Chapter-5

CONCLUSION

5.1. Summary

The study area was investigated to understand the geomorphology, sedimentology, geochemistry, viz landforms, textural parameters, light, heavy mineral, Major, Trace and Rare Earth Elements in order to find out the processes and nature of the source rocks that served as the source for these sediments.

The geomorphological studies were carried out with the help of aerial photos, satellite imageries (IRS P6 LISS-III) and converted into the GIS map for better results. The following geomorphic features, alluvial plain (26.22%), abandoned river channels (0.63%), beach (3.21%), beach ridge (20.61%), beach ridge plain (34.76%), back water body (1.42%), canal (0.96%), lagoon (0.04%), mudflat (8.70%), mangroves (0.14%), sand dune (0.30%), sandy bar (0.18%), tidal creek (0.34%), and water body (0.91%) are seen in the coast of Karaikal.

From the geomorphology of the study area, it is found out that most of the landforms are aggradational features. The landforms are oriented along the coast line with the formation of canal, back water body, abandoned river channels, tidal creek and four river namely Arasalar, Nandalar, Tirumalairajanar, Puravadairajanar. The economically viable beach sand is deposited in front of the sea and act as a barrier to these rivers. The overall geology suggests that the study area is made up of sedimentary deposits of age ranging from Mio-Pliocene to Recent. The presence of abandoned river
channel of Arasalar river provides the clue for the transportation history of the beach sand deposits.

The sedimentological study of entire coastal region is understood from a detailed study of the representative 68 trench samples, (18 locations), that have been collected and weight percentage of heavy minerals have been found. The samples are collected from beach and beach environment and maximum 120 cm depth.

Grain size studies of sediments from beaches and beach environment in the region from Sinurpet to Vanjur, divided into 3 sectors, indicate that sediments are unimodal to polymodal in nature, coarse to fine grained, very well sorted to moderately sorted, and very positive to negative skewed in character. The inference to be drawn from these studies is that the variation in sedimentological parameters is governed by fluvial input, wave dynamics, and littoral transport of the sediments.

The textural analysis i.e, bivariant plots, CM pattern, log probability curves and frequency curves suggests that beach, beach ridges, beach ridge plain, sand dune, paleo channel, estuary, alluviam and abandoned river channel sediments are influenced by the present day environments such as riverine and marine with varying degrees. Along with that reworked sediments have also played a significant role in these environments.

The scatter plot of the beach sands indicates beach sediments are moderately sorted to very well sorted with low mean size. Mean versus skewness plots of the beach sediments show a sinusoidal pattern. Most of the beach sediments are very negatively to nearly symmetrical skewed. The
beach sediments are in the range of negatively skewed to very positively skew.

The scatter plot between Mean versus Kurtosis for beach sediments gives a part of “V” shaped pattern with flattened left limb. It results and suggests that the majority beach sediments are meso kurtic to very leptokurtic, while few samples are platy kurtic to meso kurtic. The scatter plot constructed using the standard deviation and skewness for the sediments of beach a sinusoidal pattern. Even though, the whole diagram fitted well, the left hand side of the upper part leaves a slight gap due to the fewer amounts of very positively skewed samples with ranges 0.39 to 0.44. Form this plot it can be observed that while the beach sediments are very well to well sorted. This illustrates that majority of the samples are near symmetrical to positively skewed and the corresponding sorting is very well to moderate.

The standard deviation versus kurtosis scatter plot of beach is casting an inverted “V” shape trend (Fig: 3.7). A “V” shaped pattern is obtained for the deposition of sediments by tidal channel, estuarine and beach sediments. The well to very well sorted sediments shows meso to very leptokurtic nature. The beach sediments are moderately to very poorly sorted with kurtosis value indicting very platy kurtic to extremely platy kurtic nature. On the other hand, majority of the study area in southern are well to moderately sorted with platy kurtic to extremely leptokurtic nature.

In the scatter plot of skewness versus kurtosis the areas within the range of normal curve are shown by a diagonal line. In the present study, for beach sediments, half of the sample points are present in the “normal” curve,
leaving the rest away from normality. But in the case of beach sediments, the plot reveals that (Fig: 3.8) very few samples are present in the “normal” curve.

