CHAPTER-3

GEOLOGY OF THE AREA
AND STRUCTURAL STUDIES
3.1 INTRODUCTION

Dharwar craton of Karnataka State is one of the Peninsular shield areas of India. In general, the geology of the shield area is complex, and geological formations of Karnataka State form such a complexity, which has been the subject of debate over a number of years. Thus, a brief review of geology of Karnataka State will help in better understanding of the geology and correlation of the lithological formations of the present area under study.

3.2 GEOLOGY OF KARNATAKA STATE

Geologically Karnataka State consists of Archaean complex (covering an area of 1,48,500 sq kms), Proterozoics and Cretaceous traps (Fig. 3.1). The Archaean complex of Karnataka State is a part of the Dharwar Craton, which comprises of greenstone-granite belts, gneisses and granulites. Greenstone belts are prominent in the eastern and western blocks of this craton set against the back drop of Peninsular migmatitic gneiss complex. The sediment dominated younger greenstone belts of western block are categorised as greenstone, like geosynclinal piles, which include Chitradorga schist belt, Sandur schist belt and Bababudan schist belt of Chitradorga, Sandur and Bababudan basins
Fig 31 Geological map of Karnataka (After Swaminath et al., 1981)
(comprising of metavolcanics, chlorite schists, greywackes, quartzites and B.I.F s). Their grade of metamorphism is in greenschist facies. These larger and younger Dharwar schist belts are located in the northern part of the low grade terrain. The eastern block greenstone belts are the older greenstone belts, viz., Holenarasipur, Kolar and Nuggihalli schist belts and are composed predominantly of basic volcanics, (mafic-ultramafic complex, anorthosites, amphibolites, metapelites and fuchsite quartzites) and most of them are located in the southern and eastern parts and are generally in mid-upper amphibolite facies. Excluding these rocks, most of the area is composed of gneissic complex termed as Peninsular gneissic complex.

The Peninsular gneiss is a 'sack' term for the 'granitic' gneisses underlying and intervening between the schist belts (Hargraves and Balla, 1982). It includes migmatized remnants of supracrustal sedimentary and volcanic rocks, mostly in amphibolite facies, together with variably deformed and metamorphosed metabasic dyke relics. A number of more massive, apparently intrusive granite bodies (like Closepet granite, 2500-2000 Ma) are distinguished from the so called Peninsular gneisses. These schists and gneisses gradually give way to the granulites in the southern region.
In the southern part of the craton and bordering the granite-greenstone terrain are the high grade granulites, i.e., the granulitic rocks which are in association with the rocks similar to Khondalites.

Numerous acid and basic dykes of different episodes occur as intrusives, in these different formations. These Archaean formations are covered by younger Kaladgis, Badamis and Bhima sediments in the northern part of the state. The mesozoic traps overlay these younger formations at places in the northern part. The ferruginous and aluminous laterites are spread over as pockets throughout the state.

This craton with abundant exposures of Archaean formations with varied lithologies offers a unique setting for various geological studies. The general geology of this craton is well documented in the geology literature. Structurally, petrologically and chronologically the granitic and schistose rocks of Dharwad craton constitute a complex, and, have been studied by generations of geologists in the recent past.

3.3 REVIEW OF THE PREVIOUS WORK

The pioneer work on this Archaean complex was made by
Captain Nevbold (1844) and has proposed two-fold classification as Protogene and Hypogene gneisses and schists. In 1881, Bruce Foote gave a detailed account of these lithounits. Sambashiva and Slater (1894) surveyed these areas and marked the schistose formations, and described them as 'Dharwar Schists'. Later, Bruce Foote resurveyed these areas and opined that, these schistose rocks rest unconformably on the granitoid gneisses.

