CHAPTER III

GEOLOGY AND STRUCTURE OF THE STUDY AREA
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3.1 INTRODUCTION

The South Indian granulite terrain was considered as a single block comprised of charnockites. However, considerable geological work was carried out in Tamil Nadu and Karnataka regions and the question whether these are rocks older than Dharwars with reference to rocks in Tamil Nadu was posed by Gopalakrishnan et al. (1975). He has done a detailed work in the Dharwar group of rocks over a span of years. Different opinions were expressed on the origin of these rocks and the associated rocks. The Geological Survey of India (GSI) clearly indicates that the basement for the Dharwars is represented by migmatised sargurs and therefore constitute a separate entity with the group of rocks much higher in grade of metamorphism than the Dharwars.

3.2 SATHYAMANGALAM SUPER GROUP

The Sathyamangalam Super Group constitute the following rock types.

1. Fissile Mica gneiss
2. Quartzo – Feldspathic gneiss
3. Hornblende gneiss
4. Amphibolites and
5. Various types of Quartzites
Fig. 8 (after Gopalakrishnan et al. 1975)
The micaceous and fuchsite quartzites, white quartzites, garnetiferous quartzites, magnetite quartzites, ferrogenous quartzites, granite quartzites, calc-granulite, quartz sillimanite schist, kyanite quartzites in the form of diopside-granulite including basic rock and ultramafic rocks represented by calc-actinolite schists are reported.

The lenses of layered ultramafic-ultra basic rocks, small bodies and bands ranging from dunite-peridotite-eclogite-garnetiferous gabbro to anorthosite within the Sathyamangalam group rocks of possible younger intrusives into them and emplaced along reactivated lineaments, shear and fracture zones represents tectonic slices floating within Sathyamangalam group of rocks. (Fig.8). These group of rocks and the intrusives in them are deformed and highly migmatised. Different formations are seen only as enclaves of small and detached lenses and bands within the migmatitic gneisses. Sathyamangalam group of rocks swerves from WNE-ESE through EW to ENE-WSW within very short distances indicating a series of rows along NS to NNE-SSE axis. The dips of foliation are generally steep to vertical. East west trending isoclinal folds dipping steeply southwards are noticed at a number of places. A number of younger dolerite dykes are also formed.

3.3. REGIONAL GEOLOGY AND STRUCTURAL FOLD SYSTEMS

<table>
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<tr>
<th>Layer</th>
<th>Description</th>
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<tr>
<td>D&lt;sub&gt;5&lt;/sub&gt; Dykes</td>
<td>Lamprophyre, Trachyte, Phonolite,</td>
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<td>Alkali Syenite</td>
<td>Quartz barytes, Carbonatite veins, Syenite, Pyroxenite, Dunite</td>
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<td>F&lt;sub&gt;5&lt;/sub&gt; NNE-SSW Shear Folds (Dextral)</td>
<td>Epidote Amphibolite facies</td>
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<td>Formation of regional lineaments, shear zones with mylonite, phyllonite, cataclasite and flaser rocks.</td>
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<td>F&lt;sub&gt;4&lt;/sub&gt; WNW - ESE Isoclinal Folds</td>
<td>Regional warps, formation of structural basins and domes.</td>
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<tr>
<td>F&lt;sub&gt;4&lt;/sub&gt; N - S Shear Folds (Dextral)</td>
<td>Formation of regional Shears and lineament zones of mylonite, phyllonite, cataclasite and flaser rocks.</td>
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<tr>
<td>D&lt;sub&gt;4&lt;/sub&gt; Dykes</td>
<td>WNW- ESE trending dolerite, gabbro and norite dykes</td>
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<tr>
<td>F&lt;sub&gt;2&lt;/sub&gt; ENE-WSW Open symmetrical folds (Sinistral)</td>
<td>Lamprophyre, Trachyte and Basaltic Dykes</td>
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<td>Formation of regional lineaments, shear zones with mylonite, phyllonite, cataclasite and flaser rocks.</td>
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<td>METASEDIMENTS</td>
<td>VOLCANIC</td>
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<tr>
<td>Calcareous</td>
<td>Acid Flow-Rhyolite</td>
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<td>Metasomatic-Siliceous</td>
<td>Ferruginous chert with</td>
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<td>Pelitic-High aluminium</td>
<td>or without sulphides</td>
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<td>Basic Flows</td>
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<td>Theoleitic Basalts</td>
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<tr>
<th>ULTRAMAFICS</th>
<th>PRE-GRANULITIC TONALITE</th>
<th>GRANITE GRANODIORITE</th>
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<tr>
<td>Norite</td>
<td>Carpetiferous</td>
<td>Migmatite</td>
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<tr>
<td>Carnetiforous</td>
<td>quartz feldspathic</td>
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<td>Gneiss</td>
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<td>Carpetiferous</td>
<td>Cordierite</td>
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<td>Sillimanite</td>
<td>Carpetiferous</td>
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(Charnockite Khondalite Super Group)

(Charnockite Khondalite Super Group)

(Preliminary Granulite Tonalite Plagioclase Garnetite)

(Granite Granodiorite)

(after Sugavanam et al 1978)
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<th>TABLE I Contd.</th>
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<tr>
<td><strong>GINCEE</strong></td>
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<td><strong>COMPLEX</strong></td>
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<td><strong>(2450 m.y)</strong></td>
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<td><strong>D&lt;sub&gt;2&lt;/sub&gt; DYKES</strong></td>
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<td><strong>F&lt;sub&gt;1&lt;/sub&gt; FOLDS</strong></td>
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<td><strong>F&lt;sub&gt;0&lt;/sub&gt; FOLDS</strong></td>
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1. F₁ Folds, the earliest recognisable fold in the direction of NNE-SSW showing isoclines.

2. Along the limits of F₁, F₂ open folds are developed in the direction of ENE-WSW.

3. F₃ folds as an NW axial trend as evidenced by the folding of F₁ and F₂ axis along this direction.

4. A regional warping along WNW-ESW can be relegated to the next stage F₄ fold. This stage of development has resulted in number of elongated structural domes and basins.

5. Finally F₅ fold co-axial to F₁ fold trends in the direction of NNE-SSW which are open folds affecting all the earlier folds and cataclastic in nature.

