CHAPTER-VII

DISCUSSION AND CONCLUSION

7.0 INTRODUCTION

From the various studies tabulated in previous chapters it become known that the Kaliveli mangroves situated at Lat. 12° 05’ 12’’ N- Long. 79° 47’ 79’’ E become a victim of anthropogenic impacts resulting in sparse mangrove vegetation. Hence this study could be considered as a detailed one particularly on sediment characters, geochemistry and geochronology, though more detail work is warranted in near future. Most importantly the study is aimed to achieve the objectives listed in the first chapter of the thesis. Further from the field visits it is clear that this mangrove habitat is fragile one facing immediate threats from several quarters, largely anthropogenic in nature. It’s very survival is questionable as surrounded with salt pan and other industries and nearby “oblivious” coastal communities who seem to be insensitive to this vital vegetative cover and their very activities have a share in their rapid degradation. Hence it is appropriate a chapter is devoted to synthesize the data generated both in the field and laboratory to arrive meaningful conclusion after a lengthy discussion.

The present investigations cover sedimentological, geochemical, and geochronological aspects of Kaliveli mangrove near Yedayanthittu Estuary. The estuarine and lagoonal sediments are right candidates for studying palaeoweathering, provenance, palaeoclimatic, palaeoenvironmental, palaeoxygenation and pollution studies. In this study there was a sufficient focus on to understand the micro-depositional environments in the Kaliveli mangrove ecosystem through textural studies of sediment samples. Two cores, MKNM-C1 & C2 were recovered from the Yedayanthittu estuary soft fine grained sediments (up to 1 m water depth) upto a depth of 135cm and 126cm respectively and the field procedures are discussed elsewhere in the thesis. The sampling points are located approximately 5 km away from the present coastline. Major and trace element analysis was done in addition to clay mineralogy for the core sediments. $^{14}$C dating of two samples necessiated to go into insights on age and rate of
sedimentation in mangrove cover estuary during Holocene. At the end of the chapter, a list on future directions of the work is appended.

7.1 SEDIMENT CHARACTERISTICS

7.1.1 Textural Analysis

Grain size examination is one of the tools to characterise the depositional characteristics of the environment. The results from the sediment samples of the cores (MKNM-C1&C2) indicate that the silt, clay and fine sand constitutes the major composition of the sediments. In the sand-silt-clay trilinear plots, most of the samples fall in silty sand and sandy silt facies. The fine sandy facies occupying top and bottom layers have settled in a mild agitated environment. The middle part of the core with silt dominance points out a calm depositional energy. The fluctuating energy conditions that prevailed in the study area are responsible for the deposition of texturally fine sand and mud content alternatively. Besides contributions from source rocks weathering sites as particulates, dissolved, and litters from vegetal growth, effluents from neighbouring industries and salt pan work and the complex coastal processes, have shaped the sedimentary archives core sediments.

7.1.2 Calcium carbonate

Calcium carbonate is generally known as a dilutor of trace metal concentration and is contributed mainly by terrestrial run off and organisms in water column. Both the cores (MKNM C1 & C2) show enrichment of the calcium carbonate at top, middle and bottom part of the core. The association of sand particles with CaCO₃ indicates the major contribution of shell fragments to the sand fraction. Shell debris is mostly current derived, hence attributable to energy conditions in the coastal environment. The two cores (MKNM C1 & C2) reveal relatively high concentration of CaCO₃ percentage. This is due to increase in shell fragments and also due to sediment textural variation – coarser sediments preserve more shelly material. Calcium carbonate from the shelf sediments are often derived as carbonate materials and particulate matter from adjacent landmass and through inorganic and organic precipitation from the water column form the estuarine sediments (Sundararaj and Natesan, 2010a). The major
sources of carbonate in the sediments are shell fragments of organisms, and detrital/dissolved contribution of CaCO₃ from the continental part is perceived as highly minimal.

7.1.3 Organic Matter

The Organic matter concentration is high in middle part of both the cores (MKNM-C1 & C2). This is probably due to adsorption and incorporation of organic material into fine sediments, derived both from continental washings as well as in situ vegetative derived and a minimal part from the overlying water column. The dominance of muddy sediments in the middle part of the cores is considered as a major sink for organic matter. The organic matter concentration is low in the bottom and top layers of the cores. High content of the organic matter is partly derived from plant debris of terrigenous origin that accumulates in shallow water environment. Fine grained lithologies of silt and clay enhanced absorption and incorporation of organic materials of varied sources. However the oxygenated environment that prevailed at the site has aided decomposition of part of the organic matter which resulted depletion in OM.

