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Distribution of Heavy Minerals and its Provenance Studies of Mahabalipuram Beach, South East Coast of Chennai, Tamil Nadu

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ABSTRACT

The presence of heavy minerals along the Indian coast has been reported and studied by many researchers. There is a considerable accumulation of heavy minerals along the Tamil Nadu coast at certain places, but those have not been studied in detail. The present study is mainly focus on the distribution of Heavy Minerals and its provenance studies of Mahabalipuram area located south of Chennai and it falls in the survey of India toposheets 66 D/2 prepared in the scale of 1:50,000. The samples were gathered at low tide (1 no), high tide (1 no), beach(1 no) and one core sample using a Corer (hand held pvc pipe) upto 90 cm depth from the dry sandy deposits at Mahabalipuram stations and sub sampled in to 10 cms and totally 12 samples. The resutls of grain size studies show bimodal pattern in the core samples upto 10 cm depth where as unimodal pattern upto 30 cm depths. The distribution of finer sediments in this region might have accured from the dislodging of coarser lighter sediments by the panning action of high velocity waves. Based on the geology of the area, garnet can be

attributed to the rock types of charnockites, dolerite dykes derived from acid to basic igneous and high rank metamorphic rocks.

The total heavy minerals concentration by weight of different grain sizes does not show any trend in the LT and HT sediments. Further in core samples the heavy mineral distribution remains to be strongly contrasting in the vertical samples in such a way each 1 m sample shows differential enrichment of heavies in different grain sizes. Such uneven vertical distribution of heavy minerals may be attributed to the frequent sea level oscillation in this region to different environmental conditions, in such a way from offshore to beach and inland and the reverse.

1. Introduction

India endowed with a coastline of over 7500 km, hosts some of the largest and richest shoreline placers. Indian resources constitute about 35% of the world resource of Ilmenite, 10% of rutile, 14% of Zircon, 71% of monazite and 10% of garnet. However, the exploitation of these huge reserves of the placer deposits as picked up in the last few years with focus on the garnet and ilmenite (enriched titanium) which forms a large part of the export in India. Chandrasekar (1992) has undertaken detailed exploratory work of beach placers in the central Tamilnadu coast and the reserves of zircon, garnet and illmenite in the enriched zone are estimated as 1.74, 2.45, 5.97 million tons and 0.48, 1.22, 0.45 million tons in the lean zones respectively. Angusamy et al., (1992) and Angusamy (1995) have inferred from Kanyakumari- Kuttankuli beach a reserve of 0.49 MT zircon, 6.13 MT garnet, 6.01 MT, ilmenite, 10MT magnetite, 0.76 MT, rutile, 0.04 MT monazite. Loveson (1994) suggested that there is a relation between the sea level variation and heavy mineral accumulation along the southern Tamilnadu beaches as evidenced by remote sensing studies and located the enrichment of in two physiographic lowlands namely, Kallar-Vaippar and Manapad- Kanyakumari. Chandrasekar and Rajamanickam (1995) have evaluated total reserves of Zircon high content ZrO_2 in the beaches of central Tamilnadu as 1.74 MT.

Suresh Gandhi and Solai (2010) have been discussed the post tsunami heavy mineral concentration are dominant in Cuddalore and Kannikovil between Cuddalore and Pondicherry. Suresh Gandhi et al., (2011) had been studied the post tsunami heavy mineral distribution between Cuddalore and Kanyakumari along the Tamil Nadu Coast and inferred that Ovari received higher percentage of heavy minerals due to the deposition of tsunamigenic sediments towards the shore region. From the study they observed higher concentration of garnets and zircons distributed after the tsunami in the coastal region. In the Northern Tamil Nadu coast, limited works have been carried out earlier. Hence, an attempt has been made to identify the distribution of heavy minerals particularly in Mahabaipuram region.

1.2 Study Area

The present study area Mahabalipuram is located south of Chennai and it falls in the survey of India toposheets 66 D/2 prepared in the scale of 1:50,000 (fig.1). The various geomorphic landforms like beach, strandlines, sand dunes, alluvial plain, chennier, paleo lagoon, salt marshes, mudflats, flood plain, paleo-channel, salt pan, lagoons have been noticed nearby regions in the study area.

1.2 Methodology

The samples were gathered at low tide, high tide, beach including one core sample using a Corer (hand held pvc pipe) up to 90 cm depth from the dry sandy deposits at Mahabalipuram stations and subsampled in to 10 cm and totally 12 samples. Sieving was carried out in ASTM at ½ φ interval. Using graphic (Folk and Ward, 1957) and moment methods (Friedman, 1961, 1967 & 1979) the weight percentage data of 12 samples were processed in personal computer by using the modified programme of Schlee and Webster's (1967) procedure. From the statistical parameters, frequency curves, mean, standard deviation, skewness, kurtosis, bivariant plots was drawn for the analysis proceedings. For heavy mineral studies, sieved fractions of sediments have been made into light and heavy mineral fractions by following the procedure mentioned in the Muller (1967).

1.3 Results of Grain size Analysis

The various textural parameters obtained through graphic and moment methods are shown in the Table 1.

