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Texture and mineralogy of beach sediments of Chavara and Manavalakurichi, South India - A comparative analysis

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Chavara and Manavalakurichi are the two important areas with heavy mineral deposits in India. Surface samples were collected from five locations, each from Chavara and Manavalakurichi, and were analyzed for their textural parameters and mineralogy. Sediments from both regions are characteristically fine and medium sand. Chavara (CH) sands are moderately well sorted, whereas Manavalakurichi (MK) sands are moderately sorted to moderately well sorted sediments. Linear discriminate functions (LDF) calculated using the textural parameters show deposition environments of aeolian and shallow marine. Ilmenite predominantly exists along with other heavy minerals such as zircon, sillimanite, rutile, monazite, leucoxene, and garnet. The heavy minerals show an increasing trend towards, but its grain size becomes finer and well sorted. The berm and upper foreshore regions shows high concentration of heavy minerals.

[**Keywords**: Chavara, Heavy minerals, Manavalakurichi, Mineralogy, Texture]

Introduction

Geologically, texturally, and mineralogically, several studies have been carried out in the sediments of Kerala and Tamil Nadu coast. All these sediments belong to Quaternary sediments. Several authors studied about the surface and subsurface sediments for granulometric studies, especially Quaternary sediments from several parts across the world, and then they are trying to use them as a guide for the environment of deposition[1-3]. While considering the mineralogical part, most of the research is mainly focused on heavy minerals and their relation to provenance[4,5]. In spite of the vast studies on the Quaternary sediments in both the Chavara (Kerala) and Manavalakurichi (Tamil Nadu) coast, a group of literature has revealed that a relatively some special kinds of works are done only concerning both textural and mineralogical characters of the Quaternary sediments[6,7]. The present work aims to shed clear and brief light on the textural as well as the mineralogical characters of heavy minerals in these areas. Heavy minerals usually seen in 56 types of translucent species. The assemblage of heavy minerals in sediments denotes their origin as well as the parent rocks. The provenances of marine sediments were studied using Ti-Fe oxide heavy minerals like ilmenite, rutile, leucoxene, and other minerals like monazite, garnet, zircon, sillimanite based on their exclusive characteristics on structure and geochemistry[8-10]. Here the objectives of the study are to document the variation in sedimentology with the change of coastal environments and to study the mineralogical variation (heavy minerals) of beach sediments collected from the important placer deposits of India such as Chavara in Kerala and Manavalakurichi in Tamil Nadu.

Materials and Methods

Study area

The study area extends between latitudes 8°58'11.45" to 8°58'40.99" N and longitudes 76°31'33.48" to 76°31'41.93" E of Kerala and between latitudes 8°9'4.05" to 8°7'37.23" N and longitudes 77°17'39.1" to 77°18'36.45" E of Tamil Nadu. The Sampling locations are separated approximately 1 km apart (Fig. 1). The study regions are mainly occupied by crystalline rocks of Archean age comprised of charnockites, gneisses, granites, and Quaternary sediments. The study area is rich in heavy minerals that include ilmenite, rutile, leucoxene, sillimanite, garnet, zircon, and monazite. The ultimate sources of heavy minerals seen in both Chavara (Kerala) and Manavalakurichi (Tamil Nadu) coast are the Western Ghats. The Kerala segment of the south Indian peninsula has the Precambrian basement and the overlying tertiary and quaternary formation along the coastal fringes. The rock types occurring in the Kerala region can be classified into three major age groups belonging to Archean, Proterozoic, and Cenozoic. The Archean continental crust comprised of mainly granites, gneisses, granulites, etc. The granulites and associated gneisses which belong to Precambrian form the major part of Kerala. Mostly about 80 % of Tamil Nadu is comprised of crystalline rocks of Achaean to late Proterozoic age. It comprises mainly Charnockites and Khondalites and their migmatic derivatives.

