

POST TSUNAMI REBUILDING OF BEACHES AND THE TEXTURE OF SEDIMENTS

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ABSTRACT

Under CSIR-CMRI Network Programme of Coastal Placer Mining beach sand samples have been collected along the Poompuhar-Nagoor beaches of Central Tamil Nadu, India. Representative samples of 2003, 2005 and 2006 have been analysed for grain size and textural statistic studies. In view of the presence tsunami in between, the beach sand composition and texture have been drastically changed, the studies on beach re-building effort has been initiated by continuing the beach sand sample collection to 2006 at regular intervals. The textural statistics have clearly shown the shift in the mean, standard deviation, skewness and kurtosis for both low-tide and high-tide samples. The binary plots have distinctly placed each group of samples according to the period of collection such as pre-tsunami, immediately after tsunami and post-tsunami. Even after giving lapse of one year, the transformed sands though slowly ebbing to reach the 2003 stage of distribution, reaching to the pre-tsunami conditions could not be achieved by the sands. CM pattern also reflects similar condition. However, it shows that the 2003 and 2006 sands have reached similar pattern of distribution, but the grain size is coarser in 2006 when compared to 2003. Probably, in the next 2 to 3 years, it may reach the pre-tsunami condition.

1. INTRODUCTION

Grain size studies are being utilized as the primary factor in understanding the nature of sediments. In coastal mining, as there is scrapping of the upper surface sands, the nature of the sands is likely to be transformed subsequently. This type of transformation in the form of sediment texture is being applied to infer the nature of denudational processes taken place the tsunami affected beaches. Many of the earlier workers have successfully demonstrated the sediment texture and its application to understand the previous history of the

sediments (Mason and Folk, 1958; Passega, 1957, 1964, 1977; Folk, 1968; Friedman, 1961, 1967, 1979). The sediment texture has been successfully used by many authors in the Indian coast, river and offshore to interpret the depositional environment, erosion and accretion, provenance and energy distribution during transportation (Rajamanickam and Gujar, 1984, 1988, 1985, 1993, 1997; Rajamanickam and Muthukrishnan, 1995; Mohan and Rajamanickam, 1996, 1998; Udayaganesan and Rajamanickam, 1996; Chandrasekar and Rajamanickam, 2000).

The grain size data has also been effectively related to the wave refraction pattern (Rajamanickam et al., 1986; Chandrasekar et al., 1996; Angusamy et al., 1998). Grain size characters in many places have been used by the different authors to appreciate the re-building of the beaches once the stability of the beaches are disturbed for both sedimentary character and landforms (Kahn, 1986; Dingler and Reiss, 1995; Risi et al., 1995; Shaozong et al., 1995; Guntenspergen et al., 1995; Tedesco et al., 1995; Stone et al., 1997; Desrosiers et al., 2001; Jaffe and Gelfenbaum, 2002; Gelfenbaum and Jaffe, 2003; Morton and Sallenger Jr., 2003; Dougherty et al., 2004; Hill, 2004; Hussain et al., 2006; Moore et al., 2006; Srinivasalu et al., 2006).

Under CSIR-CMRI network programme, in order to evaluate the volume of sediment budget, fortnightly sampling from December 2003 to December 2004 has been taken up in a straight beach having length of 35 km, dispositioned between Poompuhar and Nagoor in the Central part of the Tamil Nadu, India (Fig. 1). The studies have been carried out on the distribution of the sediments for one year and the results have already been published (Angusamy et al., 2005; Chandrasekaran et al., 2005; Loveson et al., 2005; Soosai Manickaraj et al., 2005) on those sediments collected between 2003 and 2004. The surprise attack of 26th December 2004 tsunami has brought a drastic change in the sedimentary characters. For example, in Poompuhar not even a single grain of earlier sand has been left after tsunami (Plate 1). In such cases, every bit of sand brought forward after tsunami is expected to have a new character admixed with Aeolian source. After tsunami, these beaches have shown not only lithological changes but also in heavy mineral enrichment and sediment texture. Whatever the estimation completed on reserves of the heavy minerals, different landforms under geomorphological mapping and the sediment characteristics can not be carried over further for any other purposes because of complete change in characterization not only in the composition of the sediments but also in the significant changes of sediment texture and assemblages of different sizes of sands and biogenic products. Sediment texture being an important parameter in assessing the value of heavy mineral, environmental effect out of mining and assessing the denudational processes, etc., the continuous collection of sands and observations from December 2004 at a regular interval upto 2006 have been carried out. In this paper, the results of representative the low-tide, high tide samples of each stations. These stations are being positioned after triangulation survey, sand samples could have been collected in the same position both in pre-tsunami and post-tsunami of 2003, 2005 and 2006. The results are presented in this paper (Table 1-3, Fig. 1-5 and Plate 1).

Table 1: Textural Parameters for December 2003

Station Name	Distribution Curve	Method of Moments in Phi					Folk and Ward Method in Phi			
		Median	Mean	Sorting	Skewness	Kurtosis	Mean	Sorting	Skewness	Kurtosis
Poompuhar - High tide	Polymodal	1.753	1.784	0.578	0.413	3.623	1.819 (M.S)	0.576 (M.W.S)	0.137 (F.S)	1.422 (L)
Poompuhar - Low tide	Bimodal	1.851	1.938	0.502	0.72	3.602	1.926 (M.S)	0.491 (W.S)	0.254 (F.S)	0.933 (M)
Chinnankudi - High tide	Polymodal	2.344	2.28	0.605	-0.005	2.403	2.320 (F.S)	0.593 (M.W.S)	(-0.041) (S.S)	0.937 (M)
Chinnankudi - Low tide	Trimodal	1.879	1.942	0.519	0.561	3.029	1.906 (M.S)	0.515 (M.W.S)	0.152 (F.S)	0.737 (P)
Kuttiyaandiyur - High tide	Polymodal	2.473	2.459	0.602	-0.071	2.313	2.432 (F.S)	0.602 (M.W.S)	(-0.084) (S.S)	0.886 (P)
Kuttiyaandiyur - Low tide	Polymodal	1.927	2.037	0.712	0.13	2.595	2.018 (F.S)	0.73 (M.S)	0.177 (F.S)	0.845 (P)
Chandirapadi - High tide	Polymodal	1.953	2.048	0.776	-0.059	2.496	2.034 (F.S)	0.781 (M.S)	0.124 (F.S)	0.886 (P)
Chandirapadi - Low tide	Polymodal	2.283	2.167	0.72	-0.135	2.453	2.175 (F.S)	0.748 (M.S)	(-0.165) (C.S)	0.929 (M)
Kottucherimedu - High tide	Polymodal	1.744	1.769	0.67	0.546	3	1.826 (M.S)	0.633 (M.W.S)	0.162 (F.S)	0.952 (M)
Kottucherimedu - Low tide	Polymodal	1.487	1.637	0.767	0.108	2.839	1.587 (M.S)	0.774 (M.S)	0.166 (F.S)	0.987 (M)
Karaikkal - High tide	Polymodal	1.947	2.089	0.64	0.37	2.729	2.027 (F.S)	0.653 (M.W.S)	0.259 (F.S)	0.838 (P)
Karaikkal - Low tide	Polymodal	1.748	1.751	0.669	0.238	2.645	1.821 (M.S)	0.628 (M.W.S)	0.099 (S.S)	0.877 (P)
Vadakkuvanjiyur - High tide	Polymodal	2.09	2.13	0.598	0.619	3.12	2.129 (F.S)	0.591 (M.W.S)	0.101 (F.S)	0.887 (P)
Vadakkuvanjiyur - Low tide	Polymodal	2.502	2.466	0.561	0.337	2.697	2.513 (F.S)	0.555 (M.W.S)	0.055 (S)	1.056 (M)
Nagour - High tide	Polymodal	2.074	2.151	0.626	0.785	3.069	2.148 (F.S)	0.61 (M.W.S)	0.307 (V.F.S)	0.875 (P)
Nagour - Low tide	Polymodal	2.205	2.215	0.745	(-0.258)	2.81	2.225 (F.S)	0.688 (M.W.S)	(-0.017) (S)	0.811 (P)

