

Significance of heavy mineral suite in riverine and estuarine sediments in the southwest coast of India—A case study

D Padmalal & K K Ramachandran

Centre for Earth Science Studies, Thiruvananthapuram 695 031, India

and

P Seralathan

School of Marine Sciences, Cochin University of Science & Technology, Kochi 682 016, India

Received 16 December 1996; revised 13 October 1997

Heavy mineral studies were carried out in various size grades of sand fractions of Muvattupuzha river and Central Vembanad estuary. Heavy mineral contents are higher in the upstream reaches of the river compared to the downstream reaches. In the estuary, the total heavy mineral contents are comparatively less. The heavy mineral assemblage consists of opaques, amphiboles, pyroxenes, garnet, zircon and biotite as the major minerals and monazite, rutile and sillimanite as the minor minerals. A comparative evaluation of the morphological and optical characteristics of heavy minerals between the two environments reveals that a substantial quantity of the river sands are derived from the Precambrian crystallines, whereas a greater part of the estuarine sands are polycyclic and derived presumably from the beach ridges that bound the Vembanad estuary at many places.

The influence of size, shape and density of various heavy minerals on hydraulic sorting has been investigated by many researchers^{1,2}. In many of the above studies one or two size fractions have only been examined to represent the entire heavy mineral composition of sediments. Since heavy minerals are deposited according to the differences in size, shape and density, a single size fraction seldom represents the entire heavy mineral constitution of sediments³. This paper presents the results of the size frequency distribution of heavy minerals in the sand fraction of the Muvattupuzha river and the Central Vembanad estuary and discusses the transportational and depositional mechanism, energy conditions and source rock characteristics of the riverine and estuarine sediments.

Materials and Methods

Muvattupuzha river is one of the perennial rivers of Kerala. It has a length of about 121 km and a catchment area of about 1544 sq.km. The river originates from the flanks of the Western Ghats and drains through highly varied geological

formations⁴; of which the Precambrian crystallines constitute approximately 85% of the total drainage area of the river (Fig. 1). Physiographically, the drainage basin of the river falls within three distinct provinces—the highlands (>75 m),

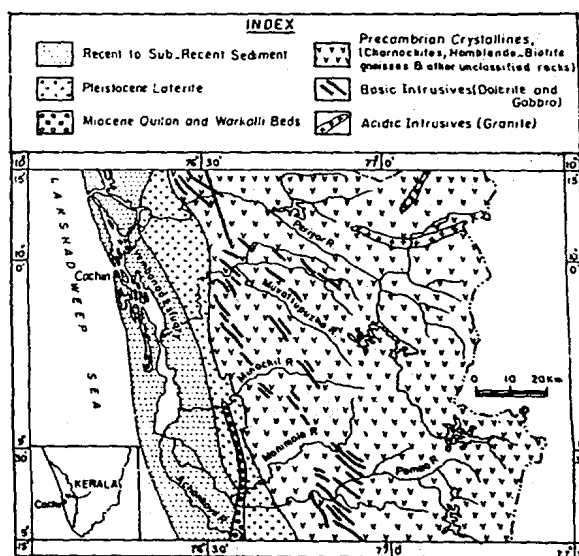


Fig. 1—Geologic setting of the study area

midlands (75-8 m) and the lowlands (<8 m). The midlands form the major physiographic unit of the basin and cover about 75% of the drainage area. The Muvattupuzha river exhibits dendritic drainage pattern and debouches into the Central Vembanad estuary near Vaikom (Fig. 2).

Thirty-two surface sediment samples (20 from the river and 12 from the estuary) were collected from the study area (Fig. 2) using a Van Veen grab, during April, 1989. The sand fraction was sieved at 1/2 ϕ interval using a standard set of ASTM sieves on a Ro-Tap sieve shaker and heavy mineral concentrates were separated from 45, 60, 80, 120, 170 and 230 mesh fractions using bromoform⁵. The mineral concentrates were mounted on glass slides and species identification was performed following Krumbein & Pettijohn⁶. The heavy minerals in the various mesh fractions were regrouped, whenever necessary, as medium sand (45 + 60 meshes), fine sand (80+120 meshes) and very fine sand (170 + 230 meshes) for better evaluation/presentation of the results.

