Chapter-1

INTRODUCTION

1.1. General:

A beach is a geological landform along the shoreline of a body of water. It usually consists of loose particles which are often composed of rock, such as sand, gravel, shingle, pebbles, or cobblestones. The particles of which the beach is composed can sometimes have biological origins, such as shell fragments or coralline algae fragments. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles.

While sediments brought by sea are being transported to the land, the beach sands form new environments creating a transition zone between the fluvial and marine environments. Greater attention is bestowed on research in beach environment during recent years and a wealth of information on biological, chemical, hydrographical and geological aspects of marine system have been gathered, and lengthy syntheses of the interaction between these subjects in several researches have been published. These literature clearly indicate that a given set of beach sands can never be identical in their environments of deposition. The interactions of so many variables and differences in the physic-chemical, biological, meteorological and sedimentological conditions that exist in the different regions of our country make this problem more complicated, it is necessary to study each coastal region individually.

Beach sands are, one of the natural resources of the coastal zone of Tamilnadu, calling for an intensive study on their distribution, modes of occurrence, and chemistry of the deposits available in the region. The
deposits have a potential to contribute to the development of the industrial economy of the state (Indian Mineral Year Book, 1999). The deposits are confined to the surface in the coastal area with a uniform width, limited overburden and only minor variations. Sands of a specific grain size and composition concentrated in these locales are unique.

A cursory analysis of the existing literature on coastal region reveals that the Karaikal coastal region has been studied regarding its biology and hydorgraphy. However, geological aspects are yet to be studied. Therefore, the present study intends to investigate the Geomorphology, Sedimentology and Geochemistry of Beach Sands of Karaikal Region, Pondicherry, India.

The investigation involved a combination of reconnaissance work and hand and trench digging at sites of potential heavy mineral deposits. Samples were taken for sedimentological and geochemical analyses. This research report provides a summary of the results (including maps, photos and figures) and describes the findings to enhance the overall understanding of beach environments in the study area.

1.2. Scope of the study:

Mineral wealth gives a fillip to a country’s economy. In India, a yawning gap, widening at an alarming rate exists between demand and supply of natural resources. In order to bridge this gap, exploratory works for locating valuable minerals are tapped up. Various agencies like Department of Atomic Energy, Indian Rare Earth’s have been commissioned to identify and prioritize the strategic and valuable deposits. Detailed studies have been undertaken with regard to the formation, nature and economic viability of
beach sands. But little has been done to evaluate the potential of fluvial deposits. Though, the shoreline have attracted oil exploration geologists, still they have-not been paid adequate attention to the heavy mineral as they deserve. The potential of alluvial deposits remains unrealized and unevaluated. This study highlights the geomorphic features, sedimentary depositional environments, evaluation of valuable minerals if any, tracing provenance of sediments and the characteristic of heavy mineral assemblages and geochemical analysis more importantly, towards the formation of beach placer sediments of the study area.

Amidst Globalization, WTO, GATT (Global), Population, Poverty, Unemployment (National) problems, “conservation and exploration of mineral deposit” alone may workout fruitfully for future economical development of our nation. Coping the Godzillaic world development, what India needs is a booming search for new mineral deposits (fuel, metallic and non-metallic).

Anbarasu (1994) stated that the present coastal configuration and the paleo coastal configuration could be studied in detail using the grain size distribution analysis from the sedimentary particles obtained through various landforms.

According to Yeong et al (1999) who have analyzed sediments from the northern coastal area of Cheju Island (South Sea of Korea, southeastern Yellow Sea) for grain size composition, elemental compositions and clay mineralogy in order to investigate their provenance. Rare earth element (REE) compositions and geochemical discrimination diagrams were revealed that both the sandy and muddy sediments originated from weathering of the volcanic rocks of Cheju Island.
Bhaskar Chandra Acharya et al (2009) have analyzed that Heavy Mineral Placer Sand Deposits of Kontiagarh Area, Ganjam District, Orissa, India. Light minerals decrease in size from the beach to the back dunes, whereas the size distribution of heavy minerals in the beach and dunes is more or less uniform. The average heavy mineral content in the beach and dunes vary from 9.38% to 24.20%. It has good economic potential for commercial exploitation of ilmenite, rutile, sillimanite, monazite, zircon and garnet.

Dill (2007) have analyzed that grain morphology of garnet shows an increase in angularity from the pyrope – through almandine-, grossularite- to the spessartite-enriched garnet solid solution series in the placers under consideration. Spessartite-enriched garnet solid solution series are widespread in pegmatites and lowgrade metamorphic rocks where they normally form euheedral crystals.

Rajesh Kumar Ranjan et al (2008) suggests that tsunamigenic sediments are rich in heavy minerals, thus resulting in increases in concentrations of heavy metals such as cadmium, chromium, nickel and lead in the Pichavaram mangrove forest of India. Mustafa Ergin et al (2007) The high concentrations of heavy minerals (chromite, magnetite and hematite) and elements Fe, Cr and Ti found particularly in dark green–black coloured beach sediments from the western Gulf of Antalya and part of the Gulf of Finike indicate formation of placer deposits which could be of economic potential in the future.

1.3. Objectives:

The present study encompasses the following objectives.
To prepare a geomorphological map of the study area by using IRS P6 LISS-III (2009) satellite imagery and aerial photos.

To decipher the depositional environments using grain statistics.

To identify heavy mineral assemblages and their percentages.

To study the maturity indexes of beach sands on the basis of geochemical studies.

To identify the anlaysed major elements, trace elements, REE of the study area.

To arrive at the provenance of sediments and the evaluation of valuable placer minerals, if any.

1.4. Study Area:

The study area falls between Nagapattinam coastal tracts, extends from Sinurpet to Vanjure (10° 49' to 10° 59' N and 79° 49' to 79° 51' E) shows (Fig: 1.1). The study area lies in Nagapattinam district in the northern and southern coastal tract of Tamilnadu covering about 18 km in length. The area bears the number 58 N/13, in the 1:50,000 toposheet prepared by the Survey of India.

1.4.1. Physiography:

Karaikal Region is situated in more or less a flat land. There are no hills or forests in this district. This region consists of almost entire by coastal alluvial soil, which is highly suitable for cultivation of paddy and pulses. Almost all the villages in the study area are well connected by the metal roads and concrete roads. The nearby airport is situated in Trichy. As for as the telecommunication is concerned the study area is well equipped with the telecommunication facilities, ie.land line phones and cell phone
towers. Study area have facilities such as Hospitals, Hotels, Major Bus stand, Railway junction, Port, Cinema Theaters, Parks and Beach.

1.4.2. Climate:

Karaikal, situated on the east coast of India, near latitude 11ºN in the deltaic region of the Cauveri, experiences tropical maritime type of climate with small daily range of temperature and moderate rainfall.

1.4.3. Rainfall:

Karaikal has an annual average rainfall of about 126 cm. 68 percent of which occurs during October to December. The amount of rainfall during the south-west monsoon period is small, being less than 20 per cent of the annual. November is the rainiest month, accounting for about a third of the annual total. The range of variation of annual rainfall is wide. Variability of annual rainfall is fairly large, so that significant variations in rain fall from year to year may be expected. Drought conditions with the annual rainfall of less than 75 per cent of the normal may be expected once in three years on an average. In a year there are on an average about 55 rainy days, i.e. Days with rainfall of 2.5 mm or more.

1.4.4. River system and Water Resources:

The main branches of Kaveri below Grand Anicut are the Kodamurutti, Arasalar, Virasolanar and the Vikramanar. Although Arasalar and its branches spread through Karaikal, the waters of Kodamurutti and Virasolanar also meet the irrigation needs of the region. The Arasalar having a total run of 24 km enters Karaikal region, a little east of Velanganni. It forms, the natural boundary line separating Niravi Commune from Tirunallar on the north-west and Karaikal on the north-east. The Nattar, branching off
from Arasalar at Sakkottai in Thanjavur District, runs a distance of 11.2 km. in the south-easterly direction across Nedungadu and Kottuchcheri Communes before emptying itself into the sea.

The Vanjur fed by Arasalar, takes its course along the northern boundary of Tirunallar Commune, drops on a south-easterly curve towards Karaikal Commune and merges with the Arasalar, south-east of Karaikal town after covering a distance of about 9 km. The Nular, also fed by the Arasalar, runs a distance of 13.77 km. before it joins Vanjir north-east of Karaikal town. The Puravadaiyanar and the Tirumalarajanar are the branches of Kodamurutti.