1.3.1 Frequency curves

In the study region the core sample shows, upto 10 cm depth it shows bimodal pattern where as form 10 to 30 cm depths it shows unimodal pattern. From 30 to 80 cm it shows bimodal distribution and up to 1m depth it is unimodal in nature. It shows an alternate source of deposition. The anthropogenic activities along the coast have established the intactness and compactness of beach sediments, resulting in the onshore and offshore drifting of sediments. The littoral currents also play a significant role in the redistribution of sediments along the beaches and core samples. The frequency pattern point towards the presence of bimodal distribution having peaks at 2.00 φ and 2.75 φ. Mostly fine grained and medium grained are dominated in this region.

1.3.2 Mean

In the study area, mean value ranges from 1.69φ to 2.34 φ at Mahabalipuram indicating a prominent distribution of medium to fine sand in this zone (Fig.2 a&b). The distribution of finer sediments in this region might have accrued from the dislodging of coarser lighter sediments by the panning action of high velocity waves.

1.3.3 Standard deviation

Accordingly, Mahabalipuram core samples sorting value ranges from -0.01 φ to 0.74 φ, indicates moderately sorted to moderately well sorted nature (Fig.2 a&b). The moderately sorting nature may be due to the addition of sediments of different grain size from the reworking of beach ridges or by alluvial action and the prevalence of strong wave convergence throughout the year. The other two zones show a similar sorting nature may be due to the prevalence of strong northerly drift. The currents moving from down south region carry the sediments to the northern regions. In this process the sediments are imparted with moderate to well sorting nature. Similar observations are found in the East Coast of India.

1.3.4 Skewness

In general, based on the classification of Folk and Ward (1957) the skewness values of these sands vary from negatively skewed to very positively skewed. In the core samples up to 30 cm depth shows positive skewed and from 50 to 1 m depth also shows positive skewed indicate the low energy environment. The low tide and high tide shows similar pattern as positive skewed.

1.3.5 Kurtosis

The moment kurtosis values are found to vary from 1.7 to 4.1 (Fig.2 a&b).. This uneven nature clearly designates the mixing of two-end populations. The movement of long shore currents and the fluvial discharge of sediments have probably brought out these two populations mixing. This is also attributable to the widely varying nature of sediments and change in gradients of the coastline.

1.4 Depositional Environment

1.4.1 Bivariant plots

In the study region various scatter using various parameters obtained from graphic method and logerthemic methods are used (Fig 3 a-f). In Fig 3 b, mean against skewness is plotted. A distinct field of separation is observed between low water mark, beach and foreshore. The values of mean and skewness of core samples indicated more fineness and sorting than the beach sands.

In Fig 3c, standard deviation Vs skewness is plotted. All the samples fall in the low water mark and strandline except a few samples at foreshore environment. The abundant fine mode in core sediments results in positive skewness for the majority of samples.

The grouping between beach and dune within these plots could rather be difficult in view of the reworking phenomena appeared by the same agents. However, the recent sediments are found to be grouped separated in all the plots from the rest. The core samples show two group. It may be due to existence of difference in their grain sizes and all other textural parameters. Scatter plots mean vs. skewness have really aided to distinguish the shallow marine sediments; i.e., the offshore sediments from the paleosediments of the same place both beach and dune.

1.5. Results of Heavy mineral studies

The heavy minerals weight percentages of various locations for Low tide, High tide and core samples are given in Table-2.

1.5.1 General distribution

In the study area, heavy minerals are found to be enriched in few selected locations. In general, they are medium to fine grained in nature. Heavy minerals are concentrated as patchy and disseminated forms in this region. Mostly light minerals are dominated than the heavy minerals. In the study region, due to the constant wind action, heavy minerals deposition establishing a clear varying of heavy and light minerals in the form of alternate layers is noticed. In core samples heavy minerals are more abundant in the deeper depths.

1.5.2 Individual Heavy Mineral Variation

1.5.2.1 Distribution

Heavy mineral by weight percentage of the all the three fractions namely, coarse, medium and fine are identified (mesh 35, 60, 120) (Figure .4 to 6) The heavy minerals are dominant in High Tide and in the 1 m depth core samples. The heavy mineral wt% for the core samples are sown in the fig 7 to 9.

1.5.3 Low Tide and High Tide Heavy Wt%

In low tide the heavy mineral wt% of medium grained samples shows 2.7%. Mostly light minerals are dominated. In High Tide region, the concentration are slightly higher and shows 5.4%. The beach environment in more amount of opaque/Non- opaque ratio, garnet colourless and zircon and lesser amount of garnet pink is noticed. The remaining minerals do not give any systematic distribution. However, the absence of augite and muscovite is noteworthy in beach samples.

1.5.4 Core Wt %

The heavy mineral wt % shows that at the depth of 0-10 cm the percentage is gradually increase and from the depth of 40 cm to 80 cm depth an appraisable rise in percentage is noticed.

1.5.5 Heavy mineral assemblages for LT, HT and core samples

The study area is characterized by a suite of kyanite (1.21% to 32.54%), garnet (12.03% to 31.76%), opaques (6.69% to 19.12%), and zircon (4.0% to 20.19%) minerals. In the study region, the counting of non opaque heavy minerals have been done and the results are tabulated. From this table one can easily infer the gradational distribution of the heavy minerals according to the grain size.

