Chapter – 2

GEOLOGY AND GEOMORPHOLOGY

2.1 GENERAL

The study area is chiefly underlain by the crystalline rocks of Archaean age consisting of gneisses, chanockites, granites, basic and acidic intrusive. The Study area falls Trivandrum Granulite Block (TGB) (Santhose 1999a,b). The eastern extension of the TGB in the study area is represented by Garnet Biotite Gneisses, Quartzite, Garnet, Biotite, Cardiorite, Spinel and Sillimanite bearing meta pelites (Khondalites), calc-silicate and pyroxene granulite. Several alkaline pegmatite, pink granite veins also occur. Typical patch and vein types of incipient charnockite representing granulite terrain. Generally, the area consists of igneous and metamorphic rocks. Charnockites, Pyroxene granulite, Garnetiferous Biotite Gneisses and migmatites. Quartz veins are present in NNE-SSW direction.

2.2 REGIONAL GEOLOGY OF TAMIL NADU

Nearly 73 per cent of the total geographical area of the state is occupied by a varity of hard and fissured crystalline rock formations of the Archaen age like charnockite, and granites.

The coastal sedimentary tract of the Tamil Nadu forms a part of the coromandal coast of India. The sedimentay deposits, comprising the semi-consolidated and unconsolidated formations can bebroadly grouped into three groups as follows. I). Mesozoic II). Tertiary and III). Quaternary Consisting of sandstones, clays, pebbles, gravels, limestones and shales. The mesozoic group of rocks in the state is represented by the fluviatile upper Gonduwanas of Jurassic age and the marine beds Createaceous age.

The Quaternary sediments in the state are represented by the laterite, the older alluvium of Pleistocene age and the recent alluvium. The eastern coastal and deltaic tracts of state are the receptacles of thick alluvial sediments. The Palar, Ponnaiyar, Cauvery and Vaigai have deposited rich alluvium in their deltaic regions. Cauvery alluvium occupying a major part of the Thanjavur district includes potential alluvial aquifers.

2.3 GEOLOGICAL SETTINGS OF TIRUNELVELI DISTRICT

The crystalline limestones falling under this group are the Ramayyanpattti-Thazhayuthu deposits of Tirunelveli. This deposit forms the most important in Tirunelveli district forming the crest of a major cross folded isoclinal antiform. The crystalline limestone is white to grey in colour, coarse grained, grading into calciphyre and calc gneisses. (Abdulla.N.M 1981; Abdulla.N.N. and Paranthaman.S 1983). In the western portion, known as the Ramayyanpatti block, it carries high grade material useful for chemical industries with coarse masses of calcite and is interbanded with quartzite. In the Thazhayuthu area, the limestone is frequently intercalated with quartzite and much admixed with it as to render it, highly siliceous and impure. In the Terku Seliyanallur area which lies further north along the strike extensions of the above, it is interbanded with quartzite which may be also form intercalations, near Kuttaitatimalai located west of Ramayyanpatti, the limestone grades into a calc-gneiss with local high grade crystalline limestone of thin impersistent nature are also observed in Madurai district.

Near the villages Apparkulam two kilometers south of Sinjikulam, crystalline limestone of dolomitic grade extends in a northwest direction for length of 1.2 kms with a width of 20 meters. It enlarges to a thickness of over 300 meters, cropping out on the western bank of Pachaiar, about 2 kms downstream of Sinjikulam. In Sankarankoil taluk, Narivalam-Vandanallur magnesite deposits are reported. M. Sankaran,(1975) GSI, has reported pyroxene granulite, quartzite, crystalline limestone, garnetiferous biotite gneisses, acid charnockite and granite forming the peninsular archaean complex and lateritic are present in the Tirunelveli area. The strike of foliation / banding varies from N20^{o}W-S20^{o}E to N80^{o}W-S80^{o}E with vertical or southwesterly dips of 45^{o}-85^{o} N-S trending vertical joints are common in the charnockites.