Puravadaiyanar runs through Tirumalarajanpattinam Commune for a distance of 5.3 km. before, it empties itself into the sea, south-east of Melvanjiyur. The flow of Tirumalarajanar which forms the natural boundary line between Niravi and Tirumalarajanpattinam communes runs a distance of 5.13 km. before it enters the sea, north of Pattanachcheri. The Nandalar takes off from Virasolan and meanders across the northern boundary of the region through Nedungadu and Kottuchcheri Communes for a distance of about 15.15 km. before, it finds its outlet into the sea a little south of Tarangambadi.

1.4.5 Ground water resources:

Karaikal region gets most of its water for irrigation from Kaveri and as such ground water resources in the region have not been fully developed. Here the water table lies at depths of 3-4 meters below ground level and during summer declines to 6-7 meters below ground level. In a number of villages filter point wells piercing sandy materials down
to about five meters and fitted with hand-pumps supply fairly good quality water. In many cases the quality of shallow ground water is rather poor. In the past, several attempts were made to tap ground water by means of deep tube-wells for drinking and agricultural purposes. The region is occupied by alluvium consisting of sands and clays. Data of bore-holes put down in the vicinity of Karaikal indicate that the thickness of the alluvium is possibly of the order of 68 meters.

The alluvium is underlain by the Karaikal beds of Pliocene age consisting of sands, gravels and clay. Wells in and around Karaikal range in depth from 3.5 to 10.7 meters with the maximum depth of water level in summer being of the order of six meters.

Ground water in Karaikal is developed chiefly by means of dug wells or filter-point wells piercing blown sands and alluvium. A few bore-holes not exceeding 30 meters in depth drilled in the vicinity of Karaikal were reported to have been abandoned on account of the poor quality of water in the granular zones in the alluvium. However the data of a deep bore-hole put down at Karaikal in 1884 indicated that confined aquifers overlain by a thin bed of clay could be expected to occur below a depth of 90 meters in and around Karaikal which is expected to be a source of potential water supply, if tapped by tube-wells.

To the south and west of Muppattankudi and towards Mathur further west, sands are met with down to depths of 8 to 12 meters below surface. Wells tapping these sand yield water in plenty. About 1.6 km, south-south-east of Nedungadu, in the western portion of the region, confined aquifers have been tapped by tube-wells. In a number of tube-well attempted
down to depths of upto five meters only brackish water is reported to have been met with. A tube-well down, to a depth of 61.7 m near Akalanganni is said to yield brackish water.

Karaikal town gets its water by means of a battery of a shallow interconnected open wells and an infiltration gallery in the bed of Arasalar. A few villages between Velanganni and Karaikal also get their water supply from this source. The town faces difficult water supply position during the months of April-June, when there is no flow in the Arasalar. Owing to the limited extent and thickness of sands in the bed of wells in Arasalar in the vicinity of the well site, attempts to increase the number of wells in Arasalar bed have been unsuccessful.

1.4.6. Temperature, Humidity, Cloudiness and Surface winds:

The level of temperatures in Karaikal is about the same as in Pondicherry. December and January are the coolest months with the maximum at about 28°C and the minimum at about 23°C. Minimum temperature, as low as 16°C is also recorded. The diurnal ranges of temperature are generally small throughout the year, being highest (about 10°C) in May and June, and the least (about 5°C) during November to February.

The level of humidity and the pattern of cloudiness and surface winds are the same as in Pondicherry. Although slight variations in the month wise occurrence of depressions and storms are noticeable, thunder-storms generally occur during April to November, particularly in April, September and October.
1.4.7. Relief:

Forming part of the fertile Cauveri delta the region is completely covered by the distributaries of Cauveri. Covered completely by a thick mantle of alluvium of variable thickness, region is flat having a gentle slope towards the Bay of Bengal in the east. It is limited on the north by the Nandalar and on the south-east by the Vetar. The group of rocks known as Cuddalore formations is met with in the area contiguous to Karaikal region in Nagappattinam District.

1.4.8. Soil Pattern:

The district is situated in more or less a flat land. There are no hills or forest in this district. This district consists of almost entirely coastal alluvial soil which is highly suitable for cultivation of paddy and pulses. The total geographical rural area of the district is 14035.56 hectares. The percentage of cultivable area to total area and percentage of irrigated area to total cultivable area are 84.92, 82.81 respectively. Pulses, cotton, chilies, coconuts, ground nuts, vegetables and sun flower are the other popular items grown in the district.

1.4.9. Mineral Wealth:

The following are the minerals met with in the region:

Brick clays:

Brick clays are won from the banks of Arasalar about 1.6 km. almost south-west of Pudutturai over an area of 0.6 sq. km. Clayey soils are also employed for making bricks near Mel Kasakkudi, Nedungadu, Ambagarattur and Vadamattam. Indicated reserves of 1.3 million tonnes have
been computed, of which the Padugai lands along the Arasalar account for million tonnes.

**Kankar:**

About 0.4 km. in a northerly direction from Mel Subbarayapuram village, small amounts of pisolithic kankar is found. It is obtained from a depth of about 1.2 km.

**Sea Shells:**

Sea-shells collected from the coast are made use of in making lime for local use. Lime kilns were observed to the west of Karaikal town, near T.R.Pattinam and Akkaravattam.

**1.4.9.1 Ilmenite and Garnet sands:**

Ilmenite and Garnet occur in varying concentrations in the beach sands along the Karaikal coast over a stretch of about 10 km, and varying in width from 20 to 100 m, from Poompuhar to Karaikal, the entire foreshore and backshore is carpeted with rich concentrations of black sands and garnets. At Karaikal, the backshore is wider for about 850 m in the enriched zones, symmetrical and asymmetrical ripple marks in the backshore and the dune areas are rich in garnets and black sands. There are no beach ridges in the heavy-mineral-rich zones.

**1.4.9.2 Oil:**

It may not be out of place to mention about the prospecting for oil going on in the area, as a result of the favorable structures and thick sediments deciphered first by the Geophysical division of the Geological Survey of India, and later on by the Oil and Natural Gas Commission.
1.5. Methodology:

1.5.1. Field Work:

In the present study the following method was adopted for understanding the grain size characteristics and transportation history. Aerial photo and Satellite imagery were interpreted for understanding the nature of the terrain and preparation of the geomorphology map. The study area in general is formed by marine and aeolian process.

To understand the general topography of the study area fieldwork was carried out. Samples were collected at specific intervals for the determination of grain size characteristics to infer the environmental conditions (Fig: 1.2).

1.5.2. Geomorphological study:

The geomorphologic features interpreted from aerial photos are transferred to the base map. This has ensured the incorporation of all the landforms interpreted from aerial photos and imagery. The various geomorphologic features like alluvial plain, beach, beach ridges, beach ridge plain, lagoon, mangroves, mudflat, paleo channel and sand spit, sand dune etc., are identified.

1.5.3. Sedimentological Study:

In this study, representative samples of the different depositional environments were studied including their grain size, heavy mineral assemblages and their properties.
1.5.3.1. Granulometric study:

Granulometric study is an essential part to understand the mode of transportation and depositional environment of sediments. Using graphic (Folk and Ward, 1957) and moment methods (Friedman, 1961, 1967 & 1979) the weight percentage data of 68 samples were processed in Grain and Orgin 6.1 software. From the statistical parameters, frequency curves, mean, standard deviation, skewness, kurtosis, CM diagram, bivariant plots and Visher’s log probability curves, a comparative statement was drawn for the analysis proceedings.

1.5.3.2. Light - Heavy Mineral Separation:

The sieved fractions of beach sands have been made into light and heavy mineral fractions by following the procedure mentioned in the Muller (1967). The individual fractions have been grouped into three different fractions coarse, medium and fine for heavy mineral separation.

From the mounted slides the individual (>300 grains) minerals were counted by using the line method described by Galehouse (1969). Various diagnostic properties of heavy minerals provided in the Milner (1962), Phillips and Griffen (1986), Ford (1951), Rothwell (1989), are utilized for the easiest identification. From the results of line counting method, the general distribution pattern of heavy minerals in the study area has been obtained.