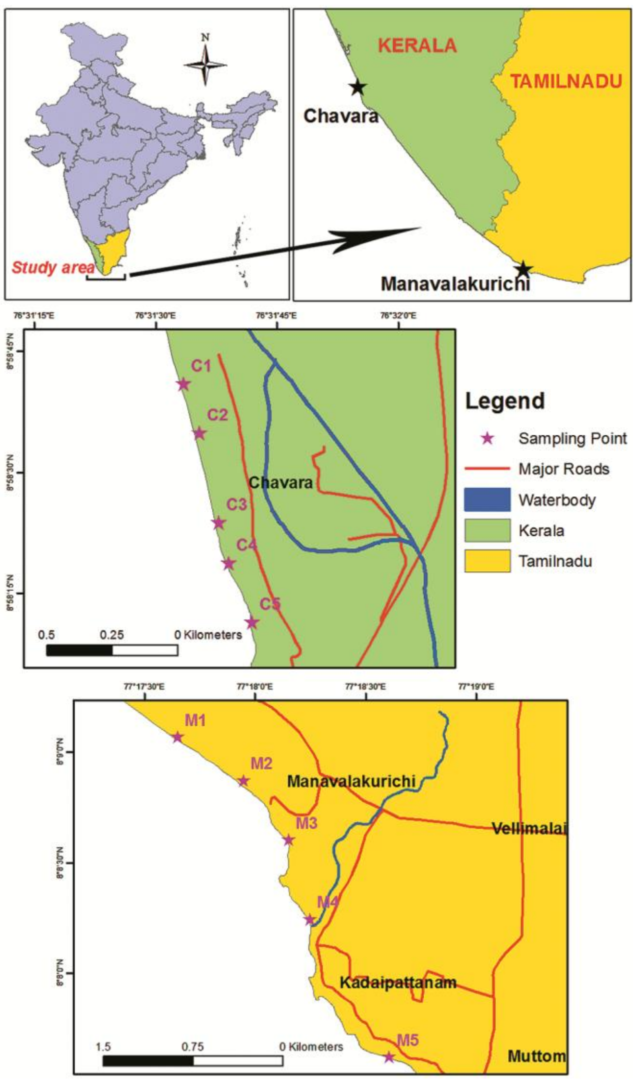

Fig. 1 — Study area map

Methodology

Totally ten samples were collected from Chavara (C1-C5) and Manavalakurichi (M1-M5) regions at a sampling interval of approximately 1 km. The bulk was dried and reduced by coning and quartering[11]. A representative sample of about 100 g was taken for textural and mineralogical analysis. Pre-treatment of the samples involves two steps (i) H_2O_2 or $SnCl_2$ (30 % by volume) for removing organic matter, and (ii) dil. HCL (1:10) for removing shells. After the pre-treatment, the dried samples were sieved at +18 to +230 mesh sizes of ASTM sieve (0.50 ø intervals) and weighed separately for estimating the weight percentage frequencies[12]. These weight percentage frequencies were used for estimating the textural parameters such as mean, standard deviation (sorting), skewness and kurtosis based on graphical method.

Linear discriminate function (LDF) analysis showing the sediment depositional environment and processes was carried out using Sahu's linear discriminate functions[13]. Heavy minerals were separated from the beach sediments using bromoform[14]. The relative abundances of individual mineral species in each heavy mineral concentrate were determined using point-counting of grain mounts under a petrological microscope (Leica). Then the number percentages of each mineral have been converted to modal percentages. R-mode factor analysis was carried out using IBM SPSS statistics 20.

Results and Discussion

The depositional environment of beach sediments can be easily reconstructed using the textural parameters[15]. The relation between grain size parameters and sediment transport processes has been studied elaborately for various sedimentary environments[12,16-21]. Figure 2 shows the grain size parameters calculated for Chavara and Manavalakurichi samples. Chavara samples show grain size completely fine grained, whereas Manavalakurichi samples ranged between medium to fine sands. Chavara samples have moderately well sorted sediments, while Manavalakurichi samples show both moderately sorted and moderately well sorted sediments. The Chavara samples are near symmetrical to fine skewed, while Manavalakurichi samples were coarse skewed to fine skewed. In Chavara sector, platy to very leptokurtic nature can be noticed while in the case of Manavalakurichi sector, the samples show platy kurtic, very platy kurtic, very leptokurtic and extremely leptokurtic nature.