2.4 GEOLOGY OF THE STUDY AREA

The following is a brief description of dominant rock types observed in the study area. The classification of the various types is based on the distinguishable field features and mineral assemblage fairly discernible in the field (Figure 2.1). As there are large differences in naming and grouping of rocks, it is suggested for the present study, those rocks with specific mineralogy may be grouped for easy identification. Rocks of Khondalite and Charnockite groups, and Migmatite Complex of Archaean age, acid intrusive of Proterozoic age and sediments of Mio-Pliocence to Quaternary age occur in this area. The study area has five types of lithologies such as Clay, sand, alluvium, Silt, clay, kankar, sand, Charnockite, Quartzite and Hornblende biotite gneiss. The Stratigraphic succession of the study area is shown in (Table 2.1).

Table 2.1 Geological Succession of Tirunelveli District

Period	Age	Lithology
Quarternary	Holocene to Recent	Soils, beach sands, Red, Teri Sands, Kankar, laterites
Tertiary	Mio-pliocene	Fossiliferous limestone Calcareous Sandstone
ARCHAEAN SUPER GROUP	Acid Intrusives	Pegmatites, quartz veins, Pink granites, Grey granites, Leucogranites
	Basic Intrusives	Basic dykes, basalt, dolerites.
		Migmatic complex, Garnetiferous-quartzo-folds-athic granulite gneisses
	Charnockite group	Charnockites, Pyroxene granulites
	Khondalite group	Crystalline limestone, Calcgranulites, Garnetiferous Biotite-Sillimanite graphite Gneiss, Quartzites

A. Balasubramanian, K.K.Sharma and J.C.V. Sastri (1985) has studied the hydrogeological studies for characterizing the crystalline aquifers of Tambaraparani basin and reported except a narrow belt of Teritiary sediments near the coast the basin exposes mainly charnockites and peninsular gneisses of Archaean age. Groundwater occurs in the weathered, semi-weathered or fractures layers of these hard rocks, under water table conditions. The extent of weathering may vary from place to place and the thickness of the weathered zone ranges from 10 to 25m. The depth to the water table ranges from 1m near the coastline to 8m bgl in the western part of the Tamiraparani basin. The valley bed is filled with present day sands and alluviam.

R.Thirugnanasambandam, et.al. (1993) studied the groundwater exploration along the Tuticorin coast and stated that the groundwater occurs under water table conditions in the fissured crystalline complex and also under water table and semi-unconfined conditions in the sedimentary aquifers. The average depth to the water table varies from 1 to 10 m below ground level (bgl) during post monsoon period (Oct-Dec) and 5 to 15 m bgl in Pre-monsoon period (Jun-Sep).

Biswas and Chatterjee (1967) has classified into zones of recharge and discharge and the discharge zones will develop seawater intrusion which needs an appropriate management strategy. Varadharaj (1989) has reported that the Tuticorin coast is covered by the Archaean, Tertiary and Recent to subrecent formations.