Reviews have appeared from time to time which mark stages in the evolution in our knowledge about the geology of this terrain (Rama Rao, 1940; Radhakrishna, 1964, 67; Nautiyal, 1966; Srinivasan and Sreenivas, 1972; Naqvi et al, 1978, 80; Iyengar, 1976; Swami Nath et al, 1976; Radhakrishna and Vasudev, 1977; Swami Nath and Ramakrishnan, 1981). The older greenstone belts particularly Sargur, Kolar, Huttı, and Javanahalli schist belts have been studied by many geologists (Janardhan et al, 1978; Naqvi, 1978; Swami Nath and Ramakrishnan, op.cit.; Shivakumar et al, 1982; Hussain et al, 1982; Scott-Argast, 1982; Chadwick, 1988; Chavadi, 1988) and equally lot of work has been done on the gneissic complex (Bhaskar Rao, 1982; Monard,1982; Stroh,1982;Kumar et al, 1982; Naqvi, 1982). Because of their complexity, granulites have been the subject of controversy in the recent past (Devaraju, 1969, 88; Friend, 1981; Raith, 1982; Taylor, 1983; Janardhan, 1990).
3.4 STRATIGRAPHIC RELATIONS IN DHARWAR CRATON

The stratigraphic position of Dharwars, in the Precambrians is still a much debated aspect. From Bruce Foote (op.cit.) to till today many classifications have been proposed by various workers (Smeeth, 1916; Narayana Rao, 1940; Nautiyal, op.cit.; Ramakrishna, 1968; Iyengar and Jayaram, 1970; Pichamuthu, 1974; Radhakrishna, 1975; Ramakrishnan and Vishwanath, 1976; Swami Nath op.cit.; Naqvi, op.cit. etc.). The classification given by Radhakrishna (op.cit.) and the recent classifications proposed by Swami Nath and Ramakrishna (op.cit.) and Naqvi (1981) are given in Tables 3.1 and 3.2.

Radhakrishna (op.cit.) divides these schistose rocks into Older-Supracrustals, which include Holenarasipura, Nuggihalli, Krishnarajpet, Nagamangala and Javanahalli schist belts, characterised by an age of about 3000 Ma. The Younger greenstone sequences are grouped in Dharwar type with < 3000 Ma. The lithounits formed within a period between 3000 - 2500 Ma marked the transition from Archaean to Proterozoic crust. However, the age relation between the gneisses and schists is an over debated problem. According to one school of thought, Peninsular gneiss is the basement for Dharwar Super group and is intrusive into Sargur
### TABLE - 3.1 : CLASSIFICATION OF RADHAKRISHNA (1968)

<table>
<thead>
<tr>
<th>Series</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaladgis</td>
<td></td>
</tr>
<tr>
<td>Supa-Dandeli series</td>
<td>Phyllites, Slates, Ankeritic limestone and minor beds of Ferruginous Quartzites</td>
</tr>
<tr>
<td>Sirsi-Ranibennur series</td>
<td>Greywacke, Slate, Tuffs, minor bands of brecciated Ferruginous Quartzites</td>
</tr>
<tr>
<td>Grey trap series</td>
<td>Epidioritic flows, Pillow lavas, Agglomerate and Tuffs</td>
</tr>
<tr>
<td>Dodguni series</td>
<td>Phyllites, Clay-schists, Dolomites and high calcium Limestone, Banded Ferruginous Quartzites and iron ores</td>
</tr>
<tr>
<td>Bababudan series</td>
<td>Massive beds of iron ore, Banded Ferruginous and magnetite Quartzite, Argillite, Quartzite and Basic lava flows</td>
</tr>
<tr>
<td>Basement complex</td>
<td>(A complex of granites and gneisses with lenses and patches of an earlier series of sediments and basic igneous rocks)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Kaladgi Group</td>
<td>Kaladgi Group (1700 M.Y.)</td>
</tr>
<tr>
<td>Profound unconformity--------</td>
<td>----Profound unconformity</td>
</tr>
<tr>
<td>Younger Granites and Peninsular Gneisses (phase II)</td>
<td>Closepet and Koppal Granites (2000 M.Y.)</td>
</tr>
<tr>
<td>Chitradurga Group</td>
<td>Ranibennur Group</td>
</tr>
<tr>
<td>---Unconformity----</td>
<td>Chitradurga granite (2500 M.Y.)</td>
</tr>
<tr>
<td>Bababudan Group</td>
<td>Grey gneisses and Mavikere trondjemute (2800-3000 M.Y.)</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Peninsular Gneisses (main phase, including Chikmagalur and Mavikere granites)</td>
<td>Bababudan Group (3000 - 3300 M.Y.)--Profound unconformity--Grey banded gneisses (3200 M.Y.)</td>
</tr>
<tr>
<td>Sargur Group</td>
<td>Javanahalli Group (3200- 3200 M.Y.)</td>
</tr>
<tr>
<td>Gorur gneisses and its enclaves</td>
<td>Gorur gneisses (3400 M.Y.)</td>
</tr>
<tr>
<td></td>
<td>Holenarasipur - Nuggihalli Group (3500 M.Y.)</td>
</tr>
<tr>
<td></td>
<td>Basic to ultrabasic lunar type crust</td>
</tr>
</tbody>
</table>
group, a stratigraphic unit older than Dharwar Supergroup. The granulites are younger than both Peninsular gneisses and Sargur group and older than Dharwar Supergroup (Swami Nath and Ramakrishnan, op.cit.). The other school believes that, there are no rocks recognisable older than Dharwar rocks (Pichamuthu, 1982).