1.5.4. Geochemical study:

The samples were prepared properly for geochemical studies. 68 bulk samples were analysed for trace, REE and major elemental analysis. The analyses of trace, REE were carried out in the geochemical lab (ICP-MS: Perkin Elmer Sciex ELAN DRC-II), National Geophysical Research Institute,
Hyderabad, India. Major elemental analyses were carried out Systronics Flame photometer (128), UV spectrometer (GBC UV/VIS 911) and Atomic Adsorption Spectrometer (GBC-932 AA), Dept of Earth Sciences, Tamil University, Thanjavur.

1.6. Regional Geology:

Precambrian super-eon:

A considerable area of peninsular India, the Indian Shield, consists of Archean gneisses and schists which are the oldest rocks found in India. The Precambrian rocks of India have been classified into two systems, namely the Dharwar system and the Archean system.

The Dharwar System:

The rocks of the Dharwar system are mainly sedimentary in origin, and occur in narrow elongated synclines resting on the gneisses found in Bellary district, Mysore and the Aravalis of Rajputana. These rocks are enriched in Manganese and Iron ore which represents a significant resource of these metals. They are also extensively mineralized with gold most notably the Kolar gold mines located in Kolar. In the north and west of India, the Vaikrita system, which occurs in Hundes, Kumaon and Spiti areas, the Dailing series in Sikkim and the Shillong series in Assam are believed to be of the same age as the Dharwar system.

The metamorphic basement consists of gneisses which are further classified into the Bengal gneiss, the Bundelkhand gneiss and the Nilgiri gneiss. The Nilgiri system comprises Charnockites ranging from granites to gabbros.
Phanerozoic:

Palaeozoic:

**Lower Paleozoic:** Rocks of the earliest Cambrian period are found in the Salt range in Punjab and the Spiti are in central Himalayas and consist of a thick sequence of fossiliferous sediments. In the Salt range, the stratigraphy starts with the Salt Pseudomorph zone, which has a thickness of 450 feet (137 m) and consists of dolomites and sandstones. It is overlain by magnesian sandstones with a thickness of 250 feet (76 m), similar to the underlying dolomites. These sandstones have very few fossils. Overlying the sandstones is the Neobolus Shale, which is composed of dark shales with a thickness of 100 feet (30 m). Finally there is a zone consisting of red or purple sandstones having a thickness of 250 feet (76 m) to 400 feet (122 m) called the Purple Sandstone. These are unfossiliferous and show sun-cracks and worm burrows which are typical of subaerial weathering. The deposits in Spiti are known as Haimanta system and they consist of Slates, micaceous quartzite and dolomitic limestones. The Ordovician rocks comprise flaggy shales, limestones, red quartzites, quartzites, sandstones and conglomerates. Siliceous limestones belonging to the Silurian overlie the Ordovician rocks. These limestones are in turn overlain by white quartzite and this is known as Muth quartzite. Silurian rocks which contain typical Silurian fauna are also found in the Vihi district of Kashmir.

**Upper Paleozoic:**

Devonian fossils and corals are found in grey limestone in the central Himalayas and in black limestone in the Chitral area. The Carboniferous is composed of two distinct sequences, the upper
Carboniferous Po, and the lower Carboniferous Lipak. Fossils of Brachiopods and some Trilobites are found in the calcareous and sandy rocks of the Lipak series. The Syringothyris limestone in Kashmir also belongs to the Lipak. The Po series overlies the Lipak series, and the Fenestella shales are interbedded within a sequence of quartzites and dark shales. In many places Carboniferous strata are overlaid by grey agglomeratic slates, believed to be of volcanic origin. Many genera of productids are found in the limestones of the Permo - Triassic, which has led to these rocks being referred to as "productus limestone". This limestone is of marine origin and is divided into three distinct litho-stratigraphic units based on the productus chronology: the Late Permian Chideru, which contains many ammonites, the Late - Middle Permain Virgal, and the Middle Permian Amb unit.

**Mesozoic:**

In the Triassic the Ceratite beds, named after the ammonite ceratite, consist of arenaceous limestones, calcereous sandstones and marls. The Jurassic consists of two distinct units. The Kioto limestone, extends from the lower the middle Jurassic with a thickness 2,000 feet (610 m) to 3,000 feet (914 m). The upper Jurassic is represented by the Spiti black shales, and stretches from the Karakoram to Sikkim. Cretaceous rocks are cover an extensive area in India. In South India, the sedimentary rocks are divided into four stages; the Niniyur, the Ariyalur, the Trichinopoly, and the Utatur stages. In the Utatur stage the rocks host phosphatic nodules, which constitute an important source of phosphates in the country. In the central provinces, the well developed beds of Lameta contain fossil records which are helpful in estimating the age of the Deccan Traps. This sequence of basaltic rocks was
formed near the end of the Cretaceous period due to volcanic activity. These lava flows occupy an area of 200,000 square miles. These rocks are a source of high quality building stone and also provide a very fertile clayey loam, particularly suited to cotton cultivation.

**Cenozoic:**

**Tertiary period:** In this period the Himalayan orogeny began, and the volcanism associated with the Deccan Traps continued. The rocks of this era have valuable deposits of petroleum and coal. Sandstones of Eocene age are found in Punjab, which grade into chalky limestones with oil seepages. Further north the rocks found in the Simla area are divided into three series, the Sabathu series consisting of grey and red shales, the Dagshai series comprising bright red clays and the Kasauli series comprising sandstones. Towards the east in Assam, Nummulitic limestone is found in the Khasi hills. Oil is associated with these rocks of the Oligo-Miocene age. Along the foothills of the Himalayas the Siwalik molasse is composed of sandstones, conglomerates and shales with thicknesses of 16,000 feet (4,877 m) to 20,000 feet (6,096 m) and ranging from Eocene to Pliocene. These rocks are famous for their rich fossil vertebrate fauna including many fossil hominoids.

**Quaternary period:** The alluvium which is found in the Indo-Gangetic plain belongs to this era. It was eroded from the Himalayas by the rivers and the monsoons. These alluvial deposits consist of clay, loam, silt etc. and are divided into the older alluvium and the newer alluvium. The older alluvium is called Bhangar and is present in the ground above the flood level of the rivers. Khaddar or newer alluvium is confined to the river channels and
their flood plains. This region has some of the most fertile soil found in the country as new silt is continually laid down by the rivers every year.

1.7. Geology of the study area:

The study area is an important stratigraphic horizon, indicated by the prospects of 'oil shows'. This in turn attracted the attention of the Geological Survey of India between 1959 -1961 and later on who carried out detailed studies for determining the possibility of the occurrence of oil.

Geological formations of the study area are completely covered by a thick mantle of alluvium and no exposures are met with anywhere. The following is the geological succession of the formations (Fig: 1.4).

Recent and Sub-recent ... Blown sands, alluvium
Pliocene ... Karaikal beds
Mio-Pliocene ... Cuddalore formations.

1.7.1. Alluvium:

Alluvium is soil or sediments deposited by a river or other running water. Alluvium is typically made up of a variety of materials, including fine particles of silt and clay and larger particles of sand and gravel.

A river is continually picking up and dropping solid particles of rock and soil from its bed throughout its length. Where the river flow is fast, more particles are picked up than dropped. Where the river flow is slow, more particles are dropped than picked up. Areas where more particles are dropped are called alluvial or flood plains, and the dropped particles are called alluvium. Even small streams make alluvial deposits, but it is in the flood plains and deltas of large rivers that large, geologically-significant alluvial deposits are found.
1.7.2. Mio-Pliocene: Cuddalore formation:

Sediments of various ages (Cretaceous to Recent) are present along the south-east coast. The Cuddalore Sandstone (of Miocene age) is a major sedimentary formation which outcrops in a discontinuous linear band running sub-parallel to the coast and extending from Cuddalore at the coast south-westwards towards Madurai in Tamil Nadu. The formation is dominantly sandstone but includes economically important occurrences of lignite. The formation is buried beneath Quaternary deposits.

1.7.3. Pliocene: Karaikal beds:

The Pliocene epoch is the period in the geologic timescale that extends from 5.332 million to 1.806 million years before present. The Pliocene is the second epoch of the Neogene period in the Cenozoic era. The Pliocene follows the Miocene epoch and is followed by the Pleistocene epoch.

The Karaikal beds occur in between Quaternary and Tertiary formations in the Region. The Karaikal beds vary in thickness from 54 m in the west to 77 m in the east. The sands and sandstones of this formation are water bearing zones whose thickness varies between 11 and 40 m. But due to the marine origin of these beds, the quality of ground water is saline in nature and found unsuitable for all purposes. Hence the yields and other aquifer characteristics of these beds were not assessed and it is not tapped in production wells in the region.