The Archaean complex includes ridges of quartzites, bands of Charnockites, Calc-granulites and the basement peninsular gneisses. The study area is chiefly underlain by the crystalline rocks of Archaean age constituting gneisses. The Khondalite group is represented by garnetiferous biotite gneiss, Calc-granulite, quartz and crystalline limestones. Garnetiferous biotite gneiss and granulite with Sillimanite is occurring in the area. The gneisses are generally medium to coarse grained bluish white to light brown in colour and contain quartz, feldspar, garnet and sillimanite. The rocks are well foliated and at places, the rock is massive and granulitic and contains small clusters of sillimanite. The quartz is identified in the field by its colourless, vitreous, absence of cleavage, high hardness nature. It is identified microscopically by its colourless nature, wavy extinction. The alkali feldspars are identified in the field by the subhedral nature, presence of two sets of cleavage, one imperfect and the other perfect, subhedral nature, R1 > CB, low relief, grey interference colour, simple Carlsbad twinning. Garnet is identified in the field by its pink colour, dodecahedran shape and microscopically it is pink in colour, RI < CB, medium relief and isotropic nature. Sillimanite is identified in the field by its needle character, colourless nature, transparent. Microscopically it is colourless, cleavage present. RI < CB, moderate relief and parallel extinction. Hornblende is identified in the field by its long prismatic character, green colour and microscopically it shows light green to dark green colour, having one set of cleavage, RI > CB, with moderate relief and inclined extinction of 18-20^{o}. The biotite is identified by its flaky nature, black colour and microscopically it shows light brown to dark brown pleochroism, one set of cleavage, RI < CB, moderate relief, under crossed nicols it shows parallel extinction. Calc-granulites occur sporadically in the area occupied by garnetiferous sillimanite gneiss. The crystalline limestone is also seen near Sankar Nagar which are trending parallel to the quartzites. The bands vary in length from 5 to 15 m with width varying from 1 to 5 m. The calc granulites are generally greenish grey in colour, fine to medium grained and contain chiefly pyroxene and feldspar. The Calcite is identified in the field by its rhomhohedral shape, cleavage and microscopically it is identified by the euhedral nature, twinkling effect, rhombohedral cleavage, higher order birefeingence. The pyroxene is identified in the field by its light greenish colour, presence of cleavage, vitreous nature, short prismatic and under microscopic it is Greenish colour, RI < CB, moderate relief, presence of cleavage, subhedral nature and inclined extinction of 38^{o} to 40^{o} indicating diopside. The sphene is identified by its wedge shape. The quartzites are occur as narrow bands in different parts of the study area. They are commonly associated with gneiss. The rock is white to dirty white in colour, highly recrystallised and closely fractured and jointed. The charnockite group comprises pyroxene granulites and charnockites. Narrow bands and lenses of pyroxene granulites occur interbedded with the charnockites. The Charnockite is exposed full in Ambasamudram taluk which is situated in the western border of the study area. Only very minor occurrence of charnockite is seen in the western part of the study area which is not in mappable area. The occurrence of Kankar and tuffaceous limestone are very common in the study area. They occur on the gneissic rock along the Tambaraparani stream courses which runs from west to east in the area and Chithar stream courses which runs from west to east. The Kankar is seen along the tanks. There are numerous tanks seen in the study area. But the above stream and tanks have water during rainy seasons only. These exposures are seen over a wide area as thick massive beds of sheet tufs resulting from the deposition of lime leached out from the underlying gneisses and the segregation of the calcareous matter brought down by the flood water. It is generally whitish, friable but hard and massive at places and shows nodular and pisolitic structures. It is siliceous at places containing fine angular grains of quartz.

2.4.1 Charnockite

Charnockites in the Tamil Nadu terrain have been classified into the massive 'high land type' of first generation charnockites and the 'lowland type' or the 'incipient type' of the second generation. Charnockites of the Nilgiri and Palani hills, as also those fo Nagarcoil and Chennai belong to the highland type. The lowland type is traced in the plain terrains of Krishnagiri, Dharmapuri, Madurai and Tirunelveli (Tamil Nadu and Pondicherry, GSI 2001).

In Tirunelveli district, the charnockite (Plate 2.1) group consists of acid to intermediate charnockite and the associated thin interbands and lenses of pyroxene granulite. The pyroxene granulite is dark grey granular to gneissic, medium grained and occurs mostly as unmappable bands within charnockite and hornblende biotite gneiss. The charnockite is grey greasy medium to coarse grained massive or gneissic rock and occupy the major part of Tirunelveli district. It occurs over the hills as well as the plains underlying the metasediments. The rock is chiefly made up of quartz, K-feldspar, plagioclase and hypersthene with apatite and magnetite as accessories. Pink garnets upto 1 or 2 mm diameter are developed in a few places.

2.4.2 Hornblende Biotite Gneiss

This is most common rock type seen all over the khondalite belt is the semipelitic equivalent of knodalite with significant absence of sillimanite. The rock contains irregular grains of quarts and feldspar with variable amount of biotite and garnet. Graphite is common. Zircon, apatite and ilmenite as accessory mineral are recognizable in thin sections. Throughout the terrain garnet-biotite gneisses are seen at various stages of conversion to orthopyroxene-bearing charnockite.

