CHAPTER I

INTRODUCTION
The Archaean domain of south Indian shield classically termed as "Dharwar Craton" exposed over a large section of the continental crust through an exceptional transition form upper to lower crust (Pichamuthu, 1965; Janardhan et. al., 1982; Raase et. al., 1986; Bouhallier et. al., 1995). Archaean Cratons typically consist of three main rock associations — TTG Gneisses, greenstone belts and post tectonic K-rich granites (Windley, 1995). Like most Archaean Cratons (Condie, 1994; Windley, 1995) the Dharwar Craton is also made up of classical 'trilogy' of Archaean terrains. Most of the Archaean Cratons consist predominantly of granite-greenstone sequences formed in the late Archaean and appear to be temporarily linked to the process of craton stabilisation.

The Dharwar Craton (3400-2500 Ma) (Taylor et. al., 1984; Balakrishnan et. al., 1999) has been subdivided in to Western Tectonic Block (WTB) and Eastern Tectonic Block (ETB) (Swami Nath et. al., 1976), based on the nature and abundance of greenstone belts, degree of regional metamorphism and melting as well as the nature and age of their gneissic basement rocks (Swami Nath and Ramakrishnan, 1981; Jayananda et. al., 2000; Chadwick et. al., 2000). The Western Dharwar Craton (WDC) is dominated by TTG Peninsular gneisses and volcano-sedimentary greenstone belts, whereas the Eastern Dharwar Craton (EDC) is dominated by late Archaean granitic rocks with minor TTG and thin narrow elongated greenstone belts. The two blocks are separated by a network of vertical shear zones, thought to represent terrane boundary and along which the Closepet granite was emplaced (Moyen, 2000). The Dharwar Craton experienced a late Archaean (2.51-2.53 Ga, Buhul et. al., 1983; Nutman et. al., 1992) high temperature-low pressure metamorphism (Rollinson et. al., 1981; Hansen et. al., 1984; Bouhallier, 1995). This metamorphism was broadly synchronous with the emplacement of the granites and is accompanied by pervasive tectonic activity (strike-slip shear zone and dome-and basin patterns, Bouhallier et. al., 1993).
The EDC displays a few elongated greenstone belts. The prominent eastern greenstone belts, viz., Sandur, Hutt-Maski, Raichur, Gadwal, Ramagiri-Penakacherla, Kustagi-Hungund, Kadiri (Fig. 1), Veligallu, Kolar, Bisanattam, Khammam and several other smaller belts like Tsundupalli, Jonnagiri, Peddavuru, Gurugunta, Mangalur, Warangal; and major enclaves of greenstone patches are now known to form a part of the EDC (Fig. 2). As they are rich in gold and contain a small amount of sediments, they are considered to belong to a distinct group (Swami Nath et al., 1976). Their age ranges from 2.7 to 2.55 Ga (Balakrishnan et al., 1990; Krogstad et al., 1991; Vasudev et al., 2000). Although typical 3.1 Ga old Peninsular gneisses are present in the southwestern part of the EDC, a large part of the basement rocks are accreted between 2.7 and 2.55 Ga (Krogstad et al., 1991; Friend and Nutman, 1991; Peucat et al., 1989, 1993; Balakrishnan et al., 1999; Jayananda et al., 2000; Chardon et al., 2002). At mid-crustal depth and in the vicinity of the granulite isograd, 2.55–2.51 Ga juvenile plutonism led to the emplacement of large migmatitic and magmatic bodies during the regional tectonometamorphic event that affected the craton at the end of the Archaean (Peucat et al., 1989, 1993; Jayananda et al., 1995, 2000; Chardon et al., 2002; Moyen et al., 2003a).

