CHAPTER I

INTRODUCTION
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1.1 INTRODUCTION

The geology in and around Elampillai gains importance as it has occurrences of economically valuable deposits of Banded Magnetite Quartzite at Kanjamalai. The detailed study of Pre-Cambrian Geology of the world in general and South Indian shield in particular, brought out several classical features like high-grade charnockite gneiss and low grade peninsular gneiss (Fig.1).

1.2 GENERAL STATEMENT

The study of geology in and around Elampillai provides an opportunity to observe the following:

1. Charnockite - Peninsular gneiss relationship.
2. Migmatite and Quartzo Feldspathic gneiss relationship.
3. Formation and Localization of Banded Magnetite Quartzite.
Elampillai town is located between latitude $11^\circ 35' - 11^\circ 40'$ and longitude: $78^0 - 78^0 5'$. Much more work have been carried out on the economically viable in banded magnetite quartzite of Kanjamalai near Elampillai, Salem district. Higher attention has been given to the studies of geology in and around Elampillai un till now.

1.2.1 Charnockitisation

Janardhan (1988) remarks on the abundance of the granulites facies rocks in the deep crustal section of the Indian shield and that of other pre-cambrian shields and infers that the lower continental crust is likely to be made up of granulitic rocks. Therefore, it is important to find out what processes and mechanisms have operated in the formation of granulites.

The following are the major mechanisms, which have been suggested for the formation of granulites:

1. Partial melting with absorption of $H_2O$ into anatectic melts leaving behind a dry residue (FyFe, 1973). A modification of the above is rock-dominated metamorphism (FyFe, 1978).

2. Dilution of initial $H_2O$ with $CO_2$. This process was involved for subsolidus conversion of amphibolite facies gneiss to charnockite by Janardhan et. al, 1979, 1989; Condie et. al, 1982 and Lamb et.al, 1986.

Sources of $CO_2$ may have been deep crustal, as form deeply buried sediments or deeply and swiftly buried sediments (Glassley, 1983, Drury et. al, 1984).
From sub-crustal, as in out-gassing of Carbonated mantle (Shearton et. al, 1973).

From a crystallising gabbroic or basaltic under-plate (Tourett, 1971, Harris et. al, 1982).

From intermediate mid-crustal intrusion (Wells, 1979).

3. By dehydration of rocks under fluid absent condition (Thompson, 1984).

4. Granulite formation by a sudden decrease of fluid pressure (Srikantappa et. al, 1985).

5. Baking out of rocks in the shallow contact aureoles prior to high pressure metamorphism as seen in the Adirondacks (Valley and O’Neil, 1984).

1.2.2 PROGRADE AND RETROGRADE CHARNOCKITISATION

The relationship between the high-grade charnockite and low grade peninsular gneiss has been the subject of discussion and debate for more than 100 years. Exposures in many quarries in South India exhibit field evidence for incipient charnockitization of tonalitic and granitic gneiss which is referred commonly as prograde relation. Retrogression of charnockite to produce tonalitic gneiss, which is commonly referred as retrograde relation are also
Allen (1985) discusses on the prograde and retrograde charnockite-gneiss relation. Prograde charnockite appears to be enriched in Ta, Pb, volatiles (chiefly CO\textsubscript{2}) and in transition metals relative to Mg, and depleted in rare earth elements and Y when compared to adjacent gneissic protoliths.

Retrograde gneisses however have higher Rb, Pb, Th, Hf, Zn relative to Ta, Hf relative to Zr and volatiles (chiefly H\textsubscript{2}O) when compared to parental charnockites.

Evidence suggests that of those elements significantly depleted in high-pressure charnockite only Pb is significantly replenished during retrogression. Further, prograde fluids are relatively rich in CO\textsubscript{2}, and retrograde fluids rich in H\textsubscript{2}O. Allen et. al, (1985) opine that the typical non-systematic geochemical variation during prograde and retrograde reaction reflect local effects at the wave front.

Allen et. al collected samples representing

1. Prograde reactions from gneiss to charnockite at three places (refer Fig.2)

1. Kabbaldurga

2. Dharmapuri and

3. Thiruvannamalai
TRANSITION ZONE

AFTER ALLEN et al (1985)
2. Retrograde reactions from charnockite to gneiss at three places (refer Fig.1)

1. Bhavani Sagar
2. Binakanahalli in the southern Biligirirangan Hills and
3. Salem.

The retrograde samples are from Bhavani-Moyar shear zone as described by Drury and Holt, 1980. All samples are from working quarries and permit examination of charnockite-gneiss relationship.

