CHAPTER II

GEOLOGICAL SETTING AND PETROGRAPHY

2.1 INTRODUCTION

In this chapter, field relationship between different types of rocks exposed in Sargur Schist Belt as well as in the Biligirirangan and Mala Mahadeswara Granulite terrane in Dharwar craton has been presented. Petrographic studies of various rock types have been carried out for samples collected from Sargur, Bettadabedu, Doddakanya, Thumbasoge, Chilckkahalli, Hadnur and Nugu dam, B.R.Hills, M.M.Hills areas. Representative samples of Meta-pelites, basic granulites, charnockites, gneisses, quartzites, calc-silicates and iron formations have been collected and studied. The petrological characteristics of different rock types of the area have been studied to document the mineral assemblages and to record micro-textures and metamorphic reactions involved in the formation of these rock types.

The rocks belonging to Sargur Schist Belt are well exposed near Bettadabedu, Chickadevibetta, Nugu dam, Doddakanya, Hullahalli towards southwest part of Mysore. The granulites are well exposed in the highland massifs of Male Mahadeswara hills (MMG) and Biligirirangan Hills (BRG) ranges. The field relationship of various rock types in Sargur Schist Belt and granulites including rock disposition, structures and micro-textures have been described and illustrated using field and petrographic description.

Peninsular Gneiss forms the basement for the SSB which forms part of the Western Dharwar Craton (WDC). The SSB contains volcano- sedimentary units and occurs as numerous minor belts and isolated enclaves within Peninsular Gneiss. The metasediments include ortho quartzites, marble calc-silicate rocks, metapelites and banded iron formations. Chromite-bearing Ultramafic to mafic layered complexes have been emplaced into the Sargur series of supracrustal rocks (Fig.2.1)

The granulites are represented by widespread massive to banded charnockites with numerous bands of meta-sediments like quartzites, meta-pelites, calc-silicates,
Iron formations and metabasic rocks occur as bands or layers within the granulites (Fig 2.1).

These granulites well exposed in the highland areas of Biligirirangan Hills and Male Mahadeswara Hills forming part of the Eastern Dharwar Craton (EDC).

These two major litho units are separated by N-S trending Kollegal Shear Zone (Fig.2.1).

2.2 SARGUR SCHIST BELT

Fuchsite quartzite, metapelites, marbles and calc-silicates rocks, denoting the basal platformal suit of sediments are well exposed as narrow bands in areas like Jayapura, Sargur and Nugu dam in the Sargur Schist Belt (Fig 2.1). Carbonate rocks are mostly marbles and calc-silicate rocks contain amphiboles, diopside, garnet and some graphite. Metapelites and some quartzites are rich in garnet (almandine-pyrope), kyanite, sillimanite, staurolite, graphite and corundum. Rarely cordierite-sillimanite-hypersthene rocks form very narrow bands. Metapelites locally contains semi precious stones like garnet, staurolite, corundum, kyanite etc. Compositionally the metapelites have high-Al and at places high-Fe as well as, various some verities are Mg rich. The Cr, Co contents are higher than average, pointing to a provenance rich in sodic gneisses containing different ultramafic-mafic components.

2.2.1 Calc-silicates

The calc-silicate and impure marble exposure near Bettadabedu area is noticed. The metasediments occur as huge curvilinear enclaves within Peninsular Gneisses. The bands have been intensely deformed and primary structures are generally not preserved. The calc-silicates rocks typically contain calcite-diopside-hornblende-phlogopite ± talc ± plagioclase ± grossular ± scapolite + epidote ± graphite. These calc-silicates exhibit sedimentary layering with alternating layers of carbonate and silica rich layers (Fig.2.2). The rock is coarse grained, light grey in colour. Thin layers of biotite rich zone are seen along biotite rich zone development of garnet is noticed. The quartz rich layers show orientation along N20⁰E dip 80⁰ west. Numerous isoclinal folds are seen in this rock.
Fig 2.1 Geological map of study area, Southern part of Dharwar craton (modified after District geological map of GSI, 2008)
In thin section the rock exhibits granulitic texture and composed of the following mineral assemblages: Calc+Plag+Qtz+Bio+Cpx+Grt+opaques. Clinopyroxene is colourless to green in colour and occurs as euhedral to subhedral grains with poorly developed cleavages. It is usually non-pleochroic, and shows alteration to epidote indicating effect of retrogression. Quartz occurs as subhedral grains and exhibits undulose extinction. Plagioclase occurs as twinned grains.