Granite-greenstone tectonics is almost systematically synchronous with large-scale crustal melting and voluminous plutonism. The development of granite-greenstone pattern was coeval and compatible with deformation during juvenile magmatic accretion and melting (Chardon et. al., 2002). Numerous plutonic bodies were emplaced during the late Archaean tectonometamorphic episode. The study of this late Archaean juvenile magmatism is complicated by the fact that these mainly mantle-derived magmas strongly interacted with the crust in which they intruded. Their mantle characters were often obliterated and altered by a superimposed crustal signature, such that they were considered as having a mixed, if not pure, curstal origin (Querre, 1985; Jahn et. al., 1988; Stern and Hanson, 1991; Jayananda et. al., 1995).
Reviews have appeared from time to time which mark stages in the evolution in our knowledge about the geology of this interesting terrain: (Smeeth, 1916; Fermor, 1936; Rama Rao, 1940; Pichamuthu, 1947, 1967; Nautiyal, 1966; Radhakrishana, 1964, 1967; Srinivasan and Sreenivas, 1972; Naqvi et. al., 1974; Iyengar, 1976; Swaminath et. al., 1976; Radhakrishna and Vasudev, 1977; Swaminath and Ramakrishnan, 1981). In pursuance of the above, the researcher has taken up an area around Dorigallu in Kadiri Schist Belt, which lies in the Eastern Tectonic Block of Dharwar Craton, for his Doctoral dissertation (Fig. 1). This dissertation is aimed to understand stratigraphy, structure, lithology and petrogenesis of the granite-greenstone terrain of the study area. An attempt is also made to understand the tectonic setting of the area based on the field, petrological and chemical parameters. FCCI (False Colour Composite Imagery) has been used to the extent needed.

1.1.0. LOCATION AND ACCESSIBILITY:

The study area forms a part of northern most part of the Kadiri Schist Belt and it lies between North latitude 14° 15' and 14° 30', East longitude 78° 0' and 78° 10' bearing Toposheet number 57 J/3 of Survey of India and is geologically mapped on 1:50,000 scale (Fig 3).

In addition to Dorigallu, Molakavemula, Mudigubba, Adavibrahmanapalli Tanda, Indukuru, Bojanampalli are some of the villages included in the study area; of them, Mudigubba and Dorigallu are bigger villages.

The village Dorigallu is located 10 Km away from Mudigubba and is located in the main line from Anantapur to Kadiri. Mudigubba being a mandal head quarter is suitable place for camping to carry out the field studies as all the basic facilities are available there. It is situated on Dharmavaram-Pakala meter gauge section of South Central Railway. The Anantapur-Chennai high way passes through this area. All the points of the area are approachable by
roads/weather roads. The interior tracts are connected by metalled/un-metalled roads. The nearest air port is at Puttaparthy, spiritual centre of Bhagwan Sathya Sai Baba, which is 30 Km. away from the study area.

1.2.0. PHYSICAL FEATURES:

1.2.1. Topography and Drainage:

The area presents an undulating topography with number of isolated clusters of hillocks. The elevation in the area ranges between 1500 and 2654 ft.

The schist belt forms high ground as well as plain dotted with occasional hills. The major part of the area surveyed is granitic, where the country has either been leveled off into undulating plains or denuded into groups of residual ridges, knolls with tars and perched blocks.

Northeasterly flowing Maddileru River which is the main tributary of the Chitravathi is the major drainage. The drainage pattern of the area is mainly fracture controlled.

1.2.2. Climate and Rainfall:

The climate of the area is marked by hot summer months with low rain fall and experiences extreme climatic conditions as it is situated in the tropical zone. The temperature varies from 38°C to 45°C in summer and 15°C to 30°C in winter. Lying off the coast, the area does not get the full benefits of the northeast monsoon; and being cut off by the Western Ghats, the rainfall from the southwest monsoon is also scanty. Thus, the area is deprived of both the monsoons and subjected to recurrent droughts. The average annual rainfall in the area is 620 mm. The area in general experiences a dry semi-arid climate and most of the precipitations are received between July to November.
1.2.3. Flora and Fauna:

There are no thick forests in the study area due to scanty of rainfall and due to discriminate felling of trees by local people. The hills in the area support only grass and shrub type of vegetation. The important forests in the area are Dorigallu Reserve Forest, Thummala Reserve Forest ad Kadiri Reserve Forest.