In areas of incipient charnockitisation in the prograde transition zone, charnockite appears as dark greasy discontinuous patches within the gneiss. The gneissic charnockite contact diffuses over 1 to 3 cm. These patches grow together into continuous branches or large masses as the degree of charnockitisation increases.

Though structural inhomogeneities in the gneiss probably control the flow of fluids responsible for the charnockitisation, they are subtle and not generally observed in the field (Allen et al., 1985). The tonalitic gneiss in the transition zone is commonly migmatitic and granitic material is frequently present within the gneiss. Amphibolite inclusions of varying sizes are frequently broken and stretched. Although charnockite cross cuts the fabrics of the gneisses, in the initial stages, it appears to develop along foliation planes in the more mafic portions of the gneisses.
In the retrograde areas, the gneiss initially develops as sub-parallel linear to curvilinear bleached zones in the charnockite with a diffuse boundary (1-3 cm) between gneiss and charnockite. As retrogression proceeds the narrow bleached zones grow into large islands of gneiss within the charnockite.

Foliation in the charnockite is not readily seen while it is distinctive in the gneisses. Bleaching at the actual boundary between charnockite and gneiss spreads locally along foliation but the linear zones of bleached gneisses are controlled by the fractures that typically cross cut the gneissic foliation.

Similar retrograde bleaching controlled by thin fractures in greenish charnockite from Southern Norway is reported by Field and Rahein (1980). These gneisses are more homogeneous than those of prograde transition zone.

From field observation, retrograde reactions, from charnockite to gneiss is observed along Grady’s N 45⁰ E Fault zone.

1.2.3 SUPRA CRUSTAL ROCKS

In Tamil Nadu high-grade rocks are called

1. Bargur (Dharwar),

2. Sathiyamangalam and

Fig. 3  TECTONIC MAP OF SOUTH INDIAN SHIELD (after Ramakrishnan, 1990)
Sathiyamangalam Supra-Crustals

Gopalakrishnan et. al, (1976) record Sathiyamangalam supra-crustal as equivalents to the Sargur schist complex described by Viswanatha and Ramakrishnan, (1976), (Fig.3).

1.2.3.1 Dharwar Groups

A small stretch of Schistose rocks belonging to Dharwar occurs as an extension of the Kolar schist belt of Karnataka near Bargur and Maharajakadai towards east and north of Krishnagiri respectively in Dharmapuri district. The longest stretch is the one to the north of Maharajakadai trending in roughly north-south directions and forms the southern extension of the Kolar schist belt. The schists are enclosed within an extensive area of migmatites. A number of small enclaves of such schist are noticed within the surrounding migmatite at number of places. The rock types noticed here are the same as those found in the Kolar schist belt and are essentially made up of hornblende schist, amphibolite ferruginous quartzite, quartz sericite schist etc. The strike of foliation of these rocks is nearly N-S with steep dips on both sides (Gopalakrishnan et. al, 1975).

1.2.3.2 Sathiyamangalam Groups

Except for the small stretch of Dharwar supergroup near Krishnagiri, the northern parts of North Arcot and Coimbatore district exhibit several linear
bands of high grade schist and gneisses interbanded with metasedimentary assemblages in close association with granulite facies rocks characterised by charnockite and its migmatised equivalents. They comprise magnetite quartzite, diopside granulite, amphibolite, layered ultramafics, biotite gneiss and hornblende biotite gneisses.

Many of the earlier workers in Tamil Nadu had included all the bands of Quartzite, magnetite-Quartzite, crystalline limestone, amphibolites etc., as belonging to the Dharwars irrespective of their association and stratigraphic position, whether they were enclosed within the migmatitic gneisses or within the charnockites or the khondalites.

The Sathiyamangalam supergroup of rocks occur in the study area and is comparable to the Sargur group of rocks of Karnataka and Wynad group of rocks of Kerala (Gopalakrishnan et. al, 1976).

It is important to recall that Dharwar greenstone and Sargur high grade terrain are distinct stratigraphical sequences separated by a angular unconformity marked by oligomigtic conglomerate at Sigegudda (Viswanatha et. al, 1982)

At Sargur the oldest quartzo-feldspathic gneiss gave an age of 3360 m.y. (Beckinsal et. al,1980) and the youngest dominant grey trondhjemitic gneisses an age of 2380 + 50 m.y. (Janardhan and Riedel 1982)
Figure 4. **SKETCH OF SOUTHERN PENINSULA OF INDIA-SRILANKA BASED ON REMOTE SENSING TECHNIQUES**

(After D. JAYAKUMAR et al., 1983)
The rock types which constitute the Sathiyamangalam groups are fissile mica gneisses, quartzo feldspathic gneiss, hornblende gneiss, amphibolite, various types of quartzite, such as pure white quartzite, micaeous and fuchsite quartzite, garnetiferous quartzite, ferrugineous quartzite, quartz sllimanite schist, calc granulites in the form of diopside granulite etc., intruded by ultramafic and basic rocks represented by talc chlorite schist, talc actinolite schist and by dolerite dykes. All the rock types are extensively migmatised.

