CHAPTER - I
INTRODUCTION

1.1. Introduction

The extensive littoral low land of coastal belt of Tamilnadu, the southern part of the East Coast of India, (Fig.1.1) is an excellent area for fundamental and strategic research on Geomorphology. While the fundamental studies are warranted in regard to tectonism, sea-level variations, coastal evolution, trends in sediment dispersal, etc., the strategic studies are required for controlling erosion around Ennore and Pondicherry and siltation around Tuticorin. The disturbances on the coastal processes due to the fast growing aquaculture industries between Nagapatnam and Tuticorin and due to the placer mining around Kanyakumari also warrant strategic studies on coastal geomorphology.

The scientific study of the coast in India is only three decades old. The central Tamilnadu coast received the attention of the Government of India in the early 60’s for the exploration of petroleum in the Cauvery basin. Oil and Natural Gas Commission, India and Geological Survey of India, the two primary organisations, involved in the geoscientific investigations, conducted several geological, geophysical and geochemical studies. Only then, geomorphological studies were carried out along the Cauvery basin as a possible tool in oil exploration. The studies of Sastri and Raiverman (1968), Kailasam (1968), Meijerink (1971), Babu (1975, 1991), Banerjee (1979) Sambasiva Rao (1982) and Ashok Sahni (1982) are some of the
important contributions on the evolution of the Cauvery sedimentary basin. The southern Tamilnadu coast especially the Rameshwaram island has also been studied by many geoscientists (Gardner, 1981; Stoddart and Pillai, 1972; Bruckner, 1988, 1989; Rajamanickam and Loveson, 1990) as it forms the only area of fringed coral reefs along the east coast of India. The unique concentration of placer minerals around Kanyakumari has also evoked keen interest among researchers and studies have been initiated on geomorphic controls on placers (Loveson, 1993). Surprisingly, however, the northern Tamilnadu coast has received little attention from Government organisations obviously because the area is devoid of any economic mineral deposits except perhaps the silica sands around Marakkanam. As a result, scientific studies on this part of the Tamilnadu coast are very few. The preserved records of Quaternary sea-level changes, the dramatic shifting of river courses, the coastal erosion around Ennore and Pondicherry, the evolution of coastal landforms, the concentration of silica sand around Marakkanam are some of the issues that need geomorphological research along the northern part of Tamilnadu coast.

Besides, global climatic oscillations that occurred during Quaternary have led to changes in the type and rate of geomorphological processes in this region also, as noticed in many parts of the world. The Holocene marine processes in particular have favoured the growth and decline of many cities and ports along the Tamilnadu coastal belt. Hence, landform studies are essentially warranted for understanding the possible
changes in geomorphic processes during the recent past and their human response.

The topic of "Global Warming" and "Green house effect" is the talk of the environmental scientists of the day. This global warming is expected to lead to a rise in sea-level and various scenario have been proposed for the rate of sea-level rise. The east coast of India with wider littoral lowlands and lower continental shelf is more vulnerable for damage than the west coast in such a situation (Shetye et al., 1988). The study of coastal geomorphology will enable the prediction and assessment of damages due to the sea-level rise.

1.2 Scope and Objectives of the present study

It is proposed to carry out geomorphological investigation over a length of 285 km of Northern Tamilnadu coast following 'The Zonal Method' (Miles, et al., 1973), proposed by the Coastal Research Group, Department of Geology, University of Carolina. The output will give regional morphology and sediment dispersal trend with maps and illustrations. This type of study forms an essential part of environmental planning and coastal management especially for third world countries like India where population is concentrated along the coastal belt. Unfortunately for the most part of the world, including the developed countries, such reconnaissance maps are not available (Miles et al., 1973). It may be added, however, that such a type of study has been carried out along Maharashtra and Goa regions of the west coast of India by Wagle (1987). The present study is the first of its kind along the east coast.
The main objectives of the proposed study are:

i) to delineate and synthesise the geomorphic units and correlate them with processes.

ii) to identify the Quaternary sea-level changes in and around the study area and to evaluate their impact on the development of landforms.

iii) to surmise the changes in the domain of fluvial sedimentation due to the shifting of river courses along the coastal belt.

iv) to understand the impact of neo-tectonic activities on the genesis of landforms and

v) to trace the coastal evolution.