The flora of the area reflects all the representative genera on a modest scale. The common species are Acacia Tamarindus Indicus (Chinta); Ficus Bengalesis (Marri); Azardhicta Indica (Vepa); Acacia Famifiana (Kampa Thumma); Anona Squamosa (Seethapalam); Mangifera Indica (Mamidi); Cassia auriculate (Thangedu) etc. The flora is of dry deciduous type.

The fauna includes rabbits, snakes, deer, monkeys, squirrels and great salamanders; the birds include woodpecker, sparrow, cuckoo, humming bird, pigeon, crow, eagle and bat. There is no wild life.

The agricultural activity is seen around the area. Groundnut, jowar, ragi, chilly and pulses are the main dry crops grown in the area. Paddy and other wet crops are grown along the river course and near major tanks.

1.3.0. PREVIOUS LITERATURE:

W. King (1872) was the pioneer who first laid his feet in the area of the 'Archaean crysatallines'. He considered the granitoids of Kadiri area as a part of the Archaean crysatallines.

Bruce Foote (1886), the first State Geologist of the newly created Mysore Geological Department has left an indelible mark on the Dharwar geology through his fundamental contributions. He carried out the earliest work in the belt and included it under the Archaeans.
Sampat lyengar (1906) reported amphibolites (now recognised as basic volcanics) and sheared mylonitic gneiss (now recognised as acid volcanics) from the belt. He considered that the belt was potential area for gold mineralisation as it had similar geological set up with that of auriferous Kolar Schist Belt.

Ballal (1965) mapped the northern part of the belt and gave an account of the geology of the area. Ranga Rao (1972) mapped the area and identified quartzite, cherty quartzite, conglomerate, sheared quartzofelspathic gneiss and metavolcanics. They included the granitoids under Peninsular Gneissic Complex.

Sinha and Sisodia (1978) carried out mapping on 1:63,360 scale with the help of aerial photographs in parts of Anantapur district. They identified amphibolite, hornblende schist, quartz porphyry, metarhyolite, metasediments and conglomerate.

Raju et al., (1979) in their "Operation Anantapur" have classified the Dharwar rocks into four linear schist belts, namely Pamidi Schist Belt, Ramagiri Schist Belt, Penukonda Schist Belt and Kadiri Schist Belt.

K. N. Rao (1983) carried out large scale geological mapping laying more emphasis on petrography and identified acid volcanics, basic volcanics and autoclastic conglomerate from the Kadiri Schist Belt.

S. M. K. Kazmi (1986) reported gold assay value of 0.72 ppm from grey quartz-rich pegmatoid intruding the metabasalt in the belt and recommended for detailed gold exploration.

C. Rama Mohana and N.S. Reddy (1990) gave a detailed account of the petrography and petrochemistry of the granitoids adjoining eastern greenstone belts. They opined that the granitoids are of magmatic nature and belong to post-Dharwar age.
K. N. Reddy (1992) during his regional geochemical surveys recommended for detailed geochemical sampling based on the field evidences and Au values obtained. S. Rama Murthy and S. Ananda Murthy (1993) carried out preliminary investigation for gold in Kadiri Schist Belt and recommended for further detailed investigation, including test drilling, to assess the potentiality of gold mineralisation.

According to R.C. Hanumanthu and P.B. Babaiah (1996), the granites of Ramagiri belt, which is adjacent to Kadiri Schist Belt, are magmatic, metaluminous, calc-alkaline and grouped under mixed origin. They suggest that tonalite-granodiorite suite of Ramagiri may be the partial melt of amphibolites of the schist belt which were recycled at the crust-mantle levels.

Meenal Mishra and V. Rajamani (1999) gave an account of the significance of Archaean bimodal volcanics from the Ramagiri Schist Belt in the formation of the Eastern Dharwar Craton. They have suggested that the phanerozoic style of magmatic and tectonic process could have operated during the Late Archaean in the generation of the continental crust of the Dharwar Craton.