1.2.3.3 Khondalite - Charnockite Groups

Granulites of different types mainly constitute khondalite-charnockite supergroup. It is composed of garnetiferous graphite sillimanite schist and gneiss, cordieritesillimanitegneiss, garnetiferous quartzo-feldspathic granulites, quartz granulites, crystalline limestone, calc granulites, quartz and calc gneiss. The magnetite quartzite is rare in khondalite group and pure quartzite is rare in the charnockite groups.

The ultramafic intrusives and dolerite dykes are almost completely absent within the khondalite group. Occurrence of migmatite is normally restricted. Structurally, the khondalite-charnockite group of rocks show a poly deformational nature. Study by Sugavanam et. al. (1974) has shown five periods of folding and deformation in the charnockite group of rocks.
PRINCIPAL IRON ORE DEPOSITS OF INDIA FIG.5.

ZONE - A = KIRIBURU, KEGHAMURU, BOLANI, GUE, KODMUNDI, CHIRIA, MALANGOTI, GORUMHISAN, BODRAPMHER
ZONE - B = CHALLIROMA, ROWGHAT, SURAJGARN HILL, BAILADILA.
ZONE - C = RAMANDUDE, DOMHALI, KUMARSHAWI, SHANKARAGUDA.
ZONE - D = GOA, REGI
ZONE - E = BARABUCAN, KURHAVHLA, CHITTER HILL, ATTUR, KOLLAKMALAI, RAMAKAL, SITAMPUNCOI, KANJNALAI.

- JHAPAMITIC ORE DEPOSIT
- MAGNETIC ORE DEPOSIT
- STEEL MILL
- PROPOSED STEEL MILL
- MAJOR SEA PORTS

Source: Geological Survey of India.
1. In North Arcot district the earliest recognisable fold is NNW - WSW trending isocline.

2. On the limbs of F₁ Fold ENE-WSW, trending open folds are developed (F₂).

3. F₃ fold has N-S axial trace.

4. F₄ a regional warping along WNW - ESE has developed along structural domes and basins.

5. F₅ fold is co-axial with F₁ Fold and trends NNE-SSW and these open folds affect the earlier folds and are of cataclastic nature. Sathyamangalam supra crustal rocks are present in the study area as small enclaves in migmatites.

Study of Jayakumar et. al (1983)

Using induced geomagnetic variation study, and correlating it with remote sensing data, Jayakumar et. al (1983) presented a correlation between precambrian tectonics and mineralization of southern peninsular India (Fig.4). Shows the permanent geomagnetic observation stations, magnetometer array station, induction vector, suggested electric current direction and graphite mineralisation. The anamalous geomagnetic variation has been attributed to tectonism and mineralisation during the precambrian period [Nityananda and Jayakumar, 1981].
1.2.4 GRANITES

Field observation on the granites suggest that anatexis of peninsular gneisses lead to the formation of granite melt and there is facial relationship among migmatite formation, charnockite development and production and emplacement of granite magma. The closepet granite has four major facies,

1. Pyroxene bearing dark grey granite,
2. Porphyritic granite,
3. Equigranular grey granite and
4. Equigranular pink granite.

1.2.5 BANDED IRON FORMATION OF INDIA

Banded Iron Formation (BIF) has a wide distribution in space within Indian shield area (Fig.5). Among them two main groupings are possible. The older (>3000 ma) of the two, the Tamil Nadu type is mainly confined to the high-grade mobile belt and is represented by oxide facies Iron formation. The second and the more extensive type, having characteristic to the Algoma type is the one confined to Archaean Schist (Greenstone) belts formed during the period 2900-2600 ma. The extensive middle to upper proterozoic sedimentary basins of India are largely devoid of representatives of, superior type iron formation (Krishna et. al 1986).
1.2.5.1 BANDED IRON FORMATION OF TAMIL NADU

Geologically Tamil Nadu can be divided into two conspicuous units with BIFs forming the index unit. Extensive incidence of BIFs are noted in the area north of Cauvery where they form closely interbanded units within charnockite - khondalite sequence as a part of supracrustal succession. In sharp contrast to this, the area south of Cauvery practically is devoid of any prominent BIF unit in an area essentially occupied by thick pile of khondalite and associated charnockite. Thus, BIF forms a major unit to divide the Tamil Nadu geology.

