International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 3 Ver.V || March 2018 || PP62-75

Grain Size Studies of Coastal Sediments of Visakhapatnam to Bheemunipatnam, East Coast of India – Statistical Approach

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Abstract:*The present work aims to address the textural studies of coastal sediments of Visakhapatnam to Bheemunipatnam coast. The textural parameters of beach sub-environments reveals that the sediments are coarse to fine sand, well to moderately well sorted, negatively to positively skewed, meso to leptokurtic in nature. The textural analysis of coastal redsediments reveals that the majority of the sediments are predominantly consists of medium sand, moderately well sorted and positively skewed in nature. The textural parameters of Gosthani estuary sub-environments indicates that the sediments are of medium grain size, moderately well sorted, symmetrical skewed, mesokurtic in nature. C-M diagram shows the most of the foreshore, backshore and Gosthani estuary sediments are deposited by rolling and bottom suspension whereas dune and coastal red sediments are deposited by graded suspension and no rolling.Q-mode factor analysis of grain size data, it is concluded that the sediments of the area are deposited under three different energy conditions. The three factors correspond well with coastal red sediments, beach sediments, Gosthani estuary sediments which corresponds to relatively three different energies of the environments viz., moderate, current energy and medium to low energy environments respectively.*

Key Words*:Grain size study,Beach and Coastal red sediments, Gosthani estuary and Factor Analysis*

Date of Submission: 15-03-2018 Date of acceptance 29-03-2018

I. Introduction

Texture refers to characteristics of the grains and the grain to grain relations among them and is the basic character of the sediments which reveal the valuable information regarding the depositional conditions that are controlled by various physical, chemical and biological forces acting on the sediment before and after their deposition. Grain size analysis, therefore, provides important clues to the sediment provenance, transport history and depositional conditions [1-2].Grain sizes of clastic sediments are important and it can help as an environment indicator, and also be related to the mechanism of sediment transportation. Grain size distribution of sedimentary deposits is related to several factors like local processes of transportation, deposition and the integrated effect of previously active processes that the sediment has undergone within the environment. Several researchers have been worked on the various aspects of the coastal sediments of Visakhapatnam to Bheemunipatnam coast. The coastal red sediments were described as bad lands based on topography[3].It has been referred highlands[4-5]. These sediments are termed as Coastal red sediments [6]. These sediments are in general loosely packed and are separated from the sea by the modern beach and dune sands. During the Holocene period the heavy winds blown particularly during the monsoon period lot of sediment blown to the interior of the present coast to the edge of Eastern Ghats.The coastal red sediments are formed by the cumulative work of both wind and running water[4].It has been considered dune environment for red sediments[5-7] based on the textural analysis. It has been inferred based on textural studies, that the red sediments are formed by the fluvial process[8-9]. Identified various coastal geomorphic features along Visakhapatnam to Bhimunipatnam coast[10].Studied textural and clay mineralogy of the Gosthani estuary [11].Studied the textural characteristics of late Quaternary red sediments of Bhimunipatnam to understand the process of formation of the sediments[12].Q-mode factor analysis applied to grain size data of different sub-environments of Mahanadi delta, East Coast of India[13].There are gaps of knowledge on textural analysis for different environments of the study area. The objective of the study is Characterization of each sub-environment through textural analysis. The study area situated between the Latitudes 17° 72' and 17° 89' N, Longitudes 83° 34' and 83° 45' E, and covers beach sediments from VUDA park to Bheemili, coastal red sediments at INS Kalinga area and Gosthani estuary sub-environments of Bay of Bengal coast of Andhra Pradesh. The location maps of the study area are given in Fig. 1. The geological formations of the study area belong to Archean and Quaternary periods. The Archean rocks comprise mainly khondalites, charnockites, leptynites, pegmatites and quartz veins. Quaternary sediments include laterite and surficial soils and coastal sand deposit