1.3. The study area

The area of study, extending for 285 km from the Pulicat lagoon in the north to the Coleroon river in the south - between latitudes 11° 20’ N and 13° 30’ N - is a part of the Coromandal Coast which encompasses the coast of Andhra Pradesh and Tamilnadu in India (Fig.1.2). The coastline of northern Tamilnadu is characterised by long sandy barrier beaches of Holocene age throughout its length except the area around Pondicherry, where the coastline is formed by low cliffs cut into marine terraces. These barriers are bordered in the west by coastal sand dunes, lagoons, deltaic plain, Cuddalore sandstone uplands and pediments and in the east by the Bay of Bengal. The width of the coastal plain varies greatly from just 0.5 km near Palar river to about 85 km in the Cauvery deltaic plain. This complex coastal belt is bordered in the west by greatly
undulating plains, formed by erosional surfaces in the rocks of Archaean which rise to hills and mountains of heights upto 2700 m. The erosional remnants of these rocks are also observed as inselbergs in the pediment highland of the coastal tract.

a. Physiography and Climate

Tamilnadu can be divided physiographically into four units (Fig.1.3) viz., high mountains, low mountains, dissected plateaus and coastal plains (Babu,1975). While the first three physiographic units are formed by crystalline rocks of Archaean, the fourth unit holds sediments ranging from Permian to Recent in an unconformable series. Laterites are noticed on almost all physiographic units irrespective of rock types and age. Coastal plains rise upto a height of 100 m from MSL.

The east-flowing rivers like Araniyar, Korataliyar, Palar, Gingeeear, Ponnaiyar, Gadilam, Vellar, Coleroon and Cauvery draining the area discharge into the Bay of Bengal (Coleroon is one of the distributaries of the Cauvery through which major portion of discharge of Cauvery water takes place). All these rivers, except Palar, have deltas at their mouths, of which the Cauvery has a well-constructed one which is actually a small surficial part of larger Cauvery sedimentary basin extending into offshore. All the rivers are seasonal in nature, water flows through them only during the monsoon period.

The study area enjoys the humid-tropical climate. The average temperatures of summer and winter are 32°C and 25°C respectively. It receives maximum rainfall during the north-east monsoon which lasts between October and December, whereas scanty
rainfall occurs during the south-west monsoon between June and September. During the north east monsoon, seasonal depressions are common in the Bay of Bengal which bring heavy rain to this region. Hence the Bay of Bengal is one of the influencing factors in the climate and rainfall of the area.

b. Continental Shelf Morphology

The width of the continental shelf in the study area varies from about 50 km off Mamallapuram to 15 km off Pondicherry. The shelf break occurs at a depth of 85 to 130 m and is often marked by minor domal shaped irregularities. (Mohapatra et al., 1992). Off Pondicherry three canyons namely (i) Palar Canyon (ii) Puducherry canyon and (iii) Cuddalore canyon have been reported (Varadhachari et al., 1968). The width of the shelf is narrow wherever the canyons are found to occur. Though they are christened as canyon by Varadhachari et al., (1968), they are also considered as valleys of local nature (Rao et al., 1992). The canyon head starts on the shelf at around 50 m depth. The Palar canyon is traceable down slope upto 2500 m isobath. Its axis trends in NW-SE direction in the upper part to E-W in the lower part. In cross section the valley is 'V' shaped in the upper part and 'U' shaped in the lower part. The next canyon in the south termed as Puducherry (Old name of the town Pondicherry) valley is 'V' shaped trending E-W and is traceable upto 2400 m isobath. The southernmost canyon termed the Cuddalore is traceable upto 2000 m isobath trending E-W and is 'V' shaped. All these canyons coalesce and give rise to a
broad fan on the continental rise occurring at the base of the continental slope.

c. Waves, Tides and Currents

The change in seasonal cycles of monsoon influences the wave characteristics of the Bay of Bengal. The waves, approaching the shore in the direction $N60^\circ E$ and $N45^\circ W$, with heights of 0.5 m to 3.5 m, and periods of 8 sec and 10 sec, are predominant. Tidal range along the coast mostly varies from 1 to 2 m. Two currents namely spring current in clockwise circulation and autumn current in anti-clockwise circulation are observed in the Bay of Bengal. Besides these, long shore littoral drifting currents dominantly occur from S to N. In general, the coast is wave dominated.

1.4. Geology of the area

Archaean, Gondwana, Cretaceous, Tertiary and Quaternary deposits are encountered in the surface and sub-surface geologic setting of the area (Fig.1.4). Except the area between Palar and south of Madras, the coastal belt of the study area is made up of sedimentary deposits of age ranging from Permian to Recent. The area between Palar and south of Madras is made up of crystalline rocks of Archaean age. A general stratigraphic succession is given in Tab.1.1 and the various formations are described below.

Archaean

The Archaean is found to be exposed along the coastal belt between Palar and south of Madras and in the remaining part of the study area the Archaean forms the basement over which the
sediments of Permian to Recent have been deposited. The Archaean rocks comprise of granites, charnockites and a variety of associated crystalline rocks. Granites occurring in the area are medium to coarse grained and pink to light grey in colour. Granitic gneisses and hornblende gneisses are associated with them.