K.N. Srinivasan (2000) who worked on the nearby Velligallu Schist Belt gave a detailed account of the geology of the area and suggested volcanic origin for conglomerate.

K. Sathyanarayana et. al., (2000) described the geochemistry of Archaean metavolcanics of Kadiri Schist Belt; they suggest that the volcanic suite was derived from an initial tholeiitic magma which gave rise to an early basaltic type and later calc-alkaline type of rocks.

According to Hanumanthu, R.C. and Padmasree, P (2003), the metavolcanics of the Kadiri Schist belt display tholeiitic to calc-alkaline affinity. The adjoining granitoids are magmatic, metaluminous and calc-alkaline and are
grouped under I-type. They suggested an island arc and continental margin tectonic setting for the evolution of the Kadiri Schist belt.

Hanumanthu, R.C. et. al., (2006) described that the volcanics of the Kadiri schist belt range in composition from basalt to rhyolite through rhyodacite; various chemical characteristics suggest that they are unaltered, sub-alkaline, and tholeiitic to calc-alkaline affinity.

A score of researchers have investigated the granite-greenstone terranes all over the world and the references from their works are mentioned at the appropriate places in the text of the thesis.

1.4.0. FCCI INFORMATION:

The study of FCCI (False Colour Composite Imagery) was done as a prelude to field work (Fig. 4) and the imagery expression is similar to the published imagery expression of granite-greenstone association of Australia (Hallberg and Glikson, 1991). Kadiri Schist Belt could be distinctly delineated on FCCI by the dark olive green tone trending in NNW - SSE in the northern part and N-S in the southern part over a strike length of 80 Kms. In the north, the belt is concealed under the cover rocks of Cuddapah basin. The light toned bodies adjoining the belt may be identified as granitoids. Discordant dark toned linear features are interpreted as dykes and are seen cutting granite-greenstone terrain but not the Proterozoic rocks of Cuddapah basin. This suggests that chronologically the dyke event is later to the evolution of granite-greenstones but prior to the evolution of Cuddapah basin. Linear leuco ridges define quartz reefs occupying faults/fractures.

1.5.0. GEOLOGICAL SETTING:

The rocks encountered in the study area are grouped in to following units:
1. Schist belt rocks comprise metabasalt, metarhyolite, metarhyodacite, quartz porphyry, quartz feldspar porphyry, volcanic conglomerate.

2. Granitoids include Tonalite-Granodiorite-Monzogranite (TGM) suite, Monzogranite-Syenogranite (MS) suite and Post-orogenic granites (Alkali Granites).

3. Mafic dyke rocks mainly dolerites and gabbros.

The Kadiri Schist Belt is unique in having larger area occupied by meta-acid volcanics and hence represents the higher stratigraphic level in greenstone model. (Anhaeusser et. al., 1969).

The enclaves of the pre-existing country rocks i.e., schist belt components mainly metabasalt are seen in both TGM suite and MS suite. The cross-cutting relation ship of Alkali granites with TGM and MS suites suggest that the last phase of granitic injection which perhaps may be correlated with pegmatite veins present abundantly in granitoids.

Numerous basic dykes are present as intrusives in all the formation representing the last phase of igneous activity in the area. The quartz reefs forming high hills in the area show abrupt end at the schist belt – granite contacts indicating their tectonic nature.

There is no direct field evidence to suggest that the greenstones were laid in sialic basement. Presence of granitoid clasts in volcanic conglomerate (indirect yet a strong evidence) points to the existence of sialic crust on which the components of the schist belt were deposited.