The recent paper in the group discussion on “Suture zones-young and old” held at Wadia Institute, Himalayan geology, Dehradun, Viswanathan et al. (1990) state that all available field and laboratory data pertaining to Tamil Nadu has brought to light that the South Indian granulite-gneiss terrain is made up of 4 distinct petro-TECTonic blocks characterised by distinct igneous intrusives, litho assemblages and by deformational styles and by different structures. They consider that these blocks are welded together by narrow linear straight belts bounded by major lineaments.
Figure 9
PRISTINE SUTURES IN GRANULITE-GNEISS TERRAIN OF TAMIL NADU, INDIA.

[Map showing geologic features and locations in Tamil Nadu, India.]
The 4 tectonic blocks are shown in the Fig.9. They are

1. The Yercaud — Madras tectonic block (YM)
2. The Dimbham — Krishnagiric block (DDK)
3. Gudiyattam — Arakkonam block (GA) and
4. Tiruchirapalli — Madurai — Palayankottai tectonic block (TMP).

The (DDK) and (YM) blocks along with Gudiyattam — Bhavani suture are separated from the TMP block by Metuppalyam — Perambalur straight belt (MPSB). In between YM and DDK blocks the Gudiyattam — Bhavani straight belts (GBSB) representing suture exists. This is an EW trending straight belt occupying the central part of Tamil Nadu and bounded by Moyar — Bhavani-Attur Lineament (MBAL) in the north and by Noyil — Cauvery (Palghat-Cauvery) Lineament (PCL) in the south. The suture zone has many characteristics of continent — continent collision including rocks of probable ophiolitic, high pressure metamorphism crest sheet and tectonic slices, large parallel zones of mylonite as well as major compressive and strike slip deformational pattern. The Salem sub-basin area falls in the truncation between Gudiyattam — Bhavani straight belt and Mettupalayam — Perambalur straight belt and exhibits characteristics common to both the suture zones.

Fig.10 showing spatial relationships of lineaments by Ahmed et al (1986) is of a similar conclusion.
FIG. 10 Map showing spatial relationship of Carbonatite Complexes with Lineaments (Compiled after, Grady, 1971; Ahmed et al., 1986)
Fig. 11 GEOLOGICAL MAP OF THE STUDY AREA

Legend:
- Meta gabbro
- Garnetiferous sillimanite gneiss
- Sillimanite quartzite + Garnet
- Banded Magnetite
- Pegmatoidal granites
- Dolerite dyke
- Biotite gneiss
- Chlorite gneiss
- Sugavandite
Acid Intrusive Ultramafic complex

PROTEROZOIC
Retrogressed gneisses
Basic Intrusives
Granitic Intrusives
Charnockites

Sathyamangalam (Sagur-type)

ARCHAEOAN
Supracrustals

Basement Gneisses

Quartz/pegmatite veins
Sagavandites
Biotite gneiss/chlorite gneiss
Dolerite dykes
Pegmatoidal granites/Gneissic granite
Charnockite + garnet
Pyroxene granulite + garnet
Banded magnetite quartzite + garnet
Sillimanite quartzite + garnet
Garnetiferous sillimanite gneiss
Metagabbro
The study area encloses or constitute the rock types of Pre-Cambrian age. It is difficult to infer the contact between the litho-units because the study area has been tectonically disturbed several times. The alternative antiforms and synforms are due to the refolding. The geological map of the study area as prepared by the author is shown in the Fig.11. The stratigraphic succession is given in the Table II.

3.4 DESCRIPTION OF THE ROCK UNITS OF THE STUDY AREA

3.4.1. BASEMENT GNEISSES:

The variety of gneisses namely peninsular gneisses and quartzo-feldspathic gneisses is commonly termed as "Basement gneisses". The quartzo-feldspathic gneiss has a considerably good representation occurring as irregular enclaves and linear remnants within gneisses and other charnockites. The basement gneisses are located around Seshanchavadi, Mudiyanur and Valapady are well foliated and are trending NE-SW. The quartzo-feldspathic gneiss under microscope exhibits gneissic texture comprising sericitized feldspar (K-feldspars, plagioclase) with biotite and zircon accessories. In hand specimen, this gneiss is well foliated, medium to coarse grained leucocratic rock comprising colourless to milky quartz and feldspar with biotite and garnet.
3.4.2. SUPRACRUSTAL ROCK TYPES

The supracrustals are well represented throughout the study area in which it is better exposed in Seshanchavadi. They are widely distributed as banded magnetite quartzite, persistent bands of pyroxene granulites, metagabbro and sillimanite gneisses. The supracrustal assemblages are enveloped in charnockitic country in the study area. The common association of banded magnetite quartzite and pyroxene granulite is lacking in the surrounding areas.

3.4.2.1 METAGABBRO

It has a very poor representation in the study area and few occurrences, one towards the north west of the hill .438 and the other towards the peak of the hill .419. The metagabbro in the north west portion of the study area occur as an altered non-garnetiferous narrow band and the other is a garnetiferous variety occurring as a highly altered and migmatised lensoidal bodies. The peak .419 is intruded by younger pegmatitic and quartz vein. Metagabbro show effects of migmatisation in all the above cited areas. Locally metagabbro bodies enclose some influx of carbonates.

Generally metagabbro is a granular, mesocratic rock, coarse grained, showing a gabbroic texture consisting of dark greenish mafics and dirty white feldspars, rarely with pale brownish fragmented garnets.
Under microscope, metagabbro exhibits coarse gabbroic texture, consisting of saussuritized plagioclase, strongly pleochroic biotite with accessory apatite and bluish green hornblende. The amphibole show high degree of alteration to epidote and chlorite group of minerals. The feldspars are almost invariably saussuritized. Alamandine rich variety of garnet is found in metagabbro in the hill .419.

3.4.2.2. GARNETIFEROUS SILLIMANITE GNEISS

The garnetiferous sillimanite gneiss occurs as small lenses of limited dimensions to the north of Mudiyanur. This kind of rocks could be easily identified by its typical smooth weathered surfaces with patchy yellow and red stains. This section of the rock exhibits a well banded gneissic texture, defined by preferred orientation of slender sillimanite prism alternating with quartzo feldspathic bands.