7.1.4 Grain morphology (SEM)

The surface textural features of sand grains are observed by scanning electron microscopic studies for the core samples (MKNM-C1 & C2) (Plate III.1A,B,C & D and Plate III.2A,B,C & D). Five subsamples of silty sand were selected from core (MKNM-C1) at the depth intervals of 0-3, 57-60, 90-93 and 117-120 cm. The sand grains from the depth of 0-3 cm are angular exhibiting conchoidal fractures where as those the depth of 57-60 cm are subrounded, showing V-shaped pattern along with deep curved grooves on their surfaces. The sand grains of 90-93 cm are subangular displaying solution pits, and at a depth of 117-120 cm, the grains illustrate grooves on their surface.

Similar micromorphological features are observed for the sand grains of MKNM-C2 core recovered from identical depths as with the MKNM-C1.

The following inferences are recorded through the micro-textural study of quartz grains from the core sediments: sub-angular grains, conchoidal fractures
associated with arcuate step features suggest that the sediments were derived largely from the crystalline source rocks. V-shaped pits along with straight scratches signify that the sand grains were transported in a rather high-energy fluvial environment before settled at the mangrove sites. V-shaped pits, arcuate steps, striations and silica globule surface textures perhaps point out a multicyclic nature of the clasts before depositing in the mangrove habitat.

7.2 GEOCHEMISTRY

7.2.1 Major Oxides

The concentration of various major elements in the cores, MKNM Core 1 & 2 can be summarized as SiO₂, > Al₂O₃, > Fe₂O₃, > CaO, > K₂O, > Na₂O, > MgO, > TiO₂, > P₂O₅, > MnO. The major oxide geochemistry reflects a higher concentrations of detrital constituents in study area. Major element analysis effectively represents the composition of the solid fraction being eroded from the continent (Taylor and McLennan, 1985).

7.2.1.1 Weathering

The CIA values of core MKNM-C1& C2 reveal moderate weathering in the source area. The PIA and CIW values of cores are greater than 60 substantiating moderate weathering condition in the source area. The ICV values of the core sediments contain low proportion of non-clay silicate minerals suggesting a immature nature of sediments. The Ruxton ratios of cores reveal that majority of the samples have one digit value (<10) illustrating a medium to high intense weathering. The values of V for both the core samples are greater than 1 indicating moderate to strong weathering in the source terrain.

7.2.1.2 A-CN-K, A-CNK-FM and A-C-N

The intensity of weathering in the source area can be quantified by the chemical alteration (Nesbitt and Young, 1982). Ternary diagrams representing A-CN-K, A-CNK-FM and AK-C-N are used to deduce the weathering trends in the source rocks from which the sediments have been derived. These plots quantify more precisely the effect of chemical weathering on the loss of labile elements of
Na, Ca, and K. All the sediment samples in the A-CN-K and A-CN-K-FM ternary diagrams plots at the field of moderate weathering.

The ternary plots of A-CN-K, (Al$_2$O$_3$, CaO*+Na$_2$O, K$_2$O) (Phanerzoic Shale, Upper Continental Crust, Pierre Shale, North American Shale Composite and Russian Mesozoic and Cenozoic Shales) show that all the sediment samples in both the cores fall parallel to the A-CN line (Fig.4.7). This indicates that the weathered clastics were derived from granitic and Charnockite sources.

The mafic ternary plot A-CNK-FM (Al$_2$O$_3$, CaO*+Na$_2$O-K$_2$O, Fe$_2$O+MgO) shows that most of the sediment particulates are falling within the compositional triangle of feldspars, garnet, and chlorite. This implies the approximate mafic minerals composition of samples in both the cores. However, recent sediments do not show any presence of garnet (Fig.4.8). Therefore, the coastal and offshore sediments fall away from the feldspar-garnet join but close to the feldspar-chlorite join, suggesting that the sediments are essentially composed of feldspars and chlorite. Plagioclase weathering corroborates the inference on silicate weathering in source terrain. The PIA values for MKNM-C1 fall between 76 and 56 with a mean of 69, and between 85 and 49 with a mean of 68 for MKNM-C2 attest the presence of plagioclase feldspars in the sediments.