Table 2: Textural Parameters for January 2005

Station Name	Distribution Curve	Method of Moments in Phi					Folk and Ward Method in Phi			
		Median	Mean	Sorting	Skewness	Kurtosis	Mean	Sorting	Skewness	Kurtosis
Poompuhar - High tide	Trimodal	2.118	2.161	0.507	0.526	2.978	2.138 (F.S)	0.503 (M.W.S)	0.139 (F.S)	0.719 (P)
Poompuhar - Low tide	Trimodal	1.673	1.811	0.491	0.899	4.004	1.793 (M.S)	0.427 (W.S)	0.398 (V.F.S)	1.201 (L)
Chinnankudi - High tide	Tri modal	2.732	2.723	0.524	-0.226	3.352	2.765 (F.S)	0.480 (W.S)	(-0.015) (S.S)	1.270 (L)
Chinnankudi - Low tide	Tri modal	1.873	1.935	0.51	0.65	3.346	1.893 (M.S)	0.495 (W.S)	0.140 (F.S)	0.761 (P)
Kuttiyaandiyur - High tide	Polymodal	2.489	2.463	0.63	0.225	2.277	2.441 (F.S)	0.670 (M.W.S)	(-0.006) (S)	0.935 (M)
Kuttiyaandiyur - Low tide	Polymodal	2.346	2.308	0.653	0.127	2.124	2.467 (F.S)	0.687 (M.W.S)	(-0.057) (S)	0.882 (P)
Chandirapadi - High tide	Trimodal	2.161	2.276	0.529	0.517	2.683	2.229 (F.S)	0.549 (M.W.S)	0.206 (F.S)	0.999 (M)
Chandirapadi - Low tide	Polymodal	2.773	2.703	0.501	-0.373	2.876	2.662 (F.S)	0.536 (M.W.S)	(-0.205) (C.S)	0.905 (M)
Kottucherimedu - High tide	Polymodal	2.113	2.165	0.566	0.578	3.212	2.142 (F.S)	0.531 (M.W.S)	0.171 (F.S)	0.752 (P)
Kottucherimedu - Low tide	Polymodal	1.722	1.921	0.58	0.703	3.718	1.928 (M.S)	0.559 (M.W.S)	0.451 (V.F.S)	1.301 (L)
Karaikkal - High tide	Polymodal	2.781	2.756	0.627	-0.17	2.169	2.798 (F.S)	0.675 (M.W.S)	(-0.042) (S)	0.850 (P)
Karaikkal - Low tide	Trimodal	2.144	2.22	0.508	0.647	3.24	2.167 (F.S)	0.509 (M.W.S)	0.149 (F.S)	0.760 (P)
Vadakkuvanjiyur - High tide	Trimodal	2.09	2.127	0.523	0.796	3.394	2.117 (F.S)	0.507 (M.W.S)	0.177 (F.S)	0.750 (P)
Vadakkuvanjiyur - Low tide	Trimodal	2.208	2.369	0.508	0.461	3.016	2.320 (F.S)	0.494 (W.S)	0.277 (F.S)	1.031 (M)
Nagour - High tide	Polymodal	2.8	2.869	0.69	-0.026	2.186	2.898 (F.S)	0.753 (M.S)	0.092 (S)	0.796 (P)
Nagour - Low tide	Polymodal	2.533	2.535	0.565	0.481	2.899	2.556 (F.S)	0.584 (M.W.S)	0.085 (S)	1.039 (M)

Table 3: Textural Parameters for January 2006

Station Name	Distribution Curve	Method of Moments in Phi					Folk and Ward Method in Phi			
		Median	Mean	Sorting	Skewness	Kurtosis	Mean	Sorting	Skewness	Kurtosis
Poompuhar - High tide	Trimodal	2.118	2.161	0.507	0.526	2.978	2.138 (F.S)	0.503 (M.W.S)	0.139 (F.S)	0.719 (P)
Poompuhar - Low tide	Trimodal	1.673	1.811	0.491	0.899	4.004	1.793 (M.S)	0.427 (W.S)	0.398 (V.F.S)	1.201 (L)
Chinnankudi - High tide	Trimodal	2.007	2.006	0.523	1.094	4.271	2.045 (F.S)	0.485 (W.S)	0.228 (F.S)	1.070 (M)
Chinnankudi - Low tide	Trimodal	2.288	2.409	0.534	0.426	2.849	2.406 (F.S)	0.526 (M.W.S)	0.324 (V.F.S)	1.208 (L)
Kuttiyaandiyur - High tide	Polymodal	2.489	2.463	0.63	0.225	2.277	2.441 (F.S)	0.670 (M.W.S)	(-0.006) (S)	0.935 (M)
Kuttiyaandiyur - Low tide	Polymodal	2.346	2.305	0.653	0.127	2.124	2.467 (F.S)	0.687 (M.W.S)	(-0.057) (S)	0.882 (P)
Chandirapadi - High tide	Trimodal	2.161	2.276	0.529	0.517	2.683	2.229 (F.S)	0.549 (M.W.S)	0.206 (F.S)	0.999 (M)
Chandirapadi - Low tide	Polymodal	2.773	2.703	0.501	-0.373	2.876	2.662 (F.S)	0.536 (M.W.S)	(-0.205) (C.S)	0.905 (M)
Kottucherimedu - High tide	Polymodal	2.113	2.165	0.566	0.578	3.212	2.142 (F.S)	0.531 (M.W.S)	0.171 (F.S)	0.752 (P)
Kottucherimedu - Low tide	Polymodal	1.722	1.921	0.58	0.703	3.718	1.928 (M.S)	0.559 (M.W.S)	0.451 (V.F.S)	1.301 (L)
Karaikkal - High tide	Polymodal	2.781	2.756	0.627	-0.17	2.169	2.798 (F.S)	0.675 (M.W.S)	(-0.042) (S)	0.850 (P)
Karaikkal - Low tide	Trimodal	2.144	2.22	0.508	0.647	3.24	2.167 (F.S)	0.509 (M.W.S)	0.149 (F.S)	0.760 (P)
Vadakkuvanjiyur - High tide	Trimodal	2.09	2.127	0.523	0.796	3.394	2.117 (F.S)	0.507 (M.W.S)	0.177 (F.S)	0.750 (P)
Vadakkuvanjiyur - Low tide	Trimodal	2.208	2.369	0.508	0.461	3.016	2.320 (F.S)	0.494 (W.S)	0.277 (F.S)	1.031 (M)
Nagour - High tide	Polymodal	2.8	2.869	0.69	-0.026	2.186	2.898 (F.S)	0.753 (M.S)	0.092 (S)	0.796 (P)
Nagour - Low tide	Polymodal	2.533	2.535	0.565	0.481	2.899	2.556 (F.S)	0.584 (M.W.S)	0.085 (S)	1.039 (M)

