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Studies on textural characteristics of sediments from Gosthani River Estuary - Bheemunipatnam, A.P., East Coast of India

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ABSTRACT
Detailed textural and clay mineralogical study of Gosthani estuary (lat. 17° 53′- 17°56′ N: long. 83° 26′- 83° 28′ E) has been carried out. The textural studies clearly establish that the sediments are of medium grain size, moderately sorted, positively skewed and deposited under moderate to low energy conditions with dominant rolling and suspension mechanisms. The observations are supported by the frequency curves, CM plot and bivariate plots between parameters, confirming the unimodal nature of sediments with dominant medium sand fraction mixed with minor amounts of silt and clay. The clay mineralogy of these sediments indicates that the most common mineral observed in all samples is illite. The other minerals namely kaolinite, montmorillonite and chlorite are occurring in minor amounts. The clay minerals are believed to be derived from the hinterland lithology composed of khondalites with associated acidic and basic rocks.

INTRODUCTION

Gosthani River is medium sized east flowing river in Andhra Pradesh, India. Originating in the Ananthagiri Hills of Eastern Ghats, it runs for a distance of 120 km and debouches into Bay of Bengal at Bheemunipatnam, forming an estuary. The coast is marked by narrow beach and bordered by eastern ghat hills composed of khondalites, charnockites and granite gneisses. Geomorphologically these hill ranges are perpendicular to the coast, resulting in rocky beaches at places. The depth in the deepest portion of the river is variable from place to place. It is 2 meter in the inlet area at the low tide, 1 - 1.5 meter in the backwaters and 1.5 - 2 meters in the middle section of the river.

Knowledge of the textural characteristics of the estuarine sediments is of great importance in differentiating various depositional micro environments. Sediment transport mechanism in the Vellar estuary, east coast of India was carried out in detail by Mohan (2000). Texture and composition of sediments of Hooghly estuary and near shore environment has been studied by Sesamal et al., (1986). Several authors have studied the textural characteristics of sediments from different environments of the east coast, (Seetharamaswamy, 1970; Jagannadha Rao and Krishna Rao, 1984; Dhanunjaya Rao et al., 1989; Krishana Rao et al., 1990; Ramesh and Subramanian, 1992; Vaithiyanathan et al., 1992; Seetharamaiah and Swamy, 1994; Bragadeeswaran et al., 2007; Rajasekhara Reddy et al., 2008; Ramanathan et al., 2009; Rajani Kumari and Mrutyunjaya Rao, 2009; Venkatramanan et al., 2010; Anithamary Irudhayanathan et al., 2011). Studies on Clay mineralogy of the riverine estuaries, east coast of India were carried out by several authors (Subba Rao, 1963; Satyakumar and Subba Rao, 1987; Raman et al., 1995; Ramamurty and Shrivastava, 1979; Reddy and Rao, 1996; Rao, 1991; Mohan and Damodaran, 1992). The results of studies carried out on the textural characters and clay mineralogy of the Gosthani estuary, which is not been dealt in recent times, are detailed below.

MATERIALS AND METHODS

Sampling and Textural Analysis

Sampling of estuary was carried out using a hand auger (Photo.1). Samples were collected at 11 stations covering the entire mouth of the estuary. At each station five to six samples have been collected and the samples were mixed thoroughly. Out of this, required quantity of bulk sample is taken for laboratory

Photo 1. Sampling in the Estuary

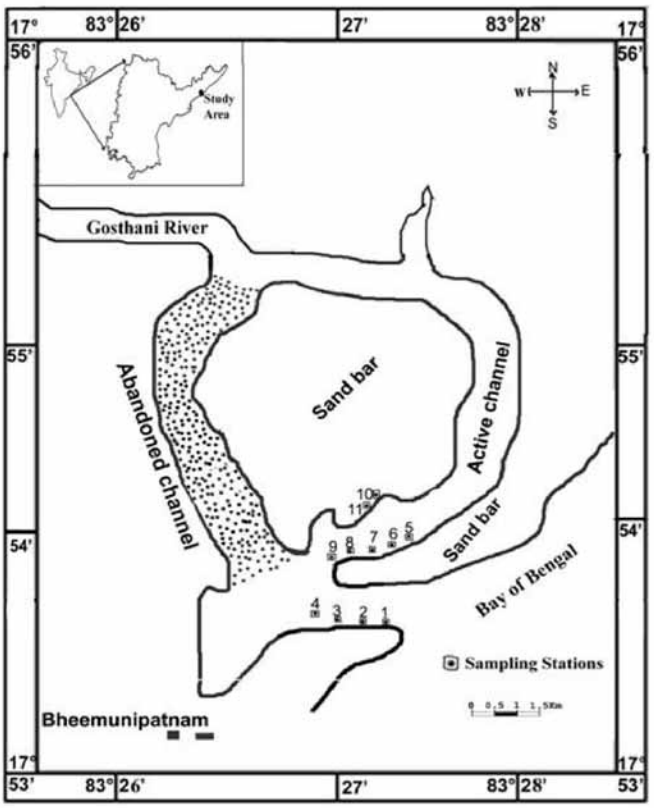

Figure 1. Location Map of Study Area

studies. The sample stations are shown in Fig.1.