The Visher diagram of the samples of the study area is characterized by traction, saltation and suspension population. Visher diagrams depict a wave shadow environment for the Northern sector, whereas the central sectors show double saltation populations characteristic of beaches, and the southern sector is characterized by a more truncated population characteristic of a plunge zone, which is a high energy environment.

The CM pattern of the beach sediments are concentrates at PQ and QR segments. This illustrates the mode of deposition of sediments by means of graded suspension and rolling. The presence of graded suspension has been attributed to the major role played by the relief sediments. Here also the contribution of southern oceanic sediments probably of Pleistocene to Holocene shelf sediments, relief nature may be mentioned. Here the samples show a clear scattering at PQ and QR segments, indicates a type of deposition by beach with fluvial influence.

The grain size data of different environments accounts coarse to fine sands. In the northern sector, mean value indicating a prominent distribution of fine sand in this zone when compared to central and southern sector might have accrued from the dislodging of coarser lighter sediments by the panning action of high velocity waves.

In the central sector major portion is categorized in the medium sand while the remaining ones are of fine sand. The lack of winnowing action due to protected nature of bay leads to the accumulation of fine sediments.
The southern regions are dominant presence of medium and fine sand. The distribution of medium sand in the central zone indicates the northerly movement of Arasalar riverine sediments by littoral currents. Based on textural studies, entire karaikal region beach sands deposited from multi environment with low to high energy conditions.

Chandrasekar and Rajamanickam (1997) have brought to light the nature, type occurrence of zircon placer deposits along the Central Tamil Nadu coast. The study has also recommended the possibilities of commercial exploitation of zircons from that region.

In the study area the average heavy mineral assemblages are represented by Zircon (10.07 %), Garnet (10.80 %), Kyanite (3.02 %), Actinolite (3.00 %), Biotite (1.64 %), Chlorite (24.99 %), Epidote (8.91 %), Glauophane (0.66 %), Hornblende (0.47 %), Hyperstherne (0.86%), Muscovite (0.51 %), Rutile (1.77 %), Sillimanite (0.53 %), Staurolite (1.42 %), Topaz (2.70 %), Tourmaline (0.82 %), Tremolite (0.52 %) and opaque minerals has (27.33%). In these assemblages, few locations nearer to Akkaravatam which lies middle portion of the study area represent the typical granular minerals, having higher density. The result of grain size studies has also substantiated a higher energy condition for those areas. The suite of heavy mineral found in the Keezhayur region again reconfirms this inference. Hence, the present study is the heavy minerals assemblages by multi environmental conditions.

Heavy mineral assemblages nearer to Sinurpet which falls in the Northern part of the study area represent a partial mixture of flaky and granular minerals. However, here the flaky minerals chlorite is very high and,
actinolite, glaucophane are meager amount. The presence of biotite along with the granular minerals indicates that this area must have had a mixture of high and low energy condition.

The grain size results have also substantiated the prevailing low energy conditions. Kyanites show even fully rounded nature. But for few grains, most of the kyanite possesses smoothened edges; few garnet grains are also present. They indicate the etched nature. The way in which more rounded nature of heavy minerals with etching and overgrowths, they direct the possibility of derivation of these minerals of multi-cycle nature mostly the contribution from the earlier sediments.

The nature of zircons shows a clear mixture of sediments by virtue of having euhedral type, elliptical type and rounded type. The zircons also carry the assemblage of outgrown and overgrown. The outgrowth and overgrowth has also obtained smoothened nature in few zircons indicate minor amount of etching also.

The light minerals distribution and its roundness and sphericity bring out a view that the sediments of different environments are contributed form metamorphic and igneous source of acidic in nature. Further, it also suggests that the sediments are reworked in nature with the addition of present day riverine a marine environment sediments.

The greater resistivity of quartz, compared to feldspar leads to the increase of quartz/feldspar ratio, in the three size grades, near downstream. This suggests that the sediments are not matured. In the beach environments, the variations in heavy minerals concentrations are mainly due to their hydraulic equivalence, longshore currents and the source rocks. Based on the
mineralogical study, the result of grain size studies has also substantiated a higher energy condition for those areas. The suite of heavy mineral found in the Keezhayur region again reconfirms this inference. Hence, the present study is the heavy minerals assemblages by multi environmental conditions.