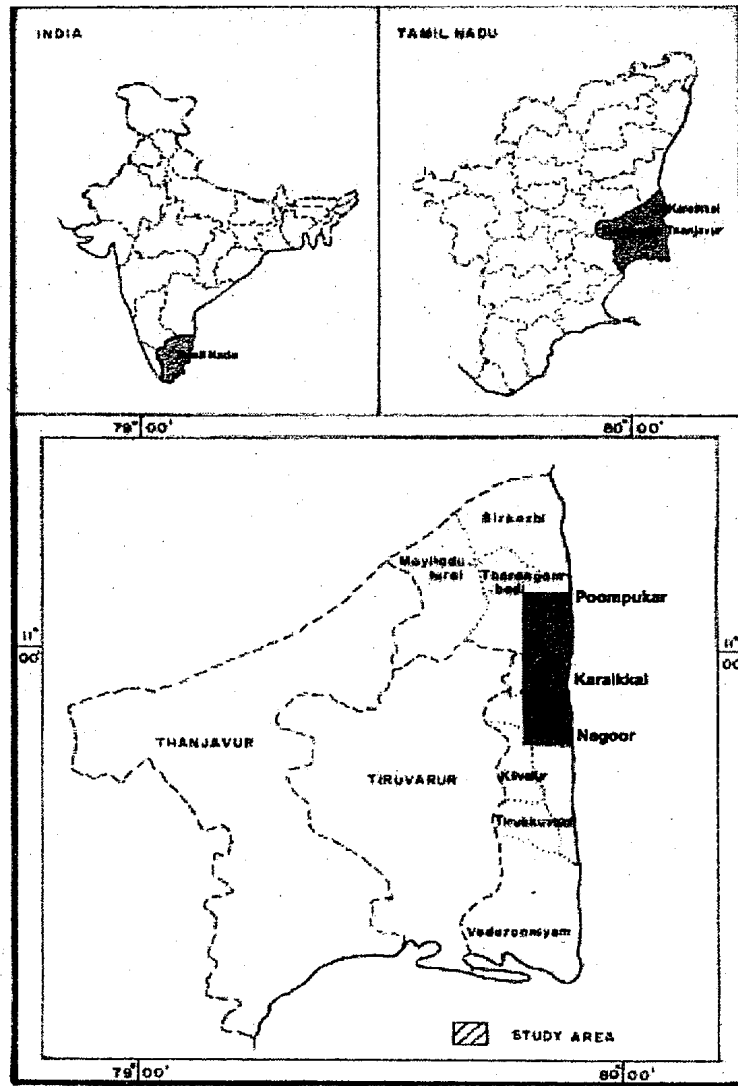


Fig. 1: Location Map

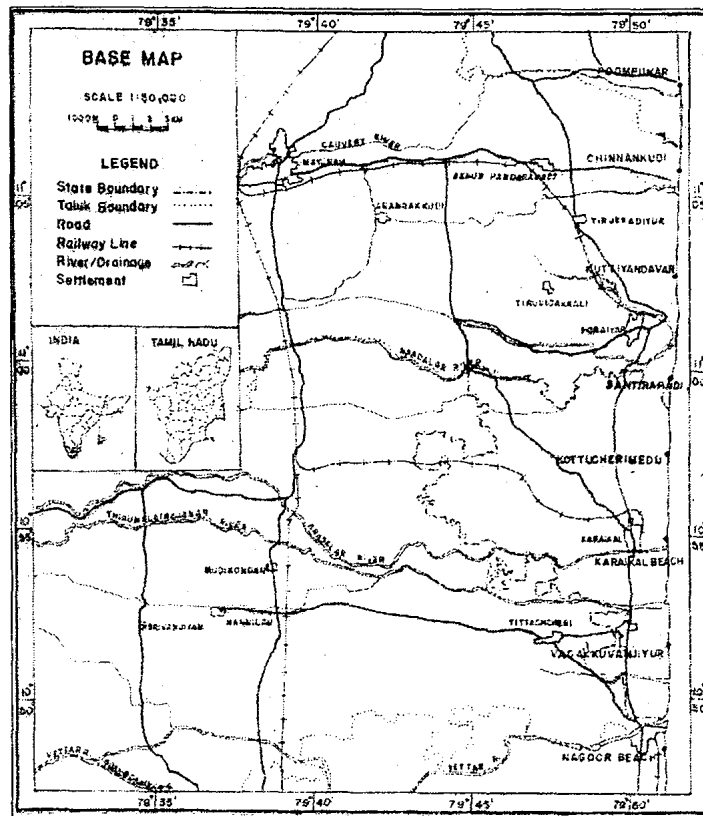


Figure 2: Base Map of the Study Area

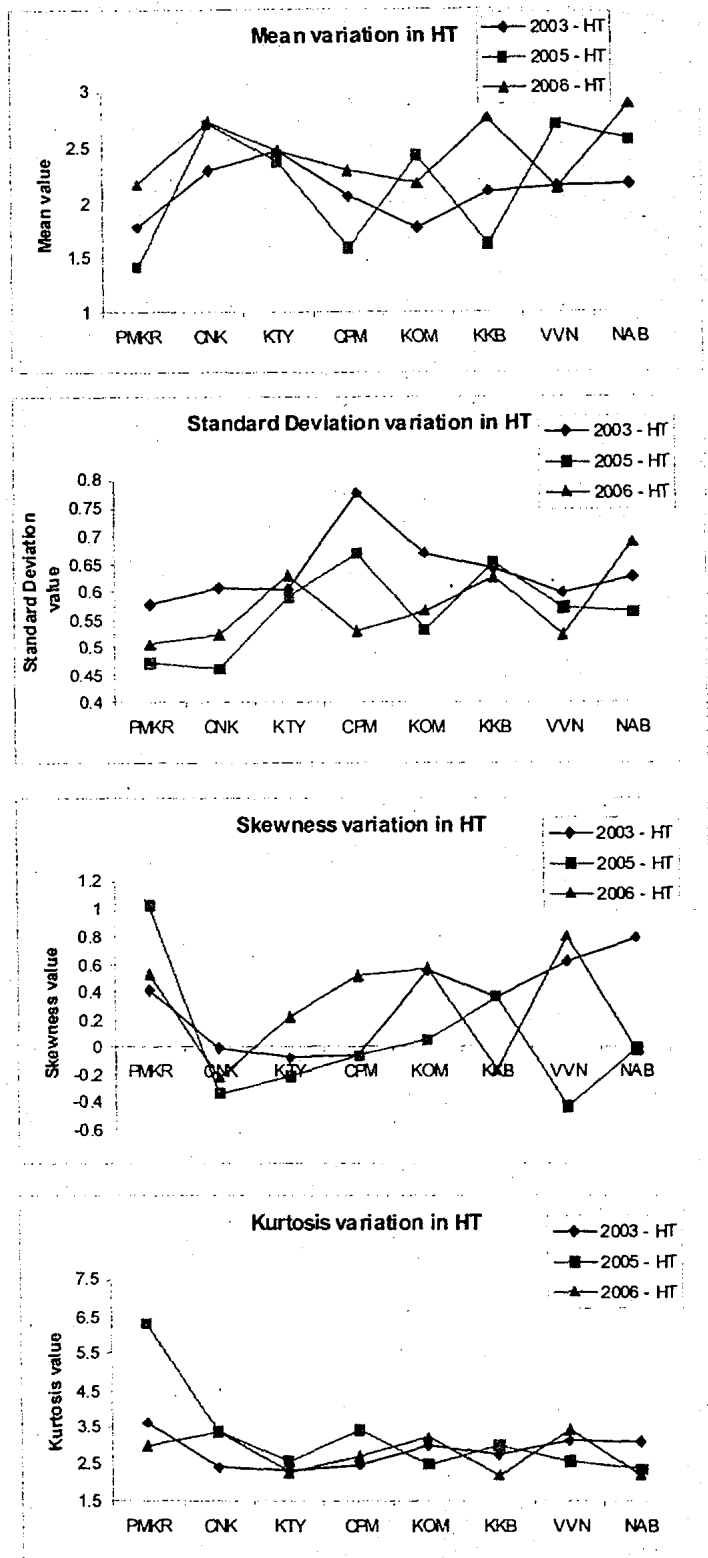


Fig. 3 (a): Mean, Standard deviation, Skewness and Kurtosis trends in the High tide region for December 2003, January 2005 and January 2006