The charnockites are exposed over a wide area and typically at St. Thomas Mount, Pallavaram, a suburb of Madras city. They exhibit a combination of properties of igneous and metamorphic origin and are ranging from acid to basic types with well-developed foliation. The general strike of crystallines is NNE-SSW. A number of dykes of dolerite cut across the Archaean rocks. All these Archaean rocks exhibit highly variable degree and intensity of weathering.

Table 1.1. Generalised stratigraphy of the study area

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Gross Lithology</th>
<th>Max. Thickness(ft)</th>
<th>Environment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Outcrop</td>
<td>Sub-surface</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alluvial sands and clays, lateritic sands, earthy sands, and ferruginous gits</td>
<td>Unconformity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late Miocene</td>
<td>Cuddalore Sandstone</td>
<td>Sandstone, claystone, and conglomerates in outcrops; Sandstone, claystone, limestone, calcareous sandstone, and traces of coal in sub-surface</td>
<td>600</td>
<td>300+</td>
<td>Continental in outcrops; marine in sub-surface Exposed in Cuddalore and Pondicherry areas</td>
</tr>
<tr>
<td>Early Miocene to Middle Miocene</td>
<td></td>
<td>Sandstone, claystone, limestone, calcareous sandstone, shale, and siltstone; traces of coal in sub-surface</td>
<td>Unconformity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
<td></td>
<td>Claystone, shale, sandstone and limestone in sub-surface</td>
<td>340</td>
<td>Marine</td>
<td>Not exposed</td>
</tr>
<tr>
<td>Eocene</td>
<td></td>
<td>Shale, claystone, sandstone, calcareous sandstone, pebbly sandstone, and bioclastic limestone in sub-surface</td>
<td>Unconformity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,150+</td>
<td>Marine</td>
<td>Not exposed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Contd...
<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Gross Lithology</th>
<th>Max. Thickness</th>
<th>Environment</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palaeocene</td>
<td>Pondicherry and Nuniyur</td>
<td>Claystone, shale, and minor sandstone, and limestone in outcrops. Claystone, shale, siltstone, limestone, bioclastic limestone, and minor sandstone in sub-surface.</td>
<td>230+</td>
<td>Marine</td>
<td>Exposed in Pondicherry area</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Unconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>Upper Ariyalur</td>
<td>Crossbedded, friable sandstone near base and greenish sandstone, intercalated with dark, green clayey sandstone and purple claystone together with bioclastic limestone.</td>
<td>2,700+</td>
<td>Marine</td>
<td>Exposed in Ariyalur, Thanjavur and Pondicherry areas</td>
</tr>
<tr>
<td>Late</td>
<td>Lower Ariyalur</td>
<td>Variegated clayey sandstone, conglomerate, and crossbedded sandstone in lower part; fine grained sandstone and siltstone intercalated with fossiliferous calcareous sandstone in middle part; argillaceous, fossiliferous limestone and calcaeous sandstone toward top in outcrops.</td>
<td>730+</td>
<td>Marine</td>
<td>Exposed in Ariyalur, Thanjavur and Pondicherry areas</td>
</tr>
<tr>
<td>Trichinopoly</td>
<td></td>
<td>Calcereous coarse-grained gritty and conglomeratic sandstone with bands of sandy limestone, gypsum claystone and calcareous limestone; alternating bands of shaly limestone and conglomeratic limestone in lower part.</td>
<td></td>
<td>Marine</td>
<td>Exposed in Ariyalur, Trichinopoly area</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Unconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uttathur</td>
<td></td>
<td>Greenish-grey to yellowish-brown, gypsum claystone and thin fossiliferous limestone, gypsum claystone, coarse conglomerate, and argillaceous limestone. Black carbonaceous shale present at base.</td>
<td></td>
<td>Marine</td>
<td>Exposed in Trichinopoly area</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Unconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>Dalciapuram</td>
<td>Reefoidal limestone and black shale; in sub-surface, Lower Cretaceous sequence consists of shale, sandstone, and minor limestone.</td>
<td>400+</td>
<td>Marine</td>
<td>Exposed at Dalciapuram area</td>
</tr>
<tr>
<td>Cretaceous</td>
<td></td>
<td><strong>Unconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>Sathyavedu</td>
<td>Coarse-gritty and pebbly sandstone in outcrops; shale argillaceous sandstone, and conglomeratic sandstone in sub-surface.</td>
<td>1,000+</td>
<td>Continental in outcrops; continental to paralic in sub-surface</td>
<td>Exposed in the area south of Palar and north of Madras</td>
</tr>
<tr>
<td>Jurassic to</td>
<td></td>
<td><strong>Unconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>Appur group</td>
<td>Fine to red mud, light brown to yellow sandstone with lenses of claystone; Greenish khaki shales; pebbles and cobbles.</td>
<td></td>
<td>Marine</td>
<td>Exposed near Chengalpet</td>
</tr>
<tr>
<td>Cretaceous</td>
<td></td>
<td><strong>Unconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archaean</td>
<td></td>
<td>Granite, gneiss, and other metamorphic rocks sandstone with lenses of claystone; Greenish khaki shales; pebbles and cobbles.</td>
<td></td>
<td>Marine</td>
<td>Exposed in the coastal belt between river Palar and south of Madras</td>
</tr>
</tbody>
</table>