Study of major element geochemistry of sediments is important since it provides information on the source of sediments and the process of sedimentation. The chemical reactions occurring within recent sediments after deposition are important in bringing about profound changes in the bulk chemical composition. Most of the chemical changes take place at or close to the sediment/water boundary and, for this reason, it is important to study the geochemical composition of bulk sediments (Hirst, 1962; Calvert, 1976). Near shore sediments have been studied by number of geologists for a considerable period of time to determine the process of deposition of ancient sediments.

In the near shore environment, three different types of components of detrital, authigenic and biogenous origin-occur in all possible mutual proportions to yield a range of sediment types, which could be distinguished by mineralogy, geochemistry or biochemistry. In particular, the Bay of Bengal has attracted scientists and oceanographers from all over the world with regard to its sedimentation geology and the history of Bengal Fan sediments (Emmel and Curray 1983; Winkler, 1987).

Major elements generally, these beach sediments are characterized by moderate contents of SiO$_2$ (60.05 -82.93%, average 72.31 ± 6.57%) and Al$_2$O$_3$ (8.31–16.89%, 12.42 ± 3.90%), and low contents of Fe$_2$O$_3$ (1.05– 9.15%,4.15 ± 2.38), MnO (0.08 - 4.74%, 0.89 ±1.47), MgO (0.11–
5.99%, 2.30 ±1.58), Na$_2$O%, (0.40-8.80, 2.53 ±1.67), K$_2$O%, 0.04-2.36, 0.78 ± 0.54), TiO$_2$%, 0.00-0.98, 0.16 ± 1.71%) and P$_2$O$_5$% - 0.00-0.93, 0.14 ±) due to their high quartz contents and lesser mafic components. The low CaO contents (0.27 - 9.11%, 2.44 ± 1.97) indicate that all the samples have very low carbonate component other elements have no such a significant concentrations. All the other major elements spread very minor in all the locations of the study area. P$_2$O$_5$ and TiO$_2$ have very low value in all the samples Quartz diorite and granodiorite could be the source rocks for the beach sediments.

Chemical maturity of beach sand deposits is expressed as a function of SiO$_2$ % and Total Al$_2$O$_3$, K$_2$O and Na$_2$O %. A humid climatic phase is identified from the chemically matured nature of these sediments.

Geochemically the beach sand corresponds to the composition of Fe-sand, Litharenite and greywacke. In the geochemical classification diagram of Pettijohn et al (1973) beach sediments plot in the Litharenite and one sample is in the arkose field. This classification is generally consistent with the petrologic data.

Plots major element composition of the Karaikal beach sands Tectonic setting discrimination diagrams based on major element proportions form TiO$_2$ vs. Fe$_2$O$_3$+MgO (Bhatia, 1983). A = oceanic island arc; B = continental island arc; C = active continental margin; D = passive margin. In the present study area northern part of three samples are fallen in the field of ABC.

Coastal sediments constitute a reservoir of trace elements and REE in aquatic environments and the distribution of metals among specific
components in sediment largely determines the fate of sediment bound
metals. In addition, the sediments act as a permanent repository for metals or
a temporary reservoir from which metals are recycled to solution or food
webs. Metal accumulation on sediment particles mainly depends on the
adsorptive bonding on fine-grained materials, precipitation of the element in
discrete compounds, co-precipitation of the element with hydrous Fe and Mn-
oxides and carbonates, association with organic compounds and
incorporation in crystalline material (Salomons and Forstner, 1980) and
moreover the enrichments of metal in mainly due to the surface absorption
and ionic attraction in clay/silt fractions (Balistrieri et al 1981; Li, 1981;
Forstner et al 1982).

The sediments in the continental shelf, which receives terrestrial
input, have high concentration of trace metals and the enrichment is more in
industrialized urban centers and moreover the enclosed and semi-enclosed
marine environments like bays and gulfs protected by the action of currents in
industrialized centers are more affected by pollution.

Tectonic setting discrimination diagrams show, in the present
study area many samples fall in the CIA, and ACM field.

As far as the Trace elements is concerned the maximum of Sr-
9.915 ppm, followed by V-380.821 ppm, Cr – 121.223 ppm, Co-55.217 ppm,
Ni-64.164 ppm, Cu- 67.962 ppm, Zn-560.204 ppm, Ga- 18.607 ppm, Rb-
33.83 ppm, Sr- 406.419 ppm, Y- 205.429 ppm, Zr- 4481.836 ppm, Nb- 97.122
ppm, Cs- 0.482 ppm, Ba- 691.018 ppm.