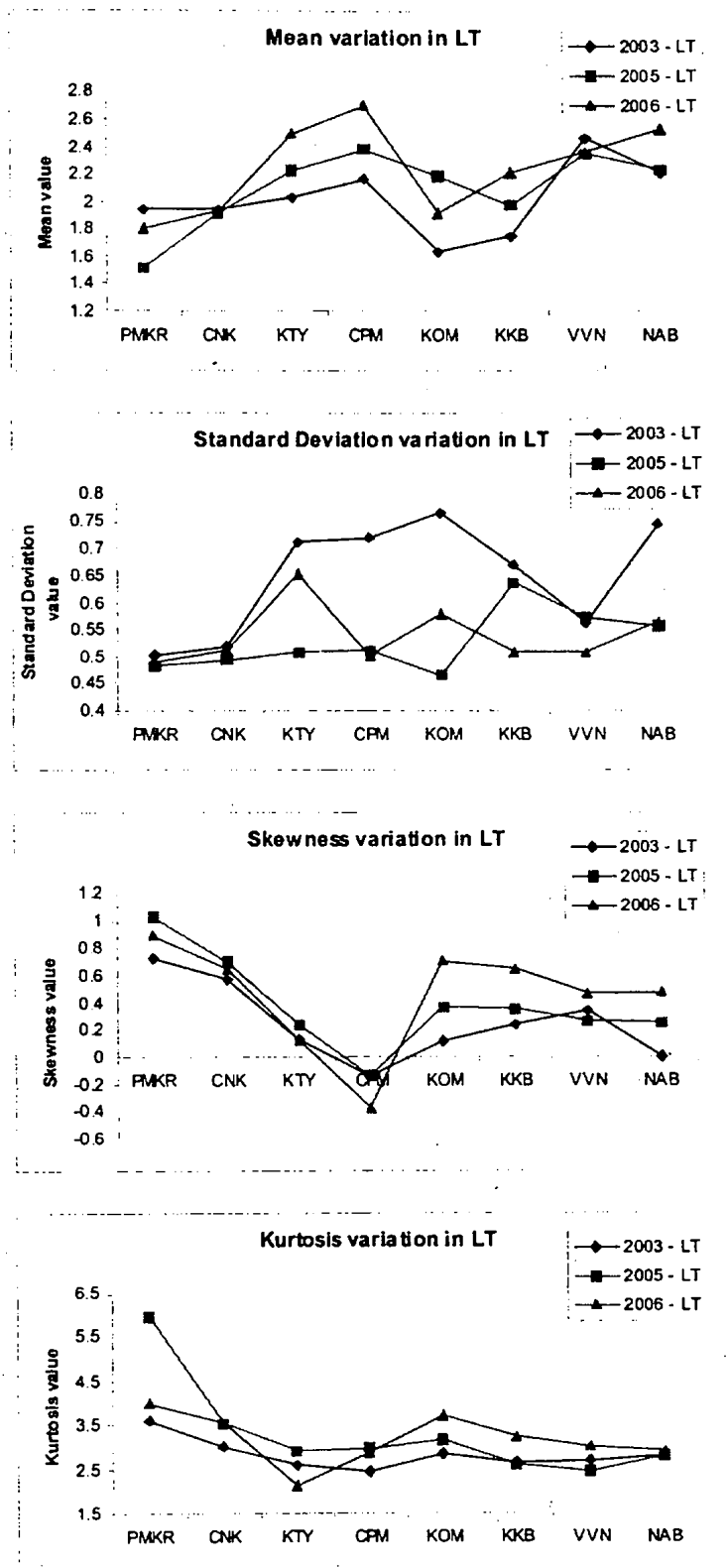
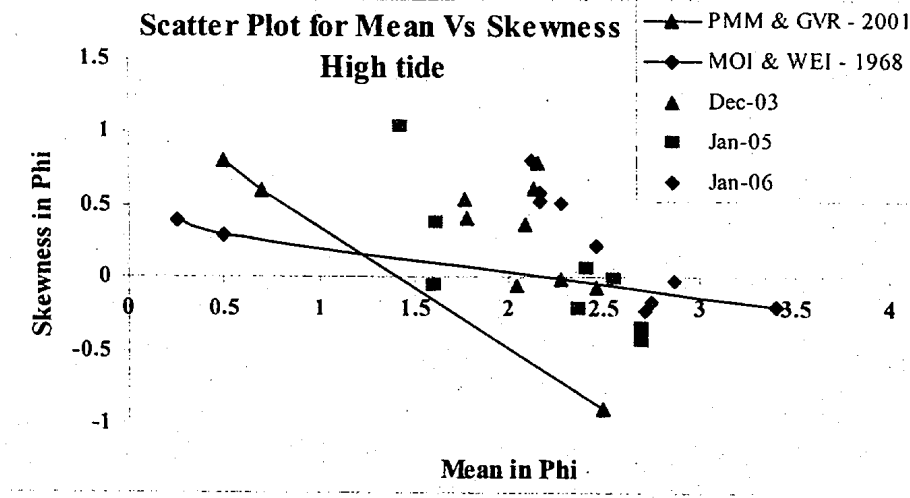
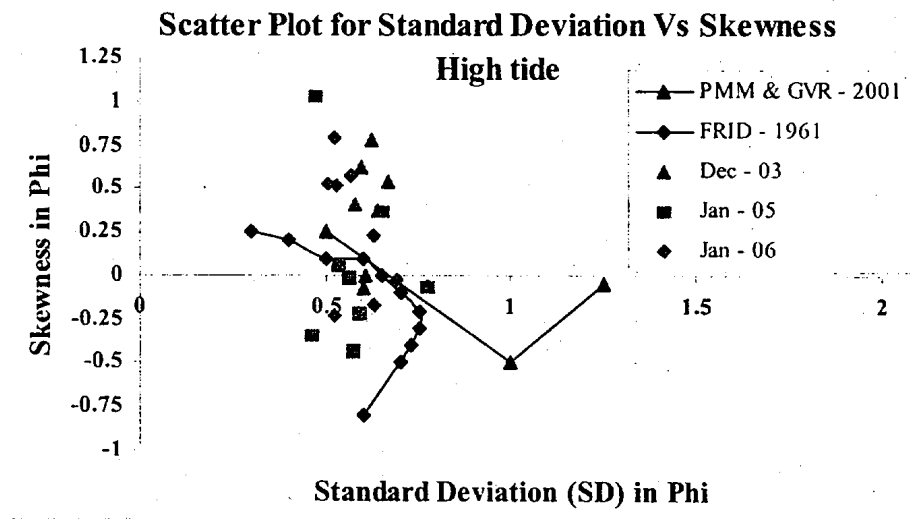
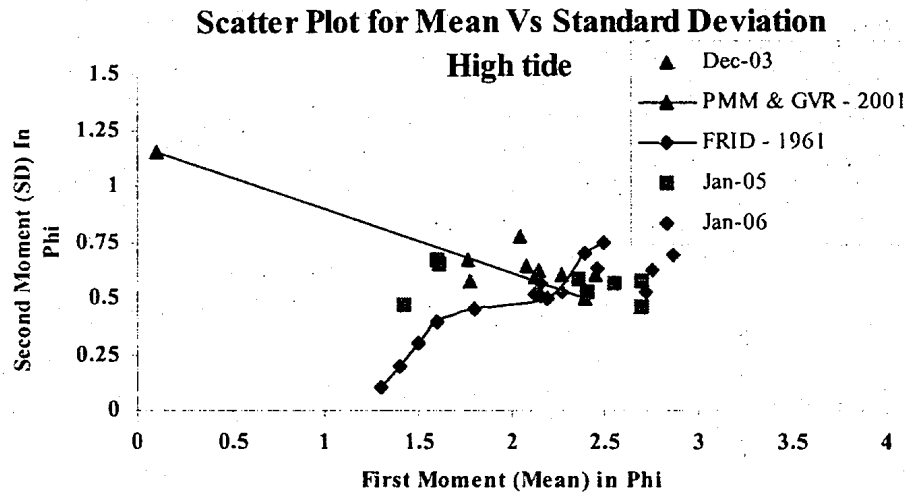