7.2.1.3 Provenance

The Al$_2$O$_3$/TiO$_2$ ratio of the present study suggests that intermediate to felsic rocks are the probable source rocks. In addition, palaeoclimatic and chemical maturity of fine grained sediments delivered to the area can also be deduced from chemical composition of the fine fraction of the sediments. The TiO$_2$ vs Zr of both cores represent predominantly felsic igneous source rocks. The interpretation is further bolstered by the TiO$_2$ vs Ni bivariate plot of the both cores which also favours that these sediments were mainly derived from felsic nature of source rocks. The average SiO$_2$/Al$_2$O$_3$ ratio of both the cores suggests that the sediments are sourced from acidic rocks. The discrimination diagrams of core MKNM-C1 & C2 suggest that the sediments are probably sourced from both felsic to intermediate igneous and degraded metamorphics provenance.
7.2.1.4 Palaeoclimate

The bivariate plot of SiO$_2$ against total Al$_2$O$_3$+K$_2$O+Na$_2$O for paleoclimatic inference during deposition of the sediments in the basin is well recognized by many workers. On this diagram, the sediment samples plot essentially in the field of semi-humid to semi-arid climate thus indicating that the sediments of the study area are deposited under a semi-humid to semi-arid paleoclimate. The Al$_2$O$_3$/TiO$_2$ ratio (<20 in humid conditions and >30 in arid climatic conditions) can be used as a climate indication for the source area. The average Al$_2$O$_3$/TiO$_2$ ratio of 18.51 implies a humid climate for the provenance area.

7.2.2 Trace Elements

The concentrations of trace elements such as Ba, Zr, Cr, Ni, Cu, Th and Pb are observed higher than average UCC values. However the overall trend in trace element distribution indicates lithogenic origin.

7.2.2.1 Provenance

The abundance of Cr and Ni in clastic sediments can be considered as proxy for provenance studies. The samples in the present study have an extremely low Cr/V ratio and a variable abundance of Y/Ni pointing to a predominantly felsic rocks of the source area. Ratios such as Cr/Th, Th/Sr, Th/Co, and Th/Cr are significantly different in felsic and basic rocks and may allow constraints on the average provenance composition. These ratios of sediments from the present study are compared with those of sediments derived from felsic and basic rocks (fine fraction) as well as to upper continental crust (UCC). These comparisons also authenticate that such ratios fall within the range of felsic source rocks.

7.2.2.2 Palaeo-oxygenation

In the present study, the silty sand and sandy silt samples show ~0.65-1.00 with an average of 0.77 Cu/Zn ratios, indicating oxic conditions. The V/Cr in the present study exhibits an oxic environmental condition. The elemental Ni/Co vs V/Cr ratios, Ni/Co vs V/(V+Ni), and Organic Matter vs Co/Ni ratios in the present study imply oxic–dysoxic conditions of the environment.
7.2.2.3 Enrichment Factor

For the core MKNM-C1, the EF values of Sr, Ba, Zr, V, Cr, Ni, Cu, Zn and Pb demonstrate moderate enrichment of these metals in the sediments and may have partly originated from anthropogenic sources such as industrial effluents and atmospheric deposition. EF values of Rb, Ba, Y, Nb, Co, and Th, illustrate no enrichment in the study area. The area is dominated by granites and gneisses, which govern the distribution patterns of all elements. Consequently, the natural lithology is having more weightage in influencing the distribution of elements, than the anthropogenic sources. Similarly in the core MKNM-C2, the EF values of Sr, Ba, Zr, V, Cr, Ni, Cu, Co, Zn and Pb demonstrate moderate enrichment of these metals in the sediments and may have partly originated from anthropogenic sources, such as industrial effluents and atmospheric deposition. Similarly EF values of Rb, Y, Nb, Co, and Th, illustrate no enrichment in the study area. Hence it is concluded that the natural lithology is the main controlling factor influencing the distribution of elements than anthropogenic sources.