Calcite occurs as small plates and exhibits characteristics rhombohedral cleavage and shows bent lamellae. Pale brown garnet occurs as subhedral to anhedral grains.

2.2.2 Garnet-biotite gneiss

The medium to coarse grained garnet bearing gneiss well exposed near Bettadabedu area and associated with calc-silicates, quartzites and impure carbonates is occurring in. The foliation defined by quartz, biotite and plagioclase trending N20°E and dipping vertically. Towards east of carbonate bands, about 40metre wide garnet-biotite gneiss is occur (Fig.2.3). Well developed banding defined by mafic and felsic minerals have been noticed in garnet biotite gneiss of Maduvinahalli area(Fig.2.4). These gneisses often show isoclinal folds (Fig.2.5).

The stable mineral assemblages of garnet bearing gneiss are quartz, biotite, plagioclase, and garnet, minor amount of opaques, monazite and zircon. The foliation is defined by biotite and plagioclase. Recrystallized aggregate of quartz, plagioclase and biotite defines the porphyroblastic texture with porphyritic garnet. Fine to medium grained garnets euhedral to subhedral in shape occur with inclusion of biotite and quartz. Many porphyroblastic garnet show good grain boundary contact with biotite. This garnet bearing gneiss contains euhedral monazite inclusions within biotite grains (Fig.2.6) are used to determine metamorphic age of this terrain by insitu monazite U-Pb geochronology in this study. The BSE image of gneisses shows abundant zircon, monazite and ilmenite (Fig.2.7).

Plagioclase grains are tabular to subhedral, fresh to altered and exhibit multiple lamellar twinning. Plagioclase shows alteration to sericite along the grain boundary.
Fig. 2.2 Biotite rich layers with compositional variation in calc-silicates. Bettadabedu, SSB

Fig. 2.3 Garnet-biotite bearing gneiss. Bettadabedu, SSB
**Fig. 2.4** Garnet-biotite bearing para gneiss exhibiting well developed banding. Maduvinahalli, SSB

**Fig. 2.5** Isoclinal fold in biotite bearing para gneiss, Maduvinahalli, SSB
Fig. 2.6 Foliation defined by biotite (contain inclusion of monazite) and quartz in Garnet- biotite bearing para gneiss. Maduvinahalli, SSB

Fig. 2.7 BSE image of biotite bearing para gneiss showing presence of highly reflective monazite, zircon and other opaque minerals. Maduvinahalli, SSB
Flaky, yellowish brown biotite occurs in two forms, the first one is fine grained inclusion in garnet. The second one is medium to coarse grained aggregate in matrix. Biotite shows exsolution of Fe-oxide along the cleavage plane and grain margin. Monazite occurs as inclusion within these biotite show pleochroic haloes around the grain boundary.

2.2.3 Metapelites

Bordering the ultramafic body near Doddakanya, sillimanite bearing para gneiss associated with garnet bearing quartzite is noticed. The foliation is defined by sillimanite and biotite. Garnet occurs as porphyry in the sillimanite-biotite-quartz-plagioclase matrix.

The sillimanite gneiss from Doddakanya contains mineral assemblages of quartz, plagioclase, sillimanite, garnet, biotite and ilmenite.

The euhedral to irregular, larger garnet porphyry occurs with numerous mineral inclusions like sillimanite, biotite and quartz. Biotite is fine to medium grained, which occur as inclusion in garnet. They also occur in the matrix as larger grains. The matrix biotite often shows bending along foliation. The fibrous to needle shaped sillimanite occur as inclusion in garnet. These colourless grains show parallel extinction. Euheadal to subhedral large sillimanite grains also occur in the matrix with well developed cleavages. Sillimanite contains inclusion of Fe-oxides.

In the top hill of Chickadevibetta near Sargur town, migmatitic gneiss is noticed with numerous clots of kyanite-garnet-biotite (Fig.2.8). The migmatitic gneiss is associated with quartzite and amphibolite. The gneiss show dextral sense of shear deformation with the formation of kyanite nodules (Fig.2.9). Numerous leucosome contains plagioclase and quartz occurs along the foliation of gneiss. The foliation defined by biotite, kyanite and plagioclase is N20°E and dip 80° towards East. In places quartz vein is seen cross cutting the gneiss and the foliation measured as N-S dip 60°East.
Fig. 2.8 Kyanite rich nodules, occurs within the migmatitic gneiss. Chickadevibetta, SSB

Fig. 2.9 Dextral sense of shear deformation in kyanite gneiss with the development of kyanite nodules, Chickadevibetta, SSB
The microscopical characteristic of kyanite gneiss is quite distinct which exhibit porphyroblastic texture with mineral assemblage garnet, kyanite, biotite, quartz, plagioclase and ilmenite. The foliation is defined by biotite and kyanite.

