Chapter 2

Geology of the Study Area
2.1 Introduction
The regional geology of the study area comprises of two major terrains, the Dharwar Craton in the north that constitutes of low grade granite-gneiss-greenstone terrain of Archaean age and Late Archaean to Neoproterozoic high grade Granulite terrain known as Southern Granulite Terrain (SGT) towards the south (Figure 2.1). These are separated by a narrow transition zone along which the low grade greenstone granite domain transforms into high grade granulite facies rocks (Swaminathan et al., 1976). A set of major faults or shear zones trending in the east west and north south direction traverse between the transition zones and the SGT some of which are the Moyar shear zone, Bhavani shear zone, Kollegal shear zone and the Palghat Cauvery shear zone.

2.1.2 Dharwar Craton
Dharwar Craton is divided into two blocks, i.e. the Western Dharwar Craton and Eastern Dharwar Craton (Swami Nath and Ramakrishnan, 1981; Naqvi and Rogers, 1987) with respect to their degree of regional metamorphism, melting, abundance of the greenstone belts, and the nature of the basement gneissic rocks (Jayananda et al., 2000; Chadwick et al., 2000). The Eastern Dharwar Craton has fewer expression of supracrustal rocks and contain many discrete granitic bodies. Of late Archean to early Proterozoic age. Western Dharwar Craton that lies north of the study area is composed mainly of Tonalite-Trondhjemite-Granodiorite (TTG) gneiss popularly known as Peninsular Gneiss which is almost 3.4 Ga old (Beckinsale et al., 1980; Taylor et al., 1984; Meen et al., 1992; Peucat et al., 1993) and highly deformed and metamorphosed supracrustal rocks known as the Sargur group. Sargur group of rocks are present as narrow belts and enclaves and are composed of metapelites, ferruginous quartzites together with gabbro anorthosite ultramafic intrusion (Ramakrishnan et al., 1978). A complex of younger gneisses and granites has later intruded the TTG. It is overlain unconformably in an extensive area with metavolcanic and metasedimentary rock which is named as Dharwar supergroup (Swaminath and Ramakrishnan, 1981). The youngest of the volcanic in the region are of latest Archean in age, dated ~2.6 G.a. (Taylor et al., 1984; Drury et al., 1984).
Figure 2.1. Geological map of Cauvery river basin modified after Santosh et al., (2009) showing different sedimentary units and high altitude hill regions. NG - Nilgiri Hills, BRG -Biligirirangan Hills, KDH- Kodaikanal Hills, PCSZ - Palaghat-Cauvery Shear Zone, CSZ- Cauvery Shear Zone, MSZ- MoyarShear Zone, BSZ – Bhavani shear Zone, ACSZ- Achankovil shear zone. Number 1 to 9 denote the sampling locations as follows: 1- MK(Moorkanad); 2-SPB (Soosaipuram); 3-TH (Talamalai); 4-DB (Dhimbam); 5-KPA (Kattabettu); 6-KTG (Addave); 7-L2 (Kaikatty); 8-B (Kurukuthy); 9-CK (Burgur road).
The TTG gneiss (Peninsular gneiss) which form the predominant lithology consists of leucocratic and melanocratic bands. The leucocratic bands consists of quartz, K-feldspar and plagioclase with traces of muscovite, apatite and Zircon while the melanocratic bands are composed of biotite, hornblende and epidote. The WDC shows an increase in regional metamorphic grade from greenschist facies in north to amphibolite facies in the south and finally ends up in the granulite facies in the southern most part. The amphibolite grade gneisses of the Dharwar Craton towards its southern margin is transformed into granulite facies rocks of higher metamorphic grade. The above transformation of metamorphic grade is through a continuous transition zone marked by the first appearance of clinopyroxene, orthopyroxene formed by breakdown of hornblende resulting in transition to typical hornblende-granulite facies assemblage. With continuous increase in metamorphic grade towards south complete breakdown of amphibole is noticed in the highest grade region giving rise to hypersthene granulite facies with mineral assemblage changing to plagioclase + clinopyroxene + orthopyroxene + garnet +quartz, although hornblende is still found to be present in quartz-deficient mafic granulites (Raase et al., 1986). The zone along which the first appearance of orthopyroxene is noted marking the change from amphibolites to granulite grade metamorphism has been used to demarcate the boundary between the Dharwar Craton (DC) and the Southern Granulite Terrain (SGT).