7.2.2.4 Contamination Factor

Contamination Factor values for MKNM-C1 shows the contamination factor of the metals in the order of Sr>Zr>Ni>Pb>Cu>Cr, and these elements reveal a moderate contamination factor. The low contamination factor has been ascribed for metals such as Rb, Ba, Y, Nb, V, Co, Zn, and Th. In core MKNM-C2, the contamination factor of the metals are expressed in the order of Zr>Pb>Ni>Cu>Cr, and these elements imply a moderate contamination factor. Similarly, a low contamination factor for metals Rb, Sr, Ba, Y, Nb, V, Co, Zn, and Th has been related to geogenic origin. In the present study a low to moderate contamination factor has been arrived for the sediment samples.

7.2.2.5 Geoaccumulation Index

In the case of geoaccumulation index, the core MKNM C1 shows relatively low levels of contamination for Rb, Sr, Ba, Y, Zr, Nb, V, Co, Ni, Zn and Th, and these metals are found to be unpolluted category. The high values for the metals such as Cr, Cu and Pb, suggest unpolluted to moderately polluted category. In core MKNM-C2, the geoaccumulation index values of the metals shows
relatively low levels of contamination for Rb, Sr, Ba, Y, Zr, Nb, V, Co, Zn, Th and Pb, as these metals are labeled as unpolluted category. The high values of the metals such as Cr, Cu and Ni, is found to be unpolluted to moderately polluted category.

7.2.2.6 Correlation matrix

In core MKNM-C1, the strong positive correlation between Al₂O₃, MgO, MnO and Fe₂O₃ clearly reveal that the geochemical composition of the cores sediments chiefly derived from Fe and Mn rich ferromagnesian mineral rich source rocks. The enrichment of K₂O rich sediment indicates that the core sediments are derived from K feldspar rich rocks subjected to chemical weathering and soil forming processes. Further the presence of Kaolinite and Illite clay also supported the above conclusion. Similarly significant correlation exists between Rb, Y and Nb implying chemical weathering process played a role in the disintegration and decomposition of rock forming minerals. The correlative analysis on concentration of ferromagnesian elements like V, Cr, Co, Ni, Cu and Zn and crustal average value has clearly brought out the geogenic source of such elements. The correlation significance of CaO, P₂O₅ and Ba illustrate that these elements enter into the mangrove environment through confluence of riverine input and further reveal the occurrence of apatite mineral in the core sediments. The high concentration of Pb with significant correlation clearly suggests its derivation through anthropogenic. The significant correlation of TiO₂ and Fe₂O₃ suggests the occurrence of heavy minerals in the core sediments.

In core MKNM-C2 a positive correlation of silt with OM which could be due to association of mangrove humus and OM from detrital preserved in muddy sediments. The significance of parameters such as clay, CaCO₃ and P₂O₅ suggest that clay sediments are moderately enriched in carbonates in composition. Further negative significance of CaO conform that the calcareous composition mainly derived from biogenic source. A strong correlation between Al₂O₃, Fe₂O₃, MnO, MgO and K₂O illustrates that the sediments chiefly are derived from granulite and charnockite rocks. The positive significant relationship of trace elements Y, Nb, V and Rb indicate that they may be due to presence of rare earth minerals such as ilmenite with the core sediments. The modest correlation that exists
between Sr and Ba point out that the sediments are chiefly through riverine process, and accommodation of Sr could be traced in feldspars and clay sediments. Similarly the correlation of CaCO3 and P2O5 on a positive side points out that the sediments has admixture of calcareous walled micro organisms and broken shell fragments. The correlation matrix studies overall imply that the sediment associated major oxides and trace elements have come more from natural origin.

7.3 CLAY MINERALOGY

The XRD analysis fine matrix rich sediments have helped to identify and interpret clay mineral assemblages towards environment of deposition and paleoclimatic. X-ray diffraction analyses are carried on selected (5 samples for both the cores) set of untreated, and glycolated representative samples. The major clay mineral groups present in the sediments are illite, chlorite, kaolinite, and non-clay minerals such as quartz and feldspar. The clay mineral illite has formed by weathering of felspathic and micaceous rocks. Illite and chlorite are the products of physical weathering of crystalline rocks. Kaolinite has formed as a weathering product of feldspar rich granitic rocks/metamorphic in a tropical humid paleoclimate. Chlorite is common in micaceous rich metamorphic and granitic terrains and calcite is sourced from the calc granulite from the hinterland, as well as partly of biogenic source (shell debris).