Based on the heavy mineral studies it is clearly observed that this Mahabalipuram coastal region is lesser percentages of heavy mineral distribution than the other coastal regions. Opaque minerals are slightly higher than the non opaque minerals in this region. Only selective minerals like garnet, zircon and tourmaline are dominated. The lesser percentage of chlorite, hypersthene, hornblende etc., are noticed. The coastal morphology may control the distribution of placer deposits. A large quantity of sediments is supplied by the major rivers along the east coast and is constantly moved by the waves either towards the north or south depending on the angle of wave approach with respect to the coast. The rate of sediment transport varies from time to time along the coastal region. Analysis presented indicates that the transport is towards the north from March to October and towards the south from November to February. The transport rate during March-October varies between 0.5 and 1.5 x10^5 m3 per month. During November-February the rate varies from 0.5 to 2.5 x 10^5 m3 per month. Northerly and southerly components of the annual sediment transport along the Chennai to Mahabalipuram are estimated to be in the order of 0.89 and 0.60x 10^6 m3, respectively. This results in a net northerly drift of 0.3x10^6m3 per year. Due to the littoral drift and sediment transport the heavy minerals percentage's also varied in this region.

The percentage distribution of the total heavy mineral concentration by weight with respect to sample to sample of individual grain sizes exhibit in beach and core sample environments display hardly any significant trend. This may be due to the fact that these environments are influenced by different factors in different times at a particular point.

1.6 Provenance

Based on heavy minerals, an attempt has been carried out to find out their parent rocks in the provenance. The minerals like garnet, kyanite, hypersthenes, may be assigned to the contribution of different high grade metamorphic rocks. The opaques (mainly of ilmenite and magnetite), zircon euhedral, topaz and rutile might have been derived from igneous rocks of acidic and basic compositions of the study area. Similarly, the rutile, rounded zircon and the remaining above said minerals having roundness in the range of subrounded nature, etching, over growths, out growths etc., can be related to the ancient sediments which have undergone the recycling.

Based on the geology of the area, garnet can be attributed to the rock types of charnockites, dolerite dykes derived from acid to basic igneous and high rank metamorphic rocks. When comparing the different rock types and the mineral assemblages of the study area, it is suggested that along with the high rank metamorphic, acid and basic igneous rocks, reworked sediments and the low rank metamorphic rocks are expected to provide significant contribution in these environments. From this, it may be concluded that along with the contribution of the minerals from the rock types of study area, some other distant sources might have also been added up to form the minerals assemblage in these environments. The minerals considered from outside contributions may be of mainly from low rank metamorpohic rock types. These rock types are located well inside the study area. However, the core sediment heavy deposits may be showing its original combination and concentration of minerals. Such lesser input of the present day riverine sediments may also be a reason for the non-availability of higher concentration of heavy minerals in the low tide and fore shore environments.

1.7. Discussion

Textural study of present day sediments as well as studies of Mohan (1993), indicate that mixed energy environment and erosion activities are more in this region. Because of this nature, the contribution of heavies are not showing any typical trend which in turn, reflect the process of sedimentation which could not concentrate the heavies by removal of more light minerals from this region.

At Mahabalipuram shore temple, towards south of the bay, heavy mineral concentration is relatively less on the surface. In order to get the enrichment of heavy minerals as beach placers, the optimum conditions are required which should be neither erosive nor accumulative in nature. Such conditions prevail in stable shores, which are signified by the presence of open seashore face, sandy beach, cliffs and high coasts. Further 10 m south, minor patches of heavy minerals are found. In the berm region, alternate heavier and lighter mineral bands with increasing width of heavy mineral bands with depth are noticed. About 70 m south of the shore temple, rock exposures constituted by graphic granite, pyrope garnet with reddish-brown colour and labradorite were observed.

When considering the low tide and high tide beach, the highest concentration of heavies is observed. The littoral drift bringing the oceanic sediments especially in the northeast and southwest monsoon enter inside this region. As they are getting refracted at the coastline, they return with the added force (a circular current or swirl) and leave out the Mahabalipuram with the coarser light fraction and fine heavies. The continuous process of such movement enable the sediments in and around Mahabalipuram to get enriched in heavies. The persistence of sand throughout the region in all depths is enriched in heavies. The persistence of sand throughout the region in all depths is supplementing such possibilities.

Based on geospatial application in the study of beach Placer along the Coast of Gulf of Mannar , Chandrasekar et al., (2008), had been developed a method for the spatial anlaysis of data using geographical information system (GIS). Specifically, creating attribute data base structure, data encoding, data interpolation, and view shed analysis are attempted to delineate the opaque and garnet occurrences in the beach sediments. Furher the study had established the digital elevation model (DEM) capability to identify the potential beach placer zones in the study area. Based on grains size studies Angusamy and Rajamanickam (2006) have been inferred the depositional environment of sediments along the southern coast of Tamil from Mandapam to Kanyakumari. They also noticed that wave shadow environment for the Mandapam sector from Visher diagrams, whereas the Valinokkam, Tuticorin and Manappad sectors show double saltation populations characteristic of beaches, and the Kanyakumari sector is characterized by a more truncated population characteristic of a plunge zone, which is a high energy environment.

Solai, et al., (2010) had been elaborately discussed about the distribution of heavy minerals along the Tamiraparani Estuary and Off Tuticorin and inferred that higher percentage is noticed in the river and estuary samples (34.8 %) may be due to due to the fast moving action of wind and water and the alternate higher and lower percentage of heavy mineral in the marine sediments may be due to the bathymetric conditions. This observation also corroborated our findings in Mahabalipuram, where that bathymetry is suddenly increased in the nearshore region where the heavy mineral concentrations are also more.