The frequency of the Trace elements is shows the maximum
concentration of Zr and the Minimum of Cs.
In the scatter plot of samples Vs Ba shows that in the northern part of the samples fall maximum 600 ppm, central part of the study area 700 ppm and southern part 600 ppm concentration. Hence, the concentration of Ba is increasing towards southern part of the study area.

Similarly the scatter plot of samples Vs Zr indicates the concentration of Zr is a very high level in North and central region. In southern region, most of the samples are below 500 ppm.

In the scatter plot of Sr Vs Ba also indicates the higher concentration of both the elements.

The elements plotted against the concentration of REE shows very lower level of concentration in all the samples in the study area. LREE plotted against HREE shows very low concentration of HREE in the beach sand samples of the study area indicates the enrichment of LREE compared to HREE (Ravisankar, et al 2006).

The scatter plot of Th Vs Ce and La Vs Ce shows the lower concentrations of the elements in all the samples of the study area.

Tectonic setting discrimination plots based on immobile trace elements, such as La, Sc and Th and La+Th+ Zr/10, showed that most data lie in the field for active continental margin and few samples are fall in the passive margin Yet, geochemical information was not sufficiently sensitive to differentiate between the three different source areas recognised by petrographic and modal analyses of beach sediments.

The irrationalities and inconsistencies outlined above seem to ally spider-diagram interpretation more with alchemy than with modern geochemistry. Indeed, the situation strongly resembles the imbroglio in
geochronology, prior to Steiger and Jaeger's (1977) highly effective rationalization of decay constants. Similar recommendations are badly needed in geochemistry to establish standards which, though not absolutely 'perfect', can nevertheless be accepted and employed consistently by all. The remainder of this note is intended as both impetus and exhortation towards such progress.

Normalized log-linear multi-element diagrams are becoming increasingly widespread, abundant and useful in the petrological and geochemical literature. It is proposed that four basic types of spidergrams should be sufficient for most purposes: (i) UCC normalization data from (Taylor and McLennan, 1985). (ii) chondrite-normalized REE (normalizing values of Thomson RN 1982); (iii) Post Archean Australian Shales (PAAS) (data from Taylor and McLennan 1985), (iv) North Archean Australian Shales (PAAS), REE data from (Gromet 1984); (v) Multi Element Normalistion (UCC) data from (Taylor and McLennan, 1985).

Compared to UCC, (Fig: 4.26 and Table:4.4) shows the concentrations of most the contents of La – Sm show a lower concentration from 1.63 to 6.25 ppm, 1.39 to 6.61 ppm, 1.41 to 5.27 ppm, 1.38 to 4.97 ppm, and 1.37 to 4.66 ppm respectively (Table 4.10). Sm value in northern region is relative to UCC. Eu – Lu in the northern region is higher concentration and Eu, Tb, Ho, Tm, Lu value in both south and center region are slightly high concentration with compared to UCC. Gd, Dy, Er, Yb value in the center region is very relative and southern region is slightly depletion to UCC.

The chondrite-normalized plots of the REE concentrations are given in Fig. 4.27 and Table: 4.5. The chondrite-normalized REE pattern in
average sample is in general similar to one another even though the concentrations of REEs in each region are higher concentration with compared to chondrite except Ti and concentration of P in the center region. Sr and K are very relative to chondrite value.

The REE concentrations of Post Archean Australian Sedimentary Rocks (PAAS) compiled by Taylor and McLennan (1985) were chosen for normalization, because it might be more relevant for samples collected in the Pacific Ocean than those compiled from the North American and European continents.

In the figure, 4.28 and Table:4.6 of the study area samples show a pattern with marked La-Sm REE negative anomaly and Eu, Tb, Ho, Tm, Lu show slightly enrichment to PAAS. In the northern region the concentration of Gd, Dy, Er, Yb is very relative. In the southern and center region these concentrations are clearly show slightly depletion to PAAS. This suggests that some REE fractionation may be taking place in the acid treatment of the sample, or naturally at the sediment-water interface and during early diagenesis of sediments.

