INTRODUCTION

The Precambrian granulite terrain of southern India offers an excellent opportunity to study lithology, structure and metamorphic history of the deep continental crust. South of the Archaean granulite gneiss – greenstone terrain of the Dharwar craton, a series of discrete crustal blocks intensely metamorphosed at granulite facies conditions have been exposed. The orthopyroxene bearing intermediate to felsic granulites and associated rocks are the characteristic rock types generally occupying the prominent hill ranges as for ex. Biligirirangan hills, Nilgiri hills, Malaimahadeshwara hills, Shevory hills in Karnataka and Tamil Nadu. Southern India, the granulite facies rocks have been transected by major shear zones like the Moyar, Bhavani and Noyal Cauvery, probably during the late Proterozoic time.

The foremost characteristics feature of granulite facies rocks are water deficient minerals like pyroxenes and/or garnet in addition to minor amounts of amphiboles and mica in different lithologies granulites contain CO₂ rich fluid inclusions, mixed CO₂ CH₄, N₂ as well as brines (Touret, 1971), Janardhan et al., 1979, Klatt et al., 1988, Srikantappa et al., 1991). Geochemistry also provides information on nature of protoliths, whether igneous or sedimentary when combined with field and petrographic data.

An attempt is made in this thesis to bring out detailed geological, petrological and geochemical data including fluid inclusion studies on the South Eastern part of the Kollegal Shear Zone and migmatitic granitoid Gneisses, around Chamarajanagara,
in Karnataka and Talavadi in Tamil Nadu, South India. The data is presented and discussed in four different chapters.

Many major shear zones discussed in literature are of Precambrian age cutting through the Archaean high grade terrain (Beach, 1973, Crawford et al., 1976, Winchester and Max. 1984, Srikantappa et al., 1988, Srikantappa et al., 1992; Prakash Narasimha 1992; Basavarajappa 1992; Basavarajappa and Srikantappa 1999; Srikantappa et al. 2003; Jain et al. 2003). Within these shear zones, the high-grade lithologies show retrograde metamorphic alteration to amphibolite to green schist facies conditions. A study of shear zone is significant in understanding the process of retrograde alteration elemental mobility and fluid movement associated with shear zones (Fig.1.1). South Indian Map.

1.1 Geology of Karnataka

The Karnataka craton in southern India is composed of granite-greenstone belts exposed in northern part of craton termed as Dharwar super group (2.4 to 2.6 b.y). The high-grade gneiss-granulite belt termed as Sargur Group (>3.0 b.y) are exposed towards southern part of the craton. Migmatitic gneiss termed as peninsular gneiss is a polyphase gneiss complex, which occupy large parts of the Karnataka Craton. Some parts of the gneissic complex give an age of 3.4 – 3.0 b.y (Beckinsale et al., 1980). The classification of various rock types of Karnataka craton proposed by Swaminath and Ramakrishna (1981).

There is no general agreement on the Stratigraphy and structure of the schist belts in Karnataka craton. The current controversies are;
1 - Shear zones, 2 - Phanerozoic sediments, 3 - Neoproterozoic granites, 4 - Closepet granite, 5 - Region of shearing and retrograde metamorphism, 6 - Granulite facies rocks, 7 - Granulite-migmatite gneiss of Dharwar craton, 8 - Greenstone belts of Dharwar Supergroup, 9 - Supracrustal rocks (Sargur-Sathyamangalam Groups). SGT - Southern Granulite Terrain; NGT - Northern Granulite Terrain; PCSS - Palghat-Cauvery Shear System; MBSZ - Moyar-Bhavani Shear Zone; ACSZ - Achankovil Shear Zone and PCSZ - Palghat-Cauvery Shear Zone.
• The Dharwar super group represent rocks of younger age than the peninsular gneiss and that the Sargur group are older than the peninsular gneiss (Swaminath and Ramakrishna, 1981).

• Dharwar – super group and Sargur group represents one super group older than the peninsular gneiss and

• The Archaean supra crystals represents belts formed at different periods covering a span of 3.5 to 2.5 b.y.

• Some of which are older and some younger than the peninsular gneiss (Naqvi, 1981)

The term Karnataka Craton was introduced recently by the geological survey of India (1978), to accommodate the already known Dharwar super group (Dharwar greenstone granite) and recently established Sargur Schist complex (Sargur type high grade terrain). Till recently the existing nomenclature still being used by some workers, viz., Dharwar supergroup. Dharwar greenstone granite, highly metamorphosed Dharwar greenstone representing the Sargur high grade terrain, is confusing. It is apparent that the prefix “Dharwar has become common to the cratonic counter parts.