Folding, faulting and rifting of this 3000 Ma old crust have given rise to long linear oval shaped basins which are named under Shimoga, Chitradurga and Sandur basins (Radhakrishna, 1982). Since the study area forms part of Shimoga basin, a brief description of the same is given below.

3.5 GEOLOGY OF THE VARADA BASIN

Shimoga basin is the largest amongst the three above mentioned basins, and covers an area of 22,500 sq kms and stretches for a length of 250 km with a maximum width of 120 km. The extension of the basin further north and west is obscured by the cover of Deccan traps and the Arabian sea. The basin is characterised in the south by mafic volcanics (Bababudans) and thick sequence of greywacke in the northern part of the basin. Here and there, the presence of ortho-quartzite and basic rocks is common.
As mentioned earlier, the area under investigation forms a part of Shimoga basin and the lithounits belong to Ranibennur-Sirsi-formation of Radhakrishna (op.cit.) (Table 3.1), Ranibennur formation of Naqvi (op.cit.) and Chitrardurga group of Swami Nath et al (op.cit.)(Table 3.2).

The major lithounits of the study area are greywackes, biotite-schists, phyllites, shales and basic intrusions. The biotite schist is confined to the south western border of the region, with laterite capping here and there which occurs as small pockets or lenses. Shales cover the smaller portion of the NE and NW part of the region. The remaining area is composed of greywacke, which forms the major lithounit of the basin. Quartzite and banded Ferruginous Quartzite occupy the ridge portions. Many basic intrusives traverse these lithounits (Fig. 3.2).

3.6 STRATIGRAPHY OF VRLB

A brief description of the stratigraphy of the region is given in the following paragraphs. The major portion of the Varada river lower basin particularly, the central, eastern and northern parts are covered by greywacke and phyllitic greywacke having general strike of NNW-SSE with varying dip from 30° to nearly vertical. According to
Radhakrishna (op.cit.) these greywackes form the Ranibennur series of Dharwars, which lie over older gneissic basement. Based on the detailed study of the greywacke he introduced the concept of geo-synclinal-cycle-of-sedimentation.

In 1972, Srinivasan et al gave a four-fold classification of Dharwars based on their tectanomagmatic evolution. Where, these phyllites and greywackes forming part of Shimoga belt, are included in the geosynclinal Flysch (Palaeo-Proterozoic age 2600-2100 Ma) facies of IIIrd cycle of sedimentation. They also include the various basic intrusives in the VIIth magmatic cycle of paleo and post paleo-proterozoic period.

The laterites occurring in this region are of later age, and have not been studied in detail. However, Rama Rao (1962) believes that, these laterites are of late tertiary period. Based on the reconnaissance study of the region, the author proposes the following sequence for the rock types of the VRLB (Table 3.3).

Since the occurrence and movement of groundwater, to a greater extent depends on lithological character, field occurrence and petrography of the major lithounits are given in the following pages:
TABLE - 3.3 : STRATIGRAPHIC SEQUENCE IN VRLB

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Lithofacies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late tertiary to Pliocene</td>
<td>Laterites</td>
</tr>
<tr>
<td>Precambrian</td>
<td>Basic dykes, Quartz veins</td>
</tr>
<tr>
<td></td>
<td>Greywackes, Biotite schists,</td>
</tr>
<tr>
<td></td>
<td>Shales and B.H.Qs.</td>
</tr>
</tbody>
</table>

3.7 FIELD OCCURRENCE AND PETROGRAPHY OF MAJOR LITHOUNITS

3.7.1 GREYWACKE

As mentioned in the previous pages, greywacke forms the major lithounit and covers more than 75% of the total area. Outcrops of greywacke are more prominent in the hilly regions around Devagiri, Haveri and Bankapur regions. At places it has given rise to phyllitic type and also resulted in the formation of product resembling shale. There is a gradational contact within these units (greywacke and phyllite). Hence, in the field, it is a very difficult task to demarcate these two units; as such, in the geological map, they are shown as greywacke only (Fig. 3.2).