Results and Discussion

Total heavy minerals (THM)

The content of *THM* in different size fractions of riverine and the estuarine sands are furnished in Table 1. In river environment, the heavy mineral occurrences are recorded in all the six size fractions of sand population, whereas in the estuary heavies are confined to the four finer fractions only. The respective ranges of *THM* values in the river environment are 1.08-21.27%

(mean = 6.08%) in the medium sand, 2.91-64.88% (mean = 14.05%) in the fine sand and 4.79-60.1% (mean = 23.83%) in the very fine sand; and in the estuarine environment are 1-8.32% (mean = 2.82%) in the fine sand and 0.91-35.92% (mean = 11.57%) in the very fine sand.

The upstream reaches (mainly the tributaries) of the Muvattupuzha river enrich substantially high content of *THM* than downstream reaches (Table 1). In an earlier communication, Seralathan & Padmalal⁷ reported high content of pebbles and granules of quartzose/feldspathic composition in these upstream samples, where *THM* spikes anomalously in the sand fraction. The admixed occurrence of pebbles and granules of lighter minerals (e.g. quartz and feldspars) as channel lags along with the high concentrations of sand-sized heavy mineral grains could be due to high energy-based sorting processes taking place upstream owing to the high gradient nature of the river profile⁸. The normalised frequency distribution of *THM* and respective size fractions (Fig. 3) depicts marked variations both in size frequency and heavy mineral contents; the former registering decreased values towards the finer end while the latter shows an opposite trend. This contrasting behaviour of size versus *THM* further exemplifies the density based sorting of minerals. The shielding effects of the coarser lighter grains also influence effective entrainment and transport of hydraulically equivalent smaller and heavier grains⁹. The heavy mineral content in the mud dominated regions of the estuary deviates considerably from the above trend, because the low energy regime prevailing in the mud dominated zones will be insufficient to induce

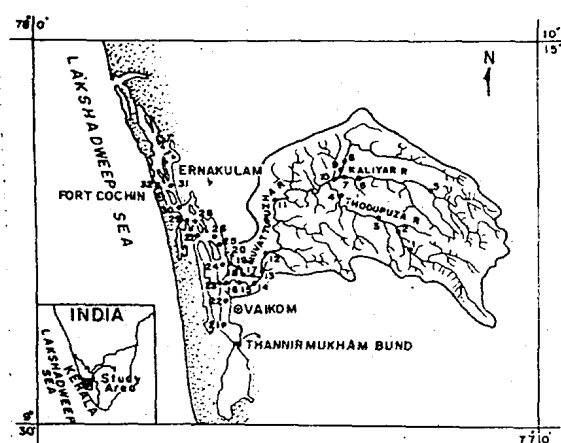


Fig. 2—Study area and sampling locations

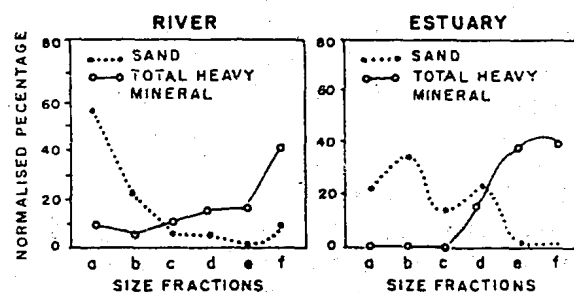


Fig. 3—Normalised frequency distribution of *THM* and size fractions in riverine and estuarine (sand dominated sample) environments