3.4.2.3. SILLIMANITE QUARTZITE

These bands intimately interbedded with magnetite quartzite, both intensively sheared are located along a linear zone extending from north west of Mudiyanur to the peak .582. The high degree of shearing parallel to their trends (E-W) has resulted in intimate inter leaving of those litho-units, giving a false impression of lateral gradation of one into other. Some of the mineral constituents show distinct gradation in the bands. Sillimanite quartzite shows highly varying sillimanite content and garnet. Sometimes these may interbed
with magnetite quartzite and this type is exposed as thin bands along railway cutting northeast of Seshanchavadi. Intense shearing of the quartzite bands was exposed northwest of Mudiyanur and it is of dark coloured with finely limited fissile rock.

3.4.2.4. BANDED MAGNETITE QUARTZITE (BMQ)

Attur valley has an extensive distribution of banded magnetite quartzite. The well known Godumalai magnetite quartzite deposits are located on the north of the Seshanchavadi area.

Most of the occurrences of banded magnetite quartzites in the study area are confined to the eastern half of the area whereas a few minor bands are found in western half. The complexly folded bands occupying the undulating ridges of NE and south of Seshanchavadi are the most important bands in the study area. Discontinuous bands and fold closures occupies the low ridges and mounds in smaller occurrences. All the major magnetite quartzite bands of Tamil Nadu are most intimately associated with pyroxene granulites bands (Reddy and Prasad, 1982).

Generally weak banding in magnetite quartzite is noticed in the study area. Obviously, this is due to their striking compositional variations along their trends. They grade from a magnetite rich quartzite to a magnetite poor ferruginous quartzite and at places becomes pure whitish quartzite. Such extreme variations are recorded along the trend of magnetite quartzites
occupying the mounds NE of Seshanchavadi (Plate-III, Fig.1). Banding in magnetite quartzites are defined by alternate layers of magnetite and quartz, which represents original compositional layering, however with a high degree of modifications due to recrystallisation and reconstitution of minerals along different layers and sometimes across the layers during metamorphism.

The common constituent of the magnetite quartzites is garnet. This amount may vary from band to band and from the same band. The eastern part of the study area comprises major magnetite quartzite which are garnetiferous, and the presence of greenish pyroxenes and idioblastic texture indicate the degree of recrystallisation in them. To the north of Mudiyanur, this magnetite quartzites bands interbedded with rich sillimanite quartzite whereas rich garnet with poorer magnetite content is noticed in the western part of the Singipuram.

3.4.2.5. PYROXENE GRANULITE

The pyroxene granulite forms the striking and most distinct lithounits having a wide distribution in the Attur valley. In the study area numerous prominent and persistent bands displays several fold patterns are found occupying ridges and hill tops [Plate-III, Fig.2] within charnockites, pyroxene granulites occurs as lensoidal enclaves and pods.

The associated magnetite quartzite and the major pyroxene granulite bands serve as marker horizons. Generally in field, these pyroxene granulite bodies exhibit a dark coloured feebly ribbed weathered surfaces with or
Fig 1. Magnetite quartzites occupying the mounds NE of Seshanchavadi.

Fig 2. The occurrence of pyroxene granulite rocks near southern part of the study area.
without a thin film of limonite, unlike the brownish weathered surfaces of metagabbro. Around the swarms of younger granitic sheets, it is observed that development of garnet is restricted to pyroxene granulites bodies of southern or southeastern parts of the present study area. Pyroxene granulites bear a sharp contact with all the other lithounits including the intimately associated magnetic quartzites. (Plate-IV, Fig.1).

The detailed studies of a large number of pyroxene granulite bodies from different parts, under thin sections has shown that they are appropriately called as “Two pyroxene granulites” as they are commonly made up of varying amounts of ortho and clino pyroxenes, amphiboles, plagioclase and other accessories.

Pale pinkish variety of garnet is present in the study area. Large garnets is noticed in pyroxene granulites exposed at railway cutting northeast of Seshanchavadi mainly at the contacts with garnetiferous magnetite quartzites.

3.4.3 CHARNOCKITE

The most predominant litho type in the whole of the study area and around it, occupying the high rising hills and major part of plains are charnockites. Generally it contains older supra crustal enclaves.

Charnockite is a medium to coarse grained rock showing apparently poor foliated nature but on weathering they show well banded mafic and felsic layers, which at places become very pronounced due to shearing parallel to
Fig 1. An occurrence of garnetiferous pyroxene granulite near south-eastern part of the study area.

Fig 2. A charnockite working exposure near Seshanchavadi.
foliation. Compositionally the rock varies from trondhjemetic to tonalite type. In the study area a fresh specimen of charnockite is either bluish grey or dark greenish blue (Plate-IV, Fig.2) is seen.

Except from the zones of retrogression and carbonitisation, detailed petrographic study of charnockite samples from the study area has revealed a more or less uniform textural and mineralogical assemblages. Textures of charnockite ranges from granulitic to granoblastic, often with a tendency of grains to align parallely to define foliation (Plate-V, Fig.1). Mineralogically, charnockites are essentially made up of quartz, plagioclase, orthopyroxene and goethite with hornblende microcline-chlorite garnet and myrmekite. Common accessory minerals include opaque ores (illmenite and or magnetite) zircon, apatite, rutile and rarely sphene.

3.4.4. GRANITIC INTRUSIVES

Granitic intrusives are not characteristic of whole of the study area. A good amount of granitic intrusives are represented by swamps of pegmatoidal granites in the southern part of the study area.

3.4.5. PEGMATOIDAL GRANITES

There are a large number of sheets, lenses and bands of pegmatoidal granites confined to southern parts in general and to the southeastern portions in particular.
Fig 1. A fresh charnockite outcrop with foliation near Singipuram.

Fig 2. The pegmatoidal granites are found at hill (.419) west of Singipuram.
To the North of .582, northeast of Δ600, South of .601 maximum concentrations of these bodies are recorded around the hill .419. (Plate-V, Fig.2).

Pegmatoidal granites in most of the cases have intruded into charnockites, whereas they are emplaced into a thick pyroxene granulite bodies. These pegmatoidal granite bodies vary in size from less than 5mts. to over a km. long with a thickness range of 1.25 metres, but on average, they are a couple of metres thick. Longest of all pegmatoidal granites are found at hill .419 (west of Singipuram) northeast of .593, which are around a km. long.

Pegmatoidal granites show a gradation from very coarse pegmatitic to fine grained aplitic nature, most of these pegmatoidal granites are leucocratic, moderate to poorly foliated and inequigranular. Some of these granites are garnetiferous, the garnet being pale brownish to pale pinkish with slight elongation along the trend of foliation. The pegmatoidal granites has shown that most of them retain a coarse grained hypidiomorphic texture and a few fine grained sections show development of gneissic texture with preferred orientation of feldspar and quartz grains.