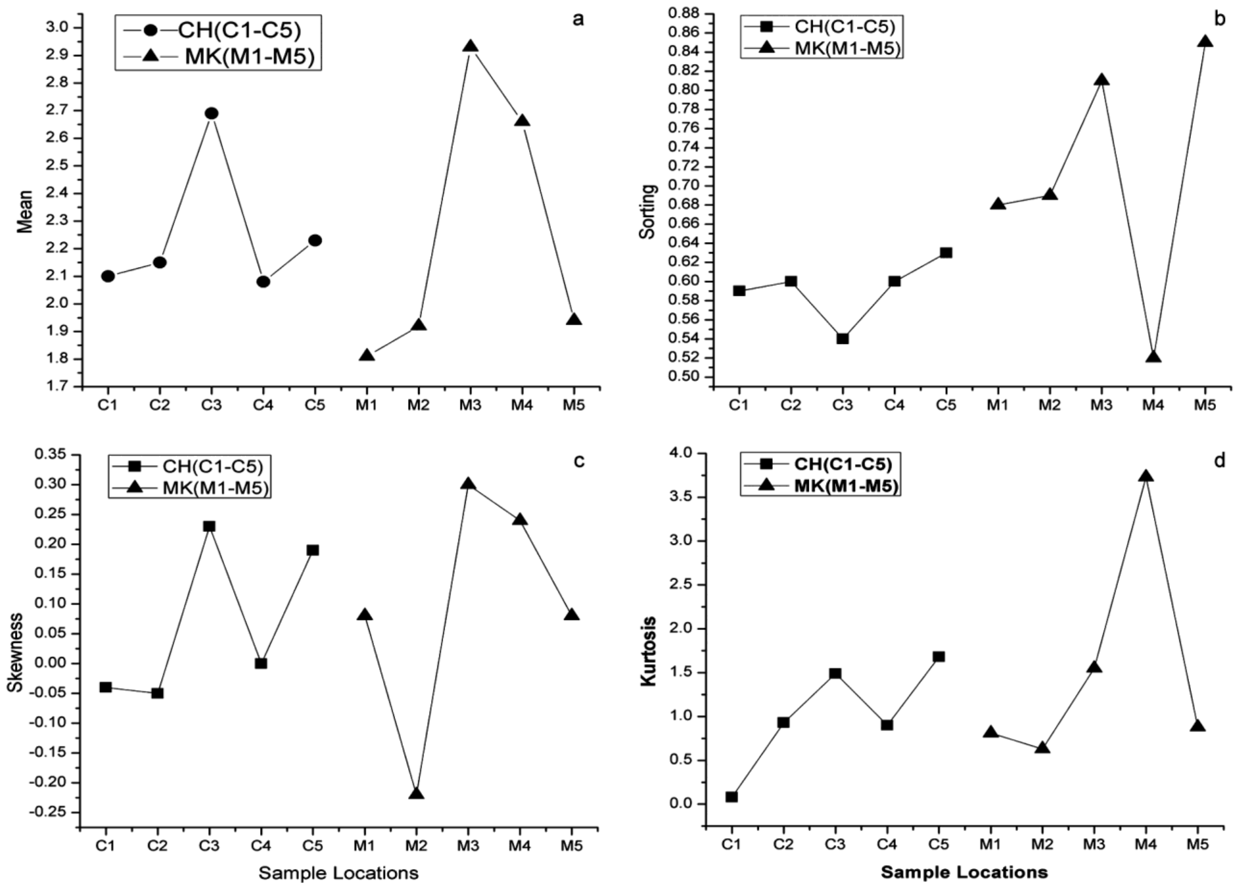

Fig. 2 — Variation of statistical parameters with location: (a) mean v/s sample location, (b) sorting v/s sample location, (c) skweness v/s sample location, and (d) kurtosis v/s sample location

Large deviation in values of kurtosis shows beach sediments are also deposited by high-energy environment[22]. The nature of sediment flow actually determines the variation in kurtosis[24], and the dominance of fine-sized grains with platykurtic nature depicts the maturity of sediments. These occur due to the presence of finer/coarser sediments in varying proportions[19].

Bivariant plots

Sedimentologists have used bivariant plots developed using textural parameters for distinguishing different depositional settings. The textural parameters clearly reflect the variations in fluid-flow mechanisms responsible for the occurrence of beach sediments[24]. Figure 3 shows the bivariant plots of textural parameters for the Chavara and Manavalakurichi samples. The results show that beach sediments are medium to fine-sized with moderately to moderately well sorting.

The fine-sized grains depict best sorting because their mean grain size and sorting are hydraulically controlled[25]. The sediments of Chavara and Manavalakurichi are moderately well sorted, and near-symmetrical- fine skewed. The genesis of sediments can be easily understood by the values of kurtosis[26]. The sediments from Chavara and Manavalakurichi coast are positively skewed with very platy to very leptokurtic in nature which clearly shows the majority of medium sized grains with subordinates of coarse and finer grains. However, the Chavara and Manavalakurichi beach sediments show a mixing of different sized sediments, with one predominant and a very subordinate.