The general strike of the greywacke is NNW-SSE, which is parallel to the general trend of the Dharwar Group of rocks. The dip varies between 30°E to nearly vertical.
At places, sedimentary features like bedding, lamination and compositional banding and minor folds are common. It is light-to-dark grey coloured massive and sometimes exhibits graded bedding. Fine grained massive variety appears like a fine grained igneous rock. Sometimes boulderary outcrops are common features, which could be easily mistaken for igneous rocks. They are tough, strongly indurated and variation in grain size is a common observation. Their main minerals are quartz, feldspars and carbonates. Iron oxide and biotite are minor minerals. The overall texture displayed by the greywackes could be described as fine to porphyroblastic. Besides, the rocks are fresh looking and bear imprints of low grade metamorphism.

Following are the minerals constituting the individual specimens/thin sections examined:

Quartz occurs as xenoblastic and interstitial grains; it also occurs as inclusions in plagioclase giving rise to sieve texture. It shows strong to moderate undulose extinction and generally contains inclusions of dusty iron oxides and biotite. And also occurs as minute granules and as larger euhedral to anhedral grains varying in size
from one grain to other (Plate I.A). Plagioclase is a common constituent of all the greywackes, but is always subordinate to quartz. It occurs commonly as laths, plates, granules and as inclusions in quartz. Occasionally oval shape is also observed. It contains tiny crystals of quartz giving rise to sieved texture (Plate I.B). Carbonate occurs as anhedral grains and displays the typical twinkling character. It occurs as fine granular and small isolated grains in the matrix. Iron oxide occurs in minute granules and as larger crystals which show well developed crystallographic boundaries corresponding to a cube. Biotite occurs as minor mineral phase. It is pale brown to dark brown, pleochroic.

Weathering of greywackes in its different stages is observed from the top, even to a depth of 15-20 meters. The elevated regions are mostly occupied by fresh and massive rocks. At some places surface weathering has given rise to variegated clays and shales. Joints of different dispositions are observed and some of these are filled by clay and kankar; also intrusion of quartz veins is a common feature.

3.7.2 BIOTITE SCHIST

Biotite schist covers an area of about 20% of the VRLB in the southern part and extends to further south and
south western parts. Very few exposures are noticed in the south of Tilavally town and west of Hospet village in the present study region. These are found to be associated with greywacke. At places biotite schist occurs as small enclaves within the greywackes and exhibit weakly developed schistosity and lamination (Plate II.A) and weathering has developed clayey or argillaceous patches within the outcrops (Plate II.B).

The biotite schist has a strike of NNW-SSE and the dip varies from zero to vertical due east with local variations.

These schistose rocks are grey, brownish/greenish coloured, strongly foliated and laminated. The laminated character of the rocks is related to variation in the grain size and/or mineralogy. The steel grey colour of the rock is easily mistaken for fine grained igneous rock. At places, it has given rise to biotite gneiss on account of granitization (Plate III.A).

Thin section examination reveals the following: 1) schistose and occasionally porphyroblastic texture and presence of essentially biotite, chlorite, carbonate and quartz (Plate III.B). Iron oxide and plagioclase are subordinate, 11) marked elongation, flattening and preferred
orientation of the minerals parallel to schistosity, (ii) occurrence of dusty iron oxide inclusions in most of the minerals, particularly in quartz. And also inclusions of coarse crystals of quartz and laths of plagioclase in carbonate is not uncommon, (iv) microbands of carbonate in mesobands of silica is occasionally seen (Plate IV.A).

Biotite occurs as discrete flakes and anhedral scales and is invariably chloritised with brownish to dark greenish brown, seen in close association with chlorite. It is strongly pleochroic in the shades of brownish to greenish brown. Chlorite is pale green to brownish green coloured, seldom clear, being usually filled with tiny granules of iron oxide. It occurs in shapeless discrete grains and patches. Carbonate occurs in close association with chlorite forming anhedral plates. It is colourless and has high relief. Inclusions of iron oxide and quartz are most common. Quartz occurs as anhedral grains showing moderate to strong undulose extinction. It is also present as small anhedral interstitial patches and small blebs in carbonate. Iron oxide forms aggregation of small shapeless grains that are frequently altered along with the grain boundaries to haematite. Feldspars, relatively turbid, contain both twinned and untwinned grains.
3.7.3 BANDED FERRUGINOUS QUARTZITES

The bands of BFQ with variable trend occupy generally the hilly regions and these bands are discontinuous and thinout along the strike. These lithounits generally follow the regional strike of the area. Minor folding, displacement, presence of numerous joints are more commonly observed.