3.4.6. BASIC INTRUSIVES

In the study area a large number of basic intrusives comprising medium to coarse grained dolerites to fine grained basalts are encountered. These dyke
bodies traverses across almost all the rock types mainly along NE-SW, E-W and NNW-SSE trends local variation of a few degrees in trends of these dykes is common. Since most of them are of swerving nature and a few are branched, the general trend of above sets of dykes roughly follow the regional fold axes and shear zones and timing of their emplacement could also be related to the regional episodes of folding and dislocations. NE-SW trending 2.5 km. long dolerite dyke showing branching and swerving at two places extends from NE of Mudiyanur, to the south of .413 (Plate-VI, Fig.1) NNW-SSE trending 2.5 long coarse grained dolerite dyke with highly varying thickness, passing between hill .601 and hill .413. Two NE-SW trending dolerite dykes, about 2 km. long, one to the NE of Palaniapuram and the other to the NW of Singipuram.

Dolerites show a wide range of grain size from very fine grained basaltic to very coarse grained gabbroic nature, but the most common are medium grained. They are generally dark greenish to black, massive and less jointed, hard and compact. Due to presence of psuedotachylite veins, a few show shearing and mylonitisation.

Even though the dolerite dykes having varying lengths, normally all of them have a thickness of 3-10 mts. and some thin branches have less than 1 metre thickness. Well developed exfoliation in coarse grained dolerite dykes could be seen along the road cutting between hills .601 and .413 and east of
PLATE VI

Fig 1. A dolerite dyke running N.E.-S.W. in direction on the southern flanks of hill .413.

Fig 2. Biotite gneiss affected by $F_2$ minor folds seen near Valapady.
The highly branched swerving dyke north of Mudiyanur shows a highly characteristic ribbed weathering.

The commonest type of texture in dolerite dyke is ophitic to sub-ophitics consisting of laths of plagioclase, partially enclosed in pyroxenes. Size and shape of pyroxenes vary widely. But plagioclase laths remain coarse to medium grained and platy. Alteration products and opaque minerals occupy intergranular spaces to surround the primary minerals. Rarely some pyroxenes are found enclosing smaller pyroxenes as well as stumpy laths of plagioclase, giving rise to poikilitic texture.

Dolerites, mineralogically composed of plagioclase, clino-pyroxenes, biotite / and or chlorite and hornblende. Some dolerites show the presence of orthopyroxenes, epidote, clinozoicite and other minerals, the most characteristic constituent of mineral is plagioclase, invariably occurring as laths of different breadths and showing lamellar twinning. Biotite and hornblende are also common secondary minerals in dolerites, occurring as marginal rims around augite or fully brown patchy grains.

In the south, southeastern spur of hill .582, a discrete body of fine grained basaltic dyke of about 1 km. length and about 2 metres width is found. In the field, it is jet black coloured, crypto crystalline with shining laths. It has a trend of N 70°E-S 70°W with a slight swing.
3.4.7. RETROGRESSED GNEISSES

There are two kinds of retrogressed gneisses from charnockite viz., Epidote chlorite gneiss and biotite gneiss in which the later is most common. The divisioning is based on dominant mafic minerals in the gneiss. Although the distribution of retrogressed gneiss is limited in the study area, they are among the most thoroughly studied lithotype, mainly because the process of retrogression is very well defined in the field.

Generally biotite gneiss occurs as linear zones both across and along the trend of foliation as well as lensoidal patches in association with other gneisses, but epidote-chlorite gneisses occurs as diffused zone within the biotite gneiss.

The transformation of charnockite to bleached biotite gneiss has progressed both along and across the steep foliation trends (Plate-VI, Fig.2). Development of biotite gneiss across the foliation commonly follows NNW-SSE or NE-SW set of fractures. The biotite gneisses are transformed to greenish epidote-chlorite gneisses and retrogression of charnockite to biotite gneiss is well exposed in a few small quarries west of Singipuram.

Under the microscope, biotite gneiss show a typical gneissic texture and presence of quartz, partially saussuritized plagioclase and a fine grained mixture of brown and green biotite. In the vicinity of biotite gneisses around
Muttampatti and Seshanchavadi area small occurrences of epidote-chlorite gneiss of unmappable dimensions are noticed. These gneisses are more altered further retrogressed variants of biotite gneisses.

3.4.8. ULTRAMAFIC COMPLEX

In the study area two lensoidal bodies of coarse grained recrystallised ultramafics (sagavandites) are located, and are tentatively grouped under the ultramafic complex, since they are carbonatized and recrystallized litho units.

Sagavandites were first described from Norway by Patterson (1883, quoted in Shreyer et al., 1972) as carbonate-bearing ultramafic rocks. Janardhan and Srikantappa (1977) first to report the occurrence of sagavandites in sargur schist complex. Sagavandites are recrystallized ultramafic rocks with characteristic mineralogy and chemistry. The most characteristic mineral assemblage of sagavandite is olivine + orthopyroxene + tremolite + carbonate + chrome spinel. Such type of coarse grained recrystallized ultramafic lenses are found in several parts of study area and two prominent lenses of sagavandites are located east of Mudiyanur.

It occurs as resistant bouldery outcrops amidst a major pyroxene granulite body in Seshanchavadi area. The outcrops in Seshanchavadi area exhibits rounded brownish orthopyroxene standing out amidst deep greenish black amphiboles. Sagavanditis are hard, compact massive brownish coloured fresh rocks. A couple of Sagavandites are essentially composed of large laths
PLATE VII

Fig 1. A charnockite outcrop with quartz veins near Vilaripalayam.
of pale greenish patchy hornblende, olivine, green spinel, bronzite and necessary carbonates in thin sections.

3.4.9. ACID INTRUSIVES

Acid intrusives are represented by swarms of quartz veins and pegmatite veins. In the study area fewer quartz veins are seen whereas pegmatite vein are very rare. Localized swarms are found along the plains NE of mound 438 (Plate-VII, Fig.1) due to preponderance of quartz vein in Vilaripalayam.

A great majority of carbonatites are intruded by cross cutting quartz veins and others have quartz veins in their close proximity. Almost all the quartz veins are pure milky white and massive with iron coatings on perting surfaces. The length of quartz veins vary from less than 5 metres to over 700 metres with a thickness range of 2 to 10 metres. Rarely they show sulphide specks and malachite stains.