Porphyritic garnet exhibit castaclastic texture with fractures filled by greenish coloured chlorite. Deformed plagioclase grains have bent twin lamellae and exhibiting multiple lamellar twinning. Plagioclase grains are highly altered and show sericitization. They appear cloudy and exhibits buff white colour. Quartz grains are anhedral in shape and shows undulose extinction. Larger grains of quartz show recrystallisation.

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The yellowish brown biotite contains exsolution of Fe-oxides along cleavage planes and grain boundary. They show bent lamellae and contain zircon inclusion, which show pleochroic haloes around the margin.

2.2.4 Basic granulites

Garnetiferous gabbro, Chilckkahalli

Exposure of garnetiferous gabbro in Chilckkahalli area is associated with garnet-biotite gneiss and calc-silicate rock. The gneiss is trending NE and dip vertically. Along with gneiss non-garnetiferrous amphibolites also seen. This gneiss is deformed with isoclinals folds. In places the allanite bearing gneiss is noticed.

In thin section the rock displays a typical granoblastic texture and essentially consists of Garnet- clinopyroxene- plagioclase-amphibole-biotite-quartz and opaque. Plagioclase occurs as tabular grains of varying size and shows multiple lamellar twinning, sometime times it is myrmekitic. Clinopyroxene is colourless to pale green grains. Opaques are concentrated around clinopyroxene.

Amphibole shows pleochroic colour from pale yellow to yellowish colour. Garnet is reddish brown in colour and occurs as anhedral forms.

Garnetiferrous gabbro, Thumbasoge

Basic granulites exposed around Thumbasoge area near Sargur village have mineral assemblages which are suitable for estimating P-T conditions of
metamorphism. Genetically related to the ultramafic rocks are a suite of mafic rocks varying in composition from gabbro to gabbroic anorthosite. They form concordant sheets with generally gradational contact relations with the ultra-mafic rocks. The basic granulites are medium-grained and typically exhibit a granoblastic texture. A small hill near Thumbasoge village, melanocratic coarse grained massive gabbro exposure with very feeble foliation probable along original igneous layering (Fig. 2.10). The strike is almost N-S and dip 80° towards east. This mafic granulite occurs in the form of dyke cross cutting the sediments with trending N50°E, S50°W.

These basic granulites in the Sargur Schist Belt are composed mainly of plagioclase- garnet- clinopyroxene- quartz- amphibole- biotite and sphene (Fig. 2.11). The presence of garnet in a few granulite samples is mainly controlled by the original chemical composition rather than metamorphic condition. The rock exhibits granoblastic micro texture.

Amphibole occurs as medium-sized matrix mineral showing pleochroism from pale yellow-green to brownish green to brown. The dominant type of plagioclase occurs as medium-sized grains with sharply defined lamellar twinning. The twin lamellae are bent by deformation at places. Plagioclase content is high in some rocks indicating variation in original rock composition from gabbro.

Garnet is present as a minor mineral in this mafic granulite. Very rarely garnet occur as anhedral pophyroblasts.

**Garnetiferrous gabbro, Hadnur**

A hill exposure of garnetiferrous gabbro near Hadnur is associated with layered gneiss and anorthosite (Fig. 2.12). Tight isoclinals fold is observed in this garnetiferrous gabbro. The mineral assemblages in this basic granulite are used for estimation of P-T condition of metamorphism.

In thin section the rock displays a typical granoblastic texture and essentially consists of Garnet-clinopyroxene- plagioclase-amphibole- biotite-quartz and opaque.

Plagioclase occurs as tabular grains of varying size and shows multiple lamellar twinning, sometime times it is myrmekitic.
Fig. 2.10 Exposure of Garnetiferrous gabbro in a mound, Thumbasoge, SSB

Fig. 2.11 Garnet-clinopyroxene-plagioclase bearing assemblages exhibiting good grain boundary contact, garnetiferrous gabbro. Thumbasoge, SSB
Clinopyroxene is colourless to pale green grains. Opaques are concentrated around clinopyroxene. Amphibole shows pleochroic colour from pale yellow to yellowish colour. Garnet is reddish brown in colour and occurs as anhedral forms. Formation of coronitic garnet (grt\(^2\)) is observed between orthopyroxene and plagioclase (Fig.2.13).