Table 1—Average heavy mineral contents (in percentages) in the sand fractions

Environment/ sub-environment	Size class	THM	OP	Non-Op	Am	Py	Ga	Zi	Bi	Ru	Mo	Si	Al
Thodupuzha tributary	MS	7.71	12.84	87.16	55.60	13.90	9.11	1.00	10.25	Rare	Rare	NR	0.55
	FS	18.02	31.14	69.27	42.12	3.88	5.75	4.85	4.57	Rare	0.55	NR	0.85
	VFS	26.21	32.77	67.24	35.31	15.07	3.84	13.51	1.17	Rare	0.71	NR	1.09
Kaliyar tributary	MS	11.39	8.46	89.48	64.49	13.49	7.89	1.03	1.72	Rare	Rare	NR	0.57
	FS	27.00	30.04	66.59	47.26	11.93	3.70	2.17	2.85	Rare	Rare	Rare	1.26
	VFS	35.77	23.83	76.18	46.05	14.17	1.80	11.33	0.86	Rare	0.50	Rare	1.13
Muvattupuzha river (main stream)	MS	4.25	5.99	94.01	57.92	16.10	6.66	Rare	4.56	NR	NR	NR	1.78
	FS	6.47	10.55	63.15	59.09	17.43	3.36	1.68	2.05	NR	Rare	Rare	1.77
	VFS	23.18	28.72	71.25	46.62	12.70	1.16	7.94	0.68	Rare	Rare	0.61	1.21
Ittupuzha distributary	MS	4.19	6.15	93.91	69.37	15.18	5.86	1.09	2.28	NR	NR	NR	Rare
	FS	9.66	10.18	80.83	67.94	14.31	2.71	3.46	0.41	Rare	Rare	NR	0.75
	VFS	17.63	24.74	75.26	14.20	14.12	1.79	6.58	0.56	NR	0.52	Rare	1.14
Murinjapuzha distributary	MS	2.04	13.52	86.36	59.81	12.82	2.61	1.10	9.72	NR	Rare	NR	0.61
	FS	6.22	11.92	88.04	61.94	14.14	1.80	5.38	2.59	Rare	Rare	Rare	0.89
	VFS	11.85	22.35	59.83	52.97	13.04	1.14	7.14	1.05	Rare	Rare	Rare	0.95
Vembanad estuary	FS	2.82	12.92	76.56	39.75	10.62	0.71	24.79	0.96	Rare	Rare	Rare	1.05
	VFS	11.57	23.31	74.69	38.25	9.58	Rare	21.54	0.85	Rare	9.97	Rare	1.33

MS=Medium sand; Op=Opagues; Bi=Biotite; FS=Fine sand; Non-Op=Non-opaques; Ru=Rutile; VFS=Very fine sand; Am=Amphibole; Mo=Monazite; NR=Not recorded; Py=Pyroxene; Si=Sillimanite; THM=Total heavy minerals; Ga=Garnet; Al=Altered minerals; Rare=<0.5%; Zi=Zircon.

size/density based sorting of grains. The cohesive nature of mud also hinders the aforesaid sorting processes to a considerable extent.

Heavy mineral assemblage (HMA)

The HMA of the riverine and the estuarine sands consists of a spectrum of minerals such as opaques, amphiboles, pyroxenes, garnet, zircon, biotite, rutile, monazite, sillimanite and some altered heavies (Table 1). Of this, the first six minerals constitute the bulk of the heavy mineral crop, while others are present only in marginal amounts. Opaques, garnet and zircon, in general, exhibit a decreasing trend downstream, whereas amphiboles and pyroxene behave oppositely.

Mineralogical diversities observed along the river profile also point to density based sorting of minerals taking place progressively downstream. Denser heavies such as opaques [Specific Gravity (SG) of ilmenite, the most dominant opaque member, is 4.7], garnet (SG=4.3) and zircon (SG=4.7) settle fast at the point of current

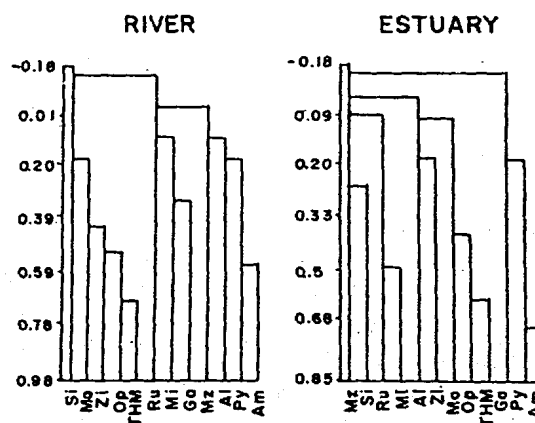


Fig. 4—Dendrogram showing clustering of heavy minerals. Mz = Phimean; other symbols are similar to that of Table 1

impingements, while the less dense inosilicates (SG of hornblende, the most dominant amphibole, is 3.21 and hypersthene the dominant pyroxene, is 3.43) are carried further downstream and deposited. Monazite, though confined only to the finer fractions follows opaques in its spatial

