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Significance of textural analysis in the sediments of Kayamkulam lake, southwest coast of India

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Surface sediment samples of the Kayamkulam lake, located within the Quaternary geological province in the southwest coast of India, have been studied for textural characteristics. Lake bed is composed of a wide spectrum of sediment types, viz: muddy sand, silty sand, clayey sand, silt, sandy mud, sand, sandy silt and mud. Most of the sediment samples are of medium to very fine grained, moderately sorted, negatively skewed and mesokurtic sands. CM pattern shows that the sediments are transported mainly by suspension and rolling. Textural parameters together with the CM pattern indicate the prominent role of ebbing and flooding in changing the characteristics of sediments in the Kayamkulam lake, especially in the estuarine mouth and adjoining areas. Present study reveals that hinterland drainages play significant role in changing the textural characteristics in the northern and southern arms of the lake.

[**Keywords**: Lake, Sediment, Hinterland, Quaternary, Salinity]

Introduction

Grain size analysis is one of the important and widely used sedimentological tools to unravel the hydrodynamic conditions of aquatic environments. The grain size distribution, its properties and the statistical parameters worked out from size population are the basic requirements in the understanding of the abiotic fabric of aquatic ecosystems[1-4]. Careful examination of granulometric parameters and their proper evaluation using standard methods could be used in the discrimination of various depositional environments[5-11]. The present study in grain size characteristics of sediments is used to examine the depositional processes in one of the marginal lagoons parallel to the coast of Southern Kerala, namely Kayamkulam lake,

Kayamkulam lake (Fig. 1) located in the costal lands of Kollam and Alappuzha districts (Lat. 9°2′ - 9°16′ N; Long. 76°25′ - 76°32′ E), is a linear water body stretching from Sankaramangalam (Kollam district) in the south to Karthikapalli (Alappuzha district) in the north. The lake has a length of about 24 km and the width varies from a few tens of meters to over a kilometre and depth of 0.5 m to 2.5 m. Salinity and temperature ranges from 0.5×10^{-3} to 33×10^{-3} and 26.9° C to 32° C respectively[12]. Average tidal range near the bar mouth[13] of the lake at Vallivathukkal *thura* is about 1.25 m Northern arm of the lake hosts an industrial establishment of National Thermal Power Corporation (NTPC). Lake spreads fully within the Quaternary geologic deposits of the coastal lands. As the gradient of the terrain is low, this

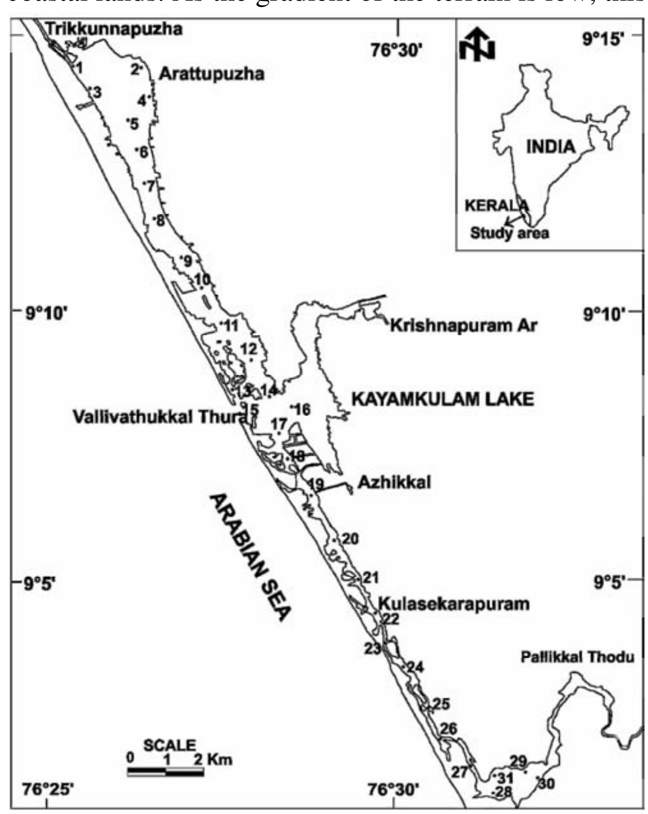


Fig. 1—Location map of the study area with sampling stations.

part of the coastal strip is susceptible to coastal hazards. The December 26, 2004 Tsunami hit a considerable portion of the study area between Neendakara and Arattupuzha and claimed the life of about 200 people in the area. An attempt has made in this paper to elucidate the sedimentological characteristics of the Kayamkulam lake to understand the depositional/erosional mechanisms and to take up mitigate measures for the coastal hazard.

