have undergone kaolinisation and sericitization. Myrmikitic texture commonly observed. Fractures are filled by opaques. The second generation of microcline feldspars are subhedral, comparatively small, no alteration/inclusions are noticed, fresh and cross hatched twinning is prominently observed.

Plagioclase feldspars are large, tabular, polysynthetic twinning is prominently observed. Mineral inclusions like biotite, quartz and orthoclase are noticed. The alterations of plagioclase grain to sericite and rarely to epidote specks are noticed.

Biotites are long, elongated with yellowish brown in colour. Cleavages are very distinct and small quartz inclusions are prominently noticed in few grains. The biotite commonly alters to chlorite. Biotites shows kink band/bent lamellae features. The pleochroic haloes are commonly seen in the bigger grains of biotite. Occasionally accessory minerals like apatite and zircon are noticed rarely.

2.4.3. Udiyur granites: Udiyur granites exposed near Chennimalai are biotite bearing granites with K-feldspars-rich in mineralogy. These granites in their mineralogy and textural features are much similar to Sankari and Tiruchengodu granites.

2.4.4. Pegmatite and Quartz veins: Quartz vein are exposed all along the shear planes along NNE-SSW to NE-SW brittle fractures around Vellar(Fig.2.2). Pegmatite veins intrusion, which are exposed around Taramangalam (SE of Mettur) and Sankari and Tiruchengodu calc-silicates and granites trending N80°W and is cross cut by another pegmatite vein trending N10°E. In outcrop, the quartz veins are made up of dirty white to grey cherty to translucent quartz. On weathered surface it is normally yellowish brown strained with limonite coating which is infact pathfinder for molybdenite mineralization. The quartz vein and sheared gneiss confined to the shear plane host the sulphide mineralization thereby indicating the molybdenite mineralization is observed. Molybdenite occurs associated with a quartz vein as well as carbonate and quartz stringers traversing the altered/sheared gneiss. Molybdenite is bluish/silky grey flaky to granular exhibiting the metallic lustre and soils the fingers on rubbing. Molybdenite occurs either as disseminations
of fracture fillings. It is normally seen occurring in association with galena, pyrite and magnetite and rarely with chalcopyrite and ilmenorutile. Wall rock alteration occurred due to hydrothermal activity is characteristically observed in the mineralized shear zone as evidenced by sericitization, chloritization, epidotization, silicification and presence of stringers and venations of carbonates and potash feldspars.

2.5. SUMMARY

Massive to banded charno-enderbitic granulites (MBC) are the predominant rock types exposed in the area with basic granulites and various types of metasedimentary units. Two types of charno-enderbitic granulites have been identified in the area based on field relationship, petrography and preliminary geochemical analyses viz., MBC-I and MBC-II.

The general N-S trending structures of the MBC-I are truncated by late N40°E trending to E-W trending ductile to ductile/brittle structures of the MBSZ. The MBSZ represent a suture zones separating the Archaean Dharwar craton and the early Proterozoic Chennimalai granulite in the south.

The following shear zones have been recognised in area:

1. Dharmapuri – Mettur Shear Zone (DMSZ)
2. Moyar-Bhavani Shear Zone (MBSZ)
3. Chennimalai Shear Zone (CSZ)

Presence of heterogeneous rock types with varying deformational styles characterise the rocks within the shear zone. The fissile biotite gneiss (Bhavani gneisses) in the MBSZ is interpreted to represent a suite of meta-sedimentary rocks belonging to Sathyamangalam Group. Careful field and petrographic study has helped to distinguish the fissile biotite gneisses from the blebby gneisses (retrogressed charno-enderbitic granulites of the BRG). Blebby gneisses have also been recorded in the Chennimalai shear zones.