The formation of garnet coronas is related to the following metamorphic reactions:

\[
\text{opx + plag} \rightarrow \text{grt}^2 + \text{qtz}
\]

\[
\text{opx + cpx ± ilm ± magt} \rightarrow \text{grt}^2 + \text{qtz}
\]

Similar symplectite and coronal intergrowths around pyroxene and amphibole are found in many other places in the Eastern Ghats Belt (Dasgupta et al., 1991, 1993; Sengupta et al., 1996, Bose et al., 2003) and other granulitic facies terranes in the world and have been related to near isobaric cooling (Ellis & Green, 1979; Harley, 1985 and 1989)

**Garnetiferrous gabbro, Doddakanya**

Garnetiferrous gabbro intruded into the hornblende-biotite gneiss near Doddakanya. This two pyroxene granulite with garnet occur in the form of dyke. Towards eastern part of ultramafic body Garnetiferrous gabbro is observed with development of porphyroblastic garnet.

In thin section garnetiferous gabbro exhibits granoblastic texture and this basic granulite mainly composed of orthopyroxene, clinopyroxene, plagioclase, garnet, amphibole, biotite minor ilmenit and magnetite.

Clinopyroxene occur as medium sized matrix grains which are subhedral, pale green to pale brown in colour and non-pleochroic. Some of the micro fractures even cross cut the clinopyroxene, orthopyroxene and garnet. Porphyroblastic garnet is larger euhedral to irregular in shape which commonly contains inclusion of clinopyroxene, plagioclase and quartz. Clinopyroxene in matrix show equilibrium texture with good grain boundary contact with porphyroblastic garnet.
Fig.2.12 A hill exposure of garnet bearing gabbro, Hadnur, SSB

Fig.2.13 Development of coronitic garnet between opx and plag in basic granulite. Hadnur, SSB.
Orthopyroxene are irregular in shape and occur as stable phase with matrix plagioclase and quartz. They are pink in colour with light green to pink pleochroism.

Fine grained subhedral plagioclase occurs as inclusion in garnet. Plagioclase in matrix is euhedral to subhedral. Plagioclase laths show multiple lamellar twinning. The larger grains of plagioclase occur as stable phase with clinopyroxene and garnet.

Amphibole occurs as euhedral grains with yellowish green to brownish green in colour. Some amphiboles show perfect diamond shaped cleavages. The brownish green amphibole in the matrix is stable with garnet, clinopyroxene, orthopyroxene and plagioclase. Amphiboles also exhibit a thin film of Fe-oxides along cleavage planes and grain boundaries.

2.2.5 Amphibolites

Amphibolites are extensively seen as N 40°E trending bodies with observable banding. The amphibolite has a close spatial association with metasediments and many times are intercalated with calc-silicates. Amphibolites are well foliated and they exhibit tight isoclinals folding related to the second deformation of the area. This point suggests them to be one of the oldest basic rock members in the area. An exposure Near Nugu dam, amphibolites are interbanded with quartzite and iron formation (Fig.2.14). leucocratic melt has been observed around the porphyroblastic garnet of this amphibolites (Fig.2.15). In Anglupur area porphyroblastic garnet have developed along the margin of amphibolite bodies, (Fig.2.16).

Thin section study of amphibolite show hypidiomorphic texture with mineral assemblage of garnet, hornblende, biotite, plagioclase. The euhedral garnet shows light brown to dark brown with moderate relief. Numerous fractures are seen within the porphyroblastic garnet. Porphyroblastic garnet occurs within the leucosome of quartz and plagioclase (Fig.2.15).

Hornblende is light green to dark green in color; two directional cleavages are present and show simple twinning with low relief. These hornblende grains are
Fig. 2.14 BIF layers alternating with amphibolites, Nugu dam, SSB

Fig. 2.15 Garnet in quartz melt of amphibolite, Nugu dam, SSB
deformed and show stretching and elongation. Biotites are seen as small grains with serrated margins. They show light yellow to dark yellow pleochroism.