Materials and Methods

A systematic field work has been carried out for the entire Kayamkulam lake during the pre monsoon and post monsoon seasons. A total of 31 sediment samples were collected from the Kayamkulam lake at regular intervals (Fig. 1) using van Veen grab. After pre-treatments, the samples were subjected to dry sieving following Carver[14]. The statistical parameters were computed from the granulometric data following the method of Folk and Ward[15]. CM model for the sediments of the Kayamkulam lake was worked out following Passega[16].

Results and Discussion

Granulometry and Textural facies: Sand, silt and clay contents in the sediment samples of the Kayamkulam lake are given in Table 1. Ranges of sand, silt and clay are 10% - 92%, 2% - 66% and 5% - 38%, for the pre monsoon and 2% - 95%, 1% - 70%, and 3% - 50% for the post monsoon respectively. Average content of sand in post monsoon season (av; 67%) is slightly higher than that of pre monsoon (av; 64%). Size spectral analysis of coarser fractions indicates that, more than 85% of the sand grains in this environment fall mainly in the grade: medium to very fine sand. Various sediment types as of Folk in the lake bed are muddy sand (mS), silty sand (zS),

Table 1—Textural terminology of the sediments of Kayamkulam lake

	PRE MONSOON				POST MONSOON			
Sample No.	Sand %	Silt %	Clay %	Sediment Type	Sand %	Silt %	Clay %	Sediment Type
1	65	25	10	Silty Sand	78	8	14	Muddy Sand
2	52	28	20	Muddy Sand	80	12	8	Muddy Sand
3	61	14	25	Muddy Sand	65	25	10	Silty Sand
4	84	4	12	Clayey Sand	88	5	7	Muddy Sand
5	79	12	9	Muddy Sand	59	27	14	Muddy Sand
6	85	3	12	Clayey Sand	22	51	27	Sandy Mud
7	88	2	10	Clayey Sand	83	5	12	Clayey Sand
8	91	2	7	Sand	64	14	22	Muddy Sand
9	86	5	9	Muddy Sand	81	7	12	Muddy Sand
10	83	6	11	Muddy Sand	18	70	12	Sandy Silt
11	29	66	5	Sandy Silt	1	66	33	Mud
12	56	30	14	Silty Sand	92	4	4	Sand
13	64	22	14	Muddy Sand	72	18	10	Muddy Sand
14	10	65	25	Silt	95	2	3	Sand
15	30	35	35	Sandy Mud	65	10	25	Clayey Sand
16	57	17	26	Muddy Sand	93	1	6	Sand
17	44	37	19	Sany Mud	95	3	2	Sand
18	76	9	15	Muddy Sand	97	2	1	Sand
19	85	8	7	Muddy Sand	79	7	14	Clayey Sand
20	89	3	8	Clayey Sand	90	6	4	Sand
21	48	26	26	Sany Mud	63	10	27	Clayey Sand
22	58	24	18	Muddy Sand	66	14	20	Muddy Sand
23	92	1	7	Sand	67	21	39	Muddy Sand
24	39	23	38	Sandy Mud	11	39	50	Sandy Mud
25	91	1	8	Sand	92	5	3	Sand
26	68	9	23	Clayey Sand	26	39	35	Sandy Mud
27	71	9	20	Clayey Sand	86	6	8	Muddy Sand
28	65	12	23	Muddy Sand	86	8	6	Muddy Sand
29	79	9	12	Muddy Sand	72	10	18	Muddy Sand
30	89	2	9	Clayey Sand	56	32	12	Silty Sand
31	66	10	24	Clayey Sand	20	43	37	Sandy Mud

clayey sand (cS), silt (Z), sandy mud (sM), sand (S), sandy silt (sZ) and mud (M); (Fig. 2). Figure 3 depicts the spatial distribution of sediment types along the lake bed. A close examination on the distribution of different textural attributes in the northern segments shows predominance of muddy sand for both pre and post monsoon indicating the dominance of flood discharge over tidal cycle. Sand, silt and clay contents vary from northern to central, and then to southern regions of the study area. In the northern segment not much change are noticed in the pre monsoon and the contents of sand, silt and clay do not show any specific trend; During the post monsoon season, the sand content increases initially towards the central, and thereafter, decreases towards the southern region. Similarly, silt decreases first and then increases towards the central part of the lake. Clay, in general, decreases in the beginning and thereafter shows an increasing trend towards the central region reflecting the flocculation processes.