Banded Iron-formations forms an integral part of the high-grade charnockite - khondalite terrain in northern parts of Tamil Nadu particularly in Salem, Dharmapuri, North Arcot and South Arcot districts. The magnetite rich iron ore bands form conspicuously thick and linear bands closely interbanded with charnockite and a group of supracrustal succession comprising ultramafics, two pyroxene granulites and khondalites. These bands range in thickness from few meters to 30-40 m. and are often traceable continuously for more than 25-30 km. Their conspicuous presence an elevated strike - aligned ridges in a directed topography make them an important "structural markers" in a multi-deformational, poly metamorphic charnockite khondalite terrain.
LOCATION MAP OF IRON ORE OCCURRENCES IN AND AROUND SALEM DISTRICT, TAMIL NADU

SCALE 1:500,000

FIG. 6.
Significant occurrences of iron ore bands are recorded in Kanjamalai, Godumalai, Chitteri hills in Salem along with a number of continuous/discontinuous band in and around Attur valley, Rasipuram and in Namakkal of Salem District. Tirthamalai and Vediappanmalai in Dharmapuri and North Arcot districts constitutes other important major iron ore bands in Tamil Nadu.

The Iron formations of Tamil Nadu occur discontinuously in a NE - SW zone extending over a length of about 200 km with a width of about 100 km. The zone is dislocated by intense folding and faulting resulting in off setting of these BIF bands. All the deposits exhibit tightly folded structural synforms. The hills, which have the magnetite quartzite, are oval in shape and the iron formations mostly encircle the hills with dips pointing towards the center, which gives them the appearances of basins. The axis of the folds and the trend of the faults are in E-W or NE - SW direction. The magnetite quartzite, being very hard, incompetent and weather resistant, stand out prominently as ridges and hillocks in otherwise highly dissected pre-cambrian topography.

In all these occurrences the iron ore bands are intensely deformed and tectonically interleaved with the surrounding high grade, charnockite-khondalite sequence, compositionally they are quartz, magnetite, grunerite with or without garnet bearing rock with profound alternating bands of silica
and magnetite. Incidence of cummingtonite - anthophyllite has also been recorded in a number of BIF bands.

In all the occurrences these BIF bands are in close association with two pyroxene granulite which are geochemically of tholeiitic metabasalts derived from basic volcanics. In sharp contrast to the Algoma type of BIF in Dharwar greenstone belt and the Lake Superior type oxide facies, the iron ore bands of Tamil Nadu have been exclusively termed as “Tamil Nadu type” by Prasad et al (1982).

1.2.5.2. BANDED IRON - FORMATION OF STUDY AREA

Salem District lies between the latitudes 11°00' and 12°00 N and the longitudes 77°40' and 78°50' E. Since the study area is vast, the area has been studied regionally, Fig.6. The magnetite quartzites of Salem constitute the most valuable group of banded iron ore deposits in Tamil Nadu.

BIF belts are tectonically divided into two unequal portions by the Attur valley which extends in an easterly direction from Salem towards Cuddalore. The northern area comprises the Shevaroys, Chitteri and Kalranyan hills and are showing NE - SW trends. The Northern extension of these is the Tirthamalai in which also some iron ore deposits occur. The central area is occupied by the Attur valley [including Kanjamalai, Vellalakundam, Palaniyapuri and Godumalai] with E-W trend.
PLATE I

Fig:1  Panoramic view of Eastern portion of Kanjamalai Location: Chandanakarankadu.

Fig:2  Panoramic view of Southern portion of Kuttikaradu Location: Perumampatti.
Southern area comprises Rasipuram, Kollaimalai and Nainamalai show again ENE - WSW trend. But in all the hills south of Namakkal, including Talamalai and Pachaimalai a nearly E-W trend is observed. Of which, the author have like to study the structural features which control the Iron formation of Kanjamalai which is located in the central area of Attur valley (Plate I, Fig.1&2).

1.2.6 PRESENT STUDY

The primary requirement to understand the geology in and around Elampillai is a detailed study of petrographic and structural aspects of the rocks. The previous work pertaining to the study area is vague.

Therefore the author made a detailed geological mapping and studied the structural pattern of the rocks of the area in and around Elampillai, and is presented in (Fig.7). Four field visits of 10 to 15 day duration each. During the field visits the author made careful examination of megascopical samples and were carried out within the limited period available [one year] for this research study. Further detailed microscopic study using thin sections was also carried out in the department to understand the petrography.