3.5. STRUCTURE OF THE STUDY AREA

A detailed structural study has been carried out by the author in the study area. Attur valley is a physiographic expression of a major deep seated lineament, located in the eastern part of the study area. Srinivasan (1974) considered the Attur valley as a rift zone between Shevaroy-Chitteri-Kalrayan and Kollaimalai-Pachamalai hill massifs and Holt (1980) interpreted Attur valley lineament as a branch of their complex curvilinear shear system, which incorporates Moyar-Bhavani, Palghat-Cauvery and several other northerly trending lineaments.
FIG. 12. STRUCTURAL MAP OF THE STUDY AREA

LEGEND

- Strike and dip of foliation
- Axial traces of major folds with plunge direction
- Axial traces of other folds
- Axial traces of minor folds
- Shear zones with dislocation
- Other shear zones
- Pyroclastic granulite bands
- Banded magnetite quartzite
- Basalt dykes
This is considered as important lineament as it forms a part of the complex shear system which practically divides in Tamil Nadu into northern and southern blocks on observation based on physiography.

The earlier analysis was based on Landsat Imagery and aerial photo-interpretations without any ground control (Grady, 1971; Srinivasan, 1974; Katz, 1978; and Drury and Holt, 1980). The study area preserves most of the earlier structures like folds, shears, faults and older minor features in spite of deformation.

The broad structural grain of the study area is reflected by the alignment of hillocks, ridges and elongated mounds. Most of the pyroxene granulites and interbanded magnetite quartzites exhibit linear to arcuate arrangement reflecting the dominance of E.W. trending fold episodes. The structural map of the study area is shown in the Fig.12.

3.6. AERIAL PHOTO INTERPRETATION
3.6.1. SRINIVASAN (1974)

Srinivasan (1974) attempted the geological structures in the Attur valley—Tamil Nadu based on aerial photographs. The two major E-W faults coincide with Vellar and Swethanadi. The interference from the azimuthal frequency diagram shows that E-W structural trends is more in Attur valley in the areas north and south of Attur valley. Srinivasan states that the Northern and Southern hill masses of Shevaroys-Chitteri-Kalrayan and Kollaimalai-
Pachamalai hills have suffered upward movement. He states that the preservation of metasediments is in basin structures in Kanjamalai and Palaniapuram. He suggest that it is an upward thrust movement due to location of Attur and the major structure of steps found on the fault planes and the northerly overturned synclinal structure of Godumalai that rests on fault-scrap and groove lineations present on the fault planes. The Attur valley has suffered a minor eastward shift as suggested by the off-sets of chlorite and faults along these two faults.

The western ghats comprises the continuous hill masses whereas the eastern ghats is discontinuous and this is due to E-W and NE-SW faults. The NE-SW trends observed in the western ghats are parallel to the oldest faults and dykes trending in NW-SE direction of this area indicating circumstantial relation. Srinivasan (1977) attempted the lineament map of Tamil Nadu and their relation of the intrusives complexes. He observed that in the E-W fault zones, dunites are associated with pyroxenites and the pyroxenites are garnetiferous variety. In the NW-SE and NE-SW fault zone garnetiferous pyroxenite is not found in the ultra basic complexes.

3.6.2. SUGAVANAM et. al (1976 AND 1978)

Sugavanam et.al 1976, 1978 represented the various stages of structure tectonics, metamorphism, magmatic activity and metallogeny in parts of northern Tamil Nadu comprising North Arcot District.
Figure 13. General tectonic map of the Precambrian of South India, Sri Lanka showing craton-mobile belt relations. In the craton the greenstone belts (dark) and the Closepet granite (crosses) are at angles to the mobile belt boundaries. Younger rocks are shown in a stippled pattern. Scale 1:12,000,000 (after Swami Nath and Karuuka Circle, 1974).

(Source M.B. Katz, 1978)
Figure 14
INTERPRETATIVE TECTONIC MAP OF THE MOBILE BELT OF SOUTH INDIA BASED ON LANDSAT-1 IMAGERY Scale 1:2,500,000.

(After M.B. KATZ, 1978)

(Source M.B. Katz, 1978)
Schematic evolution of high grade mobile belts from A) fundamental fracturing to B) tensional tectonic stage and the development of aulacogens to finally C) transform tectonic stage with internal secondary riftling and external large-scale rifting and spreading in the craton. Strain ellipses define structures in the mobile belt as a result of dextral simple shear. (after Katz, 1978).

( Source M.B. Katz, 1978 )
3.7. REMOTE SENSING TECHNIQUES FOR STRUCTURAL STUDY

3.7.1. KATZ (1978)

The regional tectonics of the Pre Cambrian shield of South India by Katz (1978) is extensively good. The Archaean granulite facies belt comprises quartzites, garnet sillimanite gneisses, marbles, diopside, scapolite, calciphyres with subsidiary iron formation representing metasediments along with quartzofeldspathic gneisses, amphibolites and hypersthene "charnockitic" gneisses of dubious origin. In this linear belts lithologies can be traced for hundreds of kilometres along the strike and the belts appear to be bounded by major tectonic lineaments (Fig.13). As these belts are fault bounded, ensialic linear zones within an older migmatitic basement they may represent intercratonic, aulacogenes.(Fig.14).

The tectonic control consists of two phases comprising structural, metamorphic and igneous events. They are

a. Tensional tectonic stage (>3000 m.y.) which led to the aulacogenes. The early structures were probably gravity influenced diapirs and Nappes (Fig.15) with quasi-horizontal structural elements and,

b. Transform tectonic stage (>2800 m.y.) which converted the aulacogenes into mobile belts.(Fig.16).
Figure 17 Progressive dextral simple shear showing relationship of strain ellipse to the structural elements.

A) Reference circle undergoing dextral simple shear on a vertical shear couple acting as mobile belt boundaries. B) resulting strain ellipse with XZ horizontal and XY the vertical plane of flattening. Compressional structures are formed parallel to X, tensional structures parallel to Z. Riedel (R) and conjugate Riedel (R') shear are also developed. C) en echelon structures are characteristic of simple shear deformation. (After Wilcox, Harding & Seely, 1973 and Escher and Watterson, 1974). Note, drawings are not in perspective.