2.1.3 Southern Granulite Terrain:
The SGT has been further subdivided into three major blocks, the Northern Granulite Block (NGB) occupying the area between Dharwars and the Palghat-Cauvery shear zone, the Southern Granulite Block (SGB) between two major shear zones viz., Palaghat-Cauvery and Achankovil (Madurai Block) and the third called Kerala Khondolite Block (KKB) to the south of Achankovil (Trivandrum Block). The present study area is confined to the Northern Granulite Block of the Southern Granulite Terrain. The Northern Granulite Block is separated from the Dharwar Craton by series of shear zones. The most prominent of them is the Moyar and Bhavani shear zone that bounds the Nilgiri hills granulite terrain and also forms the southern border of the Biligirirangan hills Granulite terrain. The Biligirirangan hills is further separated from Dharwar Craton by less studied Kollegal.
Shear Zone. The present study is confined to Northern Granulite Block and therefore it is elaborated further along with the shear zones bounding it.

2.1.4 Nilgiri granulite Terrain:
The Nilgiri hills is separated in north from Dharwar Craton by crustal scale Moyar shear zone and towards the south is bounded by Bhavani shear zone. The Nilgiri hills has exposed deep seated high grade granulite facies lower crustal rocks estimated to vary between 35km to 22 km from north to south in their paleo depth levels (Raith et al. 1999). It is predominantly composed of garnetiferous enderbitic charnockite that has been subjected to polyphase deformation. The granulite facies metamorphism in Nilgiri hills occurred about 2.5 Ga ago. (Raith et al., 1990, 1999). Mappable bodies of non garnetiferous enderbites, garnetiferous basic granulites, two pyroxene granulites with the gabbroic to anorthositic composition and pyroxenites are noted to occur as elongated lensoidal bodies within the major garnetiferous charno enderbites. These occur as lenses or elongated bodies trending parallel to the regional foliation trend. The dominant garnetiferous enderbite is composed of Plagioclase + quartz + orthopyroxene + garnet + biotite mineral assemblages. Raith et al (1999) have also reported minor presence of banded iron formation, quartzites and kyanite bearing gneisses from Nilgiri hills massif. The origin of Nilgiris is assumed to be due to the gradual block upliftment in multiple phases (Raith et al., 1990, 1999; Harris et al., 1994; Valdiaya 1998). Dodabetta is the highest peak in Nilgiris with an elevation of almost 8640 ft.

The region west and south west of Nilgiri hills in Malapuram district of Kerala lies between the western extension of Moyar and Bhavani shear zones. The major rock types in this area comprise hornblende-biotite gneiss, granitic gneiss at places with the interbanding of massive amphibolites. Another important rock type is the charnockite and charnockites gneiss with bodies of banded magnetite quartzite, meta gabbro, pyroxene granulite, amphibolites and pyroxenites. In the central and northern part, the migmatite complex is characterized by biotite hornblende gneiss, quartzo-feldspathic or garnet–biotite leucogneiss with layer of garnet–sillimanite gneiss.
2.1.5 Biligirirangan hills granulite terrain:
Biligirirangan hills also form part of the northern block of the Southern Granulite Terrain and marks the eastern fringe of the Mysore Plateau. It is bounded towards the south by E-W trending Moyar - Bhavani shear zone and towards the east by Mettur shear zone. The north south trending Kollegal shear zone forms the western border and separates the Biligirirangan hills from the amphibolite grade hornblende-biotite gneiss of the Dharwar Craton lying west of it. The early to late Archean non garnetiferous charnockite-enderbites are the predominant lithology of the Biligirirangan granulite. The charno-enderbites of BR hills are either massive or banded and numerous basic granulites occur as layer and bands within it. Apart from above small exposures of quartzites, metapellites and calc silicates occur in the area. Peaks of Biligirirangan hill ranges rise to maximum height of 1800 m and ranges between 1000 to 1800 m.