The Karnataka craton of South Indian shield exposes numerous linear greenstone belts covered by younger group of rocks in the North. The oldest group of rocks forming the craton was considered till recently as Dharwars, intruded extensively by granites of different ages (Pichamuthu, 1962). (Fig 1.2) The rocks of
Sargur schist complex are characterized by high-grade metamorphism from upper amphibolite to transitional granulite facies and have suffered intensive deformation and migmatisation. Following the identification of Sargur high-grade schist belt in Karnataka craton, rocks equivalent to the above have been recognized in other parts of Karnataka (Vishwanatha and Ramakrishnan, 1976), in adjacent Kerala (Nair et al., 1976), in Tamil Nadu, (Gopalkrishna et al., 1976) and in Andhra Pradesh (Subbaraju, 1976) regions. The Sargurs form, as it were a transitional tract between the Dharwar greenstones and the charnockite mobile belt of Nilgiris and the Eastern ghats.

1.2 Geology of Tamil Nadu:

Tamil Nadu, along with the Union Territory of Pondicherry lies between 8°00’N and 13°30’N Latitudes and 76°16’E and 80°18’E Longitudes. It is bounded on the north by Andhra Pradesh and Karnataka and on the west by Kerala. A long coast line borders the Bay of Bengal on the east. The western coast, falling within Tamil Nadu is short and it extends towards North into Kerala. The palk straits separate Tamil Nadu from Srilanka. Kanyakumari (Cape Comorin) lies at the southern most tip of the Indian peninsula and it is here that the waters of the Bay of Bengal, the Arabian Sea and the Indian Ocean mingle. The Bay of Bengal and the Arabian Sea may be considered as arms of the Indian ocean extending towards north, bordering two sides of the triangle shaped Indian Peninsula.

In the eastern part of the state, the Western ghat hill ranges, the Sahyadri, defining a conspicuous, topographically high terrain run more or less uninterruptedly, in a NNW direction from near Kanyakumari in the south, through Tamil Nadu, Kerala and Karnataka to Maharashtra. Mahendragiri, Agastyas Malai, Palani hills and the
FIG. 1.2 GEOLOGICAL MAP OF KARNATAKA CRATON
Nilgiri hills are parts of the Western Ghats in Tamil Nadu. The topography of
the hill ranges is by and large mature, with ‘U’ and ‘V’ shaped valleys, escarpments
and remnants of plateau landforms at high altitudes, as on the Palani and Nilgiri hills.
Some of the highest peaks in south India rising to altitudes of more than 2000 M in
the Western Ghats lie in Tamil Nadu and adjacent Kerala. The almost continuous
chain of the Western Ghat hill ranges is broken by the well-defined low level land
form of the Palghat gap, between the steeply rising Nilgiri hills in the north and the
Anamalai hills in the south.

Precambrian crystalline rocks cover over 80 percent of the terrain and
Phanerozoic sedimentary rocks cover the eastern coastal terrain and the river valleys
accounts for the rest. In the deeply eroded Precambrian terrain, rocks of the
Khondalite and Charnockite groups and migmatites derived from them are extensively
traced. The rocks of the Sathyamangalam group representing the geographical and
geological continuation of the Sargur Group of Karnataka occur as an E-W belt in the
central part of the state. Southerly extension of the rocks of the Kolar group and the
peninsular gneissic complex is evident in the area adjoining Karnataka and Andhra
Pradesh. Within this vast array of crystalline rocks, igneous emplacements of
anorthosites, granites, syenites, carbonatites, ultramafic bodies and basic sills and
dykes are defined. Phanerozoic rocks of fluvialite, fluviomarine and marine origin
and traced along the eastern coastal belt (Fig.1.3.) The geographical continuity of the
Sargur Group of Karnataka as the Sathyamangalam Group of Tamil Nadu and the
lithological similarities of the rocks of the two groups are suggestive of their
geological correlation and assignment of the same age to the groups. (K.S. Subramanian & T.A. Selvan (2001).