The highest palaeo-pressure data (13.98 kb) is obtained from the rocks exposed within the MBSZ (see, Chapter III). This indicates the exposure of the deeper most part of the continental crust in southern India. Structural studies have revealed that the southern block exposed around Bhavani has been upthrusted onto the N-S trending Biligiri Rangan
granulites. This interpretation is further supported by the Deep Seismic Studies (DSS), where the reflection and refraction data indicates an average 45 km crustal thickness in this region. Further, the DSS data indicates that the crustal column south of MBSZ is generally denser, when compared to northern block (Kuppam to Bommidi - Dharwar craton) (Reddy et al., 2000.a,b). This is supported by the presence of innumerable basic granulites within the MBSZ. Magnetotelluric studies have also indicated that the structure of the study area seems to be having their roots to deep crustal level (Sarma et al., 2000).

Occurrence of epidote hornblende biotite gneiss is characteristic of DMSZ, which traverse the eastern part of the MBC I. This represents another major deep seated fracture zone, which are Earthquake prone area.

The felsic igneous activity in the area is characterised by the emplacement of post-orogenic, A-type magmas, generated in a rift related environments indicating high heat flow and abundant volatile activity during an extensional tectonic regime.

The U-Pb zircon data, Rb-Sr and Sm-Nd whole rock data (Buhl, 1987; Raith et al., 1990) for the Biligiri Rangan granulites indicates the crustal growth in the range from 3.6 to 3.3 Ga and regional granulite facies metamorphism around 2.5 Ga. The Sm-Nd whole rock isochron (Bhaskar Rao et al., 1996) and zircon U-Pb age (Ghosh, 1997; Ghosh et al., 1998) indicates that the supracrustal gneiss association around Bhavani and Chennimalai region are classified as MBC-II, is at least 3.0 Ga old with regional metamorphism around 2.5 to 0.55 Ga. (Bhaskar Rao et al., 1996; Ghosh et al., 1998; Meissner et al., 2002). The detail isochron data of the study area is lacking. However, isotopic data is available for the western part of the study area (Meissner et al., 2002). Based on the Sm-Nd and Rb-Sr isotopic whole rock, mineral and small slab data for remnant granulites, mylonitic gneisses and granitoids have revealed a Neoproterozoic tectono-thermal imprint in the Moyar-Bhavani shear zone. Structurally controlled retrogression and successive cooling in the Moyar-Bhavani shear zone is recorded (garnet 624-591Ma; muscovite 594Ma; biotite 604-540 Ma) (Meissner et al., 2002).
The mineral isochron ages in the MBSZ and CSZ indicate Neoproterozoic to Pan African mineral growth, synchronous with ductile shearing. There is no Pan African overprint recorded in the massive to banded charnockitic granulites of the Biligiri Rangan granulite. This suggests that the Biligiri Rangan granulites belong to the Archaean Dharwar Craton, which has not been subjected to any deformation during Pan-African times.

The Sankari-Tiruchengodu granites represent a major structural dome with granite occupying its core. Several enclaves of crystalline limestone, calc-silicates and meta-pelites occur within these granulites. These contain considerable amount of Sn, W, Nb, Y, Yb and Zr (Nathan and Kanishkan, 1993).

The geochemical characters of these Neoproterozoic granites are broadly comparable with the A-type granites (Whalen et al., 1987) indicating their anorogenic nature. The Rb-Sr isotopic dating of the leucogranites of the Sankari-Tiruchengodu pluton has yielded whole rock isochron ages of 534±15 Ma (Pandey et al., 1993). The pink granites of the same pluton have yielded an Rb-Sr isochron age of 390±40 Ma (Nathan et al., 1994). The uniformly higher initial Sr isotopic ratio shown by these granites indicates that they were formed mainly by crustal anatexis. But these Neoproterozoic granitoids fall in the “within plate granite” (WPG) yield indicating that they were emplaced within the stabilized continental crust (Nathan et al., 2001).

Pseudotachylites commonly occurs towards western margins of the MBC-I. Formation of pseudotachylite is related to upliftment of the MBC-I along ductile/brittle shear zones as a result of frictional heating. Dating of some of the pseudotachylite by Ar-Ar methods would yield some constrains on the timing of their formation.