The textural characteristics of the lake reveals that the tidal waters influence only marginally in the northern and the southern segments. Flooding and ebbing of tidal waters constantly winnows the finer particles like silts and clays back to the sea leaving the coarser particles as lag concentrates at the central region as observed by the higher content of sand indicating high energy condition. Hence the tidal cycle dominates the flood discharge. In the southern region, a trend similar to that of northern segment is seen. Pallikkal *thodu* originating from midland contributes substantial amount of finer clastics from the hinterland area particularly during monsoon season. Hence, the southern region is characterised by comparatively higher content of silt and clay for the post monsoon season. But for the pre monsoon, onward transportation of the finer fractions to the central region may be by the fluvial induced currents at the southern region. Hence higher content of the clay and silt at the central region. For the post monsoon, the winnowing action of tides is very effective, whereby the fines are carried away to the near shore areas leaving behind the coarser particles. The general trend of the sand along with the silt and clay reflects the tidal influence over the sediment distribution in the lake. Local turbulence induced by the changes in the fluvial channel morphology of the lake have its impact in the sediment distribution pattern.

Statistical parameters

The various statistical parameters computed for pre and post monsoon sediments of Kayamkulam lake is furnished in Table 2. It is computed that, more than 90% of the pre monsoon sediments and 80% of the post monsoon sediments show phi mean values between 2 and 3. This observed similarity of phi mean values reiterates selective entrainment process operating in the environment. Pre monsoon sediments of the study area exhibit moderately well sorted to poorly sorted sediments and that of post monsoon show well sorted to poorly sorted particle dispersal pattern. Sediment sorting in the former case ranges from 0.55 to 1.13 ϕ, (av; 0.89 ϕ) and that of the latter varies from 0.47 to 1.15 ϕ, (av; 0.94 ϕ). As per the limits established by Folk and Ward[15], more than 65% of the sediments of the Kayamkulam lake, in both the seasons, belong to the moderately sorted category, and the rest is in the poorly sorted category. Skewness values of the sediment samples vary from 0.67 to 0.05 (av; 0.14) and 0.59 to 0.11(av; 0.10) respectively, in the pre and post monsoon sediments (Table 2). Negatively skewed sediments floor a major part of the area through out the year. Predominance of negatively skewed sediments underpins the above process of winnowing of finer particles by tides. Pre monsoon sediments, of Kayamkulam lake exhibit leptokurtic (0.76) to platykurtic (1.46) particle distribution. Post monsoon sediments, on the other hand, show very platykurtic to very leptokurtic (0.63 to 1.64, av; 1.10), particle distribution, indicating the change in sediment transportational/depositional mechanism between the two sampling seasons.

Bivariate Plots

The interrelationship between grain-size and frequency distribution has been widely used to discriminate the depositional environments and also to recognize the various operative processes of sedimentation of ancient and recent deposits. From the bivariate plots of phi mean vs. standard deviation (Fig. 4a), it is seen that sorting improves with decrease in grain size both for the pre and post monsoon season indicating suspension and rolling. Majority of the samples for the pre and post monsoon falls in the fine to very fine sand with an average standard deviation of 0.89ϕ and 0.94ϕ, respectively. It is inferred that the Kayamkulam lake and the nearby environment do not follow the theoretical consideration of sediment sorting. This may be attributed to various factors including contributions of sediments from older sediments like ridge and runnel systems, mixing activities etc. Bivariate plots of phi mean vs. skewness (Fig. 4b) for both pre and post