* In y unconformities that are common to sub-surface and outcrop sequence are shown.*
Permian

Permian rocks, designated as Appur group and outcropping near Chengalpet, consist of fine to medium grained, light brown to yellow coloured sandstone with lenses of grey claystones. Well-rounded concretions of claystones are common. Few rounded pebbles and cobbles of pink quartzite are associated with this formation. Early Permian Palynomorphs are recorded from this unit (Venkatachala and Rawat, 1973). The assemblage is comparable to that of the Talchir unit of lower Permian age. These marine Permian sediments indicate the existence of Paleo-shelf between Peninsular India and a land mass that lay to the east before the splitting of continents in Gondwana land during Jurassic.

Jurassic to early cretaceous

These formations that occur as isolated patches in the area south of Palar and north of Madras have been deposited in faulted troughs. A maximum thickness of 250 m has been estimated for this formation in Palar area. They comprise boulder bed, sandstone, clay and clayey micaceous sandstone. They are named as lower Sriperumpudur formation and upper Sathyavedu formation. They are considered to be of fluvial origin as varieties of plant fossils are observed in them. These rocks are overlain by Cretaceous and Mio-Pliocene formations.

Cretaceous

Among the Cretaceous formations, the reefal limestones of Dalmiapuram formation are considered to be the oldest. They are hard, massive and coralline, exposed in the Dalmiapuram and
Maruvathur area of Trichirapalli district having a maximum thickness of 400 m. They overlie an irregular basement occupied by a boulder bed probably of upper Gondwana formation. They are overlain by Late Cretaceous formation namely "Uttathur formation".

The Late Cretaceous sediments are exposed in the western parts of the Cauvery basin and are classified into Uttathur, Trichinopoly and Ariyalur formations with maximum thickness of 900 m, 600 m, and 1500 m, respectively.

The Uttathur formation consists of reefoidal limestone and minor sandstone, with rich faunal assemblages. Conglomerates and quartzites are also found to occur in the Uttathur group of rocks. These rocks are exposed only in Trichirapalli area where they are overlying Gondwana and Dalmiapuram formations. The sub-surface, equivalent of the Uttathur formation, is devoid of reefoidal elements.

The Trichinopoly formation, unconformably overlying the Uttathur formation, comprises conglomerate, pebbly sandstone as well as gritty calcareous sandstone with bands of claystone, gypseous claystone, sandy limestone, shelly limestone and clayey limestone with abundant fauna. They are exposed in Ariyalur, Vridhachalam and Pondicherry areas.

The Ariyalur formation is found to occur overlying Trichinopoly formation. They are exposed in Thanjavur, Ariyalur, Vridhachalam and Pondicherry areas. The rocks are mainly greenish grey, friable clayey sandstones, fossiliferous argillaceous limestones and sandstones. The lower part of
Ariyalur formation is highly fossiliferous while the upper is largely unfossiliferous. Equivalents to Ariyalur formation are represented by Patti limestone and Meppuliyur limestone in Vridhachalam area, Turuvai member in Pondicherry area.

Cenozoic

Paleocene

The Paleocene sequence unconformably overlies that of Late Cretaceous. It is locally designated as Niniyur stage and also Pondicherry formation. Generally, they comprise argillaceous limestones, variegated claystones, marlstones and bands of nodular limestone. The sediments of Paleocene age exposed in the eastern part of the Cauvery basin consist of marine shells, minor sandstones and limestones.

Eocene and Oligocene

The Eocene and Oligocene marine sequences are not exposed. However, they are very well-developed in the subsurface sequence. They comprise shale, sandstone and limestone. The Eocene sequence is largely clastic but in some places in the eastern part of the Cauvery basin, it comprises carbonates. The sequence is fossiliferous and has been classified into early, middle and late Eocene. Oligocene sediments are also found to occur only in sub-surface. They consist of sandstone, shale and minor limestones.

Miocene and Pliocene

Lower Miocene formations are represented by marine formations encountered only in subrocks. These rocks show a development of arenaceous facies and shaly facies with
intercalations of limestone and sandstone. A maximum thickness of 1100 m is estimated.

The late Miocene to Pliocene rocks are represented by Cuddalore sandstone formation comprising reddish brown, highly ferruginous, gritty, friable, feldspathic, clayey sandstone with or without laterite capping. They are overlapping almost all types of rocks right from the Archaean to Eocene. While the outcrops of Cuddalore sandstone formation are found to be of continental origin, the sub-surface sequence is of marine origin. **Pleistocene and Holocene**

Laterites occurring over Cuddalore sandstone constitute one of the important formations of Quaternary period. Deltaic sediments, beach sands, natural levees, channel fill deposits, lagoonal deposits, aeolian sands, etc., are the characteristic deposits of Quaternary. (Quaternary deposits are described in detail in the subsequent chapters).

