Chapter IV

STRUCTURE AND TECTONICS OF THE STUDY AREA
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4.1 EARLY LITERATURE ON STRUCTURE:

Structural patterns in high grade terrain is normally anticipated with much contortion, folding and shearing. Generally the rocks are characterised by a foliated structure. An attempt is made here to give a detailed account on the various thoughts generated by various author. Such a study will be useful in understanding the groundwater movement in hard rock terrain.

To a large extent, our present knowledge on petrology, tectonic setting and distribution of these rocks of Peninsular India is due to the work of the early pioneers. Among them may be mentioned, Bruce Foot, King, Middlemiss, Walker, Vredenberg, Holland and others of Geological Survey of India and Smith, Sampath Iyengar and Jayaram of Mysore Geological Department, Fermor, Krishnan, Rama Rao, Narayanaswami and Pichamuthu are the other geologists who have presented interpretation on the complex geological problems of this region.
4.2 RECENT WORK PRIOR TO REMOTE SENSING TECHNIQUES:


GRADY (1971):

Grady's research paper on deep main faults in South India using aerial photographs was a turning point in understanding the structure of South India. The United Nations photogeologists in the project for mineral development in India carefully studied the aerial photographs of South India and recognised several deep main faults as shown in Fig.11. In South India, a clear distinction between the south tectonic plateau and eastern Ghats, Nilgiris and Tamil Nadu hills were presented in the article. His observations generated extensive work on the tectonics of South India.
DEEP MAIN FAULTS IN TAMIL NADU
(After Grady, 1971)
DRURY et al (1984):

Drury et al (1984) carried out Landsat imagery interpretation work which is highly useful for getting an overview of granulite gneissic terrain of South India (Fig.12). He has identified the major Moyar lineament upto 20 km wide and 200 km long which appeared to be a major complex shear zone with an overall dextrall movement. His sketch of crustal thickening is South India from north to south illustrating a model for late Archean crustal shortening and thickening in South India before the development of major transcurrent shear belts is very interesting (Fig.13).

KATZ (1978):

Figure 14 shows the general tectonic map of the precambrians of South India - Sri Lanka showing craton-mobile belt relationship by Katz. He recognised three sub-belts on the basis of aulocogenes. The sense of movement along the bounding lineament is dextral in regard to the NE trending Salem and Madurai sub-belts.
Figure 12. Tectonic map of South India. Bold dot-dash line indicates the western limit of a positive Bouguer gravity anomaly (Kaila and Bhatia 1981). The mid-Proterozoic Cuddapah and Kaladgi basins are indicated by CM and KB; late-Proterozoic zones of high strain are; N-V, Nallamala-Velkonda; M-B, Maryar-Balaram; A-A, Avani; P-C, Palghat-Cauvery; A, Achankovil; lower case letters a-g are granulite facies referred to in the text; a—Gavang; b—Biligirirangan (H-R); c—Shevarut; d—Nilgiri; e—Kollimalai; f—Annamalai; g—Palani. The inset shows the main Archaean blocks in South India: EG—Eastern Ghats; NB—northern block; WSB—western sub-block; ESB—eastern sub-block; SB—southern block.

(After S.A. Drury et al, 1984)
Figure 13. 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 pecked line represents the depth of presently exposed rocks after crustal thickening, and indicates the large vertical displacements associated with the Moyar-Bhavani (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; AN—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 14: Aulacogens of South India—Sri Lanka. The northeast trending Highland Series, Madurai and Salem aulacogens and the northwest Kerala aulacogen and their boundary lineaments (Mh—Mahavelli River lineament, YG—Yan Ganga lineament, Bound—Boundary lineament, Att—Attur lineament, Ko—Kotapatti fault, Bh—Bhavani lineament, Kb—Kabhani lineament). Dextral transform movement along these bounding lineaments converted the aulacogens 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 (Nuggihalli—NU, Kolar) or granites (Closepet granite—CG) in the craton and granites within the mobile belts (Sankari granite—SG). Intersection of the TTA with the Bhavani lineament (Bh) are loci of carbonatites. Tectonic compilation based on Landsat imagery. Scale 1: 4,000,000 (after Katz, 1976c).

(Source: M.B. Katz, 1978)
The schematic evolution of high-grade mobile belt from fundamental fracturing to tensional tectonic and the development of aulocogenes and finally to transform tectonic stage is given by Katz (Fig.15). The tectonic analysis of Landsat imagery of Salem sub-belt is given in Fig.15. The Kabini lineament in north is enechelon in pattern. The Nilgiris and Biligirirangan charnockite massifs is shown in Fig.16.

SUBRAMANIAM et al (1979) :

Using lineaments, Subramaniam et al (1979) demarcated the ultramafic emplacement in Salem District (Fig.17). It can be noticed that there is a paucity of lineaments in the unsheared ultramafic intrusives.

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.18). Figure 18 shows the geomagnetic observation stations magnetometer
Figure 15. Schematic evolution of high grade mobile belts (from A) fundamental fracturing to B) tensional tectonic stage and the development of aulacogenes to finally C) transform tectonic stage with internal secondary rifting 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, 1976c).