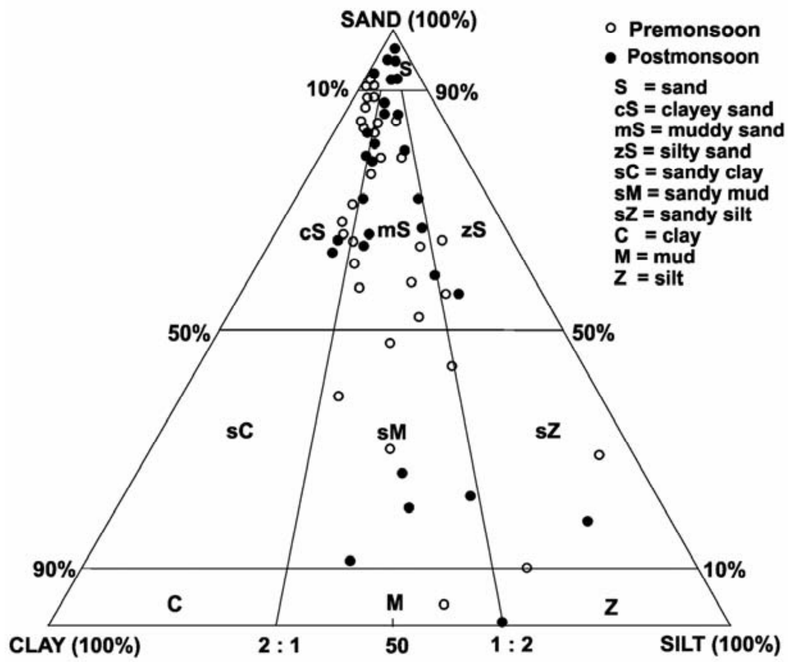


Fig. 2—Textural nomenclature of the Kayamkulam lake sediments for the pre and post monsoon seasons based on sand-silt-clay ratios (Folk and Ward, 1957).

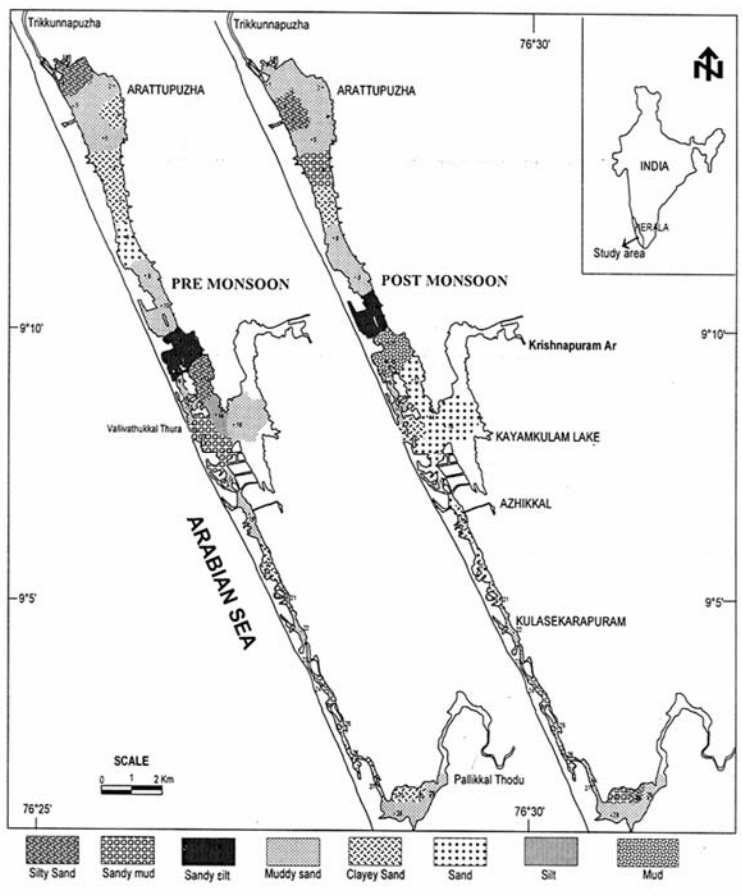


Fig. 3—Spatial distribution of the sediment facies in the substratum of Kayamkulam lake for the pre and post monsoon period.