2.2.6 Banded iron formation

A hill exposure of banded iron formation is occurring near Thumbasoge. The banding trends N25°E and dip 80° towards West. The BMQ is cross cut by N50°E trending vertically dipping brittle fractures. Different type of folds have been seen. The BMQ is associated with meta-sediments and cross cut by the mafic granulites. In a canal section near Nugu dam the BIF is enriched with numerous garnet porphyroblasts along the foliation (Fig.2.17).

The banded magnetite quartzite consists of magt+qtz+grt+bt. Quartz occurs as elongate plates and grains invariably display undulose extinction. Magnetite occurs as opaque dispersed grains. Biotite is brown in colour and shows brown to yellow pleochroism.

2.3 BILIGIRIRANGAN AND MALE MAHADESHWARA GRANULITES

Biligirirangan and Male Mahadeswara areas represent high pressure granulate facies terrains in the Dharwar craton. These granulites represent the southern continuation of Kabbaldurga-Satnur transition zone and represent the deeply exposed Archaean crust in the Eastern Dharwar Craton (Fig 2.1).

The granulate facies rocks in B.R.Hills is composed of major lithologies consisting of quartzo-feldspathic charnockites, mafic (two pyroxene) granulites and high grade metasedimentary rocks (carbonate-pelite-BIF-Mn-horizons). All these lithologies show prominent N-S structural trend. Early isoclinals folds are refolded by later shear motions (Drury et al 1984, Gopalakrishna et al 1986). Orthopyroxene frequently occupies the axial planes of isoclinals folds. Overthrust can be observed in the southern part of B.R.Hills area in the form of oblique mineral lineation plunging 60-70° southwards. Near Suwarnavathi, Naguvalli and Honganapura areas (around Chamarajanagar), discontinuous dyke like bodies of mafic granulites occur often as boudins within the charnockites. The eastern part of B.R.Hill granulites
Fig. 2.16 Porphyroblastic garnet in amphibolite, Anglupur, SSB

Fig. 2.17 Porphyroblastic garnet along the foliation of BIF, Near Nugu dam, SSB
constitutes MalaiMahadeswara (MM) Hills. Medium to coarse grained charnockites, basic granulites and cordierite-bearing gneisses are the common rock types exposed in the M.M.Hills. These rocks are interbanded with iron formations, calc-silicates, quartzites and metabasic rocks (Fig.2.18). They show a regional foliation trending N-S with dips varying from 50-80° west. Towards south, the B.R.Hills is bounded by E-W running Proterozoic Moyar shear zone (Drury and Holt, 1980). The strongly migmatised pelites show effect of partial melting with garnet development in the leucosome.

B.R.Hills granulites shown at least three deformational events based on structural investigations viz, D₁, D₂ and D₃ and the N-S regional trend massive /banded charnockitic is related to D₂ deformation (Basavarajappa, 1992). The peak metamorphic condition of 750-900°C and pressures of 6-9.5 kb have been reported based on mineral chemistry of co-existing phases in the charnockite and basic granulites of BRG (Srikantappa et al., 1992).

The charnockitic-enderbitic granulites of the BRG show evidence of ductile to ductile-brittle deformation, along the western margin of the BRG in the southern margin of Kollegal shear zone, layers of mylonites and ultramylonites occurs around Dhimbhum. Retrograde metamorphic alteration is reported along a N 10°E to S 10°W trending, narrow (8-10 km wide), shear zone, termed as Kollegal shear zone, which extends for a length of about 60-65 km (Basavarajappa, H.T. and Srikantappa.C., 1999). Southern margin of Dharwar craton contains extensively granulite facies rocks.

2.3.1Massive charnockites

Medium to coarse grained, massive, greasy grey coloured charnockite is predominant rock type in M.M and B.R.Hills. These charnockites occur with layers and bands of basic granulites and associated with metapelites, quartzite, calc-silicates and banded iron formations. Isoclinal N70°E plunging folds are noticed in charnockites of Sivanasamudra area (Fig.2.19).

In thin sections, the charnockites exhibits a granoblastic, polygonal mosaic microstructure. Charnockites normally contain the assemblage orthopyroxene-
Fig. 2.18 Alternating bands of meta-pelite and quartzite within charnockite, MMG

Fig. 2.19 Isoclinal steeply plunging (70°NE) in charnockites, Sivanasamudra, BRG
biotite-plagioclase-K-feldspar-quartz. Orthopyroxene set in a relatively fine grained quartzo-feldspathic matrix. K.feldspar is by far the most dominant mineral and is mostly perthite with microcline in subordinate amounts. Orthopyroxene which is the characteristic mineral of charnockites is pleochroic in shades of pink and green.