1.8. Review of Literature:

During recent past the coastal regions have been studied by various researchers and scientists, form various institutions and Government
organizations. Literature study has been classified under geomorphology, sedimentology and geochemistry categories, as follows:

1.8.1. Geomorphology:

Congalton et al (1998) have described a process for integrating remote sensing and spatial data analysis to accurately map and monitor agricultural crops and other land cover in the lower Colorado River basin.

Martinez et al (2001) used wide mode, beam 2 RADARSAT-1 images along with a LANDSAT TM image to prepare the geomorphological map for Buenos Aires provinces, Argentina.


Vaiopoulos et al (2003) have carried out the study through recognition, recording and visualization of geomorphological characteristics of Samaria Gorge. Geomorphological features collected through remote sensing techniques are compared with stereoscopic observation of aerial photos and field work.

Marksud Kamal et al (2004) studied detailed GIS-based geomorphological map accompanied with landfill sites of Dhaka city area which can be used for multipurpose functionality. Attainment of the geomorphological map is based upon interpretation of the oldest available
aerial photographs (1:40,000) and contemporary topographic maps (1:8000) which reflect almost pre-urban ground of Dhaka.

Benidhar Deshmukh (2005) analyzed that Eco-Geomorphological Zonation of the Bangaram Reef, Lakshadweep identified on the image are central deep lagoon, reef knolls (rising steeply from the central deep lagoon floor), reef edge, reef platform, coralline shelf, broad shallow sandy-bottomed lagoon, beach and two islets.

Hancock et al (2006) studied the SRTM data for three catchments in Australia over a range of climates, geology and resultant geomorphology and also compared the SRTM data with high resolution DEMs and the results demonstrate that the 90M SRTM data provide poor catchment representation. Khayingshing Luirei et al (2006) examined the various geomorphic features as the evidences for the occurrence of recent tectonic movements along the thrusts and faults in Dharchula and its environs, Northeast Kumaun.

Lark and Webster (2006) found that mapping geomorphic variables geostatistically, specifically by kriging, runs into difficulties when there is trend. They summarized the theory of REML as it applies to kriging in the presence of trend.

Van Asselen and Seijmonsbergen (2006) studied the semi-automated method to recognize and spatially delineate geomorphological units in mountainous forested ecosystems, using statistical information extracted from a 1-m resolution laser digital elevation dataset. The study shows that high-resolution topographical data derived from laser DTMs are useful for the extraction of geomorphological units in mountain areas.
Adel Shalaby and Ryutaro Tateishi (2007) studied that Remote Sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt.

Jacob Napieralski et al (2007) studied that Glacial geomorphology and geographic information systems and identify previously unrecognized spatial and temporal relationships and patterns in geomorphic data.

Sinha and Khan (1981) have studied that geomorphology and landuse of pasihat-Jonai bazaar area- a photo based study in a part of Dihang River basin, Arunachal Pradesh and Assam.

Wagle (1982) dealt with geomorphology of Goa coast using aerial photographs and LANDSAT imagery. He points out the evidences which show both submergent and emergent aspects along the coast with emergence succeeding the submergence during Holocene.

Jha and Roy (1985) used that remote sensing for geology, geomorphology and lineament study of Vindhyan basin, north of Shivapuri, Madhya Pradesh.

Dey, (1985) has interpreted that Geology, Geomorphology and Mineral Resources of Khodana and adjoining areas (Haryana) and their Significance in Landuse Planning.

Singh, (1987) has prepared the geomorphology map for Bist Doab tract, Punjab using LANDSAT imagery and the identified landforms are structural hill Siwaliks, table land, upper piedmont, lower piedmont, alluvial plain, sandy and saline tract, older flood plain, active flood plain. Subramanian et al (1988) have studied that coastal geomorphology and sediment
distribution mapping using LANDSAT - TM digital data - a study in coastal area of parts of Orissa, India.

Agarwal et al (1996) have identified and evaluated the process of geomorphological evolution and hydrogeological conditions, temporal changes in pattern of geomorphic elements and overall impact on environment in alluvial fan region in Nainital District (U.P) using multidate data.

Thomas Gumbricht et al (1997) used the remotely sensed data and GIS for creating data sets of elevation and vegetation over the Himalayan Sutlej River and its tributaries. GIS coupled models are used for distributed estimates of precipitations, and modeling of basin water cycle. Fuzzy logic is used for index-related erosion modeling. They have concluded that GIS integrated modeling can pave the way to sustainable landscape management.

Iqbaluddinet et al (1997) analyzed Geomorphology and Landscape Evolution of Bharatpur District, Rajasthan and results of the village level information on geomorphology has been archived.

Sushma Prasad et al (1998) classified that Geomorphic features representing three distinct depositional environments; namely, Marine, Fluvial and Aeolian could be identified from the satellite data and field studies. These are i. Inland palaeo-deltas, ii. Old mud flats, iii. Alluvial plains, and iv. Stabilized dunes.

Shibani Maitra (1999) studied that Landforms and Geomorphological Classification of Part of The Upper Baitarani River Basin and identified under three geomorphic domains viz Hill, Piedmont and Plain.
Murthy et al (1999) studied that mapping of hydrogeomorphological features of Varaha River basin using IRS data by which the extensive fluvial plain and abandoned river channels were extracted.

Arkal Vittal Hegde (2000) studied that Short-Term and Long-Term Geomorphological Dynamics of Mangalore Spits Using IRS-1A/1C data demonstrating that the multi-dated and multispectral 1RS data could be effectively used for monitoring the geodynamics of the area.

Mohammed Aslam et al (2001) identified the palaeochannels of the Cauvery River in Karnataka state through visual interpretation of IRS-IC, LISS III False Colour Composites (FCC). In order to assess their inter-relationship with other hydrogeomorphic elements, various geomorphic units have been mapped. Major geomorphic units like alluvial plain, pediplain, valley fill, residual hill, ridges, meander scar, channel bars and water bodies have been demarcated.

Obi Reddy et al (2002) have studied that Geomorphological Analysis for Inventory of Degraded Lands in a Vena River Basin of Basaltic Terrain using Remote Sensing (IRS-1D LISS-III) and GIS. The study reveals the various denudational and depositional landforms.

Chamyal et al (2002) interpreted that Late Quaternary geomorphic evolution of the lower Narmada valley, Western India: implications for neotectonic activity along the Narmada–Son Fault. It shows a large variety of geomorphic features like deep ravines, uplifted terraces, abandoned cliffs (palaeobanks), incised cliffy banks and entrenched meanders.

Ranjana R Gawande, et al (2002) made a detailed study geological, geomorphological, hydrogeological and land use/land cover for the
Kamthi and adjoining areas of Nagpur district by visual interpretation method of remote sensing data of IRS LISS III, FCC of bands 2, 3 and 4. Geomorphological units are mainly of denudational and fluvial origins and arc represented by dissected plateaus, pediplains, pediments and alluvium were explained.

Jagannadha Rao et al (2003) have identified Geomorphology and land use pattern of Visakhapatnam urban - industrial area using IRS IB and SPOT data. The geomorphic units under structural landforms, fluvial landforms and coastal landforms were identified and appropriate field confirmations were made. The geomorphic units such as inselbergs/residual hills, rolling plains, colluvial plains, fractures, piedmont fans, pediments were identified under structural landforms.

Akram Javad (2000) has identified that Remote sensing data pertaining to LANDSAT TM FCC of bands 2, 3 and 4 of 9th 1991 and IRS – 1A LISS II digital data of 3rd may 1991, utilizing for the Bulandar District, UP and separated four broad geomorphic zones, namely Varanasi Alluvial Plain, Aligarh Older Alluvial Plain, Terrace zone and Recent flood plains of Ganga and Yamuna.

Raghavendra Reddy et al (2003) analysed IRS-ID LISS-III satellite data in conjunction with field observations for geomorphological mapping and pedo-geomorphological characterisation in Mohgaon area of Nagpur district, Maharashtra.

Ranjit Rath (2003) carried out a geomorphological analysis of the Geomorphic Signatures of Ore Deposits- A Case Study from Sukinda
Chromite and Nickel Complex, Orissa substantiated by Visual interpretation of the False Colour Composite and ground truth checks.