Linear discriminate function

The LDF values clearly recognize the fluctuations in wave energy conditions and fluidity factors which show a strong relationship with various processes and different environments of sediment deposition[13]. The Y1 reveals the dominance of aeolian for Chavara samples but majority of Manavalakurichi samples fall under beach process. All samples belong to shallow marine waters (Y2). As per the values of Y3, all samples correspond to shallow marine environment

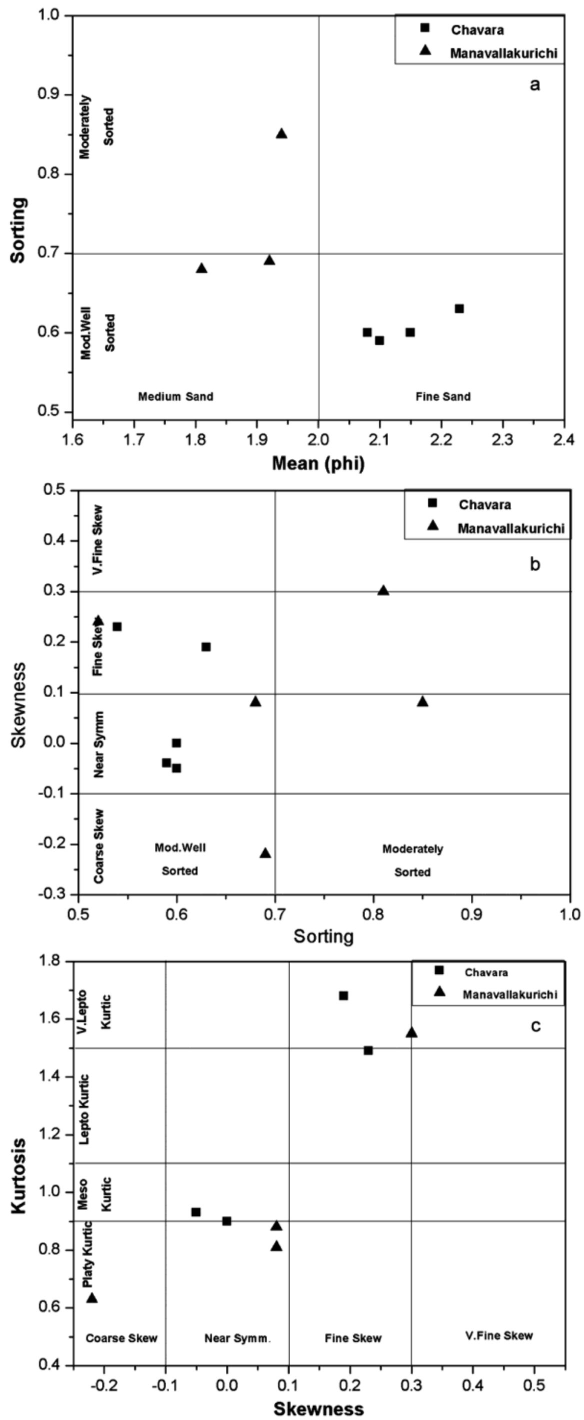

Fig. 3 — Bivarient plots: (a) mean v/s sorting, (b) sorting v/s skweness, and (c) skweness v/s kurtosis