2.1.6 Shear zones:
The major shear zones comprise Moyar, Bhavani (MBSZ), Palghat Cauvery (PCSZ), Salem-Attur shear zones (SASZ) and Cauvery shear zone Madurai block (CSZ/MB) (Swami Nath and Ramakrishnan., 1981; Harris et al., 1994; Bhaskar Rao et al., 1996; Raith et al., 1990, 1999; Valdiya., 1998; Chadwick et al., 2000; Jayananda et al., 2000; Meißner et al., 2002; Tomson et al., 2006). The shear zones are supposed to have been reactivated during later periods resulting in the formation of block mountains, dominantly made up of granulites (Raith et al., 1990, 1999; Harris et al., 1994, Valdiya., 1998). The shear zones form part of the extensive low lands between the highlands comprising of charnockites. The shear zones particularly the CSZ and CSZ/MB are made up of charnockite gneisses and migmatite gneiss along with some supracrustal rocks. In addition the CSZ also contains dismembered lenses of granulate facies layered anorthosite-gabbro-pyroxenitechromitite bodies, whereas the CSZ/MB contains granitic intrusions. The prominent shear zones present in the study area include Moyar-Bhavani shear zone, Mettur shear zone and Kollegal shear zone.

2.1.7 Moyar Bhavani shear zone:
The ESE trending Moyar shear zone along with NE trending Bhavani Shear Zone forms separately the northern and southern border of Nilgiri hills respectively. Both shear
Zones joints together at Bhavani Sagar towards the east forming the eastern border of Nilgiris. They separate the Nilgiri charnockite massif from the Dharwar Craton and the Biligirirangan hills.

MSZ was established ~2.5 Ga ago when the Nilgiri hills got welded with the Dharwar Craton of Archaean age. The associated high grade metamorphism with this event resulted in formation of migmatites in the SW Dharwar Craton and high pressure granulites of Nilgiri hills (Raith et al., 1990, 1999). In the MSZ and BSZ domain, felsic to intermediate granulite and paragneisses are retrogressed to amphibolite facies (Srikantappa and Narasimha, 1990). Shearing and flattening has led to formation of hornblende – biotite gneisses, hornblende–biotite gneisses and biotite garnet gneisses all with mylonitic fabrics. Within the low strain domain of the above reworked rocks are preserved the relict enderbite, mafic and ultramafic granulites. Pegmatites and granites occur as slices and boudins within mylonitic gneisses.

2.1.8 Kollegal Shear Zone (KSZ):
KSZ forms 8 to 10 km wide and ~65 km long NNE-SSW trending shear zone that forms the western border of the BR hills granulite terrain. It separates the BR hills from the lowland region of the Dharwar Craton, dominantly peninsular gneisses, lying towards the west. Field and petrographic studies show retrograde metamorphism of almost all the granulite facies rock types of BR hills along the KSZ during ductile to ductile-brittle type deformation. The relict orthopyroxene in the gneisses within the shear zone indicate the original rocks of granulite facies. Quartz grains in the charnockite gneisses from the shear zone contain ribboned quartz that suggests intense shearing. As a result of retrogradation, pyroxene is found to have altered to amphibole and at place the shear zone contain epidote veins. Biotite also shows serrated margins and epidote occurs as thin veins. Layers of mylonites and ultramylonites are noted to occur near Dhimbam area towards the southern end of the shear zone. The mineral assemblages in the gneisses from this zone indicate that granulite facies rocks have retrograded to epidote-amphibolite facies rocks.
2.2 Western Ghats:
The study area is bordered on the western side by high standing hills and mountain ranges with an average elevation of around 1400 m. This elevated area forms part of the continuous NNW- SSE trending chain of mountains known as the Western Ghats that border the western part of peninsular India. Western Ghats is almost 1600 Km in length and extends from Tapti estuary in the north to Cape Comorin in the south, fringing the western coast. The Western Ghats rises in elevation towards the south. The lithology of the Western Ghats changes from Deccan basalt in the northern part between Tapti to Goa to mostly gneisses, schist and charnockites in the southern part bordering Karnataka, Tamil Nadu and Kerala. The highest peaks in the northern part of the Ghats in Maharashtra includes Kalsubai (1646 m) and Mahabaleshwar (1438 m) and in the south Kudremukh at 1862 m and Mullayanagiri at 1925 m forms the highest peaks in Karnataka, whereas Ana Mudi at 2695 m in Kerala forms the highest peak in the Western Ghats. The only major gaps in the range estowards the south is the Palghat gap that provides a connecting passage between Kerala and Tamil Nadu. The elevated region of Western Ghats extend eastward in part of North West Tamil Nadu where it is joined by Eastern Ghats in the Nilgiri hills region (Gunnel, 1998; Radhakrishna, 1967). In this part the Western and Eastern Ghats enclose the Mysore plateau which forms a flat region at an elevation of ~900m.