Plagioclase grain often displays undulatory extinction. K-feldspar is an abundant constituent of charnockites. Perthitic intergrowth viz., bead perthite and string perthites are seen. Microcline with well developed cross hatched twinning is subordinate. Well twinned plates of plagioclase are common. Biotite is most abundant mineral and is associated with feldspar and quartz. Quartz grains are stretched parallel to the foliation defined by biotite.

2.3.2 Banded charnockites

The fine to medium grained massive to banded charnockites exposure is occurring in an open quarry near Gumballi. Within these charnockites numerous basic rocks are occur as folded enclaves. Parallel to the foliation of the charnockites shear planes are noticed with the development of mylonites. Numerous black ductile shears are seen in this charnockites. Amphibolite occurs as enclave within the basic rock. Along the road cutting near this quarry contains numerous quartzite bands (Fig.2.20). They are rich in zircon.

Orthopyroxene in charnockitic rocks occurs as anhedral to subhedral pophyroblasts in the interspaces of quartz, plagioclase, clinopyroxene and alkali feldspar. Orthopyroxene shows simple twinning. Orthopyroxene along with biotite is often concentrated in layers to define the gneissosity. Closely associated ilmenite also noted.

Clinopyroxene is colourless to green in colour and occurs as euhedral to subhedral grains with poorly developed cleavages.

Alkali feldspar grains are large, anhedral and perthitic. Flame shaped perthite are common. Deformed grains show undulose extinction. Extensive myrmekite intergrowths are present along the boundaries between feldspars. Plagioclase grains
are small and deformed verities have bent lamellae. Deformed biotite show undulose extinction and bent lamellae.

2.3.3 Meta-pelites

Garnet-cordierite gneiss and medium to coarse grained charnockites are the characteristic rock types exposed mainly in M.M.Hills. These rocks are interbanded with iron formation, calc-silicates and metabasic rocks. The metapelites are exposed along road cuttings in M.M.Hill ranges. It has isoclinal fold with alternating layers of mafic enclaves (Fig.2.21). The foliation trends N-S and dip 70⁰E. The clinopyroxene bearing mafic rock occurs as parrelal band with the pelitic rock. Alternate bands of charnockite with metapelite of 5 metre width is noticed, indicating the deposition in a sedimentary environment (Fig.2.22). Pure quartz and lecogranite is associated with this metapelite, which may be the product from the melting of metapelite. The leucogranite contains nemerous zircon and garnet grains and they are deformed. Nemerous quartz veins are introded into the pelitic rocks. Quartz grains in meta-pelites are highly deformed (Fig.2.23). The garnet is surrounded by quartzofeldspathic melt and are rich in cordierite, feldspar and quartz. When going from outer rim to inner core, the garnet grains are decrease in size and the equigranular grains are uniformaly distributed throughout the rock (Fig.2.24).

The assemblage garnet-cordierite-biotite-Kfeldspar-quartz-sillimanite form bands of varying width (2 to 5 m). Garnet is the most coman mafic mineral. They are normally pophyroblastic with inclusions of biotite, sillimanite and quartz. Cordierite also occurs in large size within quartzo-feldspathic matrix in meta-pelites also noticed (Fig.2.25).

Cordierite is found in different textural styles. Cordierite grains showing patchy twinning are frequent. Plechroic haloes around included zircons and pinnite alteration along the margins are characteristic. Cordierite is often seen as rim around garnet and at times as inclusion within garnet. Some of the cordierite show developement of late fibrolite sillimanite and pinnite. Spinel is an important constituent of the metapelites and the dark green to black spinels occur in association with cordierite, ilmenite and sillimanite.
**Fig. 2.20** Steeply dipping quartzite (±sill & zirc) occurring with charnockites, MMG

**Fig. 2.21** Early isoclinals fold in meta-pelites, MMG
**Fig.2.22** Garnet-cordierite gneiss alternating with mafic-rich layers, MMG

**Fig.2.23** Highly deformed quartz rich layers in meta-pelits, MMG
Fig. 2.24 Garnet-rich meta-pelite, Thalabetta, MMG

Fig. 2.25 Cordierite rich zone in metapelites, MMG
Plagioclase occurs as large well twinned laths around garnet. Antiperthite is seen occasionally. Plagioclase seen as thin rind on garnet, probably associated with the decompression reaction. K.feldspar include perthite and microcline. String perthite and bead perthite are frequent. Biotite is a common mafic mineral in metapelite. Biotite occurs as inclusion within garnet and cordierite and also in matrix. Biotite also form as retrogression product of garnet along the fractures.