### 1.5. Review of Previous Works

A review of the studies on regional geomorphology, coastal geomorphology and continental shelf morphology of the area will give an insight into the type and nature of the geomorphic work being carried out in India. From the review of literature, it is evident that the studies on erosional or planar surfaces are found to have attracted number of geomorphologists since 1850's. The coastal geomorphic and sea-level studies along Indian coast (both east and west coast) and Sri Lanka coast have also been reviewed.
a. Regional Geomorphic Studies

Blanford (1858), the pioneer in the geoscientific studies of India, recognised the gently rolling upland of Nilgiris massif, being a plain of marine origin and has visualised that the Nilgiris has been uplifted since Cretaceous. Wadia (1943) correlated the peneplains of south India with those of Sri Lanka and suggested the successive faulting and up-liftment for the development of peneplains. It indicates successively younger age for the "Peneplains", as one proceeds from the lowest—about 130 m — which is post Jurassic to the highest — about 2700 m — which is very much younger. On the other hand, Pardhasaradhi and Vaidyanathan (1974) viewed that the Nilgiris surface (2700 m) would have formed during Jurassic but uplifted later following denudation. Demongeot (1975) has also subscribed to this view.

Arogyaswamy (1963), Vaidyanathan (1967) and Babu (1975), while discussing the origin of "Palghat gap", exhibit the same view that some faults south of Nilgiris have brought the Palghat gap.

Radhakrishna (1952, 1966) and Vaidyanathan (1967) have discussed the other important surface namely "Mysore Plateau" in detail and assigned the age varying from Cretaceous to Miocene.

Radhakrishna (1968) has viewed that most of the highest mountains in the Precambrian of south India are made up of charnockites which are usually formed at great depth and this indicates that the mountains must have been block faulted and uplifted.
Krishnan (1953) is of the view that the structural trends of Dharwarian, Eastern ghats and Aravalli are responsible for the triangular shape of Peninsular India.

Vaidyanathan (1975) has inferred the presence of cymatogenic upwarps and downwarps in Peninsular India. He has also noticed that no concordant relation exists between the axes of upwarps and downwarps and the basic structure of the rocks, over which the axes are observed. He has also shown the example of the general slope of Tamilnadu upland plain being towards E when compared to the structural elements being due NE-SW. He is of the view that the reactivation of basin faults of Cauvery sediments has taken place subsequently to or during the deposition of sediments.

Babu (1975) on the basis of geomorphic study of Peninsular India, south of 13° N latitudes has observed the base levels of erosion at the elevation of 900 m, 600 m, 300 m and 150 m above MSL. The comparative datings of the same are assigned to the Mesozoic, Early Tertiary, Late Tertiary and Pleistocene cycles of denudation, respectively. The erosional surfaces are correlated with the unconformities, observed in the sediments of the adjoining Cauvery basin.

Babu (1979) has again correlated the erosional surfaces of Eastern Ghats with the unconformities observed in the Cauvery basin, taking into consideration the laterite occurrence in the sub-surface. He observes five erosional surfaces at altitudes of 1200 m, 900 m, 600 m, 450 m and 300 m, in the Eastern ghats. The post-Jurassic unconformity is correlated with 1200 m erosional
surface while the subsequent Post-Cretaceous unconformity to 900 m, the post-Eocene unconformity to 600 m, the Post-Oligocene unconformity to 450 m, and Post-Miocene to 300 m level.

Subramanian et al., (1980) have traced five planation surfaces to the south of 15° 05’N latitudes, based on the thirteen landform profiles drawn from west coast to east coast. They have also discussed the relation between the planation surfaces and products of residual chemical weathering including laterite and related ore deposits of bauxite, iron and manganese.

Vaidyanathan (1987), while reviewing the studies of planation surfaces, has pictured out depositional planar surfaces, erosional planar surfaces, and lateritic planar surfaces of Peninsular India. He has also recognised fluvial and marine planation surfaces among the Quaternary surfaces.

b. Coastal Geomorphology and sea-level studies

Chatterjee (1961) recognised seven Quaternary marine levels in different parts of India along the coast from Saurashtra in the west to Orissa in the east and correlated the high sea stands with the levels recorded in the Mediterranean sea.

Meijerink (1971) has studied the geology of the Cauvery delta with the help of aerial photographs with complementary auger data collected in the northern part of the delta. The Quaternary formations of different ages have been classified into number of "stages" viz. Orathanadu stage, Mulliyar stage, Vettar stage, Arasalar stage, Cauvery stage and Coleroon stage. With the help of geological and geomorphic details he has invoked a
fast rise of sea-level from about -70 m at the close of the Wurm glacial stage to the present sea-level. He also observes Holocene transgression during 3000-6000 BP over the Pleistocene fluvial deposits.