1.3 Southern Sathyamangalam Group and Shear Zones:

Southern part of Kollegal Shear Zones: These are Sathyamangalam Group of rocks constituted by different rock types. Quartzites with varied mineral composition, including fuchsite – quartzite, garnetiferous quartzite, magnetite. Quartzite, kyanite quartzite and white quartzite, have been traced. The rock types are mica gneiss, quartz – sillimanite schist, diopside granulite and amphibolite. Talc-chlorite schist and talc-actinolite schist bodies obviously represent intrusive mafic ultramafic bodies that have been metamorphosed. Besides, there are a number of lenses, bands and small bodies of layered ultrabasic igneous bodies of dunite, peridotite, eclogite, garnetiferous gabbro and anorthosite. A similarity in the set up to the Sittampundi complex and the Bhavani complex is evident. The mafic and ultrabasic bodies are considered to be younger intrusive, emplaced along weak zones in the rocks of the Sathyamangalam group, or as tectonic slices. Extensive migmatisation of all the rocks is a well-defined features (Gopal Krishnan et al., 1975). (K.S. Subramanian and T.A. Selvan 2001).

1.3.1 Moyar Shear Zone

Most distinct rotation of the NNE-trending fabric of the Northern massifs has been observed along their southern margin, which is demarcated by the Moyar Shear Zone, having distinct E-W, ESE-WNW and ENE-WSW trends. Gradual rotation of the regional trends on either side of the MSZ reveals its prominent dextral shear character having large strike-slip component contrast to the earlier observations by
FIG. 1.3. GEOLOGICAL MAP OF TAMIL NADU AND PONDICHERRY
Naha and Srinivasan (1996), who postulated large-scale up-thrust displacements. In the western parts, the Moyar River flows along this zone, which is then occupied by the eastward-flowing Bhavani River around Sathyamangalam. The shear zone skirts the northern margin of Sankaridurg and extends uninterruptedly eastwards Salem and Attur (Srinivasan, 1974; Chetty, 1996; Chetty and Bhaskar Rao, 1998; Bhadra, 2000).

The MSZ is characterized by strong penetrative mylonitic shear foliation, which trends almost E-W in the western parts and dips very steeply both towards the north as well as south. A subordinate trend of foliation having N 30°E orientation is also noteworthy and may correspond to the relict N-S foliation of the northern massifs within the shear zone. Numerous shear criteria like asymmetric mafic boudins within the MSZ reveal distinct ductile dextral shear sense of movement, with mylonitic foliation characterized by sub-horizontal to gently plunging mineral/stretching lineation. However, the mylonitic foliation also contains variable sub-vertical to steeply down-dip plunging lineation towards NW or SE as well as towards west. Further, one can also note the gradual rotation of axial surfaces of tight to isoclinal folds due to dextral shearing within the MSZ. The main orientation of the ductile shear zones within the MSZ is almost E-W, having both north/south dips and minor component of NE-trending sinistral shear zones. Further eastwards in the Satyamangalam region, orientation of dextral shear zones has slightly changed to S80°E with steep northerly dips, while sinistral shears remain oriented at N30°E with steep E/W dips. In the easternmost region of Attur, where both the conjugate sets are well developed, dextral shear zones trend S70°E with very steep to vertical dips, and
the sinistral ductile shear zones are oriented N20°E. All along the MSZ, mineral/stretching lineation are well developed on the mylonite foliation and within ductile shear zones, and plunge either steeply down-dip (Naha and Srinivasan, 1996; Bhadra, 2000) or undergo rotation to become moderate to gentle (Chetty and Bhaskar Rao, 1998).

1.3.2 Bhavani Shear Zone (BSZ):

Southern contact of the NM is marked by another prominent major shear zone – the Bhavani Shear Zone (BSZ), which trends almost ENE and controls the drainage system of the Bhavani river. It merges with the MSZ in the region of Bhavani Sagar and Satyamangalam. The BSZ reveals a very prominent shear fabric with mylonitic foliation trending almost N60°E and dipping steeply both towards NNW and SSE. Sub-horizontal to moderately plunging mineral/stretching lineation dominates the foliation. Numerous shear criteria within the shear zone reveal its distinct sinistral ductile character having shear zones trending N60-70°E with steep dips towards northwest, which are characterized by gently plunging lineation towards SW. In the eastern parts near Mettupalayam, lineation plunges down-dip either towards NW or SE, while its orientation around this town is towards north at moderate angle. In the Bhavani Sagar region, lineation plunges down-dip towards south at moderate to high angles. A few dextral shears within the BSZ do not show any distinct pattern. In the east, regional trends corresponding to the MSZ are prevalent, and therefore, it is likely that the MSZ extends further eastward and is superposed upon the ENE-trending BSZ, in contrast to the opinion expressed by Drury et al. (1984). In fact, most prominent character of the MSZ, i.e., bending of regional trends of the Northern
massifs, calls for the presence of a single shear zone system all through, as has been shown by Ramakrishnan (1993).