Fig. 3 (b): Mean, Standard deviation, Skewness and Kurtosis trends in the Low tide region for December 2003, January 2005 and January 2006



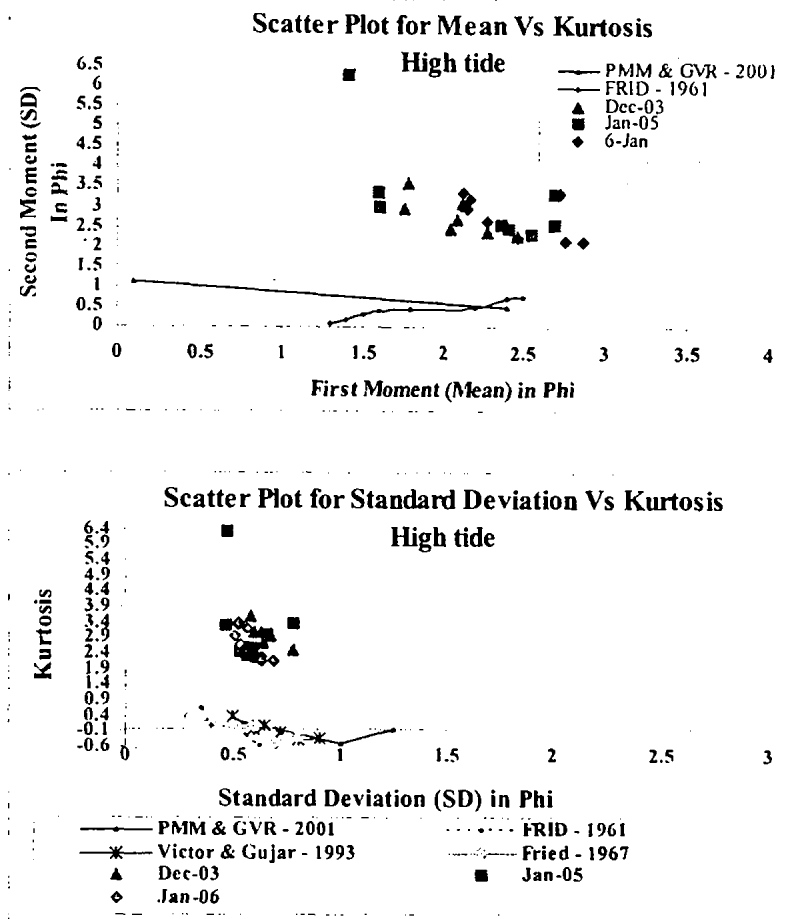
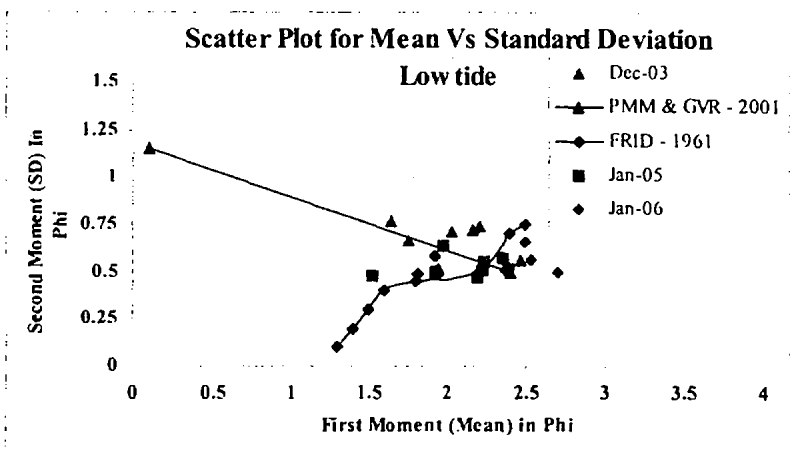


Fig. 4 (a): Scatter plots in the High tide region for December 2003, January 2005 and January 2006



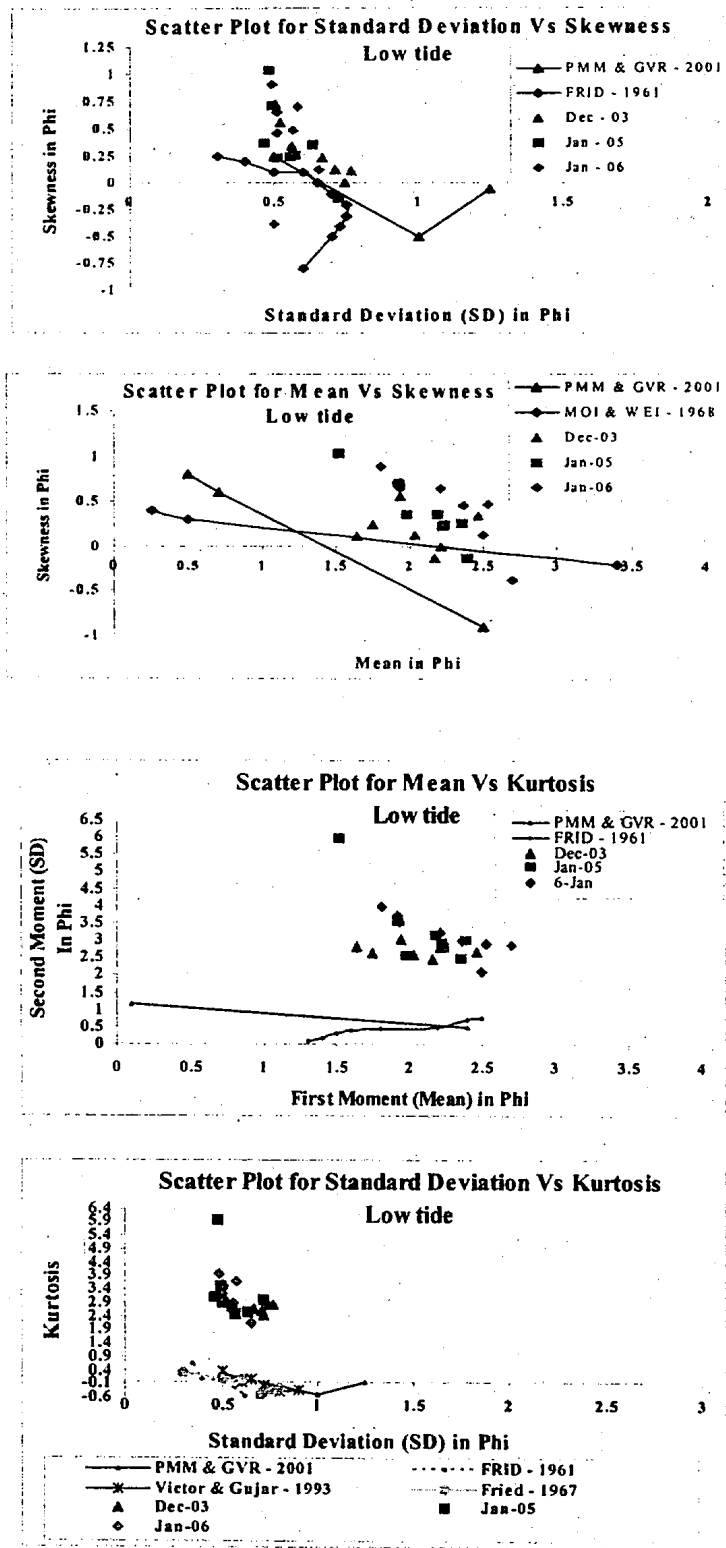


Fig. 4 (b): Scatter plots in the High tide region for December 2003, January 2005 and January 2006