1.8.Conclusion

The sediment textures area fine and medium grained innaure. It indicates beach environment and most of the grains are positive skewed. It indicates low energy condition with accumulation of finer medium sediments. In the present study area most of the grains are very platykurtic to leptokurtic. The platykurtic to leptokurtic indicates multiple environments. The study area contained high percentage of orthopyroxene (hypersthene) and garnet, rounded and broken zircons inferred to have been derived from charnockites and granulite gneiss of the study area. The present study has clearly indicated the multiple roles of tectonically controlled coastal blocks and their geomorphological influence in redistributing the sediments with favourable NE-SW configuration and wave energy conditions must have contributed to the formation of heavy minerals in a particular zone. As these factors play a major role the materials derived from a common provenance are regrouped for density and size sorting process. Further, the heavy mineral assemblage of the core sediments with respect to the nature of catchment rocks of the study region indicate the possibility of mineral supply from additional agencies such as alongshore and offshore sources.

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Table.1.Results of textural parameters(graphic and moment methods)

METHOD OF MOMENTS (Logarithmic)				FOLK AND WARD METHOD (Logarithmic)			
Mean	Skewness	Kurtosis	Sorting	Mean	Skewness	Kurtosis	Sorting
2.239	0.908	4.186	0.731	2.187	0.229	1.333	0.742
1.932	0.218	2.387	0.552	1.928	0.104	0.869	0.591
1.898	0.234	2.340	0.549	1.898	0.141	0.867	0.591
2.153	-0.195	2.262	0.584	2.164	-0.102	0.758	0.600
2.242	-0.507	3.156	0.644	2.257	-0.245	0.850	0.633
1.965	-0.253	2.295	0.743	1.957	-0.017	0.713	0.744
2.397	-1.120	3.616	0.626	2.384	-0.504	1.021	0.628
2.263	-0.839	3.019	0.697	2.281	-0.498	0.796	0.679
1.695	0.191	2.781	0.636	1.720	0.202	0.955	0.661

Table.2. Heavy Minerals Count Percentage for Fine sand samples of Mahabalipuram

Zircon	1	2	3	4	5	6	7	8	9
a.Rounded	83	45		6	4	7	12	5	36
b. Broken			8	3	2		2	5	
c. Euhedral			5	1	4	5			
d. Outgrown				1					
e. Overgrown									
Garnet	17								
a.Colourless		14	6	5	18	8	14	18	17
b. Light Pink		2	4	4	2	2	2	5	
Kyanite		3	5						
a.Colourless									
b. Blue					5	6		4	
Actinolite		1							
Biotite							1		
Chlorite	4	2		4	2	5	4	4	
Epidote							1		
Glaucophane									
Hornblende	4	4	3	5	4	6	1	5	
Hypersthene		3	2	4	5	5	1		
Muscovite									
Rutile	6	8	4	7	3	6	1	6	24
Sillimanite		3					2	2	
Staurolite									
Topaz									
Tourmaline	72	43	21	12	12	21	4	3	27
Tremolite							5	2	
Opaque									
Magnetite	18	24	18	6	4		6	2	24
Illmenite	15	18	12	11	3		4	3	18
Total	219	170	88	69	68	71	60	64	146