1.3.3 Palghat – Cauvery Shear Zone (PCSZ):

Large a wide low-lying expanse around Coimbatore-Namakkal-Tiruchirapalli and further east is characterized by E-W trends in the Palghat-Cauvery gap, which was named as the Palghat-Cauvery Shear Zone by Drury et al. (1984). In this domain, eastward draining Cauvery River flows along distinct E-W trending major shear zone boundary from south of Namakkal to Tiruchirapalli. Sigmoidal bending of NE-trends of Kollimalai-Pachaimalai hills along their southern margin indicates the presence of a distinct large-scale dextral shear zone, where numerous elliptical quartzo-feldspathic gneissic domes are located south of Namakkal. Further, NNE-trends within these massifs and adjoining areas show indisputed evidences of the continuation and presence of the Northern massifs within the PCSZ like the one shown in the geological map of Project Vasundhara (GSI & ISRO, 1994).

The main foliation within the PCSZ regionally trends almost E-W with subordinate trends towards NE and N. Most of the dextral shear zones within the PCSZ are oriented almost E-W to ESE-WNW with steep to vertical dips. Also, equally prominent N30°E trending sinistral shear zones characterize the PCSZ. Lineation on the E-W trending mylonitic foliation plunges moderately to gently either towards E or W, Map of Shear Zones of South India (Fig 1.4).
1.4 Eastern Biligirirangan Granulites:

In the Eastern margins of the Kollegal Shear Zones within the Biligirirangan hills, rocks like charno-enderbites, chamockites, basic granulites amphibolites and ultramafic rocks occur. Lenses or bands of minor metasedimentary rocks like banded magnetite quartzite, pelites, carbonates and calc-silicates (Scapolite bearing granulites) are noticed within the granulites. A set of late dolerite dykes cross cut all the rock types. Petrography and textural studies of the various rock types are presented here. The charmoenderbites occurring towards the central part of the Biligirirangan hills. These rocks are also associated with the numerous basic granulites, ultramafics, banded magnetite quartzites and pelites. The process of retrogression of charno-enderbite to gneiss, field and textural criterias are indicative of retrograde metamorphism. Local shear controlled incipient chamockitization of the gneisses are well exposed. Amphibolite facies gneisses are predominant rock types occupying western flanks of the Biligirirangan hills.

Towards southern part of the massive to banded charno enderbitic granulites with numerous enclaves of mafic granulites are the predominant rock types forming part of the Biligiri Rangan Hills. This area represents Southern margins of the Archaean Dharwar craton where the regional structural elements trend N.S. with steep dips, formed during D2 deformation (Basavarajappa and Srikantappa 1999, 2000). Structural investigations have shown that the Biligirirangan Granulites represents an uplifted landmass along the N S to N20 E trending Dharmapuri - Mettur shear zone in the east and Kollegal Shear Zone in the west (Basavarajappa and Srikantappa 1999) forming hills up to 1487 to 961 m above MSL. The charno enderbitic granulites
Fig. 1.4. SHEAR ZONES MAP OF SOUTH INDIA


Greenstone/Schist Belts: 1 - Shimoga, 2 - Bababudan, 3 - Western Ghats, 4 - Chitradurga, 5 - Sandur, 6 - Kolar, 7 - Ramagiri, 8 - Hatti, 9 - Nellore, 10 - Veligallu.

Shear Zones: N-Ca - Noyil-Cauvery, M - Moyar, B - Bhavani, CB - Cuddapah boundary shear zone, Mt - Mettur shear zone linking up with Nallamalai, Ak - Achankovil, Bh - Balehonnur, Bb - Bababudan, Cd - Chitradurga.
show ductile and sinistral sense of shear deformation. The P-T conditions of high
grade metamorphism in the Biligirirangan Granulites are estimated to be around 7.5 k
bar and temperatures of 750 °C (Srikantappa et al., 1992). Basavarajppa, (1992)
indicating the exhumation of deep seated granulates towards the western part of
Dharmapuri-Mettur Shear Zone. In contrast towards the eastern parts of Biligirirangan
Granulites and within the Dharmapuri Mettur Shear Zone, charno enderbitic rocks of
the Biligiri Rangan hills show retrograde metamorphic alterations giving rise to
middle to lower amphibolite facies metamorphic rocks, indicating lower palaeo
pressure conditions.