Coarse sillimanite blades are present only locally in this metapelite. Fine grained sillimanite needles, oriented along the particular direction are present in the matrix. Cordierite and garnet porphyroblasts are extensively replaced by biotite or fibrolite-biotite aggregate along their margins.

The peak metamorphism is characterised by the stability of the mineral assemblage garnet+sillimanite+quartz+cordierite+ilmenite+spinel with K.feldspar and plagioclase in metapelite which clearly indicates a high temperature granulite facies condition (Fig.2.27). Mineral inclusions in porphyroblastic garnet suggest that the assemblage biotite-sillimanite-quartz was stabilized prior to the formation of porphyroblastic garnet. The garnet-sillimanite bearing metapelitic rocks have undergone extensive partial melting (Fig.2.26 & 2.28) during the high grade metamorphism (M1) as evidence from the field features. Garnet porphyroblast in parts contains anhedral grain boundaries and forms symplectite (cord+k-felds+qtz) along the margin (Fig.2.29).

Garnet and cordierite in metapelites, normally contain inclusions of biotite, sillimanite and quartz (Fig.2.30) and hence should have formed by the prograde reactions:

\[ \text{Bt+Sil+Qtz} \rightarrow \text{Crd+Kfs+V} \]

\[ \text{Bt+Sil+Qtz} \rightarrow \text{Grt+Kfs+V} \]

\[ \text{Bt (+Ti,F)+Sil+Qtz±plag} \rightarrow \text{Grt+Cord+Fe-Ti oxide±Kfs+V} \]
Fig. 2.26 Melt (leucosome) producing reaction around garnet porphyroblast in garnet cordierite gneiss, Thalabetta, MMG

Fig. 2.27 Peak metamorphic assemblages (grt+cord+sil+quartz) in Garnet-cordierite gneiss. Thalabetta, MMG
**Fig. 2.28** Formation of melt(plag+quartz) around garnet in garnet-cordierite gneiss, MMG.

**Fig. 2.29** Cord+K-felds+qtz symplectite around garnet in meta-pelite. MMG
Inclusions of cordierite are also noticed in garnet crystals (Fig.2.30) indicating the following model reaction:

\[
\text{Cord} \rightarrow \text{Grt} + \text{sill} + \text{qtz} \quad \text{(Srikantappa et al., 1992)}
\]

Development of sillimanite + biotite with quartz between cordierite and K-feldspar in the gneiss suggest the following retrograde reaction:

\[
\text{Cord} + \text{K-felds} + V \text{ (or melt)} \rightarrow \text{sill} + \text{bt} + \text{qtz} \quad \text{(Srikantappa et al., 1992)}
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### 2.3.4 Basic granulites

In the top hill medium to coarse grained garnetiferrous gabbro exposure is noticed in Mudukkuthore. It shows the foliation trend towards N-S and dip towards 80° west. The N-S foliation is super imposed by E-W trending brittle shears. There are two types of gabbro observed in this area viz:- garnetiferrous (Fig.2.31) and non-garnetiferrous gabbro. In the foot hill the garnetiferous gabbro is associated with pelitic rocks.

The basic granulites exhibit granulitic to granoblastic texture. They contain mineral assemblages of garnet, clinopyroxene, plagioclase, quartz, amphibole and minor amount of opaque minerals.

Porphyroblastic garnet contains inclusion of plagioclase, quartz and clinopyroxene (Fig.2.32). Garnet core is rich in mineral inclusions and rim is free from inclusions. Plagioclase grains are tabular to subhedral, fresh to altered and exhibits multiple lamellar twinning. The deformed plagioclase show bent lamellae with kink band. Plagioclase occurs as inclusion in clinopyroxene shows polysynthetic twinning.

Flaky yellowish to brown biotite occur in different orientation related to the foliation in plane. Biotite occurs in two forms, the first one is fine grained inclusion in garnet and the second one is medium grain in matrix. In some places biotite replace the garnet along the grain boundary.
**Fig. 2.30** Inclusion (bt+sill+qtz+cord) in Porphyroblastic garnet of Meta-pelites, MMG
Bt+sil+qtz --------> grt+cord+kfls

**Fig. 2.31** Garnetiferrous basic granulites, MMG
Two textural type of clinopyroxene are present in this basic granulite. The main type occur as medium sized matrix grain, which is subhedral, pale green to pale brown in colour and non-pleochroic. The second type occurs as fine symplectite with plagioclase at the garnet grain boundary.