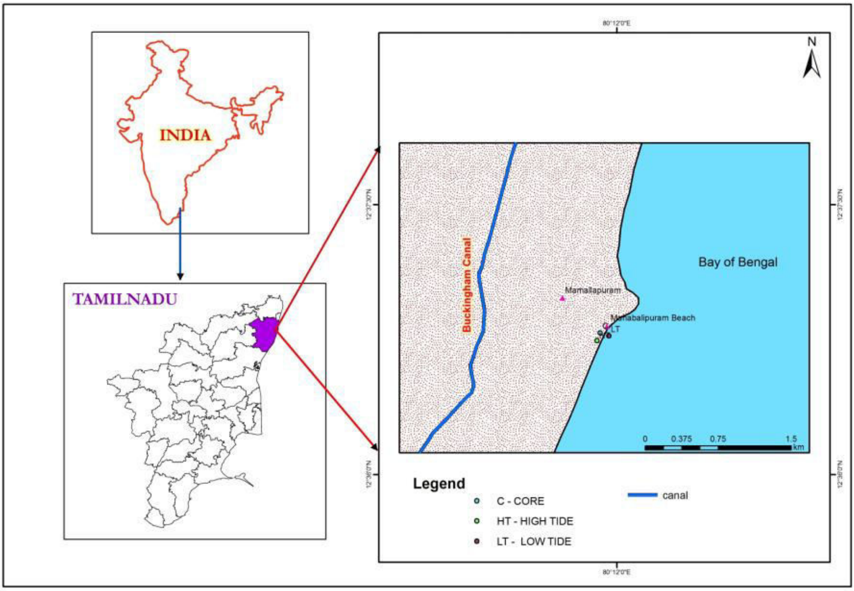


Figure.1 Location of the study area

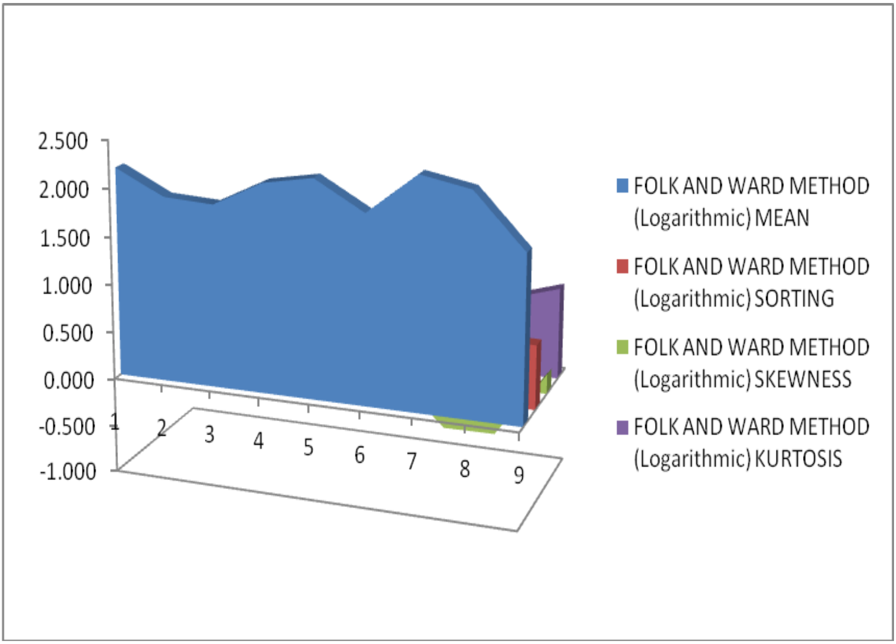


Fig.2a Textural parameters in 3D view for Core Samples in Mahabalipuram (Folk and ward Methods)

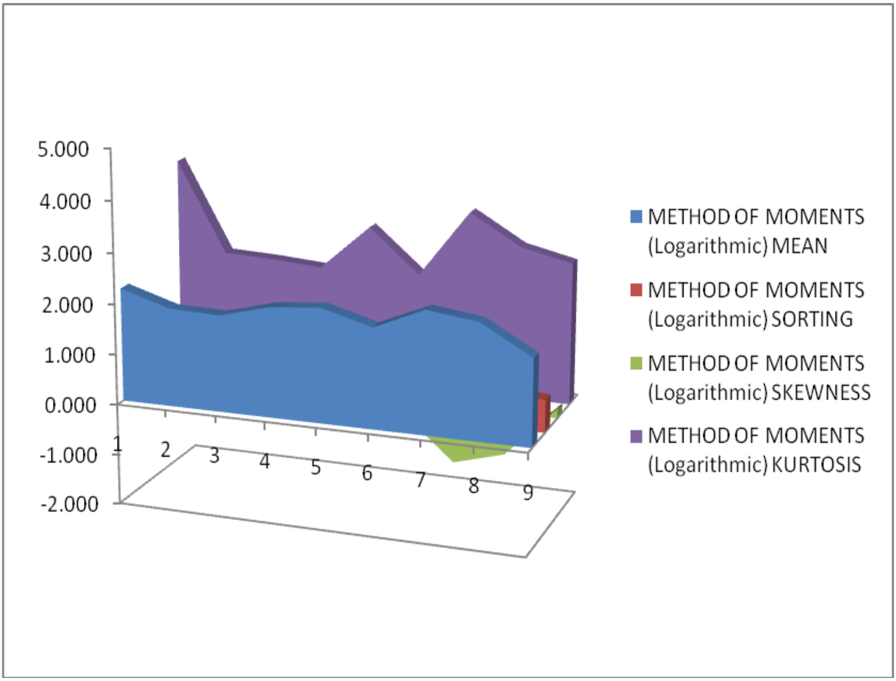
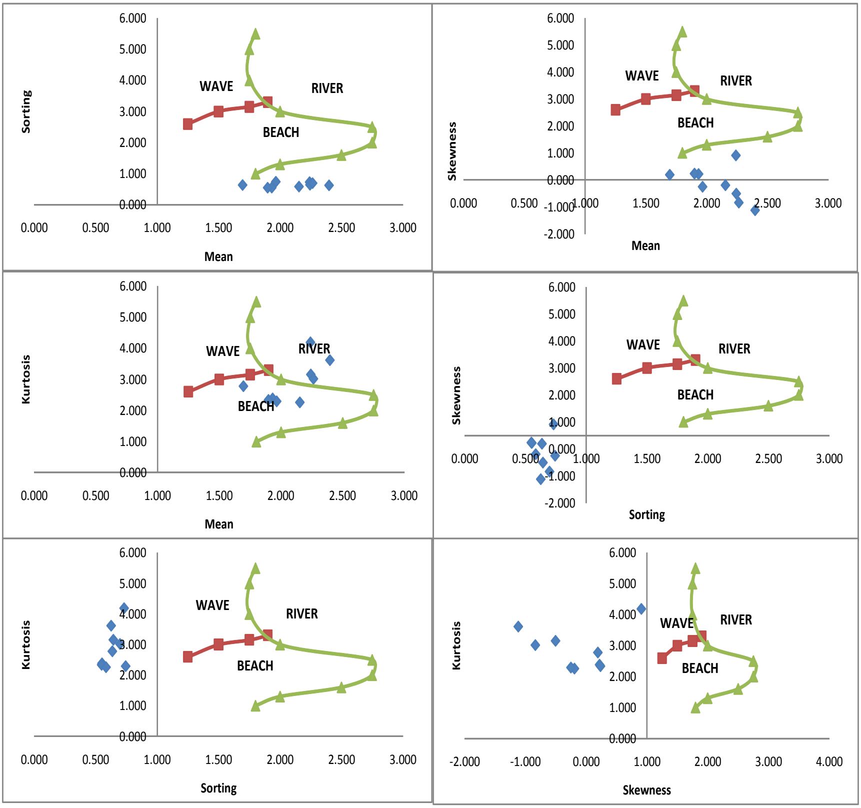