3.7.4 SHALES

Shales occur on a mappable unit in the vicinity of Bommanally village (SW region) and north of Savanur town. The colour ranges from white and yellowish to reddish brown. At places, shales exhibit well marked bedding plane, lamination and fissility.

3.7.5 BASIC INTRUSIVES

Dolerite dykes intrude the greywackes, biotite schists and shales of the area. At places, they are highly weathered and have variable strike directions and width (Plate IV. B).
3.7.6 QUARTZ VEINS

Quartz veins of various magnitudes are more common. Major ones are met within biotite schist region. These are highly jointed, fragile and brittle (Plate V.A).

3.7.7 LATERITES

Ferruginous laterites are confined to a thickly forest-covered very small region, towards SW border of the VRLB. Laterites at places are pebbly and nodular. These occur as cappings over biotite schists and are found to be traversed by quartz veins.

3.8 HYDROGEOLOGICAL CHARACTERS OF THE MAJOR LITHOUNITs

During the field investigation of the area, it was noticed that the above described rocks were characterised by different hydrogeological characters. A brief account of the same is given in the following paragraphs.

3.8.1 GREYWACKE

Since greywackes of the region exhibit a sedimentary character, it should be potential from the groundwater
availability point of view. Here, the reconnaissance hydro-
geological survey revealed that, they do not possess uniform 
hydrogeological characters (may be due to metamorphic 
effect). The greywacke which is weathered, jointed and fra-
ctured (Plate IV.B) to a greater depth is found to yield 
copious groundwater (e.g., Budagatty village). The regions 
covered by a compact and non-fractured greywacke are chara-
cterised by low yield, as such, borewells and dugwells of 
this area yielded very poor quantity of water (e.g., around 
Bankapur area).

On account of metamorphism, at places the greywacke 
has become phyllite and do possess the schistosity. Though 
this retains the original porosity, phyllite is highly im-
permeable and is not found to be suitable for groundwater 
development. Tube wells drilled in the phyllitic areas are 
found to yield low-to-moderate quantity of water (e.g., 
near Byadgi town). But, whenever, it is schistose, fract-
ured and jointed, such areas are suitable for groundwater 
development (e.g., near confluence point of Varada river).

3.8.2 BIOTITE SCHIST

In the course of investigation it was found that, 
most of the borewells drilled in the region covered by bio-
tite schist in the study area are either failures or the
water yield is low. Wherever it is fine grained and compact, it acts as impermeable rock. On account of weathering, it has given rise to a sticky clayey material to a greater depth and added to this, because of lack of fracturing, it acts like an impermeable formation. On the contrary, wherever it is coarse-grained, schistose, or granitized it yields copious amount of water (e.g., west of Hangal and Moodur villages etc., (Plate III.A). However, the openwells dug in such thickly weathered areas yielded copious water, (e.g., open wells around Konanakoppa village).

3.8.3 SHALE

Shales both in compact and highly weathered form are unsuitable for being good aquifers. However, some shales which are laminated and jointed may turn out to be good aquifers and yield good amount of water. It is also observed that, wherever the shales underly the greywackes, at depth, are found to yield good quantity of water (e.g., Mulkere village).

It is also observed that, depth to the water table varies in these formations considerably and it is quite shallow in the schistose terrain than in greywacke region.
3.9 STRUCTURAL STUDIES

Groundwater exploration in hard rock areas still remains a matter of great gambling owing to the frequently changing lithology, multivariate deformatie architecture, and rhythmically structured lineaments. At the same time, the entire hard rock terrain cannot be rejected as unfavourable zone, as more than 70% of the country is occupied by hard rocks. These hard rocks are not (themselves) porous and are capable of holding and transmitting water, in their primary state. Still the secondary processes make the hard rocks capable of holding and transmitting water, these secondary openings are due to weathering and deepseated processes like fracturing and jointing.