(Source M.B. Katz, 1978)
Figure 18. Anomalies of South India–Sri Lanka. The northeast trending
Highland series, Madurai and Salem anulogenes and the northwest Kerala
aulacogene and their boundary lineaments (Mh-Mahavelli River lineament,
YG-Yan Gampa lineament, Dour-Dour Ngami lineament, Att-Atur lineament,
Ko-Kotapani fault, DH-Dhavani lineament, KB-Kabhani lineament). Dextral
transform movement along these bounding lineaments converted the anulogenes
into mobile belts. Charnockite formation was localized along en echelon
lineaments and lineament intersections. Major transform movement in the
mobile belt caused tensional conditions in the Dharwar craton causing rifting,
spreading and emplacement of oceanic crust, the precursors of the greenstones.
Tensional thermal axes (TTA) in the mobile belts coincide with greenstone belts
(Huggallu-NU, Kolar) or granites (Closepet granite -SG) in the craton and
granites within the mobile belt (Sankari granite -SG). Intersection of the TTA
with the Dhavani lineament (DH) are loci of carbonatites. Tectonic compilation
based on Landsat-1 imagery. Scale 1:4,000,000 (after Katz, 1976c).

(Source M.B. Katz, 1978)
Figure 19: Tectonic analysis of Landsat-1 imagery of the Nilgiris (NI), Biligirirangan Hills (BG) and the Shevaroys (Sh) of Tamil Nadu. Dextral movement on the bounding lineaments, the Kabbani (Kb) and the Bhavani (Bh) has developed a regional northeasterly foliation (fine lines) and fracture patterns (dark lines) which can be fitted into approximately oriented strain ellipses. The Moyer (Mo) and the Attur Valley fault (AV) are considered as Riedel (R) shears developed from the Kabbani (Kb) - Bhavani (Bh) shear couple. (SG) Sankari granite. Scale 1:1,000,000.
The progressive dextral simple shear with reference to a reference circle is shown in the fig.17. Enechelon structures are formed on the boundaries of the belt.

Katz recognised three sub belts on the basis of the positions of the original aulacogenes in South India. They are Salem, Madurai and Kerala sub belts.(Fig.18). High land series is recognised on Sri Lanka, while the southwest group is considered as the southern extension of the Kerala sub-belt into Sri Lanka.

The movement along the bounding lineament is dextral in regard to the NE trending Salem, Madurai (of India) and high land series of Ceylon (Sri Lanka) sub belts, and sinistral in regard to the Kerala sub-belts, as many of the structures within these belts are compatible with respectively clockwise and anticlockwise rotations. The overall folding style of most of south India shows a marked dextral vergence (Narayanaswami, 1959).

The high strain has rotated the structural elements sub-parallel to the borders and the sense shearing is difficult to ascertain.

The tectonic analysis of Landsat Imagery of Salem sub-belt is given in the Fig.19. The northern Kabbani lineament (Kb) is enechelon to the penetrative Bhavani lineament (Bh) and between them lies the large charnockitic massif of the Nilgiri (NL) and Biligirirangan hills (BG).
Figure 29 Structural elements in the Attur Valley fault zone (AV- Fig. 1) en echelon fold axes, NNW dolerite dikes, NNE sinistral faults and resultant strain ellipse (inset) after Srinivasan (1974).

(After M.B. Katz, 1978)
Dextral movement along these lineaments would cause a zone of tension in the intervening region with further crustal thinning and accompanying thermal highs and hot spots, leading to local high temperature resulting in charnockite metamorphism. Charnockitic massifs were located in between the Bhavani (Bh) and Shevaroys (SH). This dextral type shear deformation is apparent in the internal structures. A major WNW shear along the Moyar river (Mo) developed from Kabbani lineament (Kb), separates the Nilgiris from Biligirirangan hills and is compatible with a strain ellipse, with X oriented about $60^0$ azimuth. This orientation is conformable to the regional foliation (xy trace) and fits tensional direction (z) of prominent NNW fractures found in the Nilgiris. A similar strain analysis for the Biligirirangan (BG) and the Shevaroys (SH) results in a strain ellipse oriented with X at about $45^0$ azimuth, which fits the trend of the regional foliation and also accounts for a conjugate fracture system NNW and EW.

The fig.20 represents the Attur valley fault zone (AV) (and not Attur lineament – AL) is another Riedel-type fault at low angles and in synthetic relationship to the penetrative Bhavani lineament (Bh). This fault zone separates Pachaimalai in the south (Srinivasan, 1974) and the Shevaroys from the Kollaimalai.
FIG. 21

DEEP MAIN FAULTS IN TAMIL NADU

(After Grady, 1971.)

[Map showing deep main faults in Tamil Nadu with various locations and faults labeled.]
Figure 22: Lineaments across Shevaroy-Chitteri-KalRAYAN-Kollaimalai & Pachaimalai Hills (based on Landsat imagery interpretation)

(After K.S. Subramanion et al., 1979)
Figure 23: SKETCH OF SOUTHERN PENINSULA OF INDIA-SRILANKA BASED ON REMOTE SENSING TECHNIQUES

A lineogenetic of Salem, Madurai, Kerala & Highland series & their boundary lineaments are shown.

LEGEND

- Permanent observatories
- Magnetometer array stations
- Induction vectors
- Graphite occurrences
- Suggested electric current directions

(After D. JAYAKUMAR et al., 1983)
3.7.2 GRADY (1971)

John C. Grady (1971) a U.N. photo-geologist in the project for mineral development in India has identified “Deep main faults in south India using aerial photographs”. The (Fig.21) shows several structural regions in South India for the first time. It represents a clear distinction between the southern tectonic plateau and eastern ghats, Nilgiris and Tamil Nadu hills were presented. His observations generated extensive work on the tectonics of South India.

3.7.3 SUBRAMANIAM et..al (1979)

Depending upon the lineaments, landform profile and unsheared nature of the ultramafic emplacements (chalk hills in Salem district) traced within the gneisses-charnockite regions. It comprises minor, intermediate and mega lineaments. It can be noticed that there is a paucity of lineaments in Salem-Attur valley zone.(Fig.22).