The surface sediment samples have been subjected to size analysis (Carver, 1971) and grain size parameters were calculated (Folk and Ward, 1957). About 150-200 grams of sample is taken in porcelain dish and air dried, taking all possible care against contamination. Sandy samples are repeatedly washed in distilled water for removal of salts and then dried. After drying, a sub sample weighing about 40-50 grams is obtained by coning and quartering. H_2O_2 and HCl were added to remove organic matter and shell material in the sample and then dried. The sub

Table 1. Particle Size Distribution of Gosthani River Estuary Sediment Samples

Particle Size in Microns (Mesh No.)	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	St.11	
	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	Wt. (%)	
1000(+18)	0.2	0.4	0.8	0.6	0.2	0.4	0.8	0.6	1.0	1.56	0.2	
710(+25)	0.6	0.4	1.8	0.8	0.8	0.4	1.8	0.8	1.0	2.23	0.6	
500(+35)	3.0	2.8	8.8	4.0	4.4	2.8	8.8	4.0	6.0	6.5	3.0	
355(+45)	36.2	32.4	47.8	30.6	26.0	22.6	46.8	20.6	30.0	28.6	26.2	
250(+60)	34.4	31.8	26.4	29.0	27.0	28.8	13.4	24.0	27.6	27.6	27.4	S
180(+80)	12.2	18.4	6.0	14.2	13.2	18.4	6.0	14.2	9.4	10.01	15.2	
125(+120)	9.6	11.2	5.8	14.4	11.2	10.0	5.8	12.08	7.2	6.2	9.2	
90(+170)	2.0	0.8	1.4	5.6	2.0	0.8	1.4	5.6	1.2	1.2	2.0	
63(+230)	0.6	0.4	0.6	0.2	0.6	0.6	0.6	0.6	0.2	0.2	0.6	
44.000	-	-	-	-	0.6	0.73	0.69	0.72	0.64	0.62	0.69	
31.000	-	-	-	-	1.11	1.23	1.18	1.40	1.32	1.17	1.21	
23.500	-	-	-	-	1.36	1.34	1.25	1.27	1.14	1.11	1.26	
15.500	-	-	-	-	2.00	2.23	2.09	2.33	1.98	1.90	2.09	Z
7.700	-	-	-	-	3.21	3.13	2.97	3.39	3.11	3.02	3.03	
3.800	-	-	-	-	2.18	2.31	2.17	2.43	2.13	2.15	2.18	
1.900	-	-	-	-	1.45	1.80	1.75	2.10	2.22	1.94	1.75	C
0.100	-	-	-	-	1.97	1.78	1.67	1.94	1.82	1.74	1.67	
Sand(S)	100	100	100	100	85.4	84.4	85.4	82.48	83.06	84.1	84.4	
Silt(Z)	-	-	-	-	10.46	10.97	10.35	11.54	11.64	11.65	11.46	
Clay(C)	-	-	-	-	3.42	3. 58	3.42	4.04	4.04	3.68	3.42	
Total	100	100	100	100	100	100	100	100	100	100	100	

sample is subjected to sieving by ASTM test sieves of 8″ diameter, with successive sieves spaced at ½ ϕ intervals. The grain size data obtained was used to determine the graphic mean (Mz), standard deviation (σ_1), kurtosis (K_G) and skewness (Sk) based on method given by Folk and Ward (1957). For analyzing silt and clay fractions of the samples the instrument, particle size analyzer (Model: Malvern Mastersizer 2000E, UK) was used. From the statistical parameters, frequency curves, bivariant plots and CM diagram were drawn and the data analyzed.

XRD Analysis

The organic matter in the sample was removed using H_2O_2. The sample was then wet-sieved through a 230 (0.063 mm) ASTM sieve and homogeneous suspension was obtained after repeated washing and decanting. The clay fraction was separated from stabilized suspension following the procedure given by Galehouse (1971) and sample was subjected to XRD analysis (Model: Xpert Pro, PANalytical, Europe).

Table 2. Grain size parameters of Gosthani river estuary sediment samples

Estuarine Stations	Sand (%)	Silt (%)	Clay (%)	Sediment Type	Mean Size (Mz)	Standard Deviation (σ_1)	Skewness (S_k)	Kurtosis (k_G)	Remarks			
Station -1	100	-	-	Sand	1.80	0.58	0.27	1.10	MS	MSo	PSk	MKg
Station -2	100	-	-	Sand	1.48	0.52	0.30	0.95	MS	MSo	PSk	MKg
Station- 3	100	-	-	Sand	1.60	0.65	0.21	0.89	MS	MSo	PSk	PKg
Station -4	100	-	-	Sand	1.49	0.70	0.27	0.70	MS	MSo	PSk	PKg
Station -5	85.4	10.46	3.42	Sand	1.93	0.69	0.24	0.88	MS	MSo	PSk	PKg
Station -6	84.4	10.97	3.58	Sand	1.92	0.67	0.22	0.86	MS	MSo	PSk	PKg
Station- 7	85.4	10.35	3.42	Sand	1.93	0.69	0.24	0.88	MS	MSo	PSk	PKg
Station -8	82.48	11.54	4.04	Sand	1.65	0.54	0.26	0.89	MS	MSo	PSk	PKg
Station- 9	83.6	11.64	4.04	Sand	1.80	0.55	0.25	0.99	MS	MSo	PSk	MKg
Station -10	84.1	11.65	3.68	Sand	1.85	0.75	0.21	1.10	MS	MSo	PSk	MKg
Station -11	84.4	11.46	3.42	Sand	1.60	0.70	0.30	0.70	MS	MSo	PSk	PKg