Thus, secondary porosities of the hard rocks are classified into two categories as:

a) joints, fissures and fractures, which are due to tectonic disturbances, and

b) inter granular porosity due to action of weathering agents.

The occurrence and movement of groundwater is also affected by permeability. Copious supply of water can be
expected where the well passes through the permeable zone. Permeability is induced in hard rocks through fracturing which allows free passage of water. In general, permeability is low in hard rocks.

Structural elements studied in the area under consideration are: lineaments including fractures, joints, and basic dykes, displacements and abrupt truncation of rocks, marked variation in the foliation trend, long and straight stream courses and the alignment of small gullies and linear sharp tonal variation/alignments and some morphological features which are the main criteria for the recognition of these features (Prudvi Raj et al, 1981; Ramasamy, 1989).

In the present investigation the structural studies are done at three levels: 1) using landsat imagery, 11) surface structural mapping and 111) identification of deep seated fractures by geoelectrical means.

3.9.1 STRUCTURAL STUDIES INCLUDING LANDSAT IMAGERY

Landsat imagery, because of its synoptic view, offers a special facility for the study of the mega fabric of the earth's surface layers. This is an excellent tool for
regional geological and structural studies. Short and Lowman (1973) have emphasized that the landsat imageries are remarkable in capturing the structural flavour. The structural study includes the study of folds, domes, fault zones, regional joint patterns etc. Lineament study gives lot of information regarding groundwater occurrence and migration from area to area, particularly, across the basin boundary.

The landsat imagery of bands 2, 3, 4 with the scale of 1:250,000 covering the entire region of study area was studied in detail for delineating fractures and fracture traces. On this basis with the help of Officers of Department of Mines and Geology, Government of Karnataka, a fracture trace lineament map has been prepared and presented in the fig. 3.3.

3.9.1.1 Classification of Lineaments

It is possible to classify the lineament - fault fracture system with regard to the groundwater potentials. They can be grouped as A, B and C types. The lineaments that extend along stream courses and in the proximity of alluvial - colluvial zones have been classed as class "A" lineaments. Those in the pediplain and dissected pediments
STRUCTURAL AND DRAINAGE MAP OF VARADA RIVER LOWER BASIN
(Based on landsat imagery)

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FIG 33
and which often cut across the low lying areas have been classified as class "B" and those in the higher slope areas and denudational hills have been grouped as class "C" lineaments, (Raju et al, 1981). Class 'A' lineaments are directly related to the occurrence of groundwater and are regarded as prospective zones for the development of groundwater. Class 'B' lineaments are also important with regard to the occurrence of the groundwater and their role appears to be mostly in transmitting groundwater across the pediplain areas, and also for inter sub-basinal transfers of groundwater. Class 'C' lineaments recognised in the hardrock terrain enable projection of their extension across pediplain.

The lineaments of the Varada river basin are classified based on the above classification. A major segment of the river falls along class 'A' lineament. Lineaments belonging to class 'B' are also common. Lineaments belonging to class 'C' are characteristic on hilly regions of the southern, north western and north eastern parts of the basin. Lineaments of class B and C are more abundant compared to lineaments of class A. As established by other exploration methods which are discussed later, there exists a fairly good correlation between the areas with class B and C lineaments and the potential zones of groundwater accumulation.
3.9.1.2 Lineament - control of river courses

As deep seated fractures are weak planes, they often control the river movement and direction. The major tributary of Varada, i.e., Dharma river in the south western portion falls along a major lineament zone. Apart from this, there are some other small stream courses following the lineaments. This type of lineaments may be younger than the river courses.

3.9.1.3 Lineament density

A concept of lineament density has been evolved by considering the total length of the lineaments over the area of the basin, in the same manner as drainage density, and drainage frequency (as quoted by Renuka prasad, op. cit.).

\[
\text{Lineament density} = \frac{\text{Cumulative length of lineaments}}{\text{Basin area}}
\]

\[
= \frac{398.4}{2900} = 0.14 \text{ km/sq km}
\]

Lineament density can be taken as an index of fracturing in the area. The value of 0.14 km/sq km can be considered as fairly high and suggestive of a favourable groundwater situation.
3.9.2 SURFACE STRUCTURAL MAPPING

The major lineaments noticed in this area are large joints, fronds of hill ranges, ridges, lines of isolated hills, straight courses of drainage system and linear igneous intrusives etc.