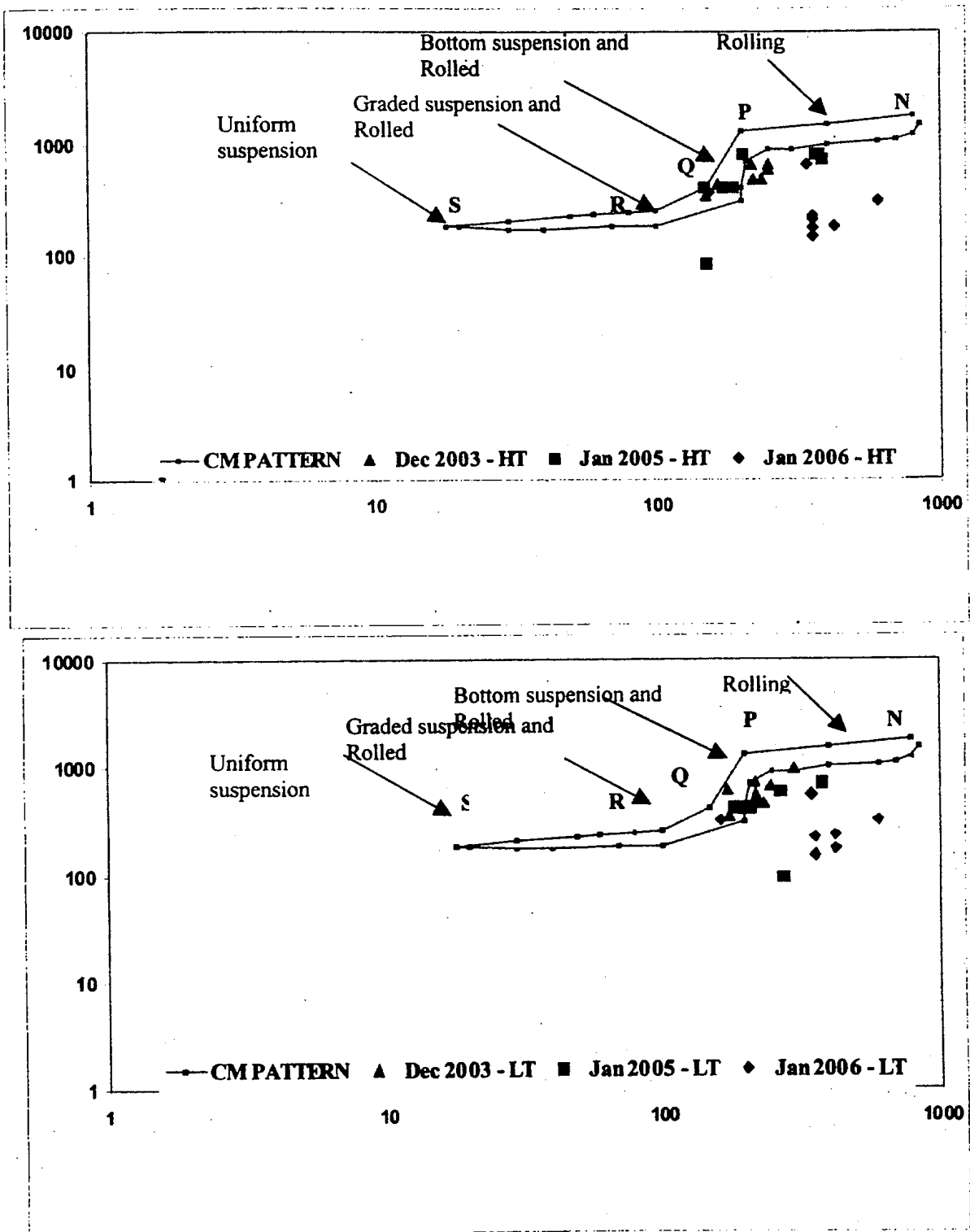
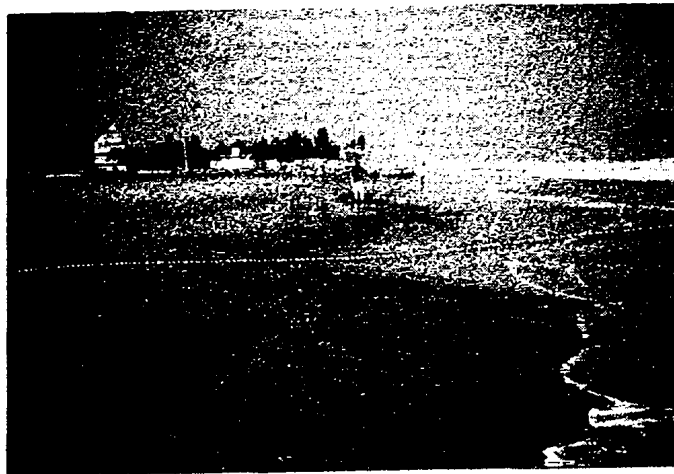


Fig. 5: CM Diagram for December 2003, January 2005 and January 2006

Plate 1 : Pre- and Post-Tsunami view of Poompuhar beach



Pre-Tsunami View, Dec.16th, 2004



Post Tsunami View, Dec.27th, 2004

2. STUDY AREA

The present study is located in the central coast of Tamil Nadu. For the present study, the region from Poompuhar to Nagoor is chosen (Fig.2). Coastline of the study region trends in N-S direction. Poompuhar region is drained by the river Cauvery while the Chinnankudi region is discharged by the river Ambanar. The shelf is very narrow at Poompuhar region where 20 m depth contours at 6 km from the shore and 100 m at 24 km from the shore. At Kuttiyandiyur, 20 m contour is located at 12 km distance whereas 100 m is dispositioned at 33 km from the shore. At Nagoor, 20 m contour is located at 12 km distance whereas 100 m contour is located at 39 km from the shore. Current velocity is 1 – 2 knots southerly in October – December whereas in February, the current velocity is reduced to 0.5 knots in northerly direction.

3. METHODOLOGY

The 35 km stretch of the study area has been (Toposheet No: 58 M/13 and 58 N/13) surveyed for detailed sample collections. Using a hand auger, sediment samples have been collected at 10 km interval between the sampling station upto 33 cm depth in the year of Dec. 2003, Jan. 2005 and Jan. 2006. Since the baseline data was available for the pre-tsunami period, systematic grain size studies were undertaken for the post-tsunami samples. Sample geographic positions were fixed using hand held GPS. Post-tsunami field changes have been noted and marked in the base map itself.