Ahmed (1972) has narrated several aspects of landforms of east coast. Significant observations are i) the beach ridges are numerous, continuous and prominent in the regions where the coast is parallel to the NE and SW monsoonal winds, ii) the Pulicat lake has formed by the piling of sediments during Dunkirkian transgression, iii) the shoreline of Tamilnadu between Kanyakumari and Point Calimere is crenulated while Point Calimere to Pulicat is a straight one, iv) the correlation of strandlines of India with the Mediterranean sea-levels of Quaternary, v) the present coastal geomorphology of India has evolved largely in the background of Flandrian Transgression and pre-existing topography in the coast.

Stoddart and Gopinadha pillai (1972) identified thirty three species of corals around Rameshwaram area and by correlating the raised reefs of this region with other Indian Ocean coral reefs concluded that the raised reefs are of local tectonic emergence nature.

Meher-Homji (1973) recognised three zones of mangrove species in Pichavaram lagoon area. By observing the distribution of species with respect to geomorphic condition, the evolutionary history of Pichavaram lagoon has been inferred.
Marine terraces around Cuddalore and Pondicherry are considered to be the result of uplift of land as well as regression of the sea (Demongeot, 1975).

Dwivedi et al., (1975), based on the study of intertidal micro fauna, classified the beaches of Tamilnadu area into two distinct categories, the sheltered and the open sea beaches. The beaches in the sheltered part have wider expanse, shallow gradient and weak wave action. On the other hand, open sea beaches have narrow intertidal expanse, steep gradient and strong wave action.

Nageswara Rao and Subramanian (1976) have recognised five geomorphological units in the Araniyar - Korataliyar river basins. They are attributing the lowering of sea-level during last glaciation as cause to the development of canyons on the exposed continental shelf. From the presence of the raised marine deposits and paleo-channels, they suggest the role of neo-tectonic activity.

Prasad (1978) noticed neo-tectonic activity along the coast of Tamilnadu from the existence of eleven meter bed of lignite at a depth of 72 m in Pondicherry and submerged forest at Vallimukkam. The occurrence of shell bed at higher elevation near Porto Novo and Cuddalore are evidences of emergence.

Prudhvi Raju and Vaidyanathan (1978) have classified Vishakapatnam geomorphology into five different environments namely hills and hillslope, intermediate lowland, coastal zone, rolling plains and laterites. Studying the logs of bore wells in the tidal basin, they have concluded that during the commencement
of Holocene, the sea-level might have been about 7 m higher than the present.

Vaidyanathan (1981) has stated that the coral reefs and a few terraces close to Rameshwaram island between Tamilnadu and Sri Lanka must have been the result of some emergence. In the south eastern coastal plain of Tamilnadu, there are a few places which are presently much inland but in historical times they have been reported to be the sites along the coast. This indicates progradation of the coast in the southeastern part of Tamilnadu.

Thin sections, TEM, SEM analysis carried out by Gardner (1981) indicated that the 'Teri' sands (Tamil = sandy waste) of Ramanathapuram have formed out of in situ weathering of coastal dune sands. It is postulated that the garnet was a major source for hematite which has reddened the sands. These dune sands are dated to $21000 \pm 2160$ years BP. by $^{14}C$ dating analysis of shells collected within it.

While tracing the evolution of Cauvery delta Sambasiva Rao (1982) has recognised the following: i) the delta has a mean gradient of 1 in 4400, ii) the asymmetrical form of delta, iii) twelve sets of abandoned river channels, iv) three strandlines at 15 km, 25 km and 4 km inland indicated by series of beach ridges, v) three stages in the growth of delta, vi) the rate of progradation as 10 km per thousand years.

Swaminathan (1985) has deciphered the interference in littoral regime by the introduction of any artificial structure resulting in the erosion on the down drift side and deposition on the updrift side as in the case of present Madras harbour.
Fontugne and Duplessey (1986), while studying the effect of glacial and interglacial epochs during Quaternary, observed not only the strong fluctuation in sea-level and intermittent exposure of the continental shelf to subaerial processes as in other parts of the world, but also the appreciable perturbation in rainfall patterns. He has also reported that during last glacial maximum the south west monsoon had disappeared from the Indian landscape.

While discussing neo-tectonic activity in India, Dhoundial (1987) demarcated seven zones of Quaternary tectonic domains with distinctive geologic, seismic, neo-tectonic and geothermal gradient characteristics. He has suggested that easterly and northerly structural trends are active in coastal and offshore areas during Quaternary.