The basic granulite exposure in M.M.Hills area is associated with alternating bands of garnet-cordierite gneiss and non-garnetiferous charnockites (Fig.2.33). These basic granulites occur as discontinuous dyke like bodies and often as boudins in charnockites. Numerous lenses and pods of meta-pyroxenites occur along the foliation of granulites.

The basic rock composed mainly of orthopyroxene-clinopyroxene-plagioclase- garnet- quartz-ilmenite.

In thin section the basic rock exhibit a granoblastic texture with garnet porphyroblasts containing inclusions of plagioclase and quartz. Garnet also occurs as rim between the mineral plagioclase and orthopyroxene (Fig.2.34). Coronitic garnet also forms around the mineral ilmenite (Fig.2.38). The BSE image of coronitic garnet has been presented in (Fig.2.35). Elemental mapping of Si, Ca, Fe and Ti has been done for this coronitic garnet to find the compositional zoning (Fig.2.36). The elements are equally distributed and there is no compositional variation observed, thus the coronitic garnet is homogenous in composition. The garnet corona suggests that the reaction occur during the late stages of granulite facies metamorphism (M2).

Garnet occurs in two modes namely coronal and porphyroblastic. Porphyroblastic garnets are euhedral, containing inclusions of quartz and feldspar. This feature suggests that porphyroblastic garnet acted as suitable nuclei for formation of coronal garnet. In the second mode, garnet occurs as corona. Garnet-ilmenite intergrowths are only present surrounding the ilmenite porphyroblasts (Fig. 2.37 & 2.38).
The formation of garnet coronas can be related to the following generalized metamorphic reactions:

$$\text{opx} + \text{plag} \rightarrow \text{grt} + \text{qtz}$$

$$\text{opx} + \text{cpx} \pm \text{ilm} \pm \text{mqt} \rightarrow \text{grt} + \text{qtz}$$

Similar symplectite and coronal intergrowths around pyroxene and amphibole are found in many other places in the Eastern Ghats Belt (Dasgupta et al., 1991, 1993; Sengupta et al., 1996, Bose et al., 2003) and other granulitic facies terranes in the world and have been related to near isobaric cooling (Ellis & Green, 1979; Harley, 1985 and 1989)
Fig. 2.32 Inclusion (cpx+plag+qtz) in Porphyroblastic garnet of basic granulite, MMG

\[ \text{cpx + plag} \rightarrow \text{grt} + \text{qtz} \]

Fig. 2.33 Basic granulites occurring in charnockites, MMG
**Fig. 2.34** Formation of coronitic garnet between opx and plag in basic granulite, Thalabetta, MMG

**Fig. 2.35** BSE image of coronitic garnet between opx and plag in basic granulite, Thalabetta, MMG
**Fig. 2.36** Si, Ca, Fe & Ti elemental concentration mapping of coronitic garnet in basic granulite, Thalabetta, MMG. Note homogeneity in chemistry of various phases with no zoning.
Fig. 2.37 Coronitic garnet formed at the contact between opx and plag in basic granulite, MMG

Fig. 2.38 Coronitic garnet formation around plagioclase and ilmenite
In basic granulite, MMG
Structural investigations in the Sargur region have shown that the supracrustal rocks, together with the ultramafics to mafic complexes, have been affected by three deformational episodes and two phases of high-grade metamorphism and magmatization (Chadwick et al., 1978; Janardhan et al., 1979; Srikantappa, 1979).

During the first deformational episode tight to isoclinals F1 folds, to trending N-S to 20°E and plunging towards the north were formed. The second deformational episode produced tight to open F2 folds which are coaxial with the F1 folds, the regional conformable schistosity which is now parallel to bedding following isoclinals folding, was developed during this episode, including high-grade metamorphism and magmatization. The third phase of folding is represented by F3 folds, trending NE to E-W, and has affected the entire Sargur region. Development of ENE to E-W trending faults subsequently resulted in displacement and rotation of the rock units. Emplacement of pink porphyritic granites is related to this episode.

The original field relationship between the high-grade Sargur supracrustal, the associated ultramafics to mafic complexes and the surrounding peninsular gneisses is difficult to establish because of polyphase deformation and high-grade metamorphism.