In the study area, the Hornblende Biotite Gneiss is medium to coarse, pale grey coloured rock and show banded structure with alternation quartz-feldspar rich layers and Hornblende-Biotite rich layers with individual layers ranging from 1mm to 1 cm width, imparting a well developed gneissosity to the rock (Plate 2.2).

2.4.3 Quartzite

In Tamil Nadu, Khondalite Group is well developed in the south, i.e., south of Palghat – Cauvery Lineament (PCL) which is considered by some workers as terrane boundary between the Archaean Craton in the north and the Proterozoic Mobile Belt in the south (GSI, 2006). The Khondalite Group essentially consists of rocks of sedimentary parentage such as quartzite and garnet-sillimanite gneiss ± graphite ± cordierite (metapelites). These are interbanded at places with mafic granulite / amphibolite and charnockite. The charnockite interbands rich in diopside are considered to be metamorphosed cafemic sediments, while mafic granulites / amphibolites probably represent mafic volcanics. The trend of quartzite is vary NW-SE to NNW-SSE and NE-SW with very steep dips of 70^{o} – 80^{o} to vertical towards NE-SW & NW-SE directions. (Plate 2.3).

2.5 STRUCTURE

The maximum elevation is 140m in the western portion and minimum elevation is 70m is in the eastern portion of the study area denotes that the slope is from west to east. They are some isolated hillocks in the northwestern, central western portion of the area. Majority of the area is having plain terrain with gentle slope towards eastern directions. The limited outcrops in the plain area, coupled with thick cover of soils and laterites have masked the structural features. Some major lineaments which are the probable faults are inferred from remote sensing. The linear segments of Tamiraparani and Chithar rivers are indicative of some fractures in the study area. A few minor lineaments are also observed in the hillock area.

2.5.1 Foliation

The foliation is one of the important planar structures developed in the garnetiferous biotite gneiss. The foliation structure also be developed in the disturbed zone like quartzites(Plate 2.4). The regional foliation varies from NW-SE to WNW-ESE direction with moderate to steep dips towards SW. The strike and dip changes from place to place. It is N60^{o}W-S60^{o}E to N70^{o}E-S70^{o}W and dipping 50^o.

2.5.2 Folds

Mesofolds of various types representing different phases of deformation have been observed in the district. Recline folds in crystalline limestone bands is noticed. A number of tight and isoclinals mesofolds have been developed by flexuring of the foliation developed as a result of the earliest deformation.

2.5.3 Faults

The presence of fault in crystalline rocks is inferred from the major lineaments which shows are location of the geological and geomorphological features. The NW-SE lineament running along the Tambaraparani river and crossing the Western Ghats is a possible a shear fault. The presence of metasedimentary rock followed by granulite facies of metamorphism, migmatisation and retrogressive to amphibolites facies, three phses of tectonic deformation with igneous activity and subsequent transgression in Mio-pliocene period followed by regression resulting in the present physiography.

2.5.4 Joints

Various sets of joints are seen traversing the granulites and other litho units. The joints trend in various directions. They are WNW-ESE dipping steeply towards south, NW, SE dipping steeply towards SW and NE, E-W dipping steeply towards south and north, N-S dipping steeply towards east and west, NNE-SSW dipping towards ESE and WNW.(Plate 2.5 & 2.6).

2.6 SURFACE SOIL TEXTURE

The soil textural map (Figure 2.2) was generated using GIS software with the help of a soil map from the National Bureau of Soil Survey and Land Use Planning Department (NBSS & LUP) published in the Tamil Nadu surface soil textural map. Four types of soil textural classes have been identified in the study area i.e. Clay, Clay loam, Loamy sand and Sandy loam. The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG (Hydrological Soil Group) also indicates the transmission rate, the rate at which the water moves within the soil. This rate is controlled by the soil profile. To determine HSGs according to the texture of soils was standardized by the soil scientists (Table 2.2) of the United States Department of Agriculture. The hydrologic soil groups based on the texture of soils of the watershed area are derived corresponding to the standard HSGs and their textural classes are presented in the Table 2.3.