(MS-Medium Sand, MSo-Moderately Sorted, PSk-Positively Skewed, PKg-Platykurtic, MKg-Mesokurtic)

The samples were scanned from 30 to 70° 2θ min-1 on a X-ray diffractometer using Nickel filtered Cu Kα radiation. Major clay minerals were identified following Brindley and Brown (1980), Roy Lindholm (1987). The areas of the principal peaks of the clay minerals Illite (5 Å, 3.3 Å and 10 Å), Kaolinite+Chlorite (3.56 Å and 7.2 Å) Montmorillonite (13-14 Å) and Chlorite (4.7 Å) were measured above the background response using X-ray diffractograms. The XRD data are presented in Table No.3

RESULTS AND DISCUSSION

The textural analysis of the samples from the study area has been carried out and the results are presented in tables 1 and 2. The detailed representation of these textural parameter in terms of frequency curves, grain size analysis, bivariate plots and CM diagrams have been presented and data are analyzed.

Frequency Curves

Frequency Distribution Curves (FDC) exhibit the pictorial representation of weight percentage of different fractions of sediments. FDC are used to describe the nature of sediments. The assemblages of FDC from different stations of the Gosthani estuary are shown in Fig.2. The total samples show unimodal nature and medium sand. The station Nos. 1, 7, 9 and 10 prominent peak shows the size of 1.5 Φ and station Nos. 2,3,4,5,6,8 and 11 shows (2 Φ), with unimodal nature. The sediment here is supplied from a single source, probably mainly from riverine environment.

Grain Size Analysis

The estuarine sediment sample stations 1, 2, 3 and 4 show medium sand. Where as stations 5, 6, 7, 8, 9, 10 and 11 show silt and clay in minute fractions.