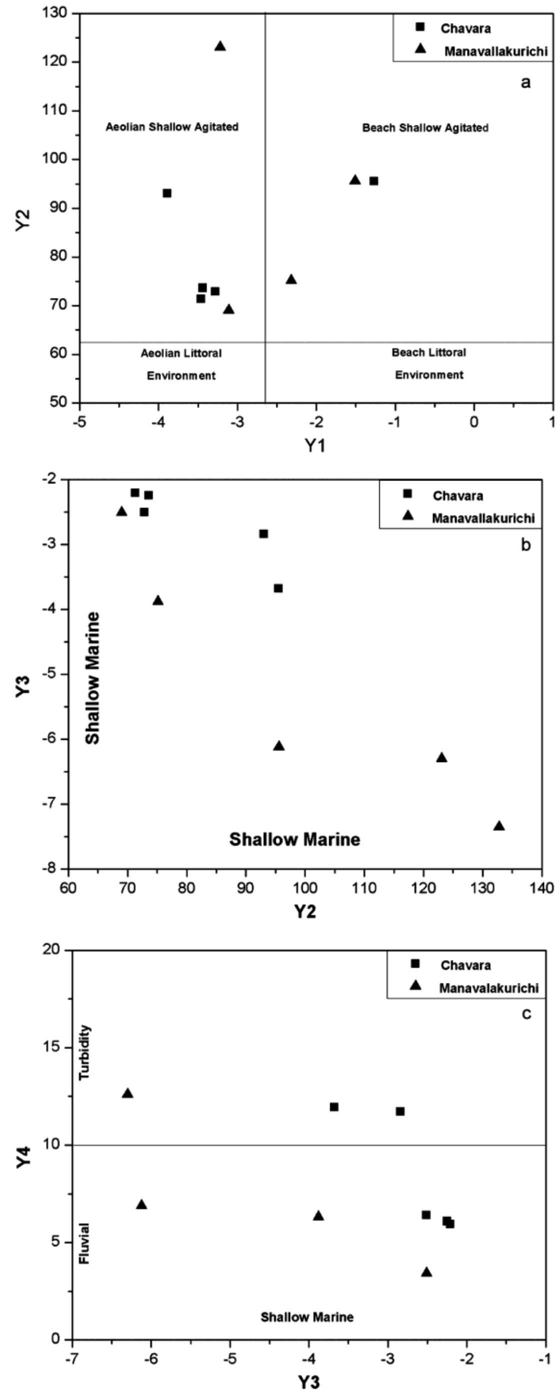

Fig. 4 — LDF diagram: (a) Y1 v/s Y2, (b) Y2 v/s Y3, and (c) Y3 v/s Y4

and finally the Y4 clearly indicates that the sample deposition was carried out by turbidity and fluvial action (Fig. 4).

CM pattern

The CM pattern helps to demarcate the beach sand based on their environments of fluvial and deltaic deposits[27,28]. Here the mode of deposition of sediments in Chavara and Manavalakurichi coastal area is analysed using CM pattern. Figure 5(a-b) shows the CM diagrams of Chavara and Manavalakurichi, and Figure 5(c-d) shows the TCD diagrams of Chavara and Manavalakurichi. The TCD diagram shows that the samples show bottom