The eastern margin of the Biligiri Rangan Hills is bounded by a narrow (10 to
15 km wide) N 30 to 40 E trending ductile shear zone, termed the Dharmapuri, Mettur
shear zone. Dextral sense of ductile shear deformation is predominant in this zone.
Within this shear zone, the charno enderbitic granulites show evidence of
retrogression giving rise to fissile, hornblende, and biotite bearing gneisses.
Development of epidote hornblende biotite gneisses around vellar and Toppur along
the Dharmapuri – Mettur Shear Zone is attributed to progressive shearing of
granulites and consequent retrograde metamorphism. Relict orthopyroxene is seen in
many of these gneissic rocks; numerous molybdenum bearing quartz veins occupy the
Dharmapuri – Mettur Shear Zone near Toppur (including the molybdenum quartz
veins of the Harur Uttangarai belt). The quartz veins occur either parallel or sub
parallel to gneissic foliation in retrogressed granulites. Field and petrographic
evidence indicates that molybdenum mineralisation in Dharmapuri – Mettur Shear
Zone is a post peak metamorphic phenomenon in granulites and is related to hydro
fracturing and fluid flow along the shear zones. The Dharmapuri – Mettur Shear Zone is considered to be a deep-seated shear zone along which the crustal blocks have moved and is a seismically active and earthquake prone area. The Dharmapuri – Mettur Shear Zone coincides with the deep-seated “B” fracture zone of Grady (1971). Alkali syenites intrude the epidote hornblende gneisses of the Dharmapuri – Mettur Shear Zone. (Memoir, 50.(2003).

1.5 Western Sargur Group:

In the western margin of the study area around Sargur is a gneiss-granulite terrain. The gneisses are of different ages, the interspersed tonalitic quartzofeldspathic gneisses are the oldest recognizable component of 3360 ma (Bekinasale et al., 1980) and the dominant gray trondhjemite gneisses are the youngest in the sequence so far dated. The latter give an age of 2830/- 50 ma an initial sr. ratio of 0.7034 (Janardhan and Vidal, 1982).

The Sargur shallow facies supracrustals include fuchsite bearing quartzite, pelite schists, calc silicate rocks and banded iron formations. They are found as enclaves ranging in size from small lenses to long linear bodies of a few kilometers in 2830 Ma trondhjemitic gneisses. Layered ultramafics, emplaced into the crustals and subsequently metamorphosed, are best exposed around Sinduvalli Dodkanya and Mannahalli area (Janardhan et al., 1978). The ultramafic traversed by dyke like bodies representing a younger sequence of metabasics commonly exhibit two pyroxene assemblages. The dyke bodies range in this from 2 to 6m and are commonly cut by pseudotachylite veins. They exhibit short contact with gneisses.
The Sathyamangalam supracrustals of Tamil Nadu are equated with Sargurs. The Bhavani layered complex comprises of dunite, peridotite, pyroxenite, gabbros and anorthosite emplaced into the Sathyamangalam supracrustals. This complex is affected by a granulite event indicating that this layered complex may be much older than 2700 Ma. The ultramafic body of Dodkanya contains numerous intercalations of tectonically included gneisses in serpentinised dunite and harzburgite which may represent the basement to the ultramafics.

The Archaean Dharwar Craton in Southern India is a classic eg: of a greenstone granite terrain from north – south. Two groups of supracrustal sequences namely the older Sargur Group (3.0 by) and the younger Dharwar Group 2.9 to 2.5) by have been identified. The schistose rocks occur as better and isolated enclaves within the vast complex of gneisses, migmatites generally termed as the peninsular gneissic complex.

The existence of gradual progression in metamorphic grade (amphibolite to granulite facies) from north to south across the Dharwar craton was recognized as early as 1960 by Pichamuthu. The arrested development of patchy charnockite is noticed along shear at Kabbaldurga and foliation planes in quartzo feldspathic gneisses in localities transitional to the granulite facies metamorphism. Further south of this zone, massive granulite facies rocks are exposed. eg: Malai Mahadeswara, Biligiri rangan and Nilgiri granulates. There appears to be a gradual increase in both pressure and temperature as one proceeds from north to south. If this is accepted then the Biligirirangan granulate massif and Malai Mahadeshwara massif, which are situated between the Nilgiris in the south and Kabbaldurga in the north represent in intermediate zone composed of granulite facies rocks and Krishnagiri granitoid
gneisses in the east and Dharwar Supracrustals those are Sargur Group of rocks in the west are well exposed in Karnataka Craton. (Fig. 1.2)

Gneisses form the most dominant rocks of the area, both in terms of volume, and in their diversity. The extensive gneisses of the area and in general, the gneisses of peninsular India are termed as peninsular gneissic complex (Ramakrishnan et al., 1976). These gneisses covering a time span of 1.5% by unfortunately still remain an unclassified unit. This draw back is seen quite clearly in a recent detailed paper on the structural studies of Sargur and Dharwar supracrustals by Chadwick et al., (1978). The author because of this reason has not used the word peninsular gneiss and on the other hand has restricted himself to describing the gneisses of the area based on their field relationship (with structure) and petrography. The various gneissic types described in the area and in Sargur and Gundlupet region are well exposed. Numerous quarries in the area expose fresh gneissic patches. Data gathered from these quarries and from out crops have helped in recognizing three types of gneisses.