Tissot (1987) carried out palynological analysis of sediments, cored in the estuaries of the Cauvery and stated that they must have been 2000 years old. Based on the palynological evidence, the evolution of Pichavaram lagoon has been described. It has been concluded that successive developments of seaward sand barriers enclosing the lagoon was favorable for the growth of mangroves.

Merh (1987) while compiling sea-level studies of Indian region agreed to the view that the level rose higher than the present level by 6-10 m during Holocene transgression. He attributed the glacio-eustatic combined with glacio-isostatic rise of sea-level by 6-10 m for this Holocene transgression.
Brückner (1988) has synthesised the geomorphological and sedimentological characters of parts of Tamilnadu, Andhrapradesh and the Andaman islands for understanding sea-levels from Jurassic to Recent. He has invoked late Quaternary transgression around 1,25,000 years BP during last interglacial period and Holocene transgression between 6000 and 4000 years BP along the coast of Tamilnadu. Brückner (1989), while studying the late Quaternary shorelines of India, has inferred that the 1,25,000 years old strandline about 4 m above present sea-level to be the outcome of the subsidence or stability of the coast rather than emergence for this. He has proposed a rise in sea-level of 1 m above present MSL during Holocene transgression.

Loveson and Rajamanickam (1988) have visualised the active progradation along the southern Tamilnadu coast from the occurrence of number of spits and beach ridges. They have divided geomorphically the coastline into four zones viz., moderately cliffed coral shoreline, gently sloped sandy shoreline, cliffed sandstone shoreline and impermeable crystalline shoreline.

Kaliasundaram et al., (1988) have identified the places of erosion and accretion along the coast of Tamilnadu based on the analysis of data collected from 30 locations for the period from 1978 to 1988. They identified erosion or accretion by measuring the distance between the berm and the reference pillar erected for this purpose in all 30 locations. They have concluded that 18 stations are of erosive and 12 stations are of accretive nature.
Vaidyanathan (1990), while discussing the morphology of deltas of east coast modern deltas, has indicated that the growth of Cauvery delta is mainly towards east and south-east portion. The occurrence of very few features of marine action in Cauvery delta is compared with the delta of Mahanadi. He has also inferred structural control for straight N-S coastline of the area.

Remote sensing application in the field of coastal geomorphology has been attempted by Loveson et al., (1990), Nagarathnam et al., (1990), Srinivasan and Srinivasan (1990), Subramanian et al., (1990). Broad geomorphic classification, strandline identification and coral reef growth rate inference are some of the studies attempted using remote sensing techniques.

Rajamanickam and Loveson (1990), based on $^{14}$C results of the coral samples collected around Rameshwaram area, have inferred that a transgression around 5000 years BP, must have resulted in the Ariyankadu coral terrace. The successive regressions left two more terraces and they have been dated 3670 ± 65 years BP and 2630 ± 50 years BP.

Rajamanickam (1991) observed the features of emergence and submergence respectively along the southern and northern parts of Tamilnadu. He has postulated that the landward migration of offshore sediments combined with terrestrial sediments accelerates the progradation along Palk strait region. He has also invoked upwarping along Tuticorin area.
Ramasamy (1991), based on interpretation of satellite imagery, has propounded his inference that it is the Cauvery river that has successively migrated south right from north of Madras to its present course.

Mathur (1993), while discussing the Quaternary sea-level records of Indian Coast, has emphasised that the sea-level fluctuation in stable Indian continent is free from tectonic effect. He has also noted the anomalous records of sea-level in Saurashtra region i.e. evidences for ca. +40 m to +70 m rise above MSL during middle Pleistocene are anomalous as the general view is that Quaternary sea-level at no time might have risen beyond + 40 m above MSL.

Varadharaj (1993) has attributed a rise in sea-level, resulting in the closing of river and lagoon mouths with sandy barrier bars, for the poor quality of water in many pockets of Madras city. Based on the bore hole data of Central Ground Water Board, the depositional environments around Madras city from Gondwana to Quaternary are discussed.

Banerjee (1993) has observed repeated sea-level changes in the tropical belt must have induced isostatic disequilibria and epiorogenic movements in the near coastal region during the Pleistocene. It is envisaged that these forces could have triggered the release of residual stress along old dislocation zones leading to inducement of different uplifts in ancient cratons.

Radhakrishna (1993) has narrated the events that have fashioned the peninsular Indian landscape. He has summarised the
sequence of events of land and corresponding effects on the east and west coasts of India. From the study of the east coast sedimentary basin, it is envisaged that the onset of the Tertiary era is indicated by oscillatory movements in response to uplift and consequent erosion on the landward side.