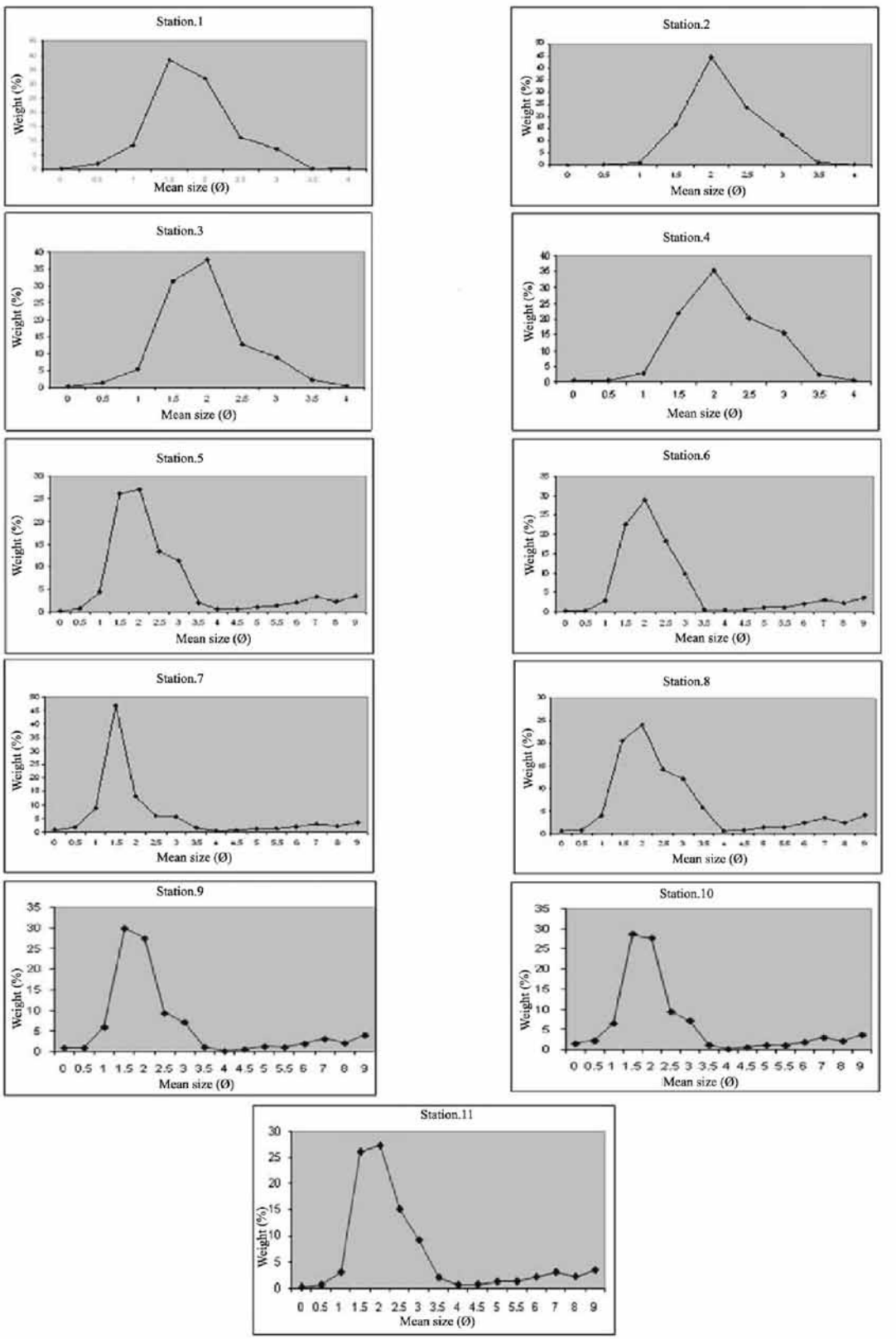

Figure 2. Frequency Distribution Curves (FDC) of sediments in different stations in estuary.

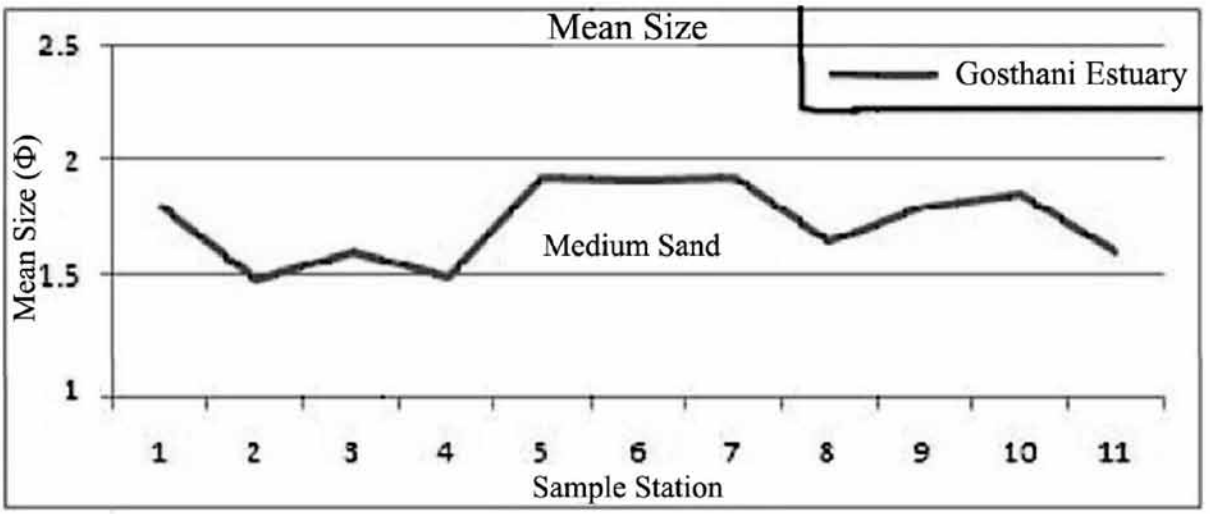

Figure 3. Variogram for Textural Parameter – Mean

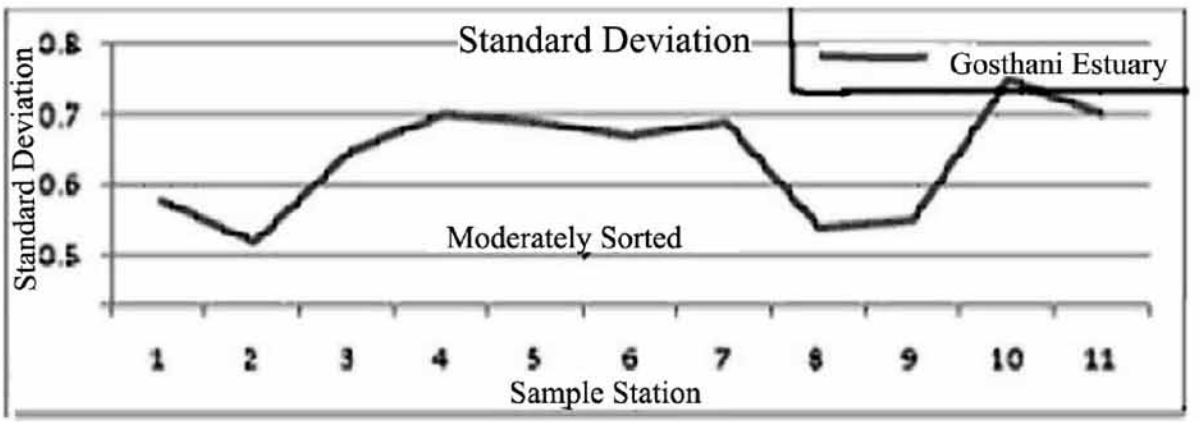

Figure 4. Variogram for Textural Parameter – Standard Deviation

Gosthani estuary sediments are medium grain size, moderately sorted, positively skewed and platykurtic nature. All these samples appear to be deposited under the low energy conditions. The textural parameters of the Gosthani river estuary sediments are shown in Table.2