7.4 GEOCHRONOLOGY

In the present study, three representative sediment samples from top, middle, and bottom core of MKNM-C1 were selected for radiocarbon dating. Since the middle core has poor preservation of organic matter, the sample could not be used for dating. The radiocarbon age determined for the sediments at depth of 0-30 cm is 2940 ± 160 yr BP, and 105-135 cm is 8350 ± 350 yr BP.

7.4.1 Rate of sedimentation

The computed sedimentation rate at a depth of 0-30 cm is 0.01 cm y⁻¹, and 0.02 cm y⁻¹ at the depth of 105-135 cm. In the present study, the radiocarbon data of MKNM-C1 core indicate that the age of the core extends up to Early
Holocene. The east coast has been modified due to repeated coastal regression and transgression process. The $^{14}$C dates and Holocene sea level curve favour a steady but slow sea level rise for the study area.

7.5 CONCLUSION

The present study of Kaliveli mangroves sediments are largely fine sand, followed by silt and clay reflecting a feeble fluctuating but dominantly a calm energy condition at the depositional sites of the cores. Organic matter content is pertained to the adsorption and incorporation process and derived through river runoff as well as from local mangrove humus. However OM is minimally sourced from productive water column. The high percentage of calcium carbonate in the sediments is due to the shell fragments and also due to the variation in sediment texture. The SEM study of quartz grains display a variety of micro-textures developed by mechanical and chemical process and it indicates the signatures of fluvial environment prior to deposition in the mangrove habitat.

Clay mineralogy analysis reveals the weathering pattern as well as paleoclimate through their detailed study. Illite, Chlorite, and Kaolinite as clay minerals along with non-clay minerals of quartz and feldspar make up the core sediments. The clay minerals are mostly geogenic in nature and derived from degraded weathering profiles of provenance.

The major elements are derived from felsic source rocks and weathering indices such as CIA, CIW and PIA values indicates low to moderate weathering. SiO$_2$/Al$_2$O$_3$, TiO$_2$ vs Zr, Al$_2$O$_3$/TiO$_2$ ratio reiterates felsic source rocks. Discriminate function points out intermediate to felsic rocks weathered under semi-arid to semi-humid climatic conditions.

Trace elements present in the Kaliveli mangroves core sediments indicate that the felsic source rocks from hinterland land are the major contributors. Palaeo-oxygenation condition that prevailed in the sediments depositional site was oxic. Enrichment factor, contamination factor, geoaccumulation index and pollution load index shows largely unpolluted nature of the ecosystem. The overall extracted correlation matrix results imply that the sediment associated major oxides and trace elements come from natural origin.
Radiocarbon age of the core is 8350 ± 350 yr BP extending up to Early Holocene period and the calculated average sedimentation rate is 0.015 cm/y\textsuperscript{1}. The radiocarbon data revealed repeated transgression and regression that have shaped the present coastal configuration since Early Holocene. The 14\textsuperscript{C} dates and Holocene sea level curve favour a gradual and slow sea level rise in the study area.

7.6 FUTURE WORK

As far as mangrove of this area is concerned, several scientific methodologies need to be adopted for their conservation and afforestation; however before venturing into such planning, it is time to take stock of the geological and environmental changes that the area underwent in the recent past along with anthropogenic threats the area faces. These challenges and related studies could form a formidable future work and are listed below.

a) The Holocene mapping of mangroves along this belt which include nearby Pondicherry and Cuddalore as several industries have sprang up in this belt and health of mangroves depends on well keeping of the coastal environment and efficient handling of industrial effluent.

b) Hence a detailed integrated study on geochemistry, micropaleontology including palynology and diatoms along with geochronology of more core samples of this belt shall be initiated at early.

c) It is highly appalling to know the shrinking habitat of mangroves of this area; hence detailed study should be initiated on physico-chemical parameters of the brackish water including the tides/wave/sediment dynamics and sand bar development and importantly on the impacts of nearby salt pan work.

d) Since mangroves are protectors of the coastal communities at times of natural calamities, sensitisation of local communities and their whole hearted involvement in regeneration of mangroves and preservation of the environment should be attempted.

e) More researchers across several disciplines such as biology, forestry, fisheries, geology, physical and chemical sciences and sociology fields should be encouraged to undertake research studies on integrated basis with liberal financial support.