Thakur and Pandey (2004) used digitally processed IRS-LISS III images for delineating geomorphic expression of different tectono-stratigraphic units and faults in Garhwal Sub-Himalayas.

Navarajan Tirkey et al (2005) analysed that a study on shoreline changes of Mumbai coast using remote sensing and GIS. From the study of satellite image and field visits; various geomorphic units could be identified; beaches, mudflats, mangroves, saltpans etc.

Dipnarayan Ganguly et al (2006) have identified geomorphological features in sundarban deltaic estuary. Mainly nine geomorphic classes are considered namely creeks, river channel, coastal alluvial plain, mud flat, alluvial plain, salt flat, mangrove swamp, dune complex, estuary and beach.

Satvindar Singh et al (2006) studied that geomorphology, pedology and sedimentology of the Deoha/Ganga–Ghaghara Interfluve, Upper Gangetic Plains (Himalayan Foreland Basin) — extensional tectonic implications and mappe the major geomorphic units, fault traces, lineaments, terminal fans and alluvial ridge.

Chaudhary and Sandeep (2009) identified the demarcation of palaeochannels and mapping of integrated water resources in parts of Hisar district, Haryana using Indian Remote Sensing Satellite (IRS-1D) LISS-III Data of December 21, 2001. The landforms identified are Sand Dune, Dune Complex, Aeolian Plain, Fluvio aeolian plain, Palaeochannel and Younger Alluvial Plain formed by aeolian, fluvio-aeolian, and fluvial processes.
Arindam Guha et al (2009) suggested that satellite-based geomorphological mapping for urban planning and development – a case study for Korba city, Chhattisgarh and it shows the capability of satellite data in delineating major geomorphological units in an industrial area like Korba city.

Patwary et al (2009) analyzed that IRS-LISS-III and PAN Data Analysis for Landslide Susceptibility Mapping using Heuristic Approach in Active Tectonic Region of Himalaya. LISS-III bands have been transformed to principal components and the FCCs created from PCA images have been carefully analyzed to interpret geology, geomorphology and vegetation cover of the region.

Tapan Chakraborty and Parthasarathi Ghosh (2010) interpreted that the geomorphology and sedimentology of the Tista megafan, Darjeeling Himalaya: Implications for megafan building processes and identified by a set of ancient and modern radial drainage systems.

Palanivelu et al (1988) identified the geomorphological features, drainage pattern and lithology of Cumbum valley of Varushanadu hills using aerial photographs.

Loveson and Rajamanickam (1988a) have visualized the active progradation along the southern Tamilnadu coast form the occurrence of number of spits and beach ridges and they reported in (1988b) the various evidences for the phenomena of Emergence along the southern Tamilnadu coast through remote sensing techniques. Srinivasan and Srinivasan (1990) attempted to infer the coastal geomorphology of the entire Tamilnadu, through
remote sensing applications without field checks. They have classified the Tamil Nadu coast into 8 blocks.

Rajamanickam et al (1990) have observed the features of emergence and submergence respectively along the southern and northern parts of tamilnadu combined with terrestrial sediments accelerating the progradation along Palk Strait region.

Mitra and Agarwal (1991) studied the geomorphological features of the Cauvery basin, Tamilnadu using IRS images with special emphasis on identification of zones of hydrocarbon occurrences. The basin exhibits landforms of fluvial and fluvio-marine plains. Mohan et al (2000) classified that Quaternary landforms into inland, beach and offshore regions and also attributed the extension of beaches even up to 25 km inland.

Ramasamy (1991) studied the morphology of the river deltas of Tamilnadu - the nature of the river delta, fluvial activity, marine influence over their growth and the Pleistocene tectonic movements. Loveson (1993) has attempted to recognize the regional tectonism of the southern Tamil nadu coast.

Chockalingam (1993) studied the coastal geomorphology of the region between Devipattinam and Mandapam, Tamilnadu. Anbarasu (1994) concluded that in the northern coast of Tamilnadu, sea has transgressed and regressed two times during Quaternary and it is in the third regressive phase at present. Loveson et al (1996) proposed the usefulness of identifying different geomorphic blocks along the coast of southern Tamilnadu.

Karikalan (1996) concluded that in the northern coast of the Tamilnadu, around Porto Novo, there are various geomorphical features like
beach ridge, Chenier, mudflat, palaeo channel and mangrove swamps. Subrahmanya (1996a&b) has observed that there are indications on the continental uplift, related to the north-south oriented regional stress field.

Loveson and Rajamanickam (1998) studied the geomorphic evolution of Rameswaram Island, South India.

Mohan and Rajamanickam (2001) discussed the depositional environment if Mahabalipuram beach ridges from the core samples and concluded that these sediments might have been the product of palaeo-shallow marine environments having hydrodynamic conditions of deposition similar to fluvio-monsoonal channel conditions.

Baskaran et al (2003) identified some of the geomorphological features as the suitable places for mangrove afforestation in Rameshwaram Island.

Baskaran et al (2004) have reported the Geomorphology of lagoons present in and around marakkanam area. The stages of formation of lagoons also discussed.


Singarasubramanian et al (2009) studied that Geomorphological and Sedimentological changes during and after the December-2004 Indian Ocean Tsunami near the Vellar River and the M.G.R. Island area of the Central Tamil Nadu Coast, India.

1.8.2. Sedimentology:

Analyzing the environment of rock formation, finding the rock, mode of weathering, medium of transportation, distance of transport with the environmental settling and setting are the main studies. Grain size analysis even though was introduced during earlier part of 20th century, attained its maximum usage during later half of the century. Environmental information has been drawn from grain size analysis by the pioneer researchers, like Udden (1914) and Wentworth (1929); with others like, Krumbein (1936), Otto, (1939); Keller, (1945); Douglass, (1946); Van Andel and Poole, (1960); Inman and Chamberlain, (1955); Davadarini et al (1977) have described the major factors of differentiation of sedimentary materials in relation to grain size analysis.

Passega, (1957 & 1977) proposed CM pattern to distinguish the mode of transportation from the values of first percentile and median. By means of sub-process like rolling, saltation and suspension within the sediments deposited, Visher, (1969) suggested the method of using the lognormal curves for classifying the various environment of deposition of sediments. Friedman (1961 & 1967) attempted to discriminate the varying environments like dune, beach and river by using textural parameters. Mason and Folk (1958) proposed the plot of skewness Vs kurtosis to differentiate the beach coastal dune and aeolian flat sands. Martin (1965) illustrated by
comparison of skewness and kurtosis of any area, interpreted various paleo environmental setting for the sediments.

Frances Firek et al (1977) studied the heavy minerals in bottom-sediment samples of the lower Chesapeake Bay show in the distribution patterns and interrelationships that denote characteristic mineral suites associated with defined geographic provinces.

Frihy (1993) studied Influence of shoreline erosion and accretion on texture and heavy mineral compositions of beach sands of the Burullus coast, north-central Nile delta, Egypt. Heavy minerals constitute two major assemblages or "factors". Factor 1 comprises mainly augite, hornblende and a lesser amount of epidote; these are associated with accreted sand that accumulated west of the western jetty. Factor 2 contains a significant amount of opaques, garnet, zircon, rutile, monazite, and a trace amount of epidote.

Awosika and Akpati (1998) reported that based on the geology of the area and the fact that the relatively small amounts of heavy minerals are derived from river sediments particularly in the coastal area and estuaries.


Spatial distributions of textural and compositional parameters in beach, dune and river sediments have been studied by means of detrital modes, grain size and provenance relationships (Kasper-Zubillaga and Dickinson, 2001; DiGiulio et al 2003)

Kasper Zubillaga et al (2007) identified textural and compositional controls on modern beach and dune sands, New Zealand. The study demonstrates the usefulness of specific minerals (quartz, plagioclase with
magnetite inclusions, monomineralic opaque grains) to interpret the physical processes (fluvial discharges, long-shore currents, winds) that distribute beach and dune sands in narrow and wide coastal plains.

Dill (2007) studied the grain morphology of major heavy minerals from various placer-type mineral deposits (aeolian, beach, fluvial, alluvial, colluvial, residual–alluvial) in Mongolia and analyzed that grain morphology of garnet shows an increase in angularity from the pyrope – through almandine-, grossularite- to the spessartite-enriched garnet solid solution series in the placers under consideration. Spessartite-enriched garnet solid solution series are widespread in pegmatites and low grade metamorphic rocks where they normally form euhedral crystals.