3.7.4 JAYAKUMAR et..al (1983)

By using remote sensing data and induced Geomagnetic variation study, Jayakumar et..al (1983) presented a correlation between precambrian tectonics and mineralization of Southern peninsular India. The permanent geomagnetic observation stations, magnetometer array station, induction vector, suggested electric current direction and graphite mineralisation is shown in the fig.23. During the precambrian period (Nityananda and Jayakumar, 1981).
The tectonic map of South India. Bold dot-dash line indicates the western limit of a positive Bouger gravity anomaly (Kaila and Bhatia 1981). The mid-Proterozoic Cublapah and Kaladgi basins are indicated by CB and KB. Late-Proterozoic zones of high strain are: N-V, Nallamah-Velikonda; M-B, Mysuru-Bhramari; At. Attur; P-Ca, Palghat-Cauvery; A. Achankovil; lower case letters a-g are granulite facies reflected in the text: a—Coorg; b—Hillgirirangan (B-B); c—Shevrol; a—Nilgiri; e—Kollimalai; f—Annamalai; g—Palni. The inset shows the main Archaean blocks in South India: EG-Eastern Ghats; NB—northern block; WSB—western sub-block; ESB—eastern sub-block; SSB—southern block.

(After S.A. Drury et al., 1984)
Figure 25. Sketch crustal section from north to south illustrating a model for late-Archaean crustal shortening and thickening in South India before the development of major transcurrent shear belts. The bold-pencilled line represents the depth of presently exposed rocks after crustal thickening, and indicates the large vertical displacements associated with the Moyar-Bhavanai (M-B) and Palghat-Cauvery (P-C) shear zones. Stippled units are Archaean supracrustal rocks, black units represent possible tectonized relics of marginal basin crust and now eroded "ophiolites," crosses indicate the possible distribution of granulites. The sigmoidal crustal underthrusts associated with crustal thickening are based on Shackleton (1981) and Coward (1983). Abbreviations: SHIM—Shimoga; HPUR—Holenarsipur; MYS—Mysore, NIL—Nilgiris; ARI—Anaimalais; KOD—Kodaikanal; AND—Andipatti (figs. 1, 2, and 3). Vertical and horizontal scale bars are 30 km.

(After S.A. Drury et al, 1984)
Figure 26: A simplified geological map of Tamilnadu - Kerala region.

(After Reddi A.G.B. et al., 1988)
The anamalous geomagnetic variation has been attributed to tectonism and mineralization.

3.7.5 DRURY et. al (1980, 1984)

Drury et. al (1980, 1984) used Landsat Imagery interpretation to carry out the works on granulite-gneissic terrain of South India. (Fig.24). The major moyar lineament (Mo) is identified up to 20 km. vide, 200 km. long and appears to be major complex shear zone with an overall dextral movement.

Fig.25 shows a sketch of the crustal thickening in South India before the development of major shear belts according to Drury et. al.

3.7.6. REDDI et. al (1988)

Aeromagnetic evidence of crustal structure in granulitic terrain of Tamil Nadu and Kerala shows the Palghat- Tiruchirapalli region is down faulted suggesting a junction of profound structural dislocation between the granulite terrain and the Karnataka craton (Reddi et. al, 1988).

Fig.26 shows a total intensity magnetic map suggesting a deeper schematic layer and therefore the "moho" by implications. The area seems to be composed of a mosaic of independent crustal block involved in a relative vertical movement.
Figure 27: BOUGUER ANOMALY MAP OF HIGH GRADE TERRAIN OF SOUTH INDIA

(After D.C. Mishra, 1988)
3.7.7 MISHRA (1988)

Bouger anamoly map presented in (Fig.27) of high-grade terrain of South India prepared by NGRI (1978) coincides for a considerable part with exposed charnockite. The northern gradient of Bouger high coincides with Bhavani fault almost parallel to Palghat-Trichy line which suggests its extension to a considerable depth.

3.7.8 GOPALAKRISHNAN et. al (1990)

Gopalakrishnan et.al (1990) demarcated the pristine sutures in granulite-gneiss terrain of Tamil Nadu. The Tamil Nadu granulite-gneiss terrain consists of four Petro-tectonic blocks.

(a) Gudiyatham – Arakonam plate in the North
(b) Yercaud – Chennai (Madras)
(c) Dimbam – Krishnagiri microplates in the middle and
(d) Trichy – Madurai microplate in the South.

In between Yercaud - Chennai (Madras) microplates, Gudiyatham-Bhavani suture zone is demarcated. Between Trichy-Madurai microplates and the DTK-YM plate in the north exists, Mettupalayam, Perambalur suture zone. The suture zones are presented in the form of

i. Remnants of oceanic crust with tectonic slices of probable ophilite sequences.
ii. Thrust slices and incorporation of marginal sequences of microcontinents.

iii. Shear zones with mylonitization.

iv. Collision or compressive mechanism manifested by high temperature, high pressure mineral assemblages, and

v. Later emplacement of alkaline and alkali carbonatite complexes along suture zones, more work needs to be done before accepting this hypothesis.

3.8 STRUCTURAL PATTERN OBSERVED IN THE STUDY AREA

The details of fold patterns, shear zones, faults and trends of foliation etc. were given emphasis during the course of the work.

Both penetrative and planar features like foliation, lineations, faults, folds and shear zones were studied in detail by the author in the study area. In the study area folds played a predominant role in the evolution of the present structural set up. Metasomatic, metamorphic and igneous activities associated with each deformational episode are recognised. In the study area various structural elements were well preserved.

3.8.1 FOLIATION

The term “foliation” generally denotes, either the compositional layering or preferred orientation of phyllosilicates or prismatic and platy mineral grains. Banded Magnetite Quartzite (BMQ) are made up of alternate
bands of magnetite, quartz, garnet and includes various minor accessories. In thickness, individual bands vary from less than 1 cm to more than 4 cm. As these bandings are primarily sedimentary in nature the reconstitution and readjustment of different layers during metamorphism justify their being consider as foliation. The foliation in sillimanite quartzites and gneiss is due to preferred orientation of prismatic sillimanite and/or garnets and their alternation with quartz or quartz-feldspar association.

Various types of older and younger gneisses and charnockites show well developed foliation as a result of both compositional variation and preferred orientation of platy/planar minerals and their alterations.

Generally, foliation trends ENE-WSW to E-W with moderate to steep dips on either one of the sides throughout the study area. Folding of rock formations into series of antiforms and synforms indicates reversal of dips. The general trend of foliation swerves at the location north east of Seshanchavadi.

3.8.2 LINEATION

In the study area well developed groove lineations are developed. They are most commonly found in the hinge regions of major fold, commonly represented as closely spaced grooves rich in quartz often with a coat of
muscovite flakes. Around the hill A600 prominent axial plane groove lineations are found at the hinge region of broad folds within the garnet bearing quartzites.