The study of cross sectional profile across the Western Ghats reveal that it forms precipitous step wise escarpments towards the west, whereas it is gently sloping towards the east where it gradually merges with the plains. On the western side it is separated from the sea by a narrow belt of lowlands ranging 30 to 90 km in width. The Western Ghats abruptly rises from the coastal plains to an elevation of ~1000 m in a short distance of 2-5 Kms (Radhakrishna 1968). In Karnataka region, the eastern side of Western Ghats forms a vast flat terrain of Mysore plateau with a table top morphology elevated to almost 900 m above sea level. The table land is surrounded by mountain ranges in all the sides except north. On moving south Mysore plateau merges with the low lying terrain of Moyar shear zone, south of which lies the abruptly rising Nilgiri hills. Similarly on the eastern side of the transition zone and Moyar shear zone the Biligirirangan hills rises sharply from the low lying areas of surrounding to a height ranging from 1000-1600 m.
2.3 Climate of the study area:
The Western Ghats play a critical role in the climate of Peninsular India. The major climate controlling factor in the Indian sub-continent is the South West (SW) monsoon. The Western Ghats acts as an orographic barrier for the SW monsoon (Balachandran et.al 2006) and it causes maximum amount of rain in lowlands of Kerala and the western slopes of the Ghats, whereas it causes the rain shadow effect for the areas falling in the eastern slope of the Ghats (Gunnel et al 2000). The western slopes are thus most wet and humid, while going eastward winds loses moisture and thus it gives very less precipitation and thus the climate changes from humid to semi arid.

![Rainfall map of the study area showing the sampling locations. Abbreviations for profile locations: MK-Moorkanad; SPB-Soosaipuram; TH-Talamalai; DB-Dhimbam; KPA-Kattabettu; KTG-Addave; L2-Kaikatty; B-Kurukuthy; CK-Burghur road. (After Gunnel 2000.)](image)

Figure 2.2: Rainfall map of the study area showing the sampling locations. Note the sharp west to east gradient in rainfall. Abbreviations for profile locations: MK-Moorkanad; SPB-Soosaipuram; TH-Talamalai; DB-Dhimbam; KPA-Kattabettu; KTG-Addave; L2-Kaikatty; B-Kurukuthy; CK-Burghur road. (After Gunnel 2000.)

Thus it results in broad linear north to South belt of high rainfall and low rainfall region almost paralleling the Western Ghats (Fig. 2.2). The clouds that loose most of their moisture after crossing over the Western Ghats again cause rainfall only after meeting the higher
ground of Central and Northern India. In general the areas of heavy rainfall on the windward side of the Western Ghats receive most of its rainfall during the south-west monsoon season. The Western Ghats thus results in large variation in the rainfall with western side of the ghats receiving rainfall of > 4000 mm that reduces to < 1000 mm on the eastern plains (Fig.2.2). Rainfall higher than 5000 mm is found only along the western slope of Anaimalai, Palani and Nilgiri ranges whose high elevations favour condensation. In the study area the Malapuram region of the Kerala receives rainfall ranging between 3000-5000 mm, whereas in Nilgiri hills it reduces from west to east and ranges between 5000 and 900 mm across a short distance of ~60 Kms. A major part of the high Nilgiri plateau receives rainfall of 1500 to 1000 mm. In the north of Nilgiri hills in the area of transition zone the rainfall decreases from 1000 mm to 800 mm, whereas towards NE direction it reduces to < 800 mm over Biligirirangan hills. The mean annual temperature of the Kaveri basin is 25°C although in summer (March to May) the maximum temperature reaches 43°C. The gradation in the rainfall has resulted in microclimatic zonation of the study area that from west to east changes from wet and humid to sub humid to semi-arid. The gradation in rainfall has also effected the weathering intensity and hence nature of soil developed in different parts of the study area.