3.9.2.1 Joints

Study of joints including their size, distribution pattern, extent of openness and vertical extent are significant in hydrogeological investigations. Joints can be classified into various types, on different criteria. They are degree of openness, force, territory, and origin (Ranga Rao, 1977). Hydrogeologically more important joints are those which are classified on the basis of origin (tectonic, weathered, drained, and gravitational: Bayer, 1968; Larsen, 1968 and Ranga Rao, op. cit.).

Since joints are the major fractures which are well developed in the area, and have been studied in detail. In the area under consideration, the spatial distribution of joints, their attitude and persistence in depth are varying from place to place. It is noticed that on the surface the joints are numerous with more interspaces (Plate VB, VI A and B) and they diminish with depth, (as observed in deep
open well). Joints are well developed in the greywackes, phyllites and banded ferruginous quartzites than in the biotite schists. The data of strike of joints is analysed and a strike frequency rose diagram has been prepared and presented in Fig. 3.4.C.

As per above classification these joints may be the results of tectonism and metamorphism.

3.9.2.2 Basic dykes

The area under study is dissected by a number of doleritic intrusives, (dykes and sills). They vary from a few meters to few kilometers, in length and a few meters to more than 15 meters in width. Most of them are trending in NNW - SSE, NW - SE, NE-SW and N - S directions and parallel to the strike of most of the lineaments of the area.

3.9.2.3 Veins and reefs

A number of quartz-veins are traversing this terrain, which have varying length and width and are highly disturbed. However, their extent is not of a mappable scale, as such, a detailed study could not be done.
FIG 3A Landsat imagery
B Drainage system
C Joints (surface mapping)
3.9.3 DRAINAGE PATTERN STUDY

Drainage net of a basin greatly influences the hydrology of the watershed. In the hard rock watersheds, drainage frequency like that of fracture density has direct bearing on groundwater occurrence. In the present case, an attempt is made, to study the flow direction of each streamlet and their relation to lineaments strike direction. Also drainage-frequency-rose-diagram has been drawn (Fig.3.4 B). This frequency rose diagram, and the frequency rose diagram for fractures, correlate very well with each other. This pattern is similar to the pattern for joint and fracture system of the area, and clearly suggests the structural control over the drainage system of the area and similar conclusion is arrived at by geomorphological studies also.

3.9.4 GEOPHYSICAL STUDIES

In order to assess the presence and persistence of sub-surface joints at deeper levels and to check the major lineaments effect over groundwater movement and occurrence, geoelectrical surveys have been conducted. They include vertical electrical soundings, profilings and radial VES. The details of which are discussed in chapter 8 of this thesis. This study has shown that, in the vicinity of major lineaments the fractures do exist at depth (between 50'-200')
and trend in three major strike directions viz., NNW-SSE, NNE-SSW and E-W.

3.10 FREQUENCY AZIMUTH ROSE DIAGRAMS

The frequency azimuth rose diagrams prepared for these fracture systems (drainage, lineaments, and joints based on landsat imagery) show 4 sets of fractures with preferred orientation in E-W, N-S, NW-SE (including those trending NNE-SSW), and NE-SW (including those trending NNW-SSE) (Fig.3.4 A). In fig. 3.4 the fractures between N 80° - 90° on either side are taken as E-W fractures, and N 0° - 10° on east and west, as N-S fracture system. From north towards east, the fracture system touches a peak between 0° to 10° and later goes down to the bottom towards east. Further east, it rises gradually with some ups and downs with culminating peaks between 50° - 70°. Between 70° and 80° the peak again touches the bottom with very low profile. At the end, again, it rises from 80° - 90° as the E-W fracture system. Towards the west, from the zero degrees, the distribution of the fractures is haphazard with several ups and downs. However, it rises between 40° - 60° and, later, it is characterised by low profiles before it rises between 80° - 90°, forming the E-W fracture system.
From these observations, it is concluded that, the area might have experienced more than one period of tectonic disturbances. Hence, the above mentioned major fracture systems might have developed in one period of tectonic episode and those irregularly distributed may be apparently related to the different tectonic periods of activity.