Quartz Feldspathic Gneiss form distinctive rock units in the area, seen extensively around Doddakanya, Marballihundi and Dura areas. The presence of gneisses similar to these as tectonically included patches in Doddakanya ultramafic body. The gneisses are dominantly tonalitic in composition and pegmatitic in appearance. They are fissile with biotite clots seen in plenty along the foliae.

The quartz feldspathic gneisses are intimately associated with basics (amphibolites which occur as intercalations and as bands in the metasediments). This association is reminiscent of Akila associations (with Sargurs representing maleness). Thus, the author feels that the quartz feldspathic gneisses may possibly be the
products of acid volcanism and the earlier amphibolites may represent original basic flows.

Augen gneiss with pinkish K-feldspar showing considerable stretching, occur locally and are restricted characteristically to areas bordering the Sargur supracrustals. Infact the occurrence of augen gneiss itself is enigmatic. In certain respects they show typical igneous characters and might represent granite sheets (with perthitic feldspar 30% modally). At other places, they show all gradations from pelitic schist, with characteristics features of migmatised supracrustals. Plagioclase (constituting 15% modally) + brownish biolite less than 20% modally) with quartz (30% modal) exhibiting deformational features. Gneisses similar to this area are found throughout Sargur terrain, at places showing definite intrusive relationship and in other parts showing migmatisation textures.

Brownish Biotite (+Hb) Gneiss characteristics the Sargur terrain as a whole, exposures of this type of gneiss are best seen around Kanyauhundi and Gopalpura area west of Doddakanya. Infact, on a regional basis the gneisses can be said to represent, recycled original quartz, feldspathic gnesis plus migmatized Sargur supracrustals.

1.6 Previous Literature

In the years 1923 and 1924, B. Rama Rao examined the northern end of this series, exposed near Sivanasamudram, Malavalli, Halagur and other parts indicated that there are no reliable evidences in the field to separate the hypersthene granulite. Charnockites and the honblende diopside granulites (Dharwars) of those areas as of two different ages, the one occurring as younger and intrusive into the gneiss.
Earlier workers of Smeeth (1916) and Pichamuthu (1969), included charnockites as major intrusive or anatectic epoch after the peninsular gneiss. Later work by Narayana Swamy (1966), (1975), Nautiyal (1966) and Srinivasan and Sreenivasa (1972), (1975) and S.V.P. Iyengar (1976) have shown that the charnockites were formed during the earliest geosynclinal cycle in southern India and it was later decharnockitised or retrograded to produce peninsular gneiss. (Devaraju and Sadashivaiah, 1969). It was Pichamuttu in the year 1953 who produced concrete field and petrographic evidences for the transformation of gneiss into charnockite at Kabbaldurga situated towards northern part of the Kollegal shear zone. Janardhan et al 1984; Basavarajappa et al 1992; Srikantappa et al 1992; Jayananda et al 1996; Basavarajappa and Srikantappa 1999 Srikantappa et al 2003; Chetty et al., 2003; Jain et al., 2003; carried out regional pressure and temperature estimates from Kabbaldurga up to Kollegal in a N-S transect reported a gradual pressure increase from 5 Kb in Kabbaldurga up to 7 Kb around Biligirirangan hills. There appears to be a gradual increase in CO₂ densities from north to south.

1.7 Aim and Scope

The aims of the present investigation are:

- To prepare a systematic and detailed geological field map of the area by the help of toposheet concerned structural investigations and interpretations have to be proposed to map the field relationship between different rock types in the area.

- To record petrographic features of different rock types, their textural features and mineral assemblages will help in estimating the grade of metamorphism.
• To obtain mineral chemistry of co-existing phases and to understand P-T conditions as well as to trace retrograde P-T paths.

• To study fluid inclusions in the rock forming minerals to get information on the composition and density of the fluid phase present during the peak metamorphism and retrogression.