Mean Size (Mz): The graphic mean size is the average size of the sediments represented by Φ mean size and mainly an index of energy conditions. The values obtained for mean size range from 1.48 Φ to 1.93Φ, with an average value of 1.70 Φ. The average value shows the dominance of medium sand (MS) size sediments and the rest comprises of smaller amounts of silt (Fig.3). The mean size indicates that the medium sand was deposited at a moderate energy conditions. The variations in Φ mean size reveal the differential energy conditions, resulting in their deposition.

Standard Deviation (σ_1): The graphic standard deviation (σ_1) measures the sorting of sediments and indicates the fluctuation in the kinetic energy (Sahu, 1964). Sorting has an inverse relation with Standard deviation. Standard deviation indicates the difference in kinetic energy associated with mode of deposition. Standard deviation of the present samples range in between 0.52 Φ – 0.75 Φ, with an average of 0.63 Φ. The sediments are of moderately sorted nature (Fig. 4). The variations in the sorting values are likely due to continuous addition of finer/coarser materials in varying proportions.

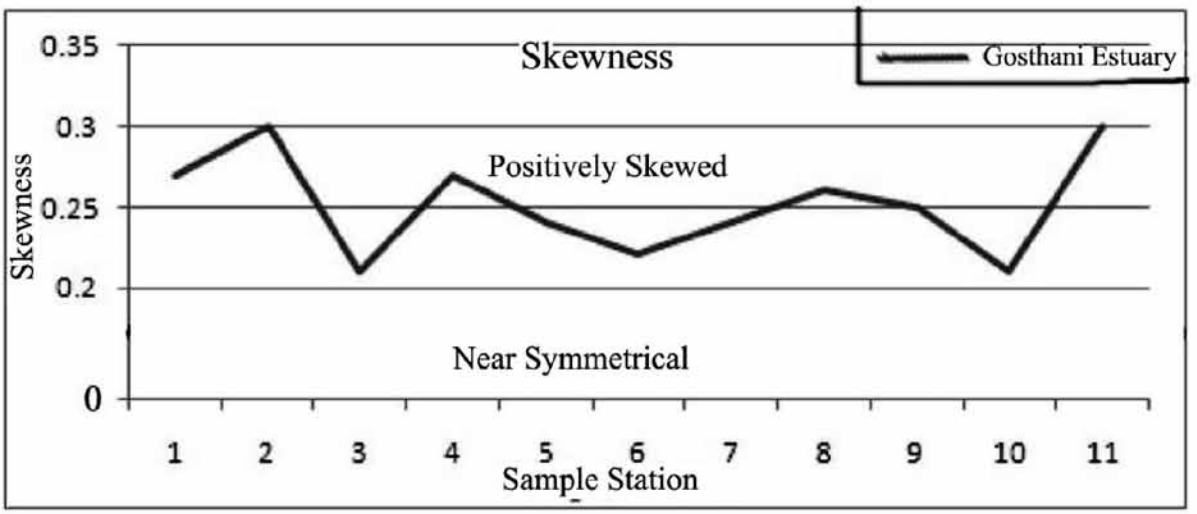

Figure 5. Variogram for Textural Parameter – Skewness

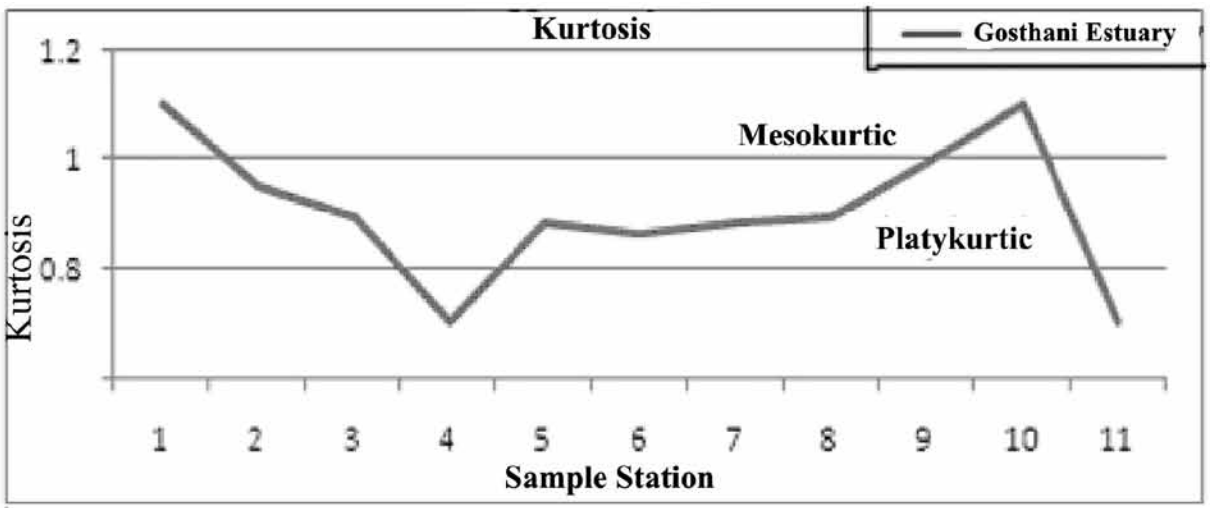

Figure 6. Variogram for Textural Parameter – Kurtosis

Skewness (Sk): The graphic Skewness is the measure of symmetrical distribution, i.e. predominance of coarse or fine sediments. Skewness value ranges in between 0.21 to 0.30 with an average of 0.25. Symmetry of the sample ranges from negative to dominant positive skewness (Fig.5). Strongly fine skewed to fine skewed sediments generally imply the introduction of fine material. Very fine skewed nature of sediments indicates excessive riverine input. Positive skewness of sediments indicates the deposition of the sediments in sheltered low energy, whereas negative skewed sediments indicate deposition at high energy environments (Rajasekhara Reddy et al., 2008).

Kurtosis (K_G): The graphic kurtosis is a quantitative measure used to describe the departure from normality of distribution. It is a ratio between the sorting in 'tails' of the curve to that of the central portion. The value of graphic kurtosis ranges from 0.70 to 1.10, with an average of 0.9. Majority of the samples fall under platykurtic type (Fig.6). Friedman (1962) suggested that extreme high or low values of kurtosis imply that part of the sediment achieved its sorting elsewhere in a high energy environment. The variation in the kurtosis values is a reflection of the flow characteristics of the depositing medium (Seralathan and Padmalal, 1994; Baruah et.al., 1997).

Bivariate Plots

Bivariate plots between certain parameters are also helpful to interpret the energy conditions, medium of transportation, mode of deposition etc. Passega (1957), Visher (1969), Folk and Ward (1957) and others described that these trends and interrelationship exhibited in the bivariate plots might indicate the mode of deposition and in turn aid in identifying the environments. However, Mason and Folk (1958), Friedman (1961) claimed to establish the differentiation between aeolian, beach and river sediments based on these bivariate plots. An attempt has been made here to utilize these bivariate plots in the Gosthani estuary sediments.

The bivariate plot between Mean size and Standard deviation (Fig.7a) of the present samples shows the clustering of values near the extreme end of right limb of inverted V-shaped established trend of Folk and Ward (1957). The nature of the sediments is dominantly unimodal, of which, the dominant constituent is medium sand. The silt is subordinate, making the admixture moderately sorted.

The bivariate plot between Mean size and Skewness (Fig.7b) clearly brings out the values, which fall in the positively skewed area, with a mean size