Vaidyanathan (1993), while summarising the geologic and geomorphic history of east coast of India, observes the dating of samples collected from different horizon along east coast invariably indicates Holocene age, though some dates point to upper Pleistocene. He has also observed tectonic effect on coastal region evidenced by abrupt changes in the course of river, the anomalous orientation of coastline and the juxtaposition of different lithological units within the Quaternary.

c. Continental Shelf Morphology

Setty (1964), Subba Rao, et al., (1967) and Varadhachari et al., (1968) have reported the presence of submarine canyons along the coast of Tamilnadu region. Varadhachari et al., (1968) have revealed the presence of three canyons off the coast of Tamilnadu namely Palar, Puducherry and Cuddalore canyons. While discussing the origin, the submarine erosion by turbidity currents triggered by the severe storm frequent in this region is attributed.

Gloss et al., (1974) have observed that the minimum width of continental shelf along east coast of India is 25 km near Madras to 210 km near Calcutta. Three submarine canyons on
the continental slope off the Andhra coast and three canyons off Tamilnadu have been observed.

Siddiquie (1975) has reviewed the marine geological, geomorphological, sedimentological, geochemical and paleontological studies in India and forms the basic literature and bibliography for the marine geological studies. Siddiquie and Rajamanickam (1978) have estimated the area of continental shelf of India to be about one third of the land area. The various places of occurrence of offshore placers, biogenous and chemogenous deposits along the shelf region have been reported by them.

Banerjee and Sengupta (1992), conducting seismic and sub-bottom profiling in the shelf area of east coast, inferred three low strands in the form of topographic highs at 30 m, 60 m, and 100 m with supporting paleontological and sedimentological evidences.

Patches of sand deposits have been observed by Shrivastava and Chandra (1993) along the shelf of northern Tamilnadu region. Off Pondicherry, sands of varying nature have been collected at different depths. Skeletal sands in the depth range of 35 to 45 m, detrital sands in the 18 to 31 m depths and pellet rich skeletal detrital sands in the 40 to 50 m depth range are discernible.
1.6. Methodology

Geomorphic Mapping

Landsat TM images (No.D142 - 052, 051, Date 24th Apr.88) in FCC of band 2,3 and 4 in diapositives were interpreted visually under optical enlarger using standard recognition elements such as colortone, texture, lineament, pattern, etc., for the delineation of coastal landforms of the study area.

Black and white aerial photographs (Year 1985) in the scale 1:50,000 were interpreted under the mirror stereoscope using standard recognition elements such as shape and form, tone, texture, drainage, lineament, pattern, vegetation, etc. As the study area has been covered by many number of aerial photographs, stripwise maps were prepared initially and these strips were compiled latter to get the map of desired size and scale. The details obtained from the interpretation of satellite images were also incorporated in it.

The features delineated in the maps were checked, modified and corrected during the field work.

Field Work

The field work involved the detailed observation of landforms, measurement of morphometric characters wherever felt necessary and collection of sediment samples and biologic remains. Morphometric characters were measured with the help of Theodelite and heights were corrected to Survey of India Bench Mark levels.

The representative sediment samples of different landforms were collected with the help of the hand auger to a
depth of 1 m. Utmost care was taken in collecting samples of undisturbed nature. Wherever the biologic remains are found to occur, they were collected after careful study of the location, altitude, possibilities of later inclusion, anthropic character of the area, etc. The locations of sediment and biologic samples were carefully determined with the help of Brunton compass and marked on the Survey of India toposheets.

**Laboratory Methods**

Post field interpretation of aerial photographs was carried out to prepare the final geomorphological map.

As an endeavour to understand the application of remote sensing technique in coastal geomorphic studies, digital interpretation of satellite images was carried out with the help of Institute of Remote Sensing, Anna University, Madras. The details of methodology of digital interpretation are given in chapter 2.

The sediment samples were analysed for grain size studies, details of which may be found in chapter 3.

Bore well data were collected, during drilling for various regions of the study area in collaboration with the Ground Water Division, Public Works Department, Tamilnadu Water and Drainage Board (TWAD) and other private agencies. Lithologic sequences along six profiles could be built up with these data.

The geomorphic, lithologic and archaeological evidences were synthesised to infer the nature and extent of Quaternary sea-level oscillation.
A tectonic map of the study area was prepared with the help of satellite images and aerial photographs coupled with field observations.

The integration of analysis of coastal landforms, Quaternary sea-level oscillation, fluvial sedimentation and tectonism could help in the understanding of landscape evolution.

Finally, for understanding the existing beach dynamics, studies on wave refraction pattern were carried out adopting the Finite Amplitude Wave Theory. A brief description of the method adopted is outlined in chapter 4.

The flow chart of methodology is shown in Fig.1.5.
Figure 1.3 Physiographic map of South India.

- High mountains - Above 900 m
- Low mountains - 300 to 900 m
- Dissected zone - 100 to 300 m
- Coastal plain - MSL to 100 m

Modified after Babu (1975)
Figure 1.4 Geological map of the study area.
Figure 1.5 Methodology in flow chart.