1.8 Location and Geography

The area investigated lies from Kollegal to Thalvadi around Chamarajanagara, Between longitude 76°15', to 77°10' and latitude 12°15'to11°40; covering approximately an area of about 45 to 60 km, NS direction with a wide of 15 to 25 km E-W, in the toposheets 57 D\16, 57 H\14, 58 A\13, 58 E\1, 58 A\14, 58 E\2 of the Survey of India. The geological map produced here based on south Indian map of the continuity of exposures in the field. (Fig. 1.1)

Information on the field relationship, petrography, geochemistry of the high grade metamorphics like amphibolite facies gneiss, with migmatitic granitoid gneisses and charnockite mixed zone around Kollegal Shear zone are very limited. To understand the protoliths characters and metamorphic evolution of these high grade metamorphic rocks of the study area, it is essential to get information of field mapping structure petrology, geochemistry and fluid inclusion characteristics of the rock types. Regional structural studies of the area around Kollegal Shear Zone and Chamarajanagar have been carried out based on field exposures and structures observed in active quarries.
1.9 Regional Geology of Kollegal Shear Zones (KSZ)

The Kollegal Shear Zones extended approximately 45 to 60 km NS direction with a width of 15 to 25 km EW. This shear zone mainly composed of gneissic exposures within this gneissic terrain migmatisation, retrogression and prograde type of processes are noticed.

The main rock types are gneiss, pink gneiss, migmatitic gneiss, biotite gneiss, banded gneiss, charnockite, dolerite, pegmatite, gabbro, amphibolite, auriferous quartz, carbonate, hornblende, garnetiferous amphibolite, ultramafic rocks, pelites, fuchsite quartzites and auriferous quartz veins are present in the study area.

There are many active quarries where features of retrograde metamorphism is observed in the KSZ of which we describe in detail five quarries studied near Aralipura, Swadasi, Kodiuggne, Chinchanahalli, Hanumanupura ductile shears measuring 2 inches to a meter size, either occur parallel to foliation (N-S) or cross cut at lower angles (N10-15°E) to the earlier metamorphic foliation (D2). They show both sinistral and dextral sense of movement. Thin layers of mylonites and ultramylonites occur towards southern margins of the Kollegal Shear Zones, around Dhimbhum and Germalam retrograde metamorphic alterations is observed along a N10°E to S10°W trending, narrow (15 to 25 km wide) shear zone, termed as Kollegal Shear Zone, which extends for a length of about 45-60 km. Few enclaves of retrogressed mafic granulites within the gneiss show retrograde metamorphic mineral assemblages like Plagioclase + Quartz + Clinopyroxene + Orthopyroxene + K-Feldspar + Hornblende + Chlorite + Opaque. In the shear zone gneisses are cut by late conjugate sets of
brittle shears trending E-W and 70°W. Many of these brittle shears are include epidote veins. Basavarajappa et al., 1992, Srikantappa et al., 1992, Basavarajappa & Srikantappa (1999).

The granulite facies orthopyroxene isograd roughly starts at 12° 45' N latitude in southern Karnataka. At Kabbal, partial transformation of Archaean grey biotite hornblende bearing gneiss (generally called peninsular gneiss) within the Dharwar craton to coarse grained, massive, greasy grey charnockite took place at about 2.5 b.y ago (Rama Rao, 1940, Pichamuthu, 1953). The transformation of gneiss to charnockite is associated with metasomatic process Stahle, et al., 1987). A metamorphic temperature estimates of 700–750°C and lower pressure of 5-6 kb is obtained for the incipient charnockitic areas and they are termed as low and high land charnockites (Janardhan et al., 1982; Basavarajappa 1992).

The highland granulite facies terrane bordered on the western margin of the low land granulites of the Biligirirangan hill ranges (Sathish 2003) by the Archaean Dharwar craton. The Dharwar craton is dominated by tonalitic to trondhjemitic gneisses, generally termed as the peninsular gneiss with ages of as old as 3.4 b.y (Backinsale et al., 1980). Younger gneisses and granitic bodies penetrate these and extensive group of metavolcanic and metasedimentary rocks termed as Dharwar Super Group (Swaminath, et al., 1974, Glikson, 1982) occur overlying the gneisses with basal unconformity in some places (Swaminath and Ramakrishna, 1981).

The existence of granulite progression in metamorphic grade (amphibolite to granulite facies) from north to south across the Dharwar craton was recognized as early was 1960 by Pichamuthu. The arrested development of patchy charnockite is
noticed at kabbaldugra along shear zones and foliation planes in quartzo feldspathic
gneisses in localities transitional to the granulite terranes was thought to represent the
onset of granulite facies metamorphism. Further south of this zone massive granulite
facies rocks are exposed for eg. Malai Mahadeshwara, Biligirirangana and Nilgiri
appears to be a gradual increase in both pressure and temperatures, as one proceeds
from north to south (Hansen et al., 1984; Asha Manjari 1988; Basavarajappa 1992;
Prakash Narasimha 1992). If this is accepted, then the Biligrirangan granulite massif,
which is situated between the Nilgiris in the south and Kabbal Durga in the north
represent an intermediate zone composed of granulite facies rocks exposed in
Karnataka.