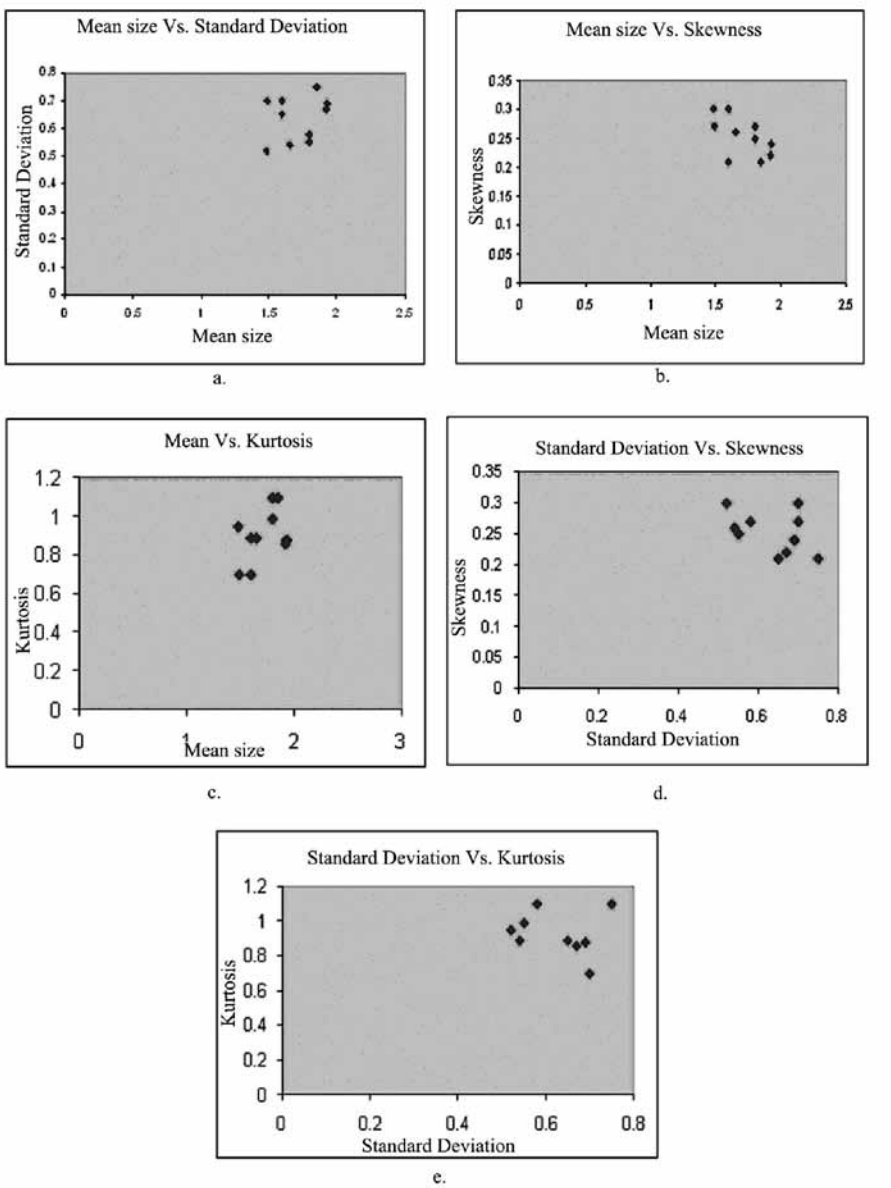

Figure 7. Variogram for Textural Parameter – Kurtosis

range of 1 Φ to 2 Φ. It further indicates a unimodal nature of sediments with higher percentage of medium sand and subordinate silt.

The relation between Mean size and Kurtosis (Fig.7c) values indicates a dominance of platykurtic (0.67 Φ to 0.90 Φ) category followed by mesokurtic (0.90 Φ to 1.11Φ), in the size class range of 1 Φ to 2 Φ i.e. medium sand.

The plot between Skewness and Standard deviation (Fig.7d) shows moderately sorted and positively skewed sediments. The plot shows clustering of grains in 0.50 Φ to 1.0 Φ sector, which establishes the presence of medium type sand.

The plot between Kurtosis and Standard deviation (Fig.7e) shows that the majority of samples are of platy to mesokurtic nature, moderately sorted and of medium sand size.

CM Diagram

The CM pattern of the sedimentary environment help in analyzing transportation mechanism, depositional environment with respect to size, range and energy level of transportation. It also determines process and segregates characteristic agents that are responsible for the formation of clastic deposits. In the present study an attempt has been made to identify the modes of deposition of the sediments of the Gosthani river estuary by CM patterns. Passega (1957) interpreted the distinct patterns of CM plots in terms of different modes of transportation by plotting coarsest first percentile grain size (C) and the median size (M) of sediment samples on a double log paper. Visher (1969) explained the log normal sub populations within the total grain size distribution curve as representing suspension, saltation and surface creep or rolling modes of transportational mechanisms. The relation between C and M is the effect of sorting by bottom turbulence. The good correlation between C, determined by only one percent by weight of the sample, and M, which represents grain size as a whole, shows the precision of the control of sedimentation by bottom turbulence. The results have been plotted in CM diagram (Fig.8). Passega (1964, 1977); Kumar and Singh (1978) have used the grain size parameters and the plots of CM patterns to distinguish between the sediments of different environments.