1.2.7 AVAILABLE DATA ON STUDY AREA REGARDING IRON FORMATION OF KANJAMALAI

The first comprehensive account of the geology on the iron formation of Salem and Tiruchirapalli districts was presented by King and Foot (1864).
They interpreted the structure of Kanjamalai as a basin and traced out several distinct bands of Iron ore and suggested that the whole mountain mass of Kanjamalai is enriched with three principal bands of Iron ores.

Sir Thomas Holland (1893) discovered the dunite outcrop with veins of magnesite at Kanjamalai and regarded them as intrusive in the earlier gneisses. He also made a modification in the map given by King and Foot (1864). He observed some dislocations near Siddhar koil adjacent to the dunite outcrop. Holland observes that the iron ores of Kanjamalai are sedimentary in origin.

Fermor (1936) suggested that the ferruginous quartzites are the oldest and the only sedimentary members in this region and occur as distinct or detached bands which are folded in the form of syncline.

Later workers, Dubey and Karunakaran (1943) also support the sedimentary origin for the Kanjamalai iron ore deposit.

Krishnan and Aiyengar (1944, 1953), in addition to the three bands previously mapped by King and Foot (1864) discovered additional bands in Kanjamalai. They also supported King and Foote in attributing a sedimentary asin structure for Kanjamalai.

Ramanathan (1956) considers that the iron ores may be either segregations from a basic charnockite magma or segregations from a leptitic magma and adds that a sedimentary origin also be acceptable.
Saravanan (1961) discussed the structure of Kanjamalai and states that the member of the Dharwars of Kanjamalai are folded into an easterly plunging syncline as indicated by the convergence of ferruginous and eclogite bands in the western portions of the area.

Saravanan (1969), in his paper “Origin of Iron ores of Kanjamalai” states the non-titaniferous nature of the Kanjamalai ores, presence of good banding and granulitic texture within them and their association with commingtonite and granulite bearing rocks indicate that the Kanjamalai ores are meta-sediments. He argues that since the associated eclogite has no iron ores, the possibility of magmatic origin does not hold good for the present.

Subba Reddy and Prasad (1982) studied the magnetite - quartzites of Tamil Nadu associated with pyroxene - granulites and gneissses, and based on the distribution of ferride group of trace elements in separated magnetites suggests that the magnetite - quartzites and pyroxene granulites may have different mode of origin metasedimentary and metavolcanic respectively. However, a volcano - sedimentary process for the magnetite - quartzite, may have to be considered in view of the close association of metavolcanic.

A systematic study was undertaken by Prasad, Subba Reddy and Windley (1982) on the iron formations in Archaen granulite - gneiss belts with special reference to Southern India. The BIF occurring in granulite - gneiss
belt of Tamil Nadu is distinctly different from those of Algoma or superior types. They have the associated lithologies of the iron formations which occur within highly metamorphosed supracrustal sequences, which form strips and stratigraphic markers within quartzo feldspathic gneisses, which are usually of tonalitic to granodioritic in composition and make up 60-85% of these terrains.

Krishna Rao and Kasipathi (1982) discussed the depositional environment of Iron formation in Kanjamalai on the basis of lithological association, petrography, minerology, chemical composition and distribution of trace elements of iron formation. They conclude that the iron formation represents original non-clastic and oxidate sediment, deposited at the same environmental conditions. It is regarded that the Iron and Silica were derived due to weathering of land masses.

1.2.8 LOCATION

The area under investigation (latitude 11°35'-11°40', longitude 78°0-78°5', falls-within the survey of India Toposheet No.58 I/2. The toposheet is of 1:50,000 scale. It was enlarged to 1:25000 scale to be used as a base map.

From Salem, the area under investigation can be conveniently reached by Salem to Vempadithalam road. It is about 18 km west of Salem and frequent bus service is available.
AREA UNDER INVESTIGATION WITH IMPORTANT LOCALITIES

INDEX

- HILL
- ROAD
- RAILWAY LINE
- SETTLEMENT

SCALE

0 1 2 Km
The important hills and hillocks in the study area, are

1. Kanjamalai in the south eastern side.
2. Kutti karadu on the east.
3. Santhai karadu in the east.
4. Mullaneri basin - north of Kanjamalai - near Mookkaraiyan teruvu
5. Vettamuthampatti basin - north near Thirumalaigiri
6. Charnockite quarry near Thirumalaigiri
7. Charnockite quarry near - Mookkaraiyan teruvu

The important villages are Thirumalaigiri, Perumampatti, Vattamuthampatti, Ariyanur and Siddarkoil (Fig.8).
GEOMORPHOLOGICAL MAP AROUND ELAMPILLAI

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HILL
BASIN
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DRAINAGE PATTERN
RAILWAY LINE
SETTLEMENT