(Source M.B. Katz, 1978)
Figure 16. General tectonic map of the Precambrian of South India-Sri Lanka showing craton-mobile belt relations. In the craton the greenschist belts (dark) and the Closepet granite (crosses) are at high angles to the mobile belt boundaries. Younger rocks are shown by a stippled pattern. Scale 1: 12,000,000 (after Swami Nath and Karnataka Circle, 1974).

(Source M. B. Katz, 1978)
Figure 17. Lineaments across Shevaroy-Chitteri-Kalmyan-Kollaimalai & Pachaimalai Hills (based on Landsat imagery interpretation).

(After K. S. Subramanian et al., 1979)
Figure 18: SKETCH OF SOUTHERN PENINSULA OF INDIA-SRILANKA BASED ON REMOTE SENSING TECHNIQUES

Legend:

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

(After D. JAYAKUMAR et al., 1983)
array stations, Induction vector, suggested electric current direction and graphite mineralization. The anomalous geomagnetic variations, has been attributed to tectonism and mineralization during Precambrian period (Nityananda and Jayakumar, 1981).

**MISHRA (1988):**

Bouguer anomaly map (Fig.19) of high-grade terrain of South India prepared by NGRI (1978) coincides with the exposed charnockite region. The northern gradient of Bouguer high coincides with Bhavani fault, almost parallel to Palghat-Trichy line suggesting its extension to very great depth.

**REDDI (1988):**

Aeromagnetic study in the granulite terrain of Tamil Nadu and Kerala suggested a junction of profound structural dislocation between the granulite terrain and the Karnataka terrain (Reddi et al, 1988). Figure 20 shows a total intensity magnetic map suggesting deeper schematic layer and therefore the "Moho" by implications.
Figure 19. BOUGUER ANOMALY MAP OF HIGH GRADE TERRAIN OF SOUTH INDIA

(After D.C. Mishra, 1988)
Figure 20. A simplified geological map of Tamilnadu - Kerala region.

(After Reddi, A.G.B. et al., 1988)
They suggest that the area is composed of independant crustal blocks of relative vertical movements.

**GOPALAKRISHNAN et al (1990):**

Pristine (very early) sutures in granulite-gneiss terrain of Tamil Nadu was demarcated by Gopalakrishnan et al (1990) (Fig.21). They consider that the Tamil Nadu granulite-gneiss terrain is made up of four petro-tectonic blocks and two sutures.

The microplates are,

1. Gudiyatham-Arakonam plate
2. Yercaud-Madras plate
3. Timbum-Krishnagiri plate and
4. Trichy-Madurai plate

The two sutures zones are (1) Mettupalayam - Perambalur suture zone and (2) Gudiyatham-Bhavani suture zone. As supportive evidences, Gopalakrishnan et al presents the following:

1. Remnants of oceanic crust with tectonic slices or probable ophiolite sequences,
PRISTINE SUTURES IN GRANULITE-GNEISS TERRAIN OF TAMIL NADU, INDIA.

FIG. 21
(2) Thrust slices and incorporation of marginal sequences of micro-continents.

(3) Shear zones with mylonitization.

(4) Collision or compressive mechanism, Manifested by high pressure, temperature mineral assemblages and

(5) Later emplacements of alkaline and alkali-carbonatite complexes along suture zones.

**NARAYANASWAMI (1967):**

Narayanaswami (1967) modified the earlier views and presented a charnockite and khondalite of the southern granulite terrain and the Eastern Ghats representing the oldest stratigraphic unit (Fig. 21A). The Geological Survey of India Officers presented two papers on 1. Geology and whole rock chemistry of granulites and 2. Structure, tectonism, metamorphism, magmatic activity and metallogeny in parts of northern Tamil Nadu (Sugavanam et al, 1976, 1978).
(After S. Narayana swami, 1975)
4.3  **PRESENT WORK BY THE AUTHOR:**

Having reviewed the above observations, the author has carefully prepared a lineament map of the study area (Fig.22), correlates with the observations made by others. Lineaments can be traced more easily when the contrast of the images is sharp. The imagery used by the author in this synoptic interpretation is on 1:10,00,000 scale. The linear features were checked by regular field visits during the periods October-November and December 1994 and January 1995. The field visits were highly useful in identifying the tonal difference and rock types occurring in the study area.

4.3.1 **LINEAMENTS AND LINEAMENT MAP:**

The term lineament conforms to the definition by 'O' Leary and others (1976) as "a mappable, simple or composite linear feature of a surface whose parts are aligned in a rectangular or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a sub surface phenomenon".
FIG. 22. Lineament map of the Study Area.

SCALE 1:250,000
Lineaments are special type of pattern used to describe linear features which are long, narrow relatively straight tonal alignments, visible in Satellite imageries and aerial photos. The lineaments are the result of faulting and fracturing, they may indicate areas of increased porosity and permeability in hard rock areas which have significance in the accumulation and movement of groundwater.