Steffen Popp et al (2007) have carried out a provenance analysis of late Quaternary deposits from tributaries of the Aldan and Lena rivers in Central Yakutia (eastern Siberia) using heavy minerals and clay mineralogy. Cluster analysis revealed one assemblage that is characterized by relatively high proportions of amphibole, orthopyroxene and garnet as well as pedogenic clay minerals, reflecting a sediment provenance from the wide catchment area of the Lena and Aldan rivers.

Kapila Dahanayake et al (2008) studied recognition of diagnostic criteria for recent- and paleo-tsunami sediments from Sri Lanka and resulted Tsunami sediments are less well sorted than storm-surge and nearshore sediments.

Jueyi Sui et al (2009) analyzed changes in sediment transport in the Kuye River in the Loess Plateau in China and studied grain size distribution.
Masson et al (2010) have studied the Sedimentology and depositional history of Holocene sandy contourites on the lower slope of the Faroe–Shetland Channel, northwest of the UK.

Mallik (1972) studied opaque mineral of shelf sediments off Mangalore; Surya Prakash rao and Kassim (1970) investigated the morphological changes along the Surathkul beach and their study indicated cyclic behavior of the beach.


Kumar (1977, 1980) has made an attempt to study the depositional environment and probable provenance of the beach sediments of
Anjidiv Island and Binge bay near Karwar. Verma et al (1985) studied the depositional conditions of beaches between Alleppy and Purmaakd using sediment characteristics. Mallik (1985) highlighted marine geological studies on the coastal zone of Kerala. Mallik et al (1987b) showed that the black sand placer deposits of Kerala beach, Southwest India consists of opaques, hornblende, tremolite-actinolite, hypersthene, clinopyroxene, zircon, monazite, garnet, sillimanite, epidote, staurolite, apatite, etc.

Rajamanickam et al (1986) have suggested probable riverine environment for Jaigad bay, beach environment for Ambwah bay and dune environment for Varvada bay.

Chavadi and Nayak (1987) studied morphological and textural aspects of Shankrubag beach, their study indicated that the beach responds to seasonal changes in waves and longshore currents (cyclic behavior). Purandara, et al (1987) studied the depositional environment and provenance of the sediment through textural and mineralogical studies. Mallik et al (1987a&b) have demarcated erosional and accretional trends for the entire coastal tract of Kerala using beach morphological studies; and black sand placer deposits of Kerala in relation to abundance, processes of deposition, transportation and provenance.


Rajamanickam and Guijar (1993) attempted to understand the possible changes in the depositional environments within the bays of Maharashtra through bi-varient plots and probability curves.

Munendra Singh et al (2007) studied about sediment characteristics and transportation dynamics of the Ganga River and discussed their textural properties, grain size characteristics, and transportation dynamics.

Narayana et al (2007) studied that Tsunami of December 26, 2004 on the southwest coast of India: Post-tsunami geomorphic and sediment characteristics Nearshore sediments and analyzed to understand post-tsunami changes in grain-size characteristics are typically poorly sorted and estuarine sediments became moderately sorted upstream and rich in heavy minerals.

Daniel Buscombe and Gerhard Masselink (2009) have studied Grain-size information from the statistical properties of digital images of sediment. Barendra Purkait (2010) studied the use of grain-size distribution
patterns to elucidate aeolian processes on a transverse dune of Thar Desert, India.

Angusamy et al (1993) have endorsed that the distribution of grains in the beaches are restricted according to their grain size.

Udayaganesan and Rajamanickam (1995) inferred the depositional environment of Vaippar basin using the grain size distribution of the sediments in the basin. Karikalalan (1996) reported that the Quaternary formations consisting sediments of fluvial, fluvio-marine and marine regime using the grain size distribution.

Anbarasu and Rajamanickam (1997) have brought out the inherent relations between the channel shifting and neo-tectonism which is exhibited by the disposition of abandoned channels of rivers flowing through the northern Tamil Nadu. Loveson and Rajamanickam (1998) have studied the geomorphic evolution of Rameswaram Island in Southern Coast of Tamilnadu.

Chandrasekar and Rajamanickam (1999) have identified three different types of environment of deposition from the grain size studies of the sediments of Central Tamil Nadu coast.

Jayaraju (2004) studied that controls on formation and distribution of heavy minerals along southern tip of India showed heavy minerals associated with sediments are derived from a metamorphic terrain dominated by Precambrian gneiss, schist and ferruginous quartzite of Indian Peninsular Shield.
Anil Cherian et al (2004) have studied in detailed on the morphology quartz grains and composition of light minerals in order to delineate the provenance of the sediments of Southern Tamilnadu coast.

Angusamy and Rajamanickam (2006) have carried out grain size studies of sediments from beaches in the region from Mandapam to Kanyakumari, divided into 5 sectors, found out the beach, riverine and dune environments with low to high energy conditions.

Rajamanicakam et al (2006) carried out studies on the deposits along the coastline between Kallar and Vembar that are well-disposed in the beaches throughout the coastline. The shorelines of these areas have been experiencing both accretion and erosion. The beaches have enriched with economic minerals such as ilmenite, garnet and zircon.

Loveson et al (2007) studied about post Tsunami rebuilding of beaches and the texture of sediments, in Tamilnadu from the grain size and statistical textural parameters using graphic and moment measures, binary plot, CM pattern.

Suresh Gandhi et al (2007) studied Benthic foraminiferal and its environmental degradation between the tsunamigenic sediments of Mandapam and Tuticorin, South east coast of India showing the various textural parameters for beach samples obtained through graphic and moment methods.

1.8.3. Geochemistry:

Forstner and Wittmann (1979) identified the total concentration and reactivity of metals in the sediments as a function of organic matter,
mineralogy and textural related qualities of sediments. Larger surface area of fine particles facilitates precipitation of metals on to them.

Spencer et al (1972) considered organic matter a very important fraction of sediment, as it plays an important role in modifying the ability of the sediments to fix trace metals and controlling the Eh, pH related stability of sedimentary minerals.

Lee (1975) studied the trace element enrichment in the sediments and linked to the scavenging reactions involving hydrous oxides, particularly iron and manganese hydroxides and oxides which constitute significant sinks of heavy metals in aquatic system and may form complexes with organic or inorganic legends. Iron and manganese in the estuarine sediments have exhibited a strong positive relationship with Cr, Zn, Ni, Pb, and Co.

Gibbs (1977) reported varying levels of enrichment of heavy metals in suspended sediments.

Ramondetta and Harris (1978) analyzed the distribution of heavy metals in Jamaica Bay sediments. The concentration of all the metals correlates with each other and with organic carbon indicating a common mechanism for enrichment in the sediment. Vanadium, Cobalt and Nickel stand out as separate component and are enriched relative to other metals in areas affected by petrolierous pollution. The metal concentration is strongly influenced by the strength of tidal currents and proximity to pollution sources.

Murty et al (1978) studied the distribution pattern of calcium carbonate, iron, cobalt, manganese, copper and zinc in the sediments of Gulf of Kutch. The distribution pattern of calcium carbonate is relatively higher than
all other elements and are associated with fine grained sediments rather than with coarse sediments.

Lyons and Gaudette (1979) remarked that in the sediment samples from Jeffreys Basin, Gulf of Maine, a strong correlation exists between the grain size and Fe, Mn, Cu, Cr, Zn, Pb, the highest concentrations being found in the clay-sized sediment fractions.

Ackermann (1980), Martincic et al (1990), and Biksham et al (1991) have reported a general increase in heavy metal with decreasing grain size in their earlier studies. Whitney (1975); Throne and Nickless (1981) have shown an increased concentration of heavy metals in the coarser size fractions due to the presence of heavy minerals or due to the presence of coarse waste products.

Francois (1988) studied the concentrations of some major and trace metal concentrations in the bulk materials to find out the major and trace metal enrichments in Saanich Inlet, British Columbia. Two hundred and eighty four surface sediment samples within Halifax Harbour were analyzed to determine the total elemental composition of silicon, aluminium, calcium, magnesium, potassium, iron, manganese, titanium and additional contaminant trace metals (Buckley and Hargrave 1989; Buckley et al 1989). In addition, Buckley and Cranston (1991) reported that geochemical analysis of bottom sediments in different size fractions helps in identifying important relationships between geochemistry and particle size distributions.

Hunt (1981) established that the cation exchange capacity of sediments improve considerably with increasing organic carbon content and fining size, in spite of being a matter of controversy that whether metal
distributions result from greater influence of grain size or organic matter content.