Fig.2b Textural parameters in 3D view for Core Samples in Mahabalipuram (Moment Methods)



Figuew.3. Bivariants plots of the study area

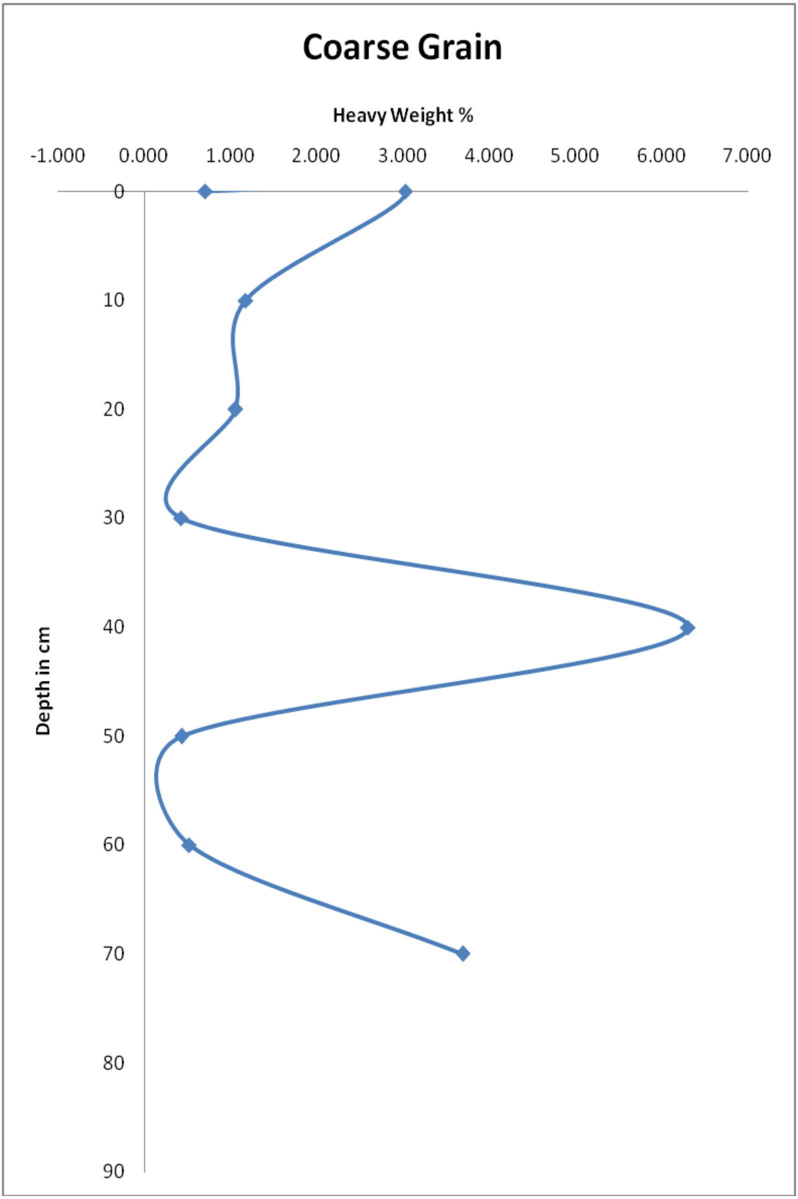


Fig.4 Vertical distribution of Heavy Mineral Percentages in Mahabalipuram Beach (Coarse Grain)