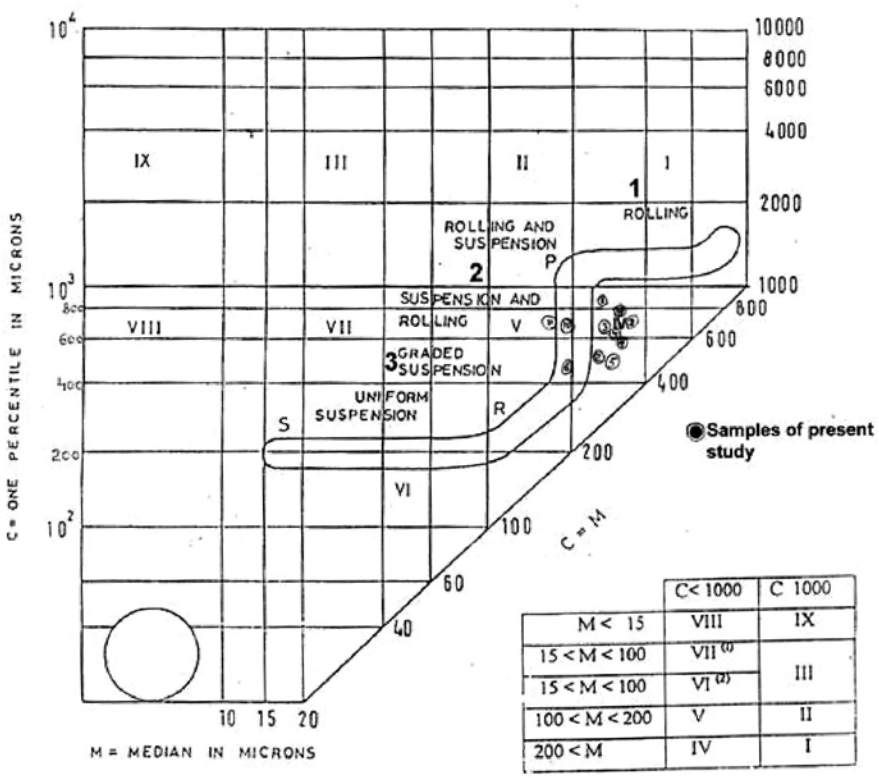

Figure 8. CM pattern of the Sediments of Gosthani River Estuary

Table.3. X-ray Diffraction pattern of Gosthani River Estuary Samples

S.No.	Station No.	D-Spacing (A^0)	Relative Intensity (%)	Name of the clay mineral
1	Station. 1	3.35 3.33 3.66 1.99 5.02 10.3	100.00 13.88 2.25 1.01 1.26 2.23	Illite
		7.17 3.56 1.49	3.19 1.03 1.03	Kaolinite
		14.1 13.6 13.1	0.98 0.60 0.71	Montmorillonite
		3.5	4.06	Chlorite
2	Station. 3	3.33 3.36 5.02 10.0	100.0 10.02 1.26 1.70	Illite
		7.12 3.56 1.49	1.85 1.03 1.43	Kaolinite
		13.80 13.0	0.30 0.70	Montmorillonite
		4.7 4.67 3.5	0.41 1.21 1.03	Chlorite
3	Station. 5	3.34 5.02 10.0	100.0 10.02 1.70	Illite
		3.55 1.49	1.04 1.42	Kaolinite
		14.0 13.2 13.6	0.99 0.78 0.71	Montmorillonite
		4.67 3.5	1.20 4.05	Chlorite
4	Station. 7	3.33 5.02 10.3	100.0 1.25 2.23	Illite
		3.56 1.49	1.02 1.42	Kaolinite
		14.1 13.1 13.6	0.98 0.78 0.70	Montmorillonite
		3.5 4.70	4.05 0.40	Chlorite
5	Station. 9	1.99 5.02 10.3	1.00 1.26 2.22	Illite
		3.56 1.49 7.12	1.01 1.40 1.85	Kaolinite
		14.1 13.1	0.99 0.79	Montmorillonite
		3.5	4.06	Chlorite
6	Station. 11	3.35 3.33 3.66	100.00 13.80 2.24	Illite
		3.56 1.49	1.03 1.43	Kaolinite
		14.1 13.1	0.99 0.79	Montmorillonite
		3.5	4.05	Chlorite

The CM pattern is sub divided into segments, namely, PQ, QR and RS (Passega, 1977). Segment PQ indicates the coarse grains transported by rolling, while QR parallel to line C=M represents the main channel deposits. RS parallel to the M axis indicates the uniform suspension. Points of (1) in the Fig.8 represent deposition from rolling. Points of (2) represent deposition from rolling and suspension. Points of (3) represent deposition from graded suspension with high turbulence. The remaining two samples show graded suspension with low turbulence.

The CM plot at the present study shows that most of the sediment samples fall in the intermediate position between S and Q. This SQ segment exhibits that the Gosthani estuary sediments underwent the rolling and suspension current, which are the prime factors for transportation. The plots occupy the zone of tractive current deposits. Finally, it may be summarized that the sediments were deposited due to rolling and suspension, under tractive current.

CLAY MINERALOGY

The XRD studies revealed that there sediments are characterized by the dominate abundance of illite. In all the samples illite is observed in higher proportions (Table.3). Other minerals like kaolinite, montmorillonite and chlorite are occurring in minor amounts.

The studies carried out by other workers also confirmed this aspect. Murty and Rao (1989) made a detailed study on the clay mineralogy of Visakhapatnam shelf sediments. The study established that the illite is the most abundant clay mineral followed by other clay minerals. Similarly the study by Sarma., et al (1993) on Sarada – Varaha estuary also confirmed illite abundance in the sediments of the area.

Illite in general is a weathering product of metamorphosed pelitic rocks mainly with abundant feldspars (Deer et al, 1975). The hinterland consists of granulitic rocks with abundant khondalites which are mainly composed of minerals like feldspars and mica, perhaps the weathering of which forms the source for the illite as well as other clay minerals of the study area.

CONCLUSIONS

The following conclusions are made:

- The textural parameters indicate that the sediments are of medium grain size, moderately sorted, positively skewed and deposited under moderate to low energy conditions with dominant rolling and suspension mechanisms.
- The variations in mean size indicate differential energy conditions at different locations. Whereas, the variation sorting values indicate continuous addition of finer to coarser material in varying proportions at different locations.
- Frequency Distribution Curves and bivariate plots drawn between different textural parameters clearly established that the sediments are unimodal and composed of mainly medium sand.
- The bivariate plots drawn between textural parameters revealed that the sediments are mainly unimodal with dominate sand fraction with subordinate silt content. These are moderately sorted and of medium sand size. The CM plots indicate that the Gosthani estuary sediments underwent the rolling and suspension under tractive current.
- The study of clay minerals indicates that the illite is the most abundant clay mineral, which is in tune with similar studies carried out by other workers in this area. It is believed the hinterland khondalites are the source for these clay minerals.

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