Krom and Berner (1981) studied nutrient budget for the Eastern Mediterranean and delineated that the phosphorous in sediments have mainly been derived from sediments deposited with organic material rather than organic in suspension. Berner (1982) considered coastal sediments as reservoirs of organic carbon, since they account for 80% global organic carbon burial.

Forstner and Wittmann (1983) have pointed out that the trace metal concentrations of the sediments are potentially good indicators of the state of an environment. They have also said that generally, the amount of trace elements, in modern sediments are controlled by the elemental solubility in the waters, feedings capacity of the drainage basin and by the prevailing environmental conditions.

Atkinson (1987) studied the sediments and inferred that they can act either as a source or as a sink of phosphorous by adsorption, desorption reaction, and therefore buffer the phosphorous concentration in the water column.

Macdonald and Pedersen (1991) reported that few chemical data exist for the sedimentary environment off the Canadian west coast. They define the chemical nature of the shelf sediments by examining the important sources of material (natural and anthropogenic) to the region and processes relevant to diagenesis.


Buckley (1991), in order to evaluate the depositional and diagenetic alteration of sediments, studied the total elemental composition of Si, Al, Fe, Mg, K and total trace metal concentrations in box core samples of Emerald basin and the surrounding Scotian shelf. As part of the EROS-2000 project, sediment samples were collected in the north western basin of the Mediterranean Sea and major and trace elements were determined to enhance the knowledge about concentration, sources and cycles of natural and anthropogenic constituents in coastal areas (Nolting and Hoogstraten, 1992). With an aim to know the abundance of chemical elements, 286 surface sediment samples were analysed from the shallow areas below 200 m of water depth from Bhoi Sea, Yellow Sea, East China Sea and South China Sea Shelf sediments (Zhao and Yan, 1992; Zhao et al 1995).

Retention of major elements and sediment accumulation rates were studied in detail in core samples of the Scheldt estuary, SW Netherlands, in order to assess their impact of pollution and to understand the diagenetic processes (Zwolsman et al 1993).

Calvert et al (1993) characterized the geochemistry of the sediments of the isolated, oxygen-deficient basin and compared them with the
sediments at equivalent water depths outside the basin, as a prelude to a further study of the response of the composition of the sediments to oceanographic changes, including possible anoxia, during the last glacial maximum.

Santiago Andrade et al (1999) carried out the concentrations of lead, cadmium, copper, chromium, iron, manganese and zinc in surface sediments collected from Potter Cove, in the 25 de Mayo Island (King George Island), Antarctica, and its drainage basin.

Caredda et al (1999) analyzed that distribution of heavy metals in the Piscinas beach sediments (SW Sardinia, Italy). The results indicate that the distribution of heavy metals in the foreshore sediments is particularly affected by the contribution of the streams, while in the shore face the distribution is affected by the currents that disperse the sediments both out to sea and southwards.

Nolting et al (1999) carried out major element analysis in sediment core samples from the continental slope of the Banc d’Arguin (Mauritania) and revealed that the sediments have calcium carbonate content >50% and, as a consequence, have low aluminium (<15%) and iron (<1%) content with a general decrease towards the coast.

Fabris et al (1999) studied the historical input of heavy metals into the Port Phillip Bay, Australia and they inferred that the accumulation of heavy metals Cd, As, Ni, Cr, Cu, Pb and Zn in surface and core samples are highest close to the input sources such as rivers, creeks and outfall from of a major sewage treatment plant in Port Phillip Bay, Victoria.
Lacey et al (2001) reported that the surface samples and cores collected in 1993 from the Burlington Harbor region of Lake Champlain showed the concentrations of cadmium, copper, silver and zinc from the partial sediment digestion correlated well with each other ($r^2 > 0.60$) indicating that either a common process, or group of processes determined the sediment concentrations of these metals.

Brunskill et al (2001) estimated that geochemistry and particle size of surface sediments of Exmouth Gulf, Northwest Shelf, Australia in which most trace elements (Ba, Li, Pb, and Cu) concentrations vary in proportion to the abundance of Al, but Cd sedimentary distribution is at least partly associated with the coarse-grained carbonate phase of the sediment.

Yang et al (2004) analyzed sediments from the northern coastal area of Cheju Island (South Sea of Korea, southeastern Yellow Sea) for grain size composition, elemental compositions and clay mineralogy in order to investigate their provenance. Rare earth element (REE) compositions and geochemical discrimination diagrams reveal that both the sandy and muddy sediments originated from weathering of the volcanic rocks of Cheju Island.

Samantha Saye, and Kenneth Pye (2006) investigated that the geochemical and textural variations in frontal dune sediments along the western coast of Jutland, Denmark, in order to identify possible sediment provinces and transport pathways. Dune sediments on this section of coast also have higher $\text{Al}_2\text{O}_3$ to $\text{K}_2\text{O}$ ratios and lower $\text{Al}_2\text{O}_3$ to $\text{Fe}_2\text{O}_3$ ratios, reflecting a lower content of feldspar and higher content of heavy minerals.

Lim et al (2006) have suggested that the geochemistry of sediment samples from Korean and Chinese rivers, find out that the elements
enriched in Chinese river sediments relative to those in Korean rivers include Ca, Na, Sr, and Cu. Korean river sediments have higher Al, K, Ba, and Li concentrations, but extremely low Ca concentrations.

Maha Ahmed Mohamed Abdallah (2007) has carried out that sediments of El-Mex Bay estuary on the southern Mediterranean Sea have been analyzed for trace metals after sediment fractionation by sequential leaching. A sequential extraction procedure was applied to identify forms of Mn, Cu, Cd, Cr, Zn and Fe.

Ahmed Alomary and Soraya Belhadj (2007) analyzed that determination of heavy metals (Cd, Cr, Cu, Fe, Ni, Pb, Zn) by ICP-OES and their speciation in Algerian Mediterranean Sea sediments after a five-stage sequential extraction procedure.

El-Kammar et al (2007) studied the mineral composition and environmental geochemistry of the beach sediments along the eastern side of the Gulf of Suez, Egypt. Hyun Ju Cha et al (2007) analyzed the geochemistry of surface sediments in the southwestern East/Japan Sea and found that the concentrations of Al, K, Ca, Ti, Cr, and Sc were highest in the coastal and upper slope areas and decreased with water depth. Elemental ratios using major and trace elements indicated that coastal and upper slope detrital sediments were mixtures of sediments derived from the Changjiang (Yangtze) and Nakdong Rivers.

Kasper Zubillaga et al (2007) analyzed the sedimentological, compositional and geochemical determinations carried out on 54 desert and coastal dune sand samples to study the provenance of desert and coastal dunes of the Altar Desert, Sonora, Mexico. Grain size distributions of the
desert dune sands were influenced by the Colorado River Delta sediment supply and wind selectiveness.

Abraham and Parker (2008) have studied that eight sediment cores recovered from Tamaki Estuary were analysed for Cu, Pb, Zn, and Cd sing downward cored sub-samples. The results indicate a significant upward enrichment in heavy metals with the highest concentrations found in the uppermost 0–10 cm layer.

Hashem Madkour and Ahmed Mohammed (2008) studied the grain size and geochemistry 58 samples collected from different areas of mangrove environment of the Egyptian Red Sea coast.

Juan Jose Kasper Zubillaga et al (2008) carried out analyses twenty-one surficial sand samples from the Altar Desert coastal and desert dune systems for rare earth elements (REE) content.

Stefan Bernstein et al (2008) studied that application of CCSEM to heavy mineral deposits; Source of high-Ti ilmenite sand deposits of South Kerala beaches, SW India and suggested the minor- and trace element inventory of ilmenite could prove useful in the use for sediment provenance studies.

Mustafa Gurhan Yalcin (2009) measured that the heavy mineral distribution as related to environmental conditions for modern beach sediments from the Susanoglu (Atakent, Mersin, Turkey). Guido Meinhold et al (2009) traced the geochemistry, provenance and stratigraphic age of the meta sedimentary rocks from northern Greece.

Arturo Carranza-Edwards et al (2009) studied the sandy sediment samples from eleven beaches in southwestern Mexico texturally, petrologic
and chemically showing the chemical index of alteration (C.I.A.) values were higher in beaches from the Armería and Coahuayana river segments.