3.8.3 FOLDS

Detailed mapping of pyroxene granulite bands and associated banded magnetite quartzites, which are utilized as marker horizons in Seshanchavadi area forms the basis for delineation of folds. Based on the interpretation of structural trends, orientation of fold axes, disposition of marker horizons and fold geometry, three different episodes of folding are delineated. Depending upon the swerving of fold limbs, they are described as F₁, F₂ and F₃ episodes.

3.8.3.1 F₁ FOLDS

The earliest folds in the study area are represented by a set of tight isoclinal folds, showing highly varying trends. Major F₁ fold area is noticed only at a few places amidst complexly folded and inter banded pyroxene granulite and magnetite quartzites lithologies. Minor F₁ folds are common in almost all the rock types and show a reasonably good preservation.

The easily recognisable F₁ folds are found in magnetite quartzite bands exposed along the ridge 2 km. west and in the bands constituting the low mounds, north of Ponnarampatti. A discrete tight F₁ fold seen along the ridge south of hill A600 shows a inflated/extended hinge margin.

The most important F₁ fold axis delineated is based on the convergence
of a set of tightly folded pyroxene granulite bands traversing the western half of Seshanchavadi area. The original E-W trending $F_1$ fold axis of the pyroxene granulite band is related in different directions due to refolding.

Around the hill A600 a set of tightly folded, thin magnetite quartzites, inter banded with pyroxene granulites and refolded along ENE-WSW axes to the west of Ponnarampatti. Due to extreme shearing and stretching inter-relationship of this bands has been ambiguous at an angle to their trends. The other set of complexly folded close-knit magnetite quartzite bands enveloped in a major pyroxene granulite body occupying the mound 438 (NE of Seshanchavadi) seems to have developed as a result of intensive lateral compression at varying angles during $F_1$ fold episode. The same set of bands extends eastwards with a swerve to occupy a ridge north of Muttampatti.(Plate-VIII, Fig.1). Minor $F_1$ folds are found at several localities in a variety of rock types.

3.8.3.2 $F_2$ FOLDS

In the study area $F_2$ folds have almost E-W axial trends thus they are almost coaxial with the earlier $F_1$ folds. To the south of Seshanchavadi area, $F_2$ folds are well represented by the folded pyroxene granulite bands and associated magnetite quartzite bands. Also, four thin folded pyroxene granulite bands are also present. $F_2$ folds are tight asymmetric folds. To the south of Seshanchavadi highly varying dips along their limbs and thus posses difficulty
Fig 1. Hornblende gneiss showing F1 folds west of Muttampatti.

Fig 2. Pink granitic-gneiss showing F2 folds near Mudiyanur
in designating them either as true synforms or antiforms. However, the northern most E-W trending tight fold consisting of the sub-parallel limbs and thickened hinge region clearly exhibits a synformal closure.

The hinges of $F_2$ antiformal and complimentary synformal folds in western sector show the development of axial plane lineation with moderate easterly plunges, whereas the hinges of major $F_2$ folds in the eastern parts are marked by intense shearing and brecciation which could be the result of late $F_2$ fold.

A glance at the geological and structural maps of the study area shows that all the major $F_2$ folds have varying degree of intense shearing both along and across [E-W, NE-SW respectively] the general trends, rather than simple folding of rock formation. The highly digitated complex, thick body of pyroxene granulite full of enclave, east of Mudiyanur may also be related to $F_2$ episodes.(Plate-VIII, Fig.2). The extreme stretching of pyroxene granulite bodies, north and east of Vellalakundam and northeast of Seshanchavadi is due to shearing along different angles.

3.8.3.3 $F_3$ FOLDS

It is the last phase of folding in the study area. It is represented by broad open folds with NNW-SSE to NW-SE axis. They are very obvious along the E-W trending lithologies as broad cross folds.
Fig 1. Hornblende biotite gneiss showing F3 folds west of Vellagundam.
In the study area these broad F₃ folds could be seen as gentle warping of the major and minor pyroxene granulite bands. Banded magnetite quartzite (BMQ) and sillimanite quartzite bands, and even the E-W to NE-SW trending dolerite dykes show warping along north westerly axes.

The north westerly trending major fractures are utilized for the emplacement of coarse grained dolerite dykes with sheared / chilled contacts. A large number of minor NNW-SSE fractures which sites retrogression of charnockite to biotite gneiss are also related to F₃ deformation. The fractures serve as channels for the fluids bringing about retrogression.(Plate-IX, Fig.1).

3.9 FAULTS / SHEAR ZONES

The study area has long been known as a zone of intense dislocations and shearing. It is traversed by several wide shear belts with its synthetic and antithetic fracture cutting across the whole rock formations in the area. Throughout the Seshanchavadi area wide spread shearing and mylonitisation with attendant dislocations are noticed. The prominent shear zones of the study area are in E-W, NE-SW and NNW-SSE directions, among which are E-W and NE-SW are of intense nature. Generally small scale minor fractures are widely distributed along the related shear zones with NNW-SSE trending.

The major shear zones / faults encountered in the study area are given below.

(i) Singipuram shear zone

(ii) Mudiyanur shear zone.
3.9.1 SINGIPURAM SHEAR ZONE

This is a NE-SW trending narrow linear shear zone, the trend of which is followed by Singipuram Aru (river). The north-easterly stretching of pyroxene granulite bands and other associated rocks in the vicinity of this shear zone is attributed to strong northeasterly movements. It extends from south of Singipuram towards SW for a distance of about 6 kms. It forms the southeastern boundary of the study area.

3.9.2 MUDIYANUR SHEAR ZONE

A long zone of intense shearing and mylonitisation extending from northwest of Mudiyanur to hill .582 and further eastwards in a E-W direction is termed as “Mudiyanur shear zone”. The eastern end of this shear zone coalesce with NE-SW trending shear zone along Singipuram Aru (river), whereas its western end leads into the major Kammalapatti valley in the adjacent area. This shear zone could be traced along the strike of a prominent intimately interbanded sequence of sillimanite quartzite and banded magnetite quartzite. As a result of intense shearing, the interbands of sillimanite quartzite are so thoroughly mixed up that one can get the gradation from magnetite quartzite to sillimanite quartzite. Here feeder dyke cuts across the zone. A dolerite dyke is emplaced parallel to this shear zone from a point north of Mudiyanur.