In the laboratory, samples were dried in the oven at 60°C and stirred with a mechanical stirrer for 10 minutes to remove clay and silt content. The weight loss was weighed. Using H₂O₂, organic matter content was estimated. The dried samples were treated with 10 % HCL to estimate the carbonate content of the samples. Then, it was oven dried. After weighing, it was sieved at ¼ f intervals in ASTM sieve sets stacked from +7 to +230 mesh sizes. It was shaken using a mechanical shaker for 10 minutes and then the samples retained in the individual mesh sizes were weighed. Using Folk and Ward (1957) formula, textural parameters of the sediments were estimated.

4. RESULTS AND DISCUSSION

The different values of textural statistics obtained by both graphic and moment measures for the periods 2003, 2005 and 2006 are given in Table 1 to 3. The textural statistics of Mean, Sorting, Skewness and Kurtosis clearly establish a characteristic shift in their values. In order to appreciate the changes effected in the texture after tsunami and the extent of normalization the respective textural parameters' values are shown in a graphic pattern (Fig.3a, b). In the figures, one can easily observe the approach of 2006 sediment to the vicinity of 2003. The drastic shift seen in those samples collected immediately after tsunami during 2005 is seen in all the stations, whether the station has faced high order of impact or less order of impact. In the low tide, the northern four stations have shown a systematic order of distribution. Here, in the low tide particularly skewness displays a more or less close distribution with minimum change. The standard deviation of low tide as well as high tide shows strong difference between pre- and post- tsunami sands. Among the stations, Kuttiyandiur sediments show ebbing of normalcy in the distribution of sediments.

However, when the binary plots of the textures of these three periods are compared in standard deviation Vs skewness plot, it shows the presence of the sands from December 2003 and January 2006 in one zone. Similarly, mean Vs skewness first moment to second moment, standard deviation to kurtosis display similar trend for high tide whereas the distribution of the low tide in this area is not yet normalized. All the plots show the Dec. 2003 and Jan. 2006 are separated by Jan. 2005 sample segregations. From this, it clearly depicts that high tide samples are reaching the previous status faster than the low tide (Fig.4a, b).

With the view to understand the energy level of deposition during this period, the year 2003 high tide samples show their presence in the PQ sector reflecting the dominance of rolling and suspension. In the same, Jan. 2005 is dominantly present in the higher turbulent energy zone of NOP, reflecting the deposition in turbulent condition.

Jan. 2006 high tide samples are segregated in NOP sector but with less energy, the coarseness remains to be of 100 microns whereas 2005 has reflected a turbulent level bringing particles of 1000 microns. The 2003 high tide samples are in the PQ rolling sector or a graded suspension. Till 2006, the sediments have not reached the level of 2003. In low tide, the 2003 samples characterize a similar condition of high tide but Jan. 2005 reflects a very scattered irregular mix-up of the sediments. It can be surmised that the low tide sediments do not represent onward push of tsunami waves-brought sediments. Probably, low tide sands are expected to

have been dominated by the under-tow or the receding current situation. 2006 sands are once again reflecting the condition of high turbulence in the zone of NOP but to a low energy turbulence of 100 microns levels. Low tide and high tide on the basis of CM pattern reflect a strong diversity among the sands of those three periods (Fig.5). Though 2006 emphatically indicates presence of low energy condition, it has also reached the graded suspension stage, but with the higher coarser particles. In due course of time, there is a possibility of those sands attaining the PQ distribution. In short, it can be surmised that the disturbance created by the tsunami waves to the sands in the beaches are rebuilt, the pre-tsunami condition of the graded suspension character is normally seen in all beaches of Quaternary sediments.

5. CONCLUSION

The sediment character and textural characteristics have been obtained for the representative samples of three years 2003, 2005 and 2006. They have been analysed for grain size characteristics and the statistical textural parameters have been estimated using both graphic and moment measures. The graphical presentation of the textural characteristic in addition to the binary plot, CM pattern clearly bring out the existing sands have not yet reached the pre-tsunami level of 2003.

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REFERENCES

1. Angusamy, N. Udayaganesan P. and Victor Rajamanickam G (1998) Wave refraction pattern and its role in the redistribution of sediments along the southern coast of Tamilnadu India. *Ind. Jour. Mar.Sc.i* v.27. pp. 173-178.
2. Angusamy, N. Soosai Manickaraj, D. Chandrasekaran, R. Chandrasekar N Loveson, V. J. Gujar, A. R. and Victor Rajamanickam G (2005) Heavy mineral Distribution in the beaches of Nagapattinam District, Tamilnadu, India, *In: Development Planning of Coastal Placer Minerals (Eds. V.J. Loveson; N. Chadrasekar and A. Sinha) Allied Publishers Pvt. Ltd., New Delhi 80-92*
3. Chandrasekar, N. and Rajamanickam, G. V. (2000) Grain size distribution of beach sediments along central Tamilnadu. *Tamil Civilization Publ., Tamil University*, pp.1-9.
4. Chandrasekar, N. Sudhir A. S. Rajamanickam, G. V. and Loveson V. J. (1996) Study on Littoral Sediments Transports along the Southern Coast of Tamilnadu. *In: Acquisition and appreciation of modern techniques in earth sciences, related industries (Eds.O. P. Varma and G. Victor Rajamanickam) Published by the Indian Geological congress, Roorkee*, pp. 60-63.
5. Chandrasekaran, R. Angusamy, N. Soosai Manickaraj, D. Loveson, V. J. Gujar, A. R. Chandrasekar N. and Victor Rajamanickam G (2005) Grain Size Distribution and Annual Variation Along the Beaches from Poompuhar to Nagoor, Tamilnadu, *In: Development Planning of Coastal Placer Minerals (Eds. V.J. Loveson, N. Chadrasekar and A. Sinha) Allied Publishers Pvt. Ltd., New Delhi pp.156-170.*
6. Dinger, J.R. and Reiss, T. (1995) Beach Erosion on Trinity Island, Louisiana Caused by Hurricane Andrew (1995) *Journal of Coastal Research*, Special Issue No. 21, pp. 254-264.