The locations characterised by intersection of various lineaments could be taken as the groundwater potential zones. Hence, from the study of lineament fracture trace map of such locations, potential zones have been demarcated: (Fig. 3.5) viz., a) two locations south of Tilavally village, where small lineaments intersect, b) intersection of major lineaments south of Haven town, c) NW of Hosaritty village in the border of the basin, d) east of Shiggaon town. And some of these areas fall in low apparent resistivity zones (Fig. 8.8 A-C).

3.11 SOILS OF THE AREA

Soil is a natural material, consisting of mineral matter, decayed organic matter and micro-organisms. It is a product of the action of climate and living organisms upon the parent material through ages and it is conditioned by local relief, (Arakeri et al, 1960).
LINEAMENT MAP OF
VARADA RIVER LOWER BASIN &
GROUNDWATER POTENTIAL ZONES

FIG 3 5
Soils of the area exhibit a marked diversity in different parts of the area depending upon the nature of the parent rock, and the climatic conditions prevailing in the region. These soils of the area are classified into four categories: 1) Deep black soil/black cotton soil, 2) Red soil, 3) Red and black mixed soil and 4) Lateritic soil. In the soil map of the area only the mapable units are shown (Fig. 3.6).

3.11.1 DEEP BLACK/BLACK COTTON SOIL

This soil covers nearly half of the basin, and occurs mainly in gently sloping to plain topographic areas and transported soils occurring along the courses of the river. The texture is clayey throughout the area and has a high water holding capacity. Most of the hard and corrosive waters observed in the area are from this soil covered area.

3.11.2 RED SOIL

It covers north western and south eastern parts of the area. This soil occurs on hilly to undulating topographic areas. The chief characteristics of the soil are low to moderate thickness, well drained, and poor in bases, and low water holding capacity.
3.11.3 RED AND BLACK MIXED SOILS

These soils occur in the central and southern parts of the basin and pockets of it are sporadically distributed throughout the basin. These soils are moderately deep and common on very gently sloping areas. Texture is usually clayey, moderately well drained with low permeability.

3.11.4 LATERITIC SOILS

Lateritic soils cover the south western part of the basin and some part of Mangal taluka. These soils occur on hilly and rolling topographic areas. These are deep red to brown in colour and are usually formed under heavy rainfall and humid climatic conditions; where, intensive weathering and leaching of bases and silica, and the later processes lead to accumulation of sesquioxides (Soils of Karnataka, 1979). These soils are shallow to moderately deep with ferruginous gravelly material and low in water holding capacity.

3.11.5 SUB-SURFACE GEOLOGY

After the surface geological mapping, to understand the sub-surface geology (lithology), lithologs of boreholes covering the entire basin has been collected. A few
SUBSURFACE GEOLOGY MAP OF
VARADARIVER LOWER BASIN
(AS FENCE DIAGRAM)

(FIG. 37)

(MODIFIED MAP OF SHARMA, 1982)
borehole litholog data for this purpose was borrowed from the Department of Public Health Engineering, Government of Karnataka. Using this data, sub-surface geological fence diagram has been prepared (Fig. 3.7). It is quite revealing to note that the surface geological studies (Fig. 3.2) very much corroborate with the sub-surface lithology.

3.12 CONCLUSIONS

1 The major lithounits of the study area are greywacke, biotite schist, and shale with a strike direction of NNW-SSE.

2 The area forms a part of the Shimoga basin and the lithounits belong to Ranibennur-Sirsi formation of Radhakrishna (op.cit.), Ranibennur formation of Naqvi (op.cit.) and Chitradurga group of Swami Nath (op.cit.).

3 Various fracture systems that have been developed in this area are the results of tectonic disturbances of more than one episode.

4 There are four sets of major lineaments running in different directions, N-S, E-W, NW-SE (including those trending NNE-SSW) and NE-SW (including those trending NNW-SSE).

5 Lineament density of the area is 0.14 km/sq kms.
6 The area possesses different sets of joints which run in NNW-SSE, NNE-SSW and E-W directions.

7 The persistence and existence of deeper (sub-surface) fractures are clearly brought out by REVS studies.

8 The drainage system and fracture systems are tectonically controlled.

9 The well developed fracture systems, joint systems, and confluence of streams are the potential zones from the point of occurrence of groundwater.

10 The potential zones demarcated by landsat imagery study coincide with potential zones demarcated by geophysical studies (chapter 8).

11 The high density lineament zones South of Tilavally, Haven, SW of Shiggaon town, and on either side of Dharma tributary can be considered as groundwater potential zones.