Juracek and Ziegler (2009) studied the sediment sources using selected chemical tracers in the Perry lake basin, Kansas, USA.

Charline Giguet Covex et al (2010) studied the sedimentological and geochemical records of past trophic state and hypolimnetic anoxia in large, hard-water Lake Bourget, French Alps.

Jianting Ju et al (2010) analysed the water and sediment chemistry of Lake Pumayum Co, South Tibet, China: implications for interpreting sediment carbonate.

Wang Chunlin et al (2010) carried out speciation analysis of metals (Tl, Cd and Pb) in Tl-containing pyrite and its cinder from Yunfu Mine, China, by ICP-MS with sequential extraction.

Jin Zhangdong et al (2010) analyzed that concentrations and contamination trends of heavy metals in the sediment cores of Taihu Lake, East China, and their relationship with historical eutrophication.

In the past, several papers have appeared reporting bulk as well as partition geochemistry of sediments of the western continental shelf of India. Sediment chemistry from shelf and slope regions between Mumbai and Ratnagiri on the west coast of India was established on a limited number of samples (Gogate et al 1970). Likewise, the elemental concentrations of sediments in Harbour bay, between Dharamtar creek and Thane creek, where low level radioactive waste effluents were discharged, were studied and the concentration factors for the major and trace elements presented by Gogate et al (1976). Numbers of workers have investigated the distribution and
partition pattern of iron from the northern half of the western continental shelf of India (Marchig, 1972; Murty et al. 1973).

Investigations on the sediment geochemistry of the continental shelf off the east coast are limited and very few authors (Subba Rao 1962; Rao, 1964) have investigated the region. Coastal sediments of Viskhapatnam, in particular, were analyzed to understand the geochemical nature of the sediments (Rao and Rao, 1969).

Rajamanickam and Setty (1973) suggested that the degree of concentration of organic carbon and phosphorous varied considerably with sediment texture and they are in direct relationship with each other. Though, organic carbon and phosphorus are related with each other their variability fluctuates in terms of pre and postmonsoon periods in the region. Higher concentration of phosphorus noticed in post monsoon period, is considered to be due to large supply of the terrigenous apatite brought in by the rivers. This is in addition to contributing factors like organic productivity, upwelling and pollutants in the region of Goa. Since the sediment in the region falls within the range of 0.5-5.0 % P$_2$O$_5$, it can be considered to be “phosphate bearing”.

Paul and Pillai (1976) have reported that the elemental concentration of sediments depends not only on anthropogenic and lithogenic sources but also upon the textural characteristics, organic matter contents, mineralogical composition and depositional environments of the sediments.

Rao and Setty (1976) have reported that iron has both a lithogenous and Non-Lithogenous component, in the recent shelf sediments of Ratnagiri in the south and Indus canyon in the north. They have also inferred that sediments in the southern shelf region are characterized by higher
concentration of iron than that of the outershelf. However, the concentration of iron in the innershelf region has an inverse relationship with the acid soluble. Thus, the occurrence of the rivers may be responsible for higher concentration associated with non-lithogenous fraction of the fine grained sediments.

Rao et al (1978) explained the calcium carbonate content high (50 to 94%) in the outershelf sediments than the innershelf clays or clayey silts (5 to 25%). Ca$^{2+}$ is relatively high in the outershelf sediments while Mg$^{2+}$ is conspicuously low, especially in the Gulf of Cambay and Ratinagiri and it is relatively high in the sediment of the middle shelf.

Knedler et al (1983) studied the mineralogy and geochemistry of sediments off Goa and observed that Fe is present in much higher concentrations in the fine-grained sediments of the inner shelf off the west coast of India than in the sediments in the outer shelf where carbonates dominate. Paropkari et al (1981) estimated that the total phosphate in sediments, ranges from 0.15 to 0.23% in the bulk samples and from 0.09 to 0.23% in the acid soluble fractions of the samples, the higher are attributed the acid soluble fractions.

Tapas Kumar Mallik (1986) identified that Scanning Electron Microscopic studies of placer minerals such as ilmenite, rutile, sillimanite, zircon, monazite and garnet from beach sediments of Kerala indicate a number of microfeatures.

Rao and Murty, (1990) made a detailed study on the distribution pattern of bulk and partition geochemistry of Si, Al, Fe, P, Mn, Zn, Cu, Ni and
Sr in continental margin sediments off the central west coast of India and described the geochemical processes which control them.

Selvaraj (1999) with an aim to study the distribution of major elements off Kalpakkam coast, analyzed Si, Al, Fe, Ca, Mg, Na, K and P and found that the sediments are detrital in nature with high silica and relatively low alumina and iron.

Mohanty et al (2003) investigated the geochemical characteristics of monazite sands of Chhatrapur beach placer deposit of Orissa, by proton induced X-ray emission and energy dispersive X-ray fluorescence methods. The investigation showed chondrite-normalized REE distribution pattern of monazite sand grains are uniformly enriched in LREE with prominent Eu anomaly, which could be due to the preferential incorporation of lighter lanthanides formed during the partial melting. The monazites with other heavy mineral sands of Chhatrapur beach placer deposits were derived from Eastern Ghats Group of rocks which closely resembles with mineralogical composition of khondalites, charnockites, leptynites and pegmatites group of rocks. Finally they concluded that the Eastern Ghats provenance appears to be major source for the heavy mineral assemblages of the Chhatrapur placer deposit.

Unmesh Chandra Panda et al (2006) established the natural processes and geochemical factors responsible for enrichment of trace metal ions (Cu, Co, Ni, Zn and Cr) with respect to textural parameters (sand, silt and clay weight percentages) along with depth using multivariate statistical approach for sediments in different water zones of Chilika lake, the largest brackish water lagoon in Asia.
Hegde et al (2006) identified that heavy mineral assemblage and geochemistry of ilmenite from the Honnavar beach, Karnataka, central west coast of India to understand their provenance. The heavy mineral assemblage of ilmenite, magnetite, zircon, hornblende, epidote, sphene, kyanite, garnet and staurolite indicates its derivation from mixed sources of gneissic/granitic, basic and high-grade metamorphic rocks. Trace element content of ilmenite like Co, Cr, V and Ni suggests gneissic to basic provenance.

Ajay Singh et al (2008) analyzed the relationship of heavy metals in natural lake waters with physico-chemical characteristics of waters and different chemical fractions of metals in sediments.

Chakravarty and Patgiri (2009) have suggested that the degree of contamination in the sediments of the Dikrong river, NE, India for the metals Al, Fe, Ti, Mn, Zn, Cu, Cr, Ni and Pb, has been evaluated using Enrichment ratio (ER), Pollution load index (PLI) and Geo-accumulation index (Igeo).

Mohan (1997) reported the distribution of chemical constituents such as organic carbon, carbonates, Al, Fe, Mn, Ti, Cu, Ni, Cr, Cd, and Co which is in the Vellar river estuary and nearshore environments. He has observed that they are mainly influenced either by grain size variation or iron and manganese precipitation or composition of the minerals in the sediments or desorption of elements from the precipitates.

Padma and Periakali (1998) indicated the presence of organic carbon percentage, iron, manganese and cadmium concentrations and the percentage of clay are more during post monsoon period, when compared to premonsoon. This may be attributed to heavy rainfall, high run-off and supply
of fresh water during monsoon resulting into an increase in the trace metals Fe, Mn and Cd.

Jonathan et al (2004) studied that geochemical variations of major and trace elements in recent sediments, off the Gulf of Mannar, the southeast coast of India.

Martin Deva Prasath and Hidayathulla Khan (2008) have investigated on the accumulation of heavy metals (Zn, Cu, Fe, Mn, Co, Pb, Cd and Ni) in water, sediments and fish (Mugil cephalus) using Atomic Absorption Spectrophotometer at Poompuhar coast, lying along the southeast coast of India before and after tsunami.

Sundararajan and Usha Natesan (2009) collected the core sediments from Mullipallam Creek of Muthupet mangroves on the southeast coast of India and analyzed for their texture, CaCO3, organic carbon, sulfur and acid leachable trace metals (Fe, Mn, Cr, Cu, Ni, Co, Pb, Zn and Cd).

The study of beach sands and related research works were analyzed theoretically as well as practically to obtain the utmost result from the National and International contributors based on their study, work and experiments. In this present study the beach sand samples of the study area have been analyzed thoroughly for their geomorphological, sedimentological and geochemical characters, the results are presented and discussed in the following chapters.