7. Dougherty, A.J., Fitzgerald, D.M. and Buynovich, I.V. (2004) Evidence for storm-dominated early progradation of Castle Neck barrier, Massachusetts, USA. *Marine Geology*, v.210, pp. 123-134.
8. Folk R L. (1968) Petrology of sedimentary rocks. *Hampill. Texas*.
9. Folk, R.L. and Ward, M.S. (1957) Brazos river bars: A study in the significance of grain size parameters. *Jour.Sed.Petrol.*, v.27, pp.3-27.
10. Friedman, G.M. (1961) Distinction between dune, beach and river sands from textural characteristics. *J.Sed. Petrol.*, v.31, pp.3-27.
11. Friedman, G.M. (1967) Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sand. *J.Sed. Petrol.*, v.37, pp.327-354.
12. Friedman, G.M. (1979) Differences in size distributions of populations of particles among sands of various origin. *Sedimentol*, v.26, pp.3-32.
13. Gelfenbaum, G and Jaffe, B. (2003) Erosion and sedimentation from the 17 July, 1998 Papua New Guinea tsunami. *Pure and Applied Geophysics*, v.160, pp. 1969-1999.
14. Guntenspergen, G.R., Cahoon, D.R., Grace, J., Steyer, G.D., Fournet, S., Townsend, M.A. and Foote, A.L. (1995) Disturbance and Recovery of the Louisiana Coastal Marsh Landscape from the Impacts of Hurricane Andrew. *Journal of Coastal Research*, Special Issue No. 21, pp. 324-339.
15. He'quette, A., Desrosiers, M., Hill, P.R. and Forbes, D.L. (2001) The influence of coastal morphology on shoreface sediment transport under storm-combined flows, Canadian Beaufort Sea. *Journal of Coastal Research*, v.17, pp. 507-516.
16. Hill, H.W., Kelley, J.T., Belknap, D.F. and Dickson, S.M. (2004) The effects of storms and storm-generated currents on sand beaches in Southern Maine, USA. *Marine Geology*, v.210, pp. 149-168.
17. Hussain, S.M., Gandhi, M.S., Krishnamurthy, R.K. and Nagendra, R. (2006) Micropaleontological investigations of tsunami sediments of Tamil Nadu and Andaman Islands. In: *26th December 2004 Tsunami: Causes, effects, remedial measures, pre and post tsunami disaster management-A Geoscientific perspective (Ed-in-Chief: G. V. Rajamanickam)*, New Academic Publishers, New Delhi, pp. 83-115.
18. Jaffe, B.E. and Gelfenbaum, G. (2002) Using tsunami deposits to improve assessment of tsunami risk, *Solutions to Coastal Disasters 2002*, pp. 836-847.
19. Kahn, J.H. (1986) Geomorphic recovery of the Chandeleur Islands, Louisiana, after a major hurricane. *Journal of Coastal Research*, 2 (3), pp. 337-344.
20. Loveson, V.J, Barnwal, R.P, Singh, V.K., Gujar, A.R., and Rajamanickam, G.V., (2005) Application of Ground penetration Radar in placer mineral exploration for mapping subsurface sand layers: A case study In: *Development Planning of Coastal Placer Minerals (Eds. V.J. Loveson, N. Chadrasekar and A. Sinha) Allied Publishers Pvt. Ltd., New Delhi pp.71-79*
21. Morton, R.A. and Sallenger Jr., A.H. (2003) Morphological impacts of extreme storms on sandy beaches and barriers. *Journal of Coastal Research*, v.19, pp. 560-573.
22. Mason, C.C. and Folk R.L. (1958) Differentiation of beach dune, and Aeolian flat environment by size analysis, Mustang Island, Texas. *J. Sed. Petrol.*, v.28, pp.211-226.
23. Mohan, P.M. and Rajamanickam, G. V. (1996) Depositional environments: Inferred from grain size along the coast of Tamilnadu. *Jour. Geol. Soc. Ind.* v.52, pp.95-102.
24. Mohan, P.M. and Rajamanickam, G.V. (1998) Depositional environment: Inferred from grain size along the coast of Tamil Nadu, India. *Jour.Geol.Soc.India*, v.52, pp.95-102.
25. Moore, A., Nishimura, Y., Gelfenbaum, G, Kamataki, T. and Triyono, R. (2006) Sedimentary deposits of the 26 December 2004 tsunami on the northwest coast of Aceh, Indonesia. *Earth, Planets and Space*. Volume 58, pp.253-258.
26. Passega R. (1957) Texture as characteristics of clastic deposition. *Amer. Assoc. Petrol. Geol.*, v.41 (9). Pp.1952 – 1984.

27. Passega R. (1964) Grain size representation by CM pattern as a Geological tool, *Jour. Sed. Petrol.*, v.34 pp 830 – 847.
28. Passega R. (1977) Significance of CM diagrams of sediments deposited by suspensions, *Sedimentology*, v.24, pp723 – 733.
29. Rajamanickam, G. V. and Gujar, A.R. (1984) Sediment depositional environment in some bays in Central West Coast of India. *Indian Jour.Mar. Sci.*, v.13, pp. 53-59.
30. Rajamanickam, G. V., Vethamony, P. and Gujar, A. R. (1986) Effects of waves in the redistribution of sediments in Jaigad, Ambwah and Varvada bays, Konkan coast, Maharashtra, India. *Proc. Ind. Sci. (Earth and Planet. Sciences)*, v.95, pp. 237-244.
31. Rajamanickam, G. V. and Gujar, A. R. (1988) Depositional Environment of the sediments in Konkan Bays: Inferred from Multigroup discrimination analysis using grains size distribution statistics. *Indian Jour.Ear. Sci.*, v.15, pp.234-247.
32. Rajamanickam, G. V. and Gujar, A. R. (1993) Depositional Processes inferred from the Log Probability distribution. In: *Recent Researches in Sedimentology (Ed.V. Jhingran) Hindustan Publishing Corporation, Delhi*, pp. 154-164
33. Rajamanickam, G. V. and Muthukrishnan, N. (1995) Grain size distribution in the Gadilam river basin, northern Tamil Nadu. *Jour. Indian Asso. Sed.*, v.14, pp. 55-66.
34. Rajamanickam, G.V. and Gujar, A.R. (1985) Indication given by median distribution and CM pattern on classic sedimentation in Kalbadevi, Mirya and Ratnagiri Bays, Maharashtra, India. *Gironale di Geologia Ser. 3a*, v.47, pp.237-251.
35. Rajamanickam, G.V. and Gujar, A.R. (1993) Depositional processes inferred from the log probability distribution. In: *Recent Researches in Sedimentology. (Ed. V. Jhingran), Hindustan Publishing Corporation, Delhi*, pp.154-164.
36. Rajamanickam, G.V. and Gujar, A.R. (1997) Grain size studies on the nearshore sediments of Jaigad, Ambwah and Varvada bays, Maharashtra. *Jour.Geol.Soc.India*, v.49, pp.567-576.
37. Risi, J.A., Wanless, H.R., Tedesco, L.P. and Gelsanliter, S. (1995) Catastrophic Sedimentation from Hurricane Andrew Along the Southwest Florida Coast. *Journal of Coastal Research*, Spl. Issue No.21, pp. 83-102.
38. Shaozong Shi, Dawson, A.G. and Smith, D.E. (1995) Coastal sedimentation associated with the December 12th, 1992 tsunami in Flores, Indonesia. *Pure & Applied Geophysics*, v.144, pp. 525-536.
39. Soosai Manickaraj, D. Chandrasekaran, R. Gujar, A. R. Loveson, V. J. Angusamy, N. Victor Rajamanickam G. (2005) Stability of Beach in Nagapattinam District, Tamilnadu, India. In: *Development Planning of Coastal Placer Minerals (Eds. V.J. Loveson, N. Chadrrasekar and A. Sinha) Allied Publishers Pvt. Ltd., New Delh*, pp. 171-182.
40. Srinivasalu, S., Ramanathan, A. L., Rajamanickam, G. V., Nagendra, R., Singarasubramanian, S. R., Mukesh, M. V. and Manoharan, K. (2006) Post tsunami sediment characterization of Tamil Nadu Coast. In: *26th December 2004 Tsunami: Causes, effects, remedial measures, pre and post tsunami disaster management- A Geoscientific perspective (Ed-in-Chief: G. V. Rajamanickam), New Academic Publishers, New Delhi*, pp. 59-82.
41. Stone, G.W., Grymes III, J.M., Dingler, J.R. and Pepper, D.A. (1997) Overview and significance of hurricanes on the Louisiana coast, U.S.A. *Journal of Coastal Research* v. 13, pp. 656-669.
42. Tedesco, L.P., Wanless, H.R., Sesua, L.A., Risi, J.A. and Gelsanliter, S. (1995) Impact of Hurricane Andrew on South Florida's Sandy Coastlines *Journal of Coastal Research*, Spl. Issue No.21, pp. 59-82.
43. Udayaganesan, P. and Rajamanickam, G. V. (1996) Grain size distribution and depositional environment of the Vaippar river sediments, Tamil Nadu. In: *Acquisition and Maharashtra, techniques in Earth Sciences, related industries (Eds .O.P.Varma and G.Victor Rajamanickam) Publ. by the IGC, Roorkee*, pp. 44-53.