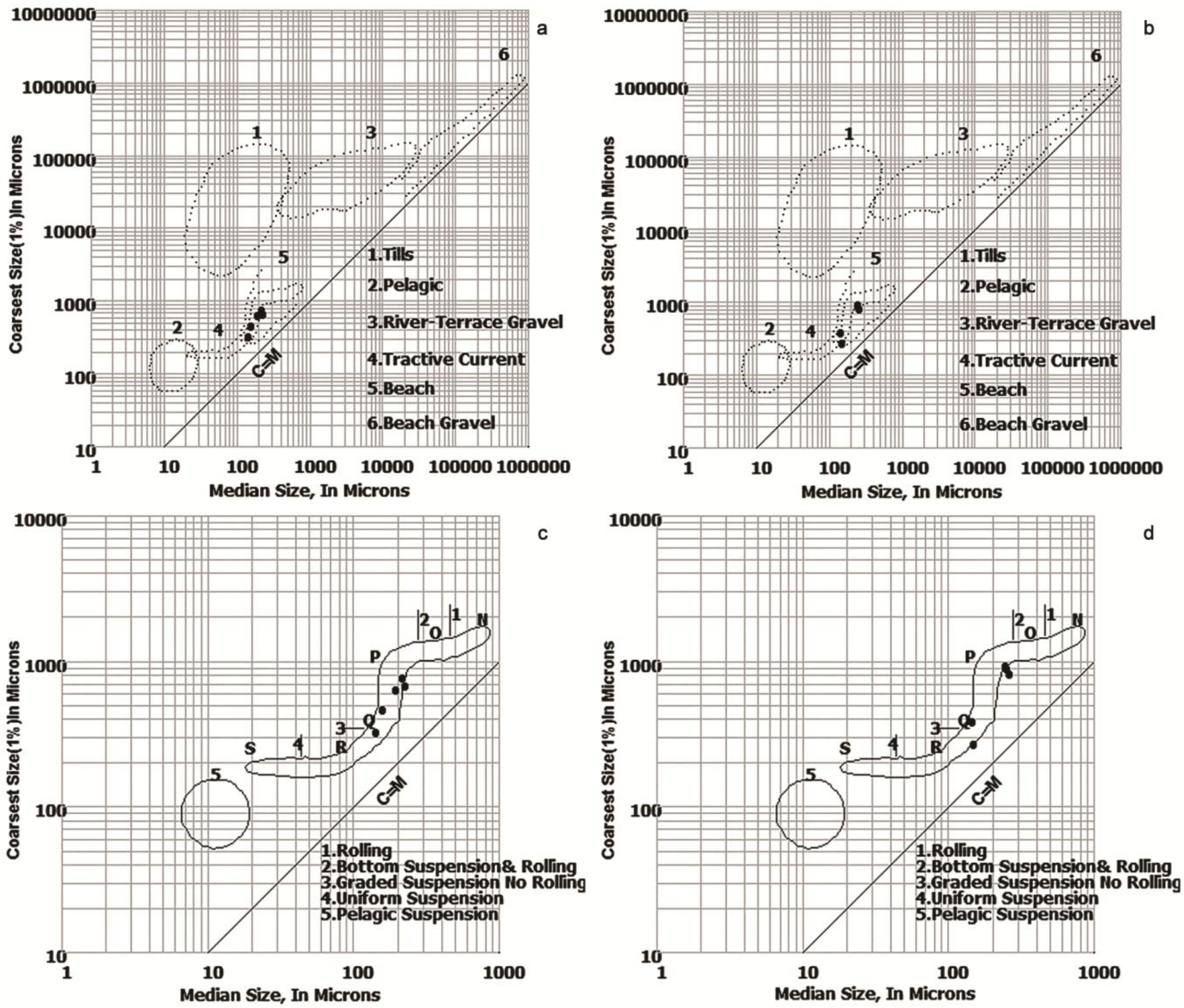

Fig. 5 — CM and TCD diagrams: (a) CM diagram of Chavara, (b) CM diagram of Manavalakurichi, (c) TCD diagram of Chavara, and (d) TCD diagram of Manavalakurichi

suspension rolling to graded suspension. On comparing with the CM diagram, it can be noticed that the samples comes under beach and tractive current environment.

Heavy mineral study

The analysis of heavy minerals helps to understand the nature of source rock, weathering, transportation, and depositional environment[29]. Once the material reaches the basin it gets redistributed based on their variation in grain size, shape and specific gravity. High specific gravity and variation in grain size made the minerals to separate category of heavy minerals. These minerals are heavier and not hydro-dynamically mobile compared to light minerals.

Beach is a temporary or short-lived deposit on the shore. Most of the materials are sand and silt-sized grains. The results of heavy mineral analysis are given in Tables 1 – 3. The action of waves and tides has played an important role in shaping of shoreline. Weight percentage of heavy minerals varies from 28.55 to 3.36 % in Chavara with an average of 15.955 % in medium-grained samples, 67.04 to 50.43 % with an average of 58.73 % in fine-grained samples and 29.66 to 4.03 % with an average of 16.845 % in very fine-grained samples (Fig. 6). But the situation is quite different in the case of Manavalakurichi. Here heavy minerals ranges from 27.77 to 0.87 % with an average of 14.32 % in medium-grained samples, 55.24 to 30.42 % with an average of

42.83 % in fine-grained samples and 28.7 to 3.5 % with an average of 16.1 % in very fine-grained samples. Relatively higher percentage was shown in the Chavara region.

Optical microscopic studies

The heavy minerals of different texture *viz*., medium (1-2 Ø), fine (2-3 Ø), and very fine (3-4 Ø) sands were mounted on the slides to study the mineralogical distribution. Sufficient care was taken to maintain a minimum of 300 grains in each mounted slide and to ensure the uniform spread of grains all over the slide and were examined under the petrological microscope. The mineral counting was done by line counting method and count percentages were calculated[30]. According to the grain count percentage values, the ilmenite is majorly present and is followed by rutile, leucoxene, and sillimanite. This is the case of Chavara region and followed by ilmenite, monazite, zircon, and garnet are abundantly present in the Manavalakurichi region. Figures S1 & S2 shows the optical microscopic images of heavy minerals recovered from Chavara and Manavalakurichi. These are in the case of fine-grained sediments. All these abundances in minerals present in fine-grained sediments (Tables 2 & 3).

Table 1 — Heavy mineral weight percentage

		Heavy minerals weight %			
		Total heavy minerals (THM)	Medium	Fine	Very fine
Chavara	Avg	85.86	15.95	58.73	16.84
	Min	72.87	3.36	50.43	4.03
	Max	98.86	28.55	67.04	29.66
Manavalakurichi	Avg	61.76	14.32	42.83	16.1
	Min	46.86	0.87	30.42	3.5
	Max	76.67	27.77	55.24	28.7

Factor analysis

R-mode factor analysis identifies the reason for the variation in heavy mineral concentration and its influence on sediment depositional environment (Fig. 7). In the case of Chavara and Manavalakurichi heavy minerals, factor one is almost influenced by high order positive scores while, some second and third factors show negative scores. It represents the leading influence of a combination of low graded sediments.