According to Drury and Holt (1980). The Archaean (southern Indian shield)
can be divided into northern and southern blocks, separated by a large east-west, post
Archaean shear system occupying the palghat – Cauvery – Bhavani low lands. This
division was later modified by Ramakrishnan (1988) into the Northern Dharwar
Craton (Archaean) and the southern Pandyan Mobile Belt (Proterozoic). The southern
and northern blocks appear to be structurally different. There is no evidence in the
southern block for the North South Striking shear belts which dominate the northern
block. Instead, the strike and altitude of both compositional banding and tectonic
fabrics are extremely variable (Drury et al. 1984). The dominant later Archaean
structures of the northern block are North South Shear belts which refold and obscure
earlier structural features. They probably affect upto 75% of the exposed Archaean
terrain, In the southern block, the major NE-SW Structure has essentially the sense of
movement and may be related, although correlation may be hindered by the younger Palghat – Cauvery shear belt displacements along the Archaean shear belts are of the order of tens of hundreds of kilometers (Drury et al. 1984).

Drury et al (1984) adopted division of northern block into eastern and western blocks as proposed by Swami Nath et al 1976. A narrow N–S trending shear zone which was correlated with an east dipping thrust revealed by Deep – Seismic Sounding (Kaila et al. 1979) acts as the boundary between the western and eastern sub-blocks of the northern blocks. This Shear Zone coincides roughly with the eastern flank of the Chitradurga supracrustal belt in the northern part of blocks and the western flank of the Biligiri Rangan Hills granulites in the southern part (Drury 1983).

1.10 Methodology

The methodology followed during field work and sample collection is given here. Information about the procedures followed for geochemical analysis and fluid inclusions study is given in appropriate chapters. Geological mapping was carried out initially, on 1:50,000 scale without modifying any of the original findings, collected fresh samples along road cuttings from numerous active quarries and exposures in the field from the study area. Due to the inaccessibility of the terrain, particularly in high land area of Biligirrangan massif in the eastern margin of the Kollegal Shear Zone. In order to bring out major structural features, foliation and shearing detailed mapping of the exposed areas was carried out.

More than 200 rock specimens were collected and for detailed investigation, more than 150 thin sections were studied to get information on textures and minerals paragenesis. Optical work was carried out using 4 axial universal stage to determine
optical axial angle (2V) as also anorthite content of plagioclase and cleavage angle. Model analysis was carried out using point counter. After microscopic observation few samples were selected for major elemental geochemical whole rock analysis, microprobe as well as for fluid inclusion studies.

For mineral chemistry microprobe analysis for selected minerals like garnet, quartz, biotite and other accessory minerals present in the rock have done. The probe analysis were done in CAMECA SX 50 France, Paris based instrument at University of Mysore, Department of Geology, Manasagangotri, Mysore.

The operating conditions were 15 Kv accelerating voltage and 10 nA sample current with a beam diameter of 3 to 5 microns. Synthetic Mgo, Al₂O₃, TiO₂, Cr₂O₃, metallic Fe and Mn Narasasuckite for (Na), Wollastonite for (Si and Ca) and glass of 65% diopside, 35% leucite composition for (K) were used as standards. The analysis reported the mean of 1-4 point analysis for the homogenous phases. Core and Rim composition were analysis to find out zoning in minerals.

For geochemical analysis each sample weighing approximately 400gm was powdered using a TEMA AGATE MORTAR. The powders were dried out 100°C in a hot air oven before the sample were ready for analysis. Major element data were obtained using by Philips X Unique II X-ray Spectrometry system at Geological Survey of India, Bangalore.

Fluid inclusion study was carried out on doubly polished thin sections (100x120microns) with Leitz ortholux microscope using UT 40x objective. microthermometric studies were carried out using the Lincom (T.H.M.S model)
U.K. make heating freezing stage in the range of $-195$ to $+600^\circ$ c at Geological Survey of India Bangalore. The stage was calibrated at low temperature using pure $\text{CO}_2$ (triple point at $-56.6^\circ$ C) inclusion in natural quartz and using various standards of E. Merk for higher temperatures. Microthermometric data reported are within the $\pm 0.2$ c.