Table.2.2 USDA – Soil classification in the study area

Group	Description
A	These soils have low runoff potential and infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission.
D	These soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

Table.2.3 HSGs and their textural classes in the study area

Soil Textural Classes	Hydrological Soil Group
Sandy loam & Loamy sand	A
Clay & Clay loam	D

2.7 GEOMORPHOLOGY

Geomorphology is defined as scientific study of landforms. Geo means ‘earth’, Morpho means ‘form’ and Logy means ‘discourse’ or ‘science’. It is a branch of Earth Science, which has grown after the advent of Aerial photographs and satellite data. Geomorphology is the science of study of the landforms of the earth. Both the disciplines are exhaustingly covered in literature (Fairbridge, Rhodes W 1968; Lillesand & Kiefer 2000). The synoptic coverage and high precision of remotely sensed data, coupled with marked cost-effectiveness and time efficiency of the data acquisition and analysis procedures have made satellite based geomorpholog!cal mapping an extremely effective tool for management of natural resources in recent times (Srinivasan, 1988). The geomorphological maps portray the forms of the surface, the nature and properties of the surface materials and indicate the kind and magnitude of the processes involved (Shibani Maitra 1999). Geomorphological features are manifestations of under laying parent material and the nature and duration of geomorphic processes. Geomorphological analysis and mapping allows understaning of the landscape-soil relationship for better land use planning, watershed management and landscape ecological planning (Fairbridge, 1968).

The geomorphic units were interpreted based on colour/ tone, texture, pattern, shadow, association and drainage pattern. The different hydrogeomorphological units in the study area is interpreted from Landsat 7 ETM+ satellite data, using digital Image processing technique and interpretation of digital data with the help of computer so that the interpretability of the interpreter can be enhanced. Digital image processing involves the modification of digital data (Lillesand and Kiefer, 1979) for improving the image qualities with the aid of computer and gives better results as compared to that of visual interpretation. The chief advantage of digital data is that they allow us to apply computer based analysis techniques.

Table 2.4. Hydrogeomorphic units, their characteristics and GW potential

Geomorphic unit	Description	Influence on GW regime
Structural hill	Linear to arcuate hills showing definite structural trends.	Mainly act as run-off-zone. Large hills contribute significant recharge to the narrow valleys and other favorable zones with in the hills and to the adjoining plains.
Residual hill	A group of hills occupying comparatively smaller area.	Limited prospects along the valleys and limited recharge potential to the surrounding plains.
Pediment	Gently undulating plains dotted with rocky outcrops with or without thin soil cover.	Forms run-off and recharge zones with limited prospects along favorable locales.
Burried Pediment Shallow/Deep	Gently sloping topography, clay to fine medium loamy soils	receive good recharge
Flood Plain	Alluvium deposited along the river / streams courses due to repeated flooding.	Flood plains receive good recharge and form good shallow aquifers depending on the type of sediments, their thickness and recharge conditions.

The important hydrogeomorphic units in the study area are Burried Pediment Deep, Burried Pediment Shallow, Flood Plain, Pediment, Pediment Inselperg, Residual Hill and Structural Hill. The various hydrogeomorphic units, the description of such units and their groundwater prospects are illustrated in Table 2.4. The hydrogeomorphic units were integrated with geology through GIS spatial analysis and the combined output map shown in Figure 2.3.

2.7.1 Geomorphology of the Study area

Landform of denudational origin is formed where the denudation process dominates over the other process. Most of the landform resulting due to this process is the combined effect of mechanical and chemical weathering. Denudation is the process of removal of material by erosion and weathering. This has direct influence on the relief of the area especially in the reduction of relief to the base level. The agents are mostly water, ice and wind. The major factors affecting denudation are geology, climate, tectonics and anthropogenic effects. All rocks and minerals at or near surface are attacked by physical and chemical process. The effect of this process is not same everywhere because of rocks varying resistance to change. As a result weathering and erosion yield number of landforms, which have typical shape and forms. Weathering is an essential part of the rock cycle. The parent material, or rock weathered material is disaggregated to form smaller fragments and some of the minerals are dissolved and removed by the agent of water. This removal of material is erosion and is accomplished by running water, wind, glacier etc.