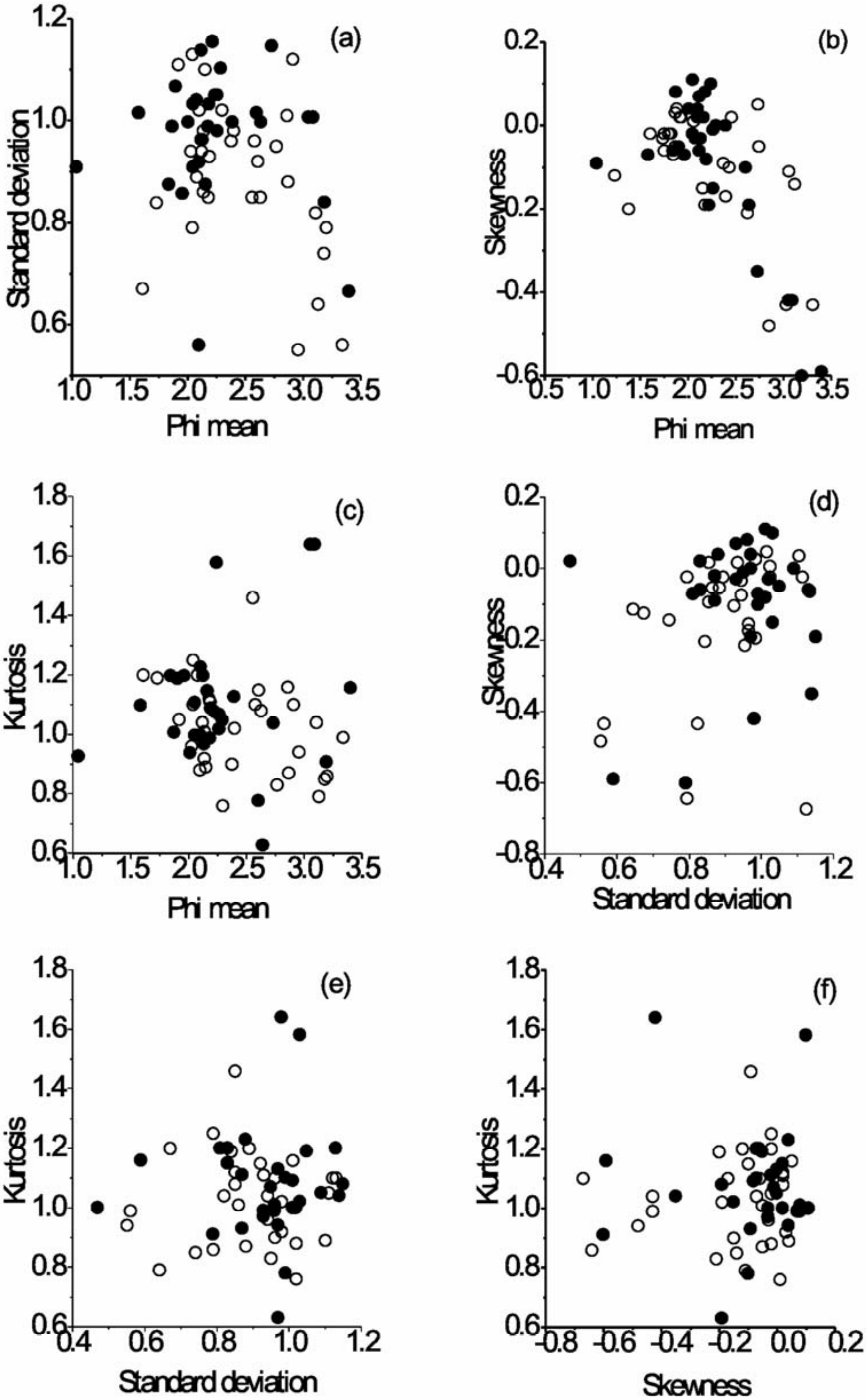
Table 2—Textural parameters for the Pre monsoon and Post monsoon sediments of Kayamkulam lake