Based on the field observations and reports of the earlier workers the following stratigraphic succession has been worked out for the granite-greenstone terrain of the study area.
1.5.1. Stratigraphic Succession:

Quartz reefs
Gabbro, dolerite, granophyre, anorthosite

--------- Intrusive Contact ---------

Pegmatite, Quartz veins
K-rich granites
Mafic Dyke Swarms

Post-orogenic granite suite
(Alkali Granite)

Monzogranite-syenogranite including
brittle-ductile shears controlled medium
to homophanous granite

Monzogranite-syenogranite including
brittle-ductile shears controlled medium
to homophanous granite

Tonalite-granodiorite-monzogranite
with synplutonic microgranitoid mafic
dyklets and mafic enclaves.

Homblendite-Diorite sub-suite with injections
of net-veined bodies/veins of diorite, potash
rich pegmatites and aplites.

--------- Intrusive Contact ---------

Porphyries (quartz porphyry and quartz feldspar porphyry)
Dacite-rhyodacite with volcanic conglomerate/agglomerate
and Rhyolite

Schist belt
litho-units

Metabasalt (pillowed and vesicular/amygdular)

--------- Unconformity ---------

Gneiss Basement (Sialic?)
1.6.0. METHOD OF STUDY:

An area of about 305 sq. km. has been geologically mapped on 1:50,000 scale. Nearly 150 rock samples of various litho-units are collected and thin sections are made for mineralogical and petrographic studies. The inter-relationships of rocks are worked out by the contact studies. The optical properties of the minerals like optic axial angle (2V), extinction angle (ZAC), the birefringence value (Nz-Nx) are determined with the help of Leitz-4 axes universal stage. The anorthite content and twin laws of plagioclase are determined by the method of Reinhard (1931). The complex laws are checked following the methods suggested by Nikitin (1936) and Berek (1924). The birefringence of the mineral is determined by computing its thickness with the help of plagioclase or quartz. The modal compositions of various rocks are determined in Leitz-6 spindled integrating stage.

After careful petrological examination of the thin sections of rocks from different formations, appropriate samples are selected for geochemical analysis taking the aerial extent of the formations and unaltered nature. They are powdered for major, trace element analysis and REE. The analytical techniques outlined by Shapiro and Brannock (1962) and Shapiro (1975) are followed for major element analysis. Spectronic-20 (Baush and Lomb Spectrophotometer) is used to determine SiO₂, Al₂O₃ total Iron as Fe₂O₃, MnO, P₂O₅, TiO₂; Elico-flame photometer is used to determine Na₂O and K₂O; CaO, MgO and FeO are determined by titrimetric methods. Loss on Ignition (LOI) is determined by loss of weight of 1gm of the sample after it is dried over night at 110°C.

The standards are readily checked against the standard specimen of the granite (G1) and the diabase (W1) described by Fairbairn et. al., (1951). Trace elements like, Co, Ni, Cr, Cu, Pb, Zn, V, Ba, Sr, Rb are estimated for all these rocks by Varian-Techtron Atomic Absorption Spectrophotometer and Zr is determined with the help of Direct Current Plasma Spectrometer. The ICP-MS
chemically analysed for major and trace element analysis and 14 rock samples are
analysed for REE. Major element analysis has been carried out in the Department
laboratory; the trace element and REE analysis has been carried out in the GSI
laboratories, Hyderabad.

The present investigation is limited to field, petrographic and petrochemical
(major and trace element analysis and REE) studies only. Though the author is
aware of the use of advanced techniques like x-ray studies, microprobe analysis,
mass spectroscopy, etc., in the petrological studies, he could not employ these
methods for want of necessary equipment.
FIG. 1: LOCATION MAP OF THE AREA INVESTIGATED
INDEX

- DECCAN BASALT
- PHANEROZOIC SEDIMENT
- LATE PROTEROZOIC BASINS
- GRANITE
- SCHIST BELTS
- UNDIFFERENTIATED GNEISS
- GNEISS GRANULITE TRANSITION
- THRUST

FIG. 2: EASTERN DHARWAR CRATON SHOWING DISTRIBUTION OF MAJOR GREENSTONE BELTS.
FIG. 4: FALSE COLOUR COMPOSITE IMAGERY MAP (FCCI)
KADIRI SCHBET BELT