Table 2 — Heavy mineral count percentages for the medium, fine, and very fine fractions of Chavara

	Heavy mineral count %	Ilmenite	Rutile	Monazite	Zircon	Garnet	Sillimanite	leucoxene	Others
Medium	Avg.	1.646	1.260	0.716	0.966	0	1.169	0.540	0.367
	Max.	20.626	2.297	1.249	1.677	0	2.101	1.006	0.671
	Min.	2.321	0.223	0.184	0.254	0	0.238	0.074	0.063
Fine	Avg.	41.170	4.688	2.806	3.265	0.088	4.943	1.401	0.656
	Max.	46.970	5.879	3.458	3.870	0.175	6.206	2.250	0.950
	Min.	35.370	3.496	2.154	2.660	0	3.681	0.552	0.361
Very fine	Avg.	12.204	1.249	0.665	0.949	0	1.342	0.342	0.127
	Max.	21.539	2.175	1.163	1.692	0	2.411	0.613	0.240
	Min.	2.870	0.324	0.167	0.207	0	0.273	0.071	0.015

Table 3 — Heavy mineral count percentages for the medium, fine, and very fine fractions of Manavalakurichi

	Heavy mineral count %	Ilmenite	Rutile	Monazite	Zircon	Garnet	Sillimanite	leucoxene	Others
Medium	Avg.	7.996	1.474	1.153	1.3039	1.675	0.432	0.424	0.164
	Max.	15.446	2.845	2.231	2.532	3.323	0.854	0.525	0.322
	Min.	0.545	0.104	0.075	0.076	0.028	0.024	0.009	0.007
Fine	Avg.	25.868	4.688	3.463	3.905	2.682	1.346	0.428	0.337
	Max.	34.88	6.572	4.418	5.143	3.879	1.718	0.621	0.600
	Min.	16.848	2.804	2.507	2.666	1.484	0.974	0.235	0.074
Very fine	Avg.	9.8430	1.806	1.042	1.532	0.78458	0.144	0.113	0.121
	Max.	17.757	3.249	1.804	2.72	1.3223	0.201	0.2114	0.23
	Min.	2.1088	0.363	0.280	0.336	0.2467	0.086	0.0158	0.014