Sample No	Pre monsoon				Post monsoon			
	Mean(phi)	Standard deviation	Skewness	Kurtosis	Mean (phi)	Standard deviation	Skewness	Kurtosis
1	2.61	0.92	-0.10	1.15	2.73	1.14	-0.35	1.04
2	2.14	0.98	0.03	0.92	3.09	0.98	-0.42	1.64
3	2.63	0.85	0.02	1.08	3.05	0.98	-0.42	1.64
4	2.10	1.02	-0.02	0.88	2.29	1.09	0.00	1.05
5	2.40	0.98	-0.19	1.02	2.08	1.02	-0.03	1.00
6	2.38	0.96	-0.15	0.90	2.19	1.01	-0.08	1.09
7	3.11	0.82	-0.43	1.04	1.87	0.96	0.08	1.01
8	2.58	0.96	-0.17	1.10	2.26	0.95	-0.01	1.07
9	2.18	0.85	0.02	1.12	2.05	0.87	-0.02	1.11
10	2.19	0.93	0.02	1.11	2.05	1.01	0.11	1.00
11	2.86	1.01	0.05	1.16	2.18	0.96	0.08	0.99
12	3.34	0.56	-0.43	0.99	2.01	0.97	0.04	0.94
13	2.96	0.55	-0.48	0.94	2.12	0.93	0.07	0.99
14	2.91	1.12	-0.67	1.10	3.40	0.59	-0.59	1.16
15	1.61	0.67	-0.12	1.20	2.10	0.47	0.02	1.00
16	2.08	0.89	-0.02	1.20	2.13	0.93	-0.03	0.97
17	2.77	0.95	-0.21	0.83	2.39	0.97	0.00	1.13
18	2.30	1.02	0.01	0.76	1.96	0.81	-0.07	1.20
19	2.15	1.10	0.04	0.89	2.22	1.15	-0.19	1.08
20	1.73	0.84	-0.20	1.19	2.26	1.03	-0.15	1.02
21	2.14	0.86	-0.05	1.01	2.16	0.83	0.02	1.15
22	2.12	0.94	-0.07	1.04	2.10	0.88	0.04	1.23
23	3.13	0.64	-0.11	0.79	1.58	0.99	-0.07	1.10
24	3.18	0.74	-0.14	0.85	1.84	0.83	-0.06	1.20
25	2.03	0.94	-0.03	0.96	1.04	0.87	-0.09	0.93
26	2.56	0.85	-0.09	1.46	2.64	0.97	-0.19	0.63
27	2.04	0.79	-0.02	1.25	2.60	0.99	-0.10	0.78
28	2.87	0.88	-0.05	0.87	2.24	1.03	0.10	1.58
29	1.92	1.11	-0.02	1.05	1.90	1.05	-0.05	1.19
30	2.04	1.13	-0.06	1.10	2.12	1.13	-0.06	1.20
31	3.20	0.79	-0.64	0.86	3.19	0.79	-0.60	0.91

monsoon seasons, remains all most same. Sorting becomes better with the coarser as the fines gets depleted. The phi mean Vs kurtosis (Fig. 4c) reveal that the spread decreases with increase in phi mean size reflecting the addition or removal of fines. Similarly from the standard deviation versus skewness it can be seen that the sorting becomes poor with the addition of finer particles for the pre monsoon. During post monsoon sorting increases with the removal of fines (Fig. 4d). The bivariate plots of skewness vs kurtosis (Fig. 4e) for the pre monsoon show that the well sorted fine mode loses its sorting which is noticed for the entire estuary and is due to depletion of finer sediments from the coarser fractions. But for the post monsoon the reverse of the process takes place.

CM Pattern

The CM pattern worked out for the Kayamkulam lake sediments for the pre and post monsoon seasons is shown in the figure 5. The pattern represents a complete model of tractive current (depositional process) as shown by Passega[16], which consists of several segments such as NO, OP, PQ, QR and RS indicating different modes of sediment transport. Plots exhibit specific segregation pattern. The entire samples of both pre and post monsoon seasons are scattered in the sectors PQ and PR. Scattering is imparted due to the drastic differences in the hydrodynamic regimes prevailing in the area. The entire samples in both seasons have first percentile values falling between 100 and 1000 microns. This group reflects suspension and rolling as well as



o Pre monsoon ? Post monsoon

Fig. 4—Bivariant plots of textural parameters for the pre and post monsoon period.