2.4 Weathering profiles:

For the present study samples were collected from the weathering profiles from total of nine locations, four over gneisses and five over charnockites.

The weathering profiles developed over gneissic rocks constitute (1) MK over hornblende biotite gneiss located at Moorkanad in Malappuram district of Kerala (2) SPB profile over quartzo-feldspathic biotite gneiss from Soosaipuram, Thalavadi (3) TH profile over migmatitic garnetiferous Quartzo-feldspathic biotite gneiss from Talamalai region and (4) DB profile over mylonitized Charnockitic gneiss from Dhimbam and five weathering profiles developed over charnockitic rocks includes there over garnetiferous charno-enderbites from (1) Kattabettu (KPA profile), (2) Addave (KTB profile) and (3) Kurukuthy (B profile) and two over non garnetiferous charno-enderbites from (1) Kaikatty (L2 profile) and Burgur Road (CK profile).
The following charts give summary of the studied weathering profiles. The detailed descriptions of the profile are given in subsequent chapters

<table>
<thead>
<tr>
<th>Profile Code</th>
<th>Location</th>
<th>Latitude Longitude</th>
<th>Parent rock</th>
<th>Altitude</th>
<th>Temperature (°C)</th>
<th>Annual Rainfall (mm/year)</th>
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</thead>
<tbody>
<tr>
<td>1. MK profile</td>
<td>Moorkanad, Malappuram dist, Kerala</td>
<td>N11°14’10.68” E76° 03'44.02”</td>
<td>Hornblende biotite gneiss</td>
<td>~70 m</td>
<td>27.2</td>
<td>&gt;3000 mm</td>
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<td>2. SPB profile</td>
<td>Soosaipuram, Talavadi</td>
<td>N11°45’48.05” E76° 58'05.46”</td>
<td>Quartzofeldspathic biotite gneiss</td>
<td>800 m</td>
<td>23.9</td>
<td>~690 mm</td>
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<td>3. TH profile</td>
<td>Talamalai</td>
<td>N11°36’41.8” E7°04’15.3”</td>
<td>Garnetiferous Quartzofeldspathic biotite granite (Migmatitic/mylonitic)</td>
<td>1150 m</td>
<td>~22</td>
<td>950 mm</td>
</tr>
<tr>
<td>4. DB profile</td>
<td>Dhimbam</td>
<td>N11°36’75” E77°07’74”</td>
<td>Charnockite gneiss (Migmatitic/mylonitic)</td>
<td>1060 m</td>
<td>23</td>
<td>&lt;800 mm</td>
</tr>
<tr>
<td>5. KPA profile</td>
<td>Kattabettu</td>
<td>N11°24’05” E76°48’76”</td>
<td>Garnetiferous charnockite (charnoenderbite)</td>
<td>1989 m</td>
<td>15.6</td>
<td>~1600 mm</td>
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<td>6. KTG profile</td>
<td>Addave</td>
<td>N11°25’575” E76°50’57”</td>
<td>Garnetiferous charnockite (charnoenderbite)</td>
<td>1980 m</td>
<td>16.2</td>
<td>~1400 mm</td>
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<td>7. B profile</td>
<td>Kurukuthy</td>
<td>N11°28’22.63” E76° 53’50.18”</td>
<td>Garnetiferous charnockite (charnoenderbite)</td>
<td>1900 m</td>
<td>16</td>
<td>~1334 mm</td>
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<td>8. L2 profile</td>
<td>Kaikatty</td>
<td>N11°26’79” E76°53’64”</td>
<td>Enderbitic charnockite</td>
<td>1890 m</td>
<td>~16</td>
<td>1400 mm</td>
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<td>9. CK profile</td>
<td>Burgur road</td>
<td>N11°42’35.9” E77°34’02.3”</td>
<td>Enderbitic charnockite/Basic granulite (intlayered)</td>
<td>650 m</td>
<td>27.7</td>
<td>&lt;750 mm</td>
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