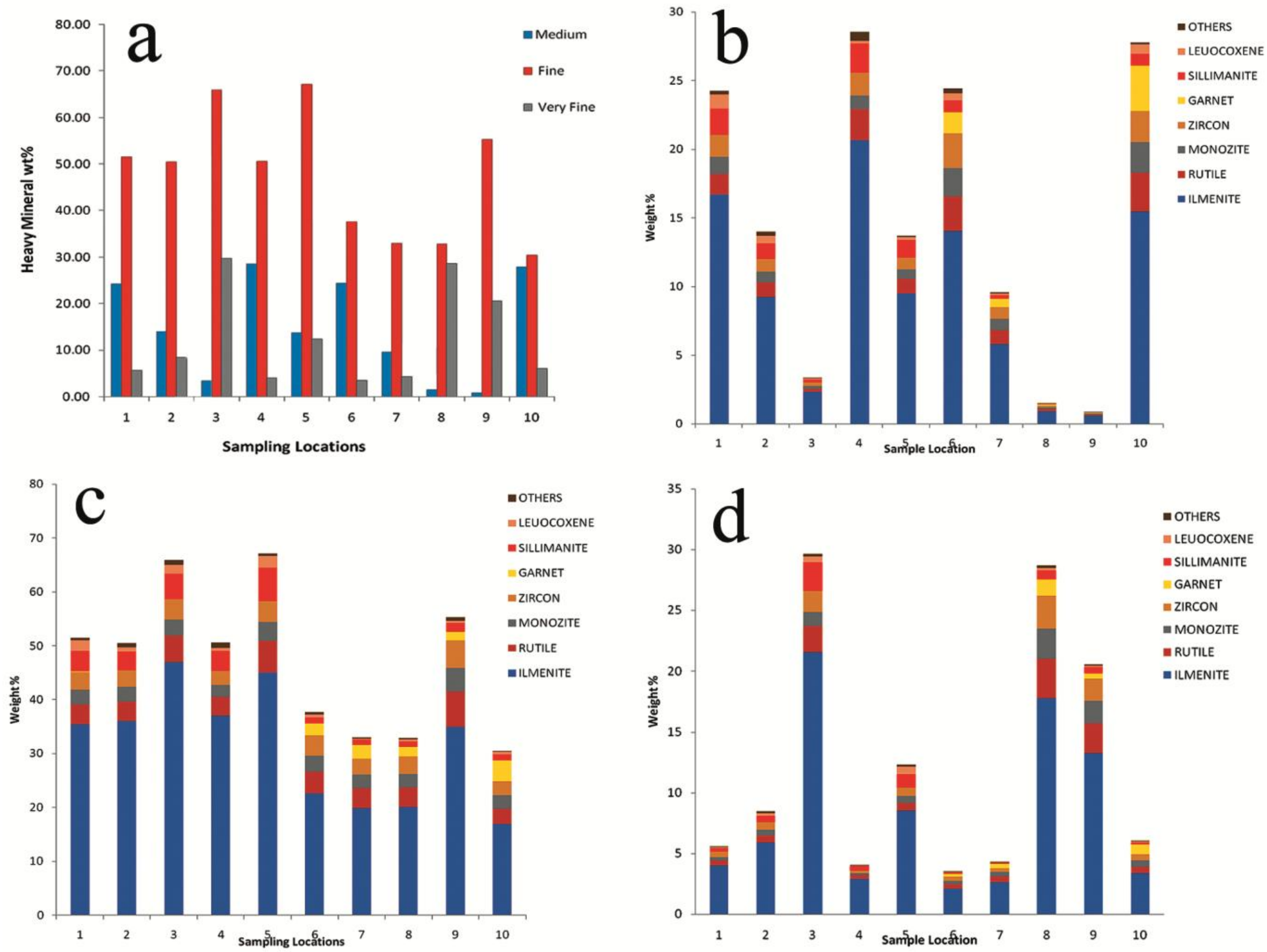

Fig. 6 — Graphs showing weight of the heavy minerals: (a) Total, (b) Medium, (c) fine, and (d) very fine

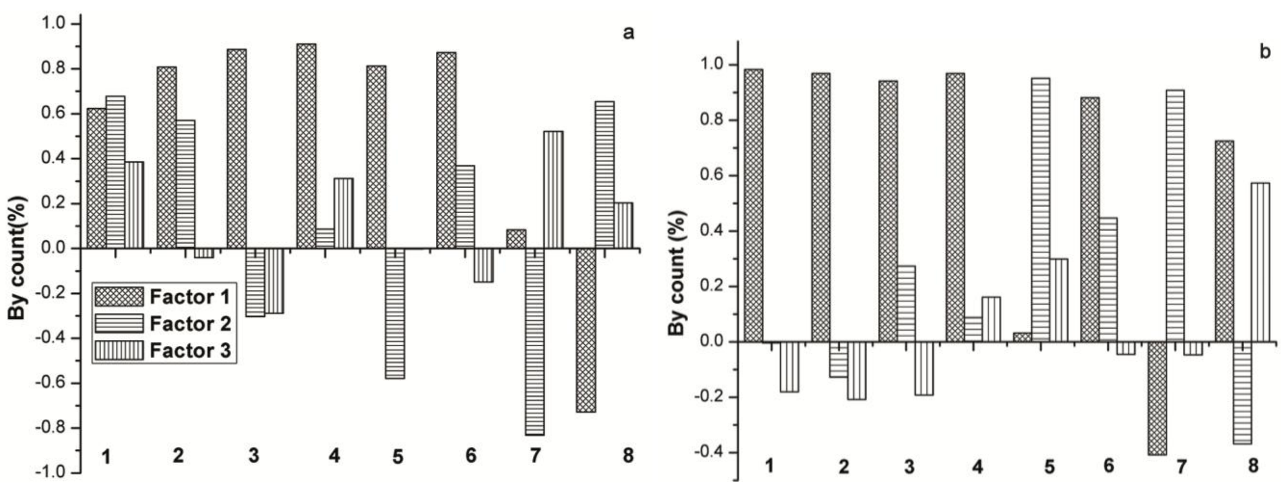

Fig. 7 — R-mode analysis factor for total heavy mineral data: (a) Chavara, and (b) Manavalakurichi

Conclusion

From the detail sedimentological studies of Chavara and Manavalakurichi samples, it revealed that the size distributions of the mean values indicate the dominance of fine-grained nature in Chavara samples and both fine- and medium-grained in the Manavalakurichi samples. LDF results in both study areas show the domination of shallow marine deposits. The CM pattern clearly depicts that most of the grains from both locations show bottom suspension rolling to graded suspension. According to the grain count percentage values, the ilmenite mineral is majorly present in both the regions. All these mineral abundances were present in fine-grained sediments. The factors of these heavy minerals represent dominant influences of the mixture of low graded sediments. It also suggests that these minerals are the derivates of common sources like paleosediments influence, which are reworked by present-day coastal processes.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at http://nopr.niscair.res.in/jinfo/ijms/IJMS_50(03)203-211_SupplData.pdf

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

MS involved in overall project design and coordination. GSG, RGR, SS & NP carried out the analysis, discussed the results, wrote and revised the manuscript. SRS advised and reviewed the manuscript.

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