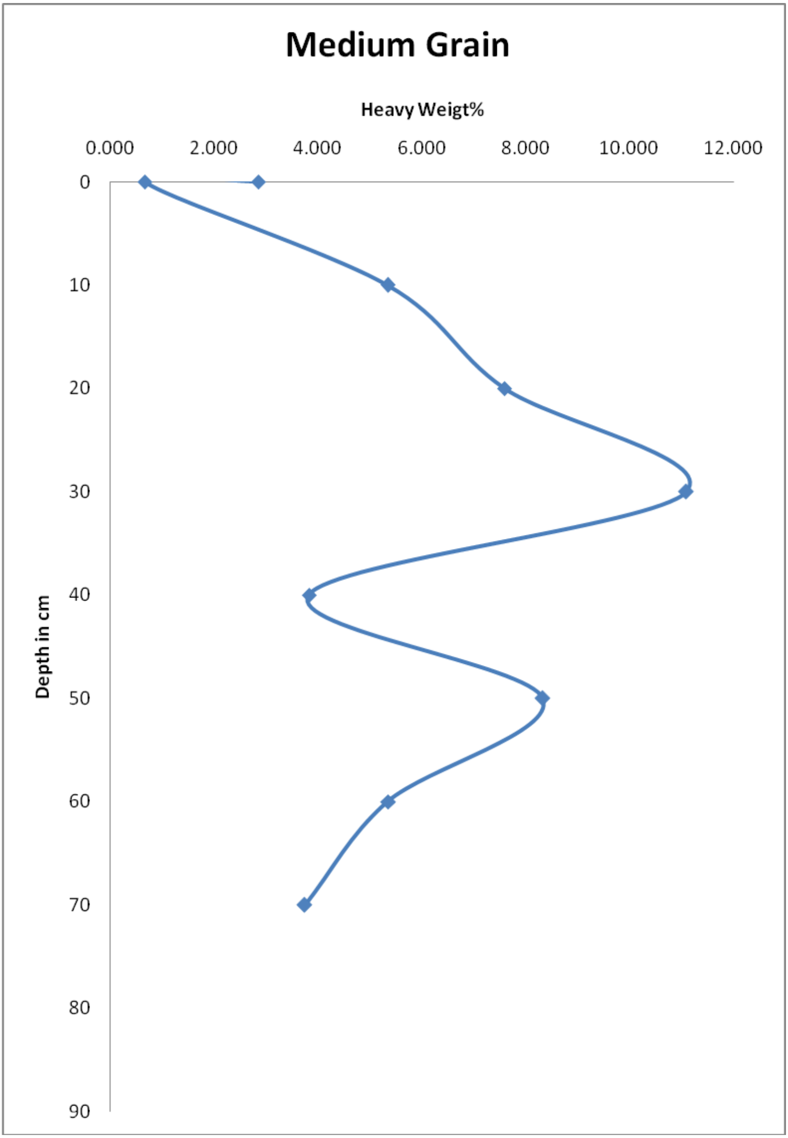


Fig.5 Vertical distribution of Heavy Mineral Percentages in Mahabalipuram Beach (Medium Grain)

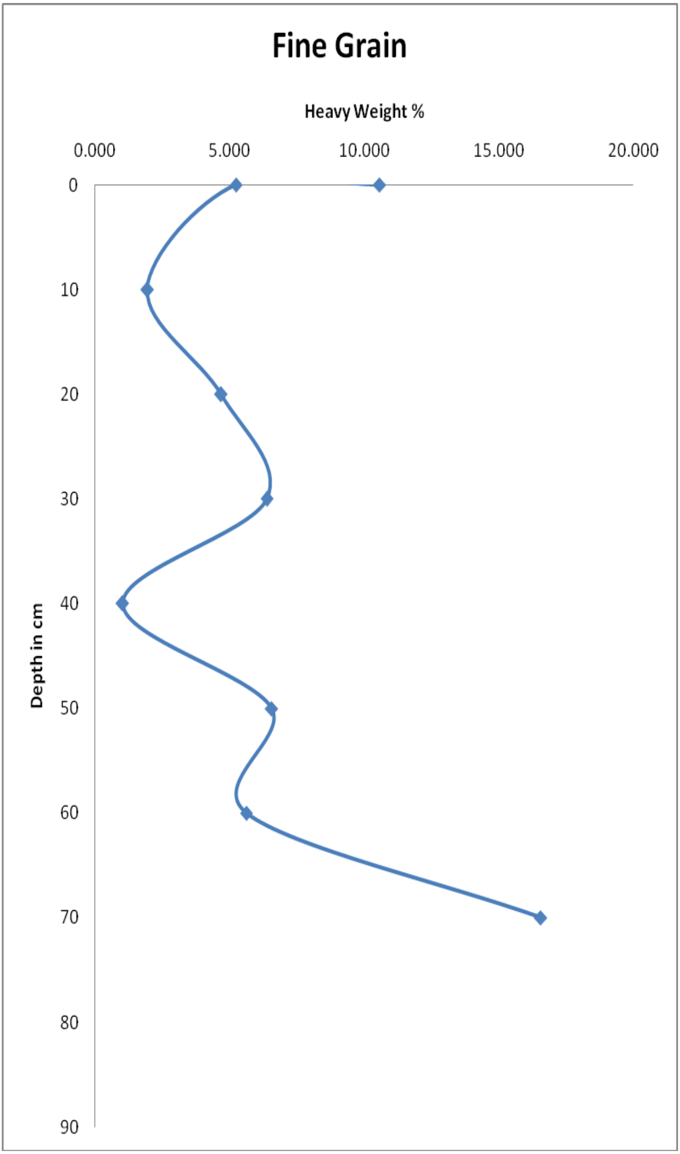


Fig.6 Vertical distribution of Heavy Mineral Percentages in Mahabalipuram Beach (Fine Grain)

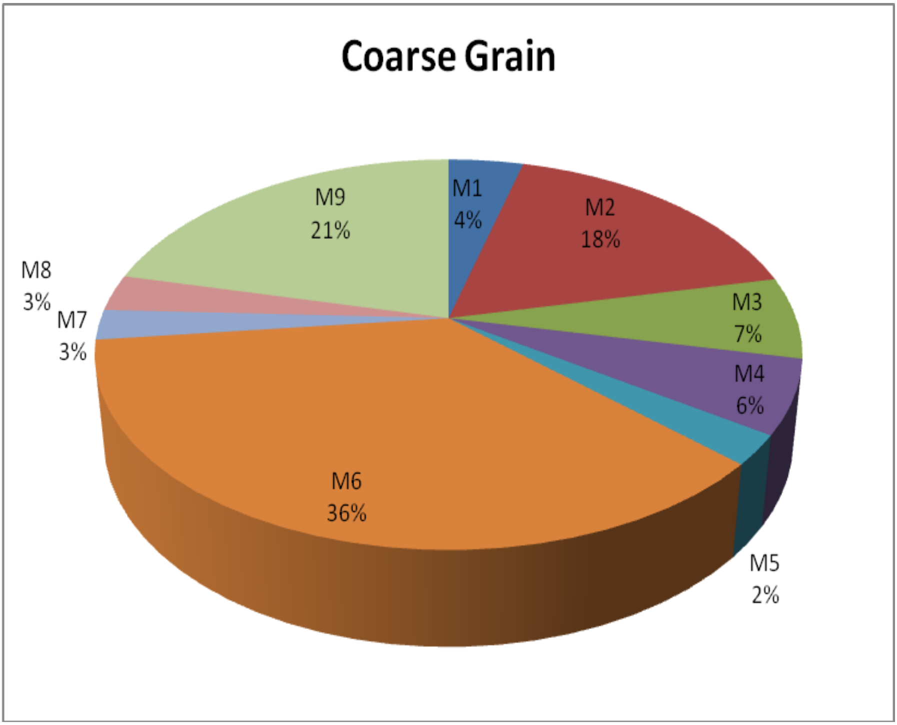


Fig.7 Heavy Mineral Weight % in Phi diagram for Coarse Grain (Mahabalipuram)