It is of significant to understand geochemistry processes in marine environment to demonstrate the relative REE abundance in coastal sediments similar to the upper continental crust. For this, the REE concentrations in the samples were normalized to the average REE concentrations of the North America, European, and Russian shales (Yusof and Wood., 1993). The shale-normalized ratio of one indicates similar mobilization of REEs to the shale. The shale-normalized REE patterns in the average beach sediment samples are shown in Fig.4.29 and Table: 4.7. The
ratios of REEs are less than one, which indicates a lower degree mobilization of REEs to the shale, except for Eu, Tb and Lu. This suggests that the REEs in the sediments may have originated from terrigenous and riverine sources. The linear-shaped behavior of the shale normalized REE patterns indicates the relative REE abundances are slightly departed from the shale. The ratios greater than one was dominated by Eu, Tb and Lu. In the southern region the Eu concentration is very relative to NASC and all regions Tb, Lu concentration slightly high compared to NASC.

Multi-element normalized diagram for the Beach sediments, normalized against average upper continental crust (Taylor and McLennan, 1985). In the study area samples average value normalized to upper continental crust. Figure: 4.30 and Table: 4.8 shows and results major elements, $\text{Al}_2\text{O}_3$, $\text{CaO}$, $\text{Fe}_2\text{O}_3$, $\text{K}_2\text{O}$ and $\text{Na}_2\text{O}$ are weakening to upper continental crust (UCC) and $\text{TiO}_2$ show clearly slightly enrichment of north and south region.

Compared with UCC (Taylor and McLennan, 1985), in the beach from the study area Sc, V, Cr, Co Ni, Zn, Ga, Sr, Ba, are distinctly depleted whereas Rb and Cs is weakly enriched (Fig: 4.30). Hf is slightly enrichment of northern region and it is very relative in the center, south region compared to UCC. The concentration of Th is very great degree in the north to south region ranges from 1.53 ppm to 7.51 ppm.

**5.2. Conclusion**

These studies reveal that the variation in geomorphology, texture, mineralogy and geochemistry of the sediments are useful in characterizing the sediments in different environments of the study area. Geomorphologically the
present study exhibits various landforms such as beach, beach ridges, beach ridge plain, sanddune, paleo channel, estuarine and abandoned river channel. Of these, a well developed three series of beach ridges and three series beach ridge plain are found to be widespread in the study area. These landforms help to infer the various stages of sea level regression and transgression taken place in the study region.

Sediment logically, the Visher diagram indicates that they were obtained from a high energy environment. The CM pattern of the beach sediments are concentrated at PQ and QR segments and indicates deposition in the beach with fluvial influence.

Mineralogically, heavy minerals distribution has a multi-cycle nature mostly the contribution from the earlier sediments and in a mixture of high and low energy condition.

The light minerals distribution and its roundness and sphericity bring out a view that the sediments of different environments are contributed form metamorphic and igneous source of acidic in nature. Further, it also suggests that the sediments are reworked in nature with the addition of present day sediments from the riverine and marine environments.

The suite of heavy mineral found in the Keezhayur region again reconfirms this inference. Hence, the present study is the heavy minerals assemblages by multi environmental conditions.

Geochemically, the beach sediments can be said to be derived from a source region consisting of Granite, Quartz diorite and Granodiorite.

The beach sand corresponds to the composition of Fe-sand, Litharenite and greywacke. In the geochemical classification diagram of
Pettijohn et al (1973) beach sediments plot in the Litharenite and one sample is in the Arkose field. This classification is generally consistent with the petrologic data.

Tectonic setting discrimination diagrams show, in the present study area many samples fall in the CIA, and ACM field. Most data lie in the field for active continental margin and few samples fall in the passive margin yet, geochemical information was not sufficiently sensitive to differentiate between the two different source areas recognized by petrographic and modal analyses of beach sediments.

Normalized log-linear multi-element diagrams are becoming increasingly widespread, abundant and useful in the petrological and geochemical literature. This suggests that the REEs in the sediments may have originated from terrigenous and multi sources.

These studies reveal that the variation in geomorphology texture, mineralogy and geochemistry of the sediments are useful in characterizing the sediments in different environments and multi sources rocks. The studies on the trace element and rare earth elements suggest a real mechanism of the sediment interactions.