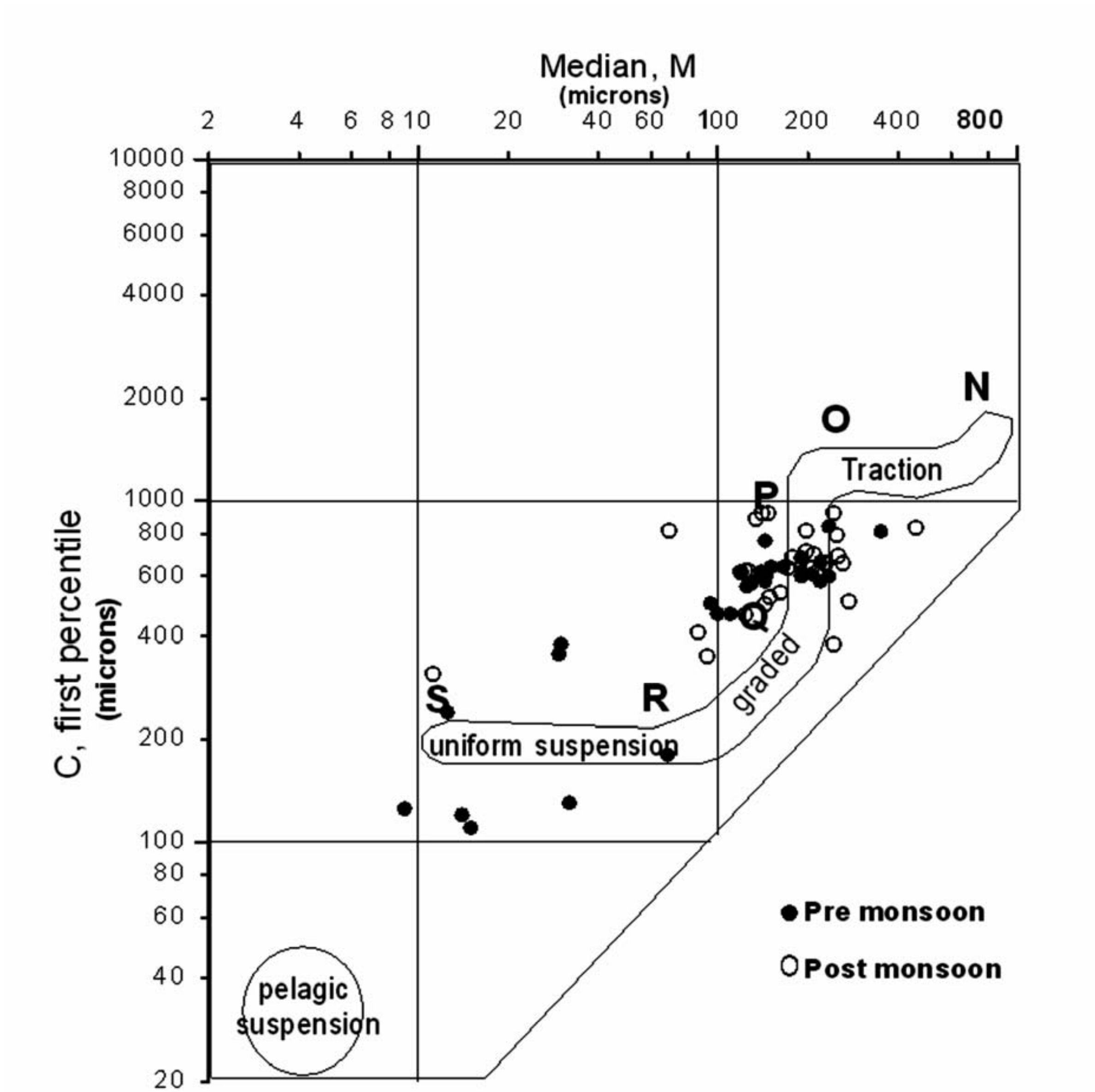


Fig. 5—CM pattern of the sediments of Kayamkulam lake for the pre and post monsoon period (after Passega, 1972).

graded suspension mode of transportational history, indicating the complexity in the hydrodynamic processes operating in this system. Therefore it is to say that the lake bed is influenced both by the marine and fluvial processes rather than the terrestrial processes besides the morphology of the lake.

Conclusion

Textural analysis carried out for the sediments of the Kayamkulam lake reveals that the northern sector is dominated by muddy sand in both pre and post monsoon seasons. Central sector is dominated by muddy sand for the pre monsoon while, sand becomes the most prominent textural class in the post monsoon. It is seen that the entire Kayamkulam lake sediments are floored mainly by medium to very fine sand. Variation in sand, silt and clay for the pre and post monsoon season reflects the source as well as the transporting agent. Thrikkunnapuzha Ar and the network of minor streams that drain into the northern sector of the lake are not competent enough to transport significant quantities of sediments during pre monsoon, but can contribute considerable amount of coarser clastics from the paleobeach ridges and runnels during the monsoon flows in particular to the central regions of the lake. Krishnapuram Ar and the

Pallikkal *thodu*, the two low order perennial streams emptying into the central and southern sectors hardly supply sediments to the respective sectors in the pre monsoon, but contribute substantial amount of sediments in the monsoon period. CM pattern divulges that the sediments are transported mainly by suspension and rolling as well as graded suspension. Textural diversity in the sediments of the Kayamkulam lake is due to the working and reworking of the marine and fluvial processes. Also the morphology of the lake too contributed in the textural complexity.

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