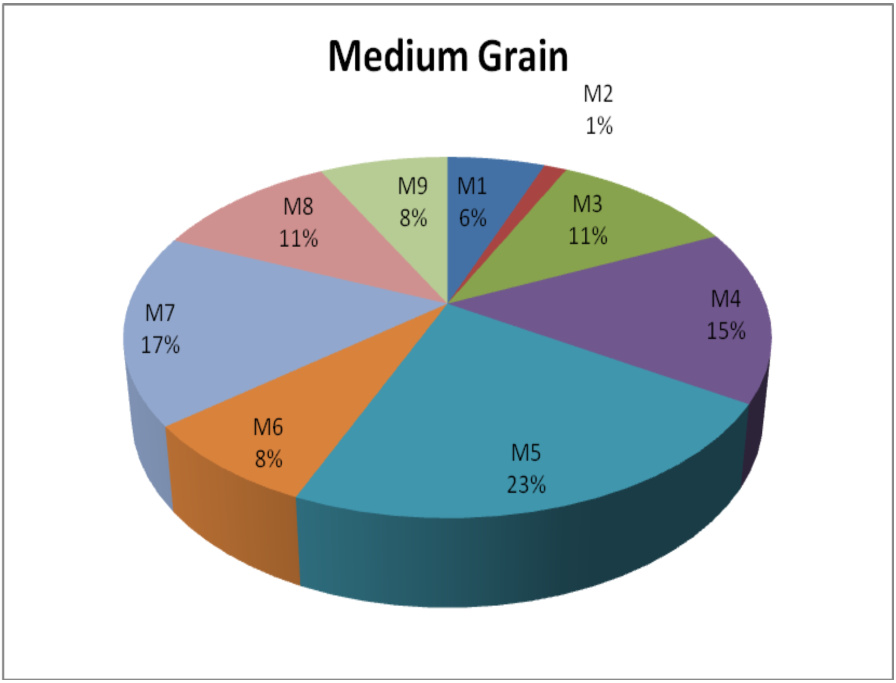


Fig.8 Heavy Mineral Weight % in Phi diagram for Medium Grain (Mahabalipuram)

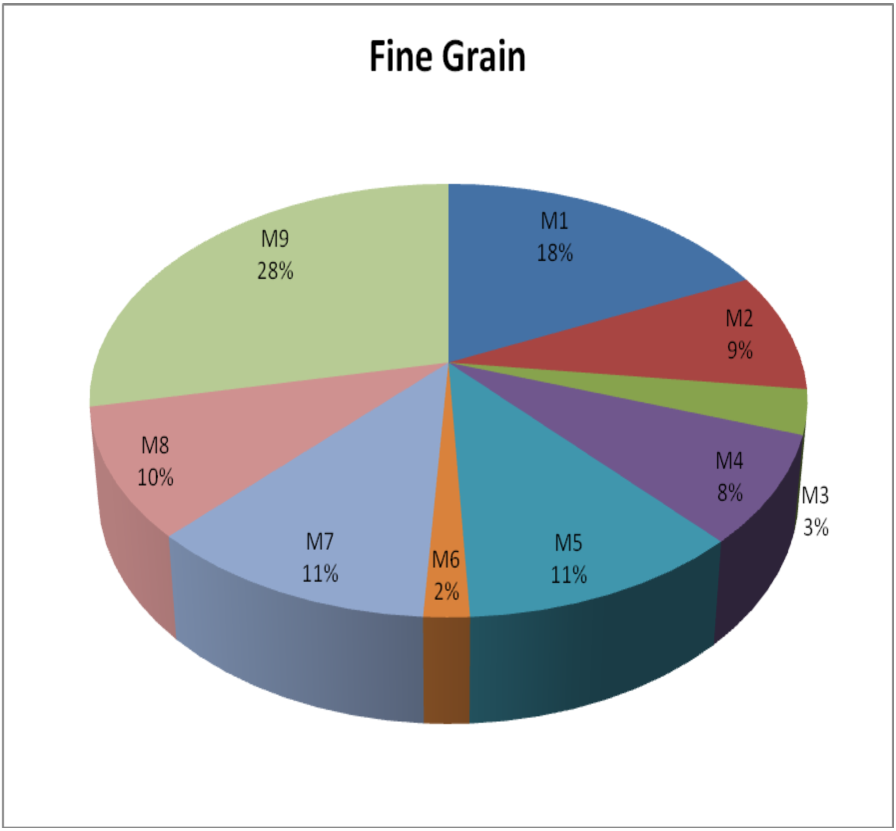


Fig.9 Heavy Mineral Weight % in Phi diagram for Fine Grain (Mahabalipuram)