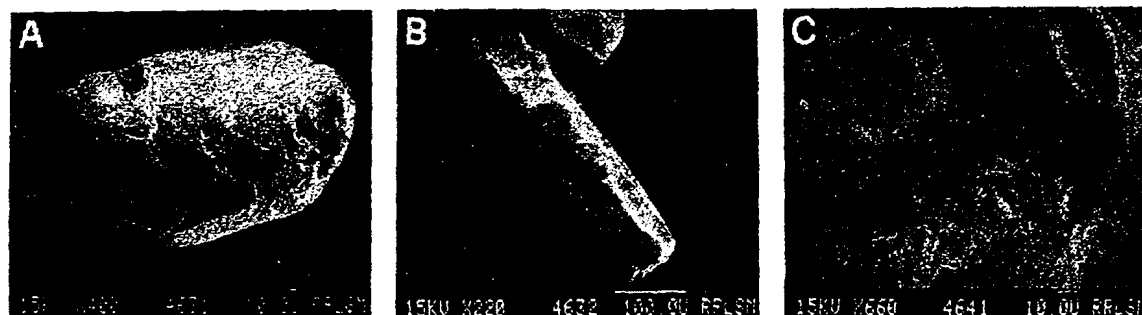


Fig. 5—SEM photograph of (A) estuarine zircon, (B) estuarine sillimanite and (C) surface textural features of quartz grain

behaviour. Further, the higher values of amphiboles and pyroxenes (lighter heavies) are found shifted slightly downstream with respect of opaques and other denser heavies within an identical energy regime of the river channel. All these reiterate the density based segregation of heavy minerals progressively taking place in the Muvattupuzha river downstream. In the estuarine environment, the composition of heavy minerals is highly variable on account of the heterogeneity in the distribution pattern of sediment classes. The antipathetic relationship between denser and lighter heavy minerals is found to exist in this environment too, except in the mud dominated regimes. The deviation noted in the dispersal pattern of heavy minerals in mud dominated estuarine regimes is resulted from the inefficient sediment sorting due to the low energy conditions prevailing there.

Cluster analysis

Dendrogram prepared based on correlation matrix of heavy minerals also supports the density based segregation of mineral grains. Clustering pattern (Fig. 4) shows a closely knitted group of minerals such as opaques, zircon and monazite along with the total heavies which forms a group obviously denoting a high energy denser category. Amphiboles and pyroxenes exhibit strong bonding as they represent a comparatively low energy regime. Other heavy minerals (e.g. biotite) do not show any appreciable clustering as either they are available in traces or their differential behaviour during transportation/deposition.

Provenance

Hornblende is usually bluish green in colour and

indicative of metamorphic provenance¹⁰. Occurrence of substantial amounts of hypersthene and the presence of garnet suggests the role of charnockites in contributing sediments to the Muvattupuzha river. Sediments of the Central Vembanad estuary also exhibit similar suite of heavy minerals as that of the Muvattupuzha river. However, the former can easily be distinguished from the latter by distinct variations in the morphological and optical characteristics of mineral grains. The percentages of zircon, monazite, sillimanite and rutile are substantially high in the estuarine sediments than river sediments. In contrast to the river sands, heavy minerals of the estuarine sands exhibit perfect rounding and unique surface textural patterns. Surface textures of zircon, sillimanite and the light mineral quartz (Fig. 5) distinctly indicate subaqueous agitation with prolonged chemical activity and long residence time for the estuarine sands. All these suggest a different source contribution (presumably from the beach ridges) to a greater portion of the estuarine sands.

Acknowledgement

The financial support from CSIR, New Delhi to one of the authors (D.P.) during the course of this investigation is gratefully acknowledged.

References

- 1 Singerland R L, *J Sed Petrol*, 47 (1977) 753.
- 2 Komar P D, Clemens K E, Liz & Shih S M, *J Sed Petrol*, 59 (1989) 590.
- 3 Blatt H, Middleton G V & Murray R C, *Origin of sedimentary rocks*, (Prentice Hall, New Jersey) 1972, pp. 631.
- 4 CESS, *Resource Atlas of Kerala* (Centre for Earth Science Studies, Trivandrum) 1984, pp.34.

- 5 Carver R E, *Procedures in sedimentary petrology*, (Wiley Inter Science, New York) 1971, pp.478.
- 6 Krumbein W C & Pettijohn F J, *Manual of sedimentary petrology*, (Appleton Century Crafts Inc, New York) 1938, pp. 549.
- 7 Seralathan P & Padmalal D, *J Geol. Soc. India*, 43 (1994) 179.
- 8 Padmalal D, *Mineralogy and geochemistry of the sediments of Muvattupuzha river and central Vembanad estuary, Kerala, India*. Ph.D thesis, Cochin University of Science and Technology, India, 1993.
- 9 Seralathan P, *Studies on texture, mineralogy and geochemistry of the modern deltaic sediments of Cauvery river, India*, Ph.D thesis, Andhra University, India, 1979.
- 10 Van Andel T H & Poole D M, *J Sed Petrol*, 38 (1960) 91.