2.7.1.1 Structural Hills

These are the resistant isolated, steep sided, usually smoothened and rounded hill or rock outcrops of circumdenudation rising abruptly from and surrounded by an extensive and nearly level plains in tropical regions called inselbergs those residual hills resulting from scarp retreat and pediplanation. Sometimes these inselbergs occur in rolling plains in the study area. Structural hills are type of landform formed due to complex erosion process controlled by sheet erosion, circum denudation, weathering, mass wasting and regional tectonics.

2.7.1.2 Pediment

These are the gentle sloping surfaces with erosional bed rock. These are lying between hills and plain. Pediments are broad, concave or gently sloping rocky-floored erosional surface of low relief extending from the periphery of the debris slope of the hill/mountain till it reaches the next geomorphic unit (Jagannadha Rao, 2003). The groundwater conditions in pediment zone are expected to vary depending upon the type of underlying materials. Groundwater prospect in pediment is considered as poor to moderate (Sankar, 2002). Pediments are erosional geomorphic features and are considered as suitable sites for ground water prospection. Pediments (Plate 2.7) are generally developed by process of plantation of hills, having thin vaneer of soil cover and gently, concave surface mapped adjacent to high relief outcrops. If the pediments are covered by alluvium or weathered material, they are termed buried pediments. It is identified on Landsat ETM+ FCC by undulated topography, accidented slope. This zone is identified on the remotely sensed data by light to medium tone, sharp contact with the adjacent geomorphic zones, irregular boundary outline and partly internal drainage with low drainage density.

2.7.1.3 Residual Hill

Isolated discrete hills of round to cone shaped crest with altitudes varying from 400 - 500m above m.s.l, within the planation surface are considered collectively as significant erosional unit of remnant hilly topography (Shibani Maitra, 1999). These are the resistant isolated, steep sided, usually smoothened and rounded hill or rock outcrops of circumdenudation rising abruptly from and surrounded by an extensive and nearly level plains in tropical regions. The occurrence of these hills as isolated patches is found at comparatively lower altitudes. The shape of the residual hill is controlled by the different lithological composition, distribution and spacing of joints and fractures (Thornbury, 1990). The residual hills are identified in the imageries grey tone and coarse texture in black and white images and dark reddish colour in standard false colour composite with radial drainage pattern. Residual hill of the area is generally identified in the imagery by grey tone and coarse texture and due to dark reddish colour in standard false colour composite with radial drainage pattern. In the study area these are found in the center portion as isolated pockets. It generally acts as run off zone and is considered very poor to poor in terms of groundwater prospects.

2.7.1.4 Pediments and Buried Pediments

These landforms are erosional geomorphic features and are considered as suitable sites for ground water prospecting. Pediments are generally developed by process of planation of hills, having thin vaneer of soil cover and gently, concave surface mapped adjacent to high relief outcrops. If the pediments are covered by alluvium or weathered material, they are termed buried pediments (Plate 2.8 & 2.9). In the study area, such features have been located on air photos in almost all rock formations, being characterised by their light to medium tone, and somewhat plain topography (Sinha, 1998).

Buried pediplains are formed due to coalescence of buried pediments having thick overburden of weathered materials. These landforms are characterized by high porosity, permeability and infiltration rate and as such the groundwater prospects of the buried pediplain are good (Girish Kumar, et.al. 2008). In the FCC these units show dark blue to light blue tone and most of the study area.

2.7.1.5 Flood plain

The river in their nature stage pass their life with 'watch and walk' phase and show varied landforms amongst the floodplains are most important. These landforms not only provide substantial clues about the life history of the rivers but also have direct bearing on the groundwater. This is the youngest geological unit and including various landforms formed by fluvial action. This consists of sand, silt and clay and facilitates channel bed infiltration. It is a highly permeable zone helping the partial bank recharge and subsurface flow of groundwater occurs under semi-confined to perched water table conditions with shallow water levels. Groundwater prospects in flood plains are almost invariably found to be good (Sharma and Jugran, 1992). (Plate 2.10).