4.3.2 FOLD PATTERNS:

Charnockite and high grade gneisses are integral part of Archaean granulite terrain. With their multistructural and polymetamorphic characteristics, working out stratigraphy by mapping in these complex terrain is beset with the problems of recognising the primary characters of rocks of diverse origin. In high grade granulite terrain which have witnessed multiple phases of folding, complex metamorphic processes, involving anatectic, palingenetic conditions, migmatisation, metasomatism, repeated cycles of emplacement of rocks of plutonic origin, the chances of retension of primary features by known sedimentary and volcanic assemblages are very remote.
The area investigated, around Jalakandapuram being a part of the high grade terrain of South India shows complex structural and metamorphic history. Detailed geological and structural mapping have established three distinct phases of folding ($F_1$, $F_2$ and $F_3$), two phases of retrogression of charnockite and associated assemblages but none of them retains its primary characters. In the absence of any primary features, it has been possible to use the concordant nature of several bands of pyroxene granulite and pyroxenite as "structural markers" for working out the complex structural history.

Based on structural mapping the following structural features have been recognised in the Jalakandapuram sub-basin.

$F_1$ FOLDS:

These are regional, longitudinal folds with their axial traces in NNE-SSW direction and are essentially isoclinal, asymmetrical in nature with steep westerly dipping axial planes and are composed of broad synforms with narrow tightly appressed aniforms. Isoclinal $F_1$ folds have been recognised
FIG. 1. *F*₁ folds with axial plane in the direction of NNE - SSW, South of Selavadaí.

FIG. 2. HIGHLY CONFORTED MIGMATITE CHARNOCKITE BODY EXPOSED NEAR PERIVASORAGAI WITH LENSOIDAL MAFIC ENCLAUSES.
in the area mapped near Periyasoragai. In Jalakandapuram area, $F_1$ folds are seen as a number of rootless relict folds within prominent $F_2$ folds. Plate VIII, Fig.1 shows $F_1$ deformation near Selavadai.

$F_2$ FOLDS:

$F_2$ folds are recognised as a series as sinistral shifts in the marker horizons. These folds are more or less co-axial and coplanar with $F_1$ folds having NNE-SSW axial trace and low to moderate plunges towards NNE. The axial trace of $F_2$ are slightly oblique ($>10^\circ$) to $F_1$ fold axis.

In smaller scale $F_2$ folds are very well identified by pyroxenite and pyroxene granulite bands within migmatised charnockite exhibiting refolded folds.

$F_3$ FOLDS:

$F_3$ folds are orthogonal or at right angles to $F_1$ and $F_2$ folds with N50°-60°E axial trace and steep axial plane, plunging at moderate angles to ESE. They are recognised as series of warps on the outcrops of pyroxene granulite, pyroxenite as well as in foliation trends of charnockite and
fuchsite-quartzite. $F_3$ folds are identified near Periyasoragai. (PLATE VIII. Fig.2).

4.3.3 FAULTING AND SHEARING:

There are a number of shears and faults in Slem District such as Mettur fault, Godumalai shear zone, Manjavadi fault, Gangavalli shear zone etc. These faults and shears trend mostly in Northeast-Southwest direction while a few are trending east-west like that of Godumalai shear zone. In the study area, the rocks show a well marked "strain slips" cleavage, a peculiar phenomenon called "Trap sch" gneiss by Kind and Foote (1864). In the study area, two minor faults are noticed. One of them is identified in between Vanavasimalai (Δ 685) and Kundamalai (Δ 613), (Δ 557) (Refer Fig.10). The trend of the fault is NE-SW in direction marked F-F₁ in the Fig.10. Another minor fault trending in the same direction (NE-SW) is observed at Chittirapalayam and Samudram is marked as F'-F" in Fig.10. The younger intrusives like alkali syenite and pyroxene granulite occurs in these fault zones.
4.4 CONTROL OF STRUCTURE ON GROUNDWATER MOVEMENT:

In Jalakandapuram sub-basin four types of lineaments in the directions of NNE-SSW, N-S, E-W, WNW-ESE were noticed. The structural hills, Kundamalai (△613), (△557), Vanavasimalai, Kanjamalai hill and Periyasoragai hill exhibits a NNE lineaments to NE lineaments. When one or more lineaments cuts across each other a good source for groundwater is encountered (Refer Fig.21).

4.5 CASE STUDIES:

(i) When the north-south lineament cut across NE-SW trending lineament and E-W trending lineament as in Savuripalayam and Irupali a good source of groundwater is encountered.

(ii) In Nachampatti of Jalakandapuram sub-basin EW lineament is cut by N-S and WNW-ESE lineaments and this area has very high potential of groundwater.

(iii) In Sanarappatti only E-W trending lineament is noticed and wells in that area suffers seasonal dry.
iv) The lineament in Pallipatti is in the direction of NE-SW only and has very low groundwater potential.

v) The villages Tirumalur, Chittrapalayam and Samudram that are situated along the shear zone marked as F'F" (Refer Fig.10) yield good ground water potential.

vi) The villages Mulakkadu and Tanavadiyur are more favourable for groundwater, when compared to its surrounding areas because they lie along the shear zone marked as F. F1 (Refer Fig.10).