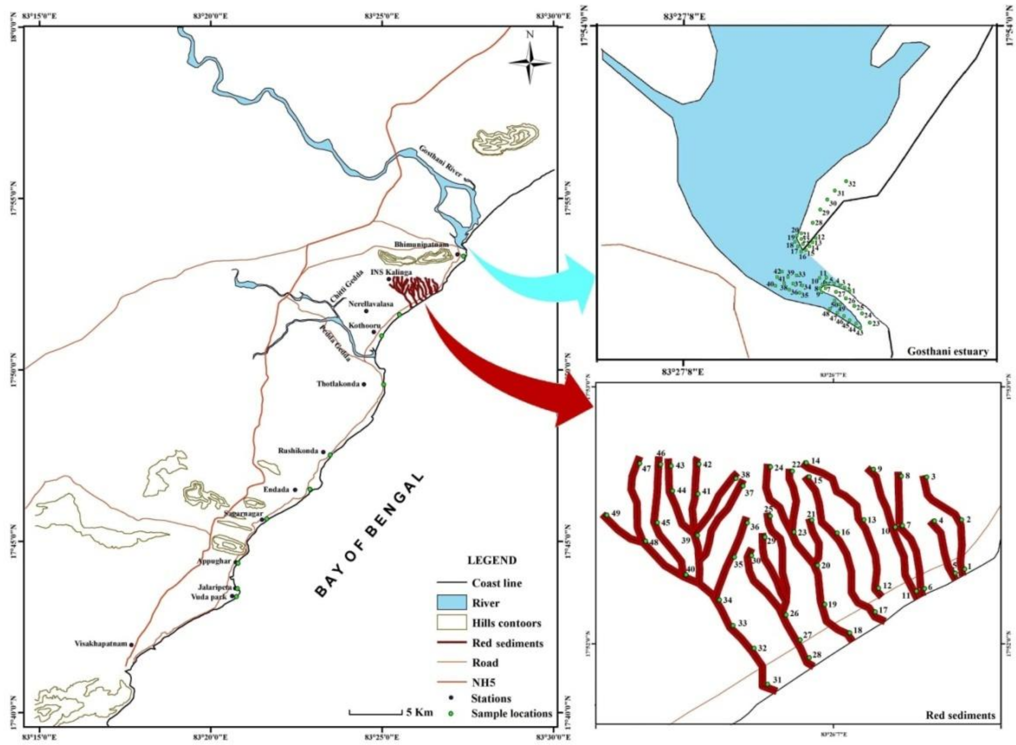

Fig. 1.Location map of the study area.

II. Methodology

One hundred and twenty-nine sediment samples were systematically collected from different sub-environments of beach sediments (30), coastal red sediments (49) and Gosthani estuary (50) from Visakhapatnam to Bheemunipatnam Coast. The beach, barrier bar, swash bar, and estuary bar sediment samples were collected by penetrating a plastic tube to a depth of about 10-15 cm. In the case of coastal red sediments were collected by hand auger from the depths below the root. The back barrier sediment samples of the Gosthani estuary were collected by grab. All the surface sediment samples have been subjected to size analysis by sieving and using Particle Size Analyzer (Master Sizer 2000E). The texture of the sediment was determined and calculated using by a computer program by name “G-Stat” (Grain size Statistics).For Factor analysis,Grain size data of one hundred and twenty nine samples are subjected to Q-mode factor analysis, in order to group the sediments into categories on the basis of variations in grain size distribution and to attach environmental significance to these categories[14]. Statistical analysis is done using Statistica 13.2 software.

III. Results And Discussion

The results of the grain size analyses carried out consisting of beach environments, coastal red sediments and Gosthani estuary sub-environments of grain size parameters are presented in tables Nos. 1, 2 and 3 respectively. Range and average values of grain size parameters of different sub-environments of beach, coastal red and Gosthani estuary sediments are presented in table No. 4. Eigen value, Percent of total variance, cumulative eigen value and cumulative percentage of grain size data - Q-mode analysis are presented in tableNo. 5.

Table 1. Grain size parameters of Beach sub-environments.

S. No.	Location	Mz	SD	Sk	Kw	Sand (%)	Remarks
Foreshore							
1	Vuda park	0.20	0.32	0.31	0.85	100	CS, VWSd, VPSk, PK
2	Jalaripeta	0.37	0.38	0.06	0.80	100	CS, WSd, SySk, PK
3	Appugar	1.30	0.46	0.18	1.04	100	MS, WSd, PSk, MK
4	Sagarnagar	0.57	0.47	0.20	1.11	100	CS, WSd, PSk, LK
5	Rushikonda	0.33	0.37	0.17	0.89	100	CS, WSd, PSk, PK
6	Endada	0.57	0.30	-0.27	1.25	100	CS, VWSd, NSk, LK
7	Thotlakonda	0.72	0.36	-0.12	1.29	100	CS, WSd, NSk, LK
8	Kothooru	1.08	0.50	0.05	1.03	100	MS, WSd, SySk, MK
9	Nerellavalasa	0.81	0.65	0.09	1.18	100	CS, MWSd, SySk, LK

10	Bheemili	1.03	0.37	-0.01	1.16	100	MS, WSd, SySk, LK
Backshore							
11	Vuda park	0.20	0.31	0.29	0.88	100	CS, VWSd, PSk, PK
12	Jalaripeta	0.85	0.39	0.15	1.22	100	CS, WSd, PSk, LK
13	Appugar	0.63	0.26	-0.01	1.13	100	CS, VWSd, SySk, LK
14	Sagarnagar	0.66	0.34	0.14	1.25	100	CS, VWSd, PSk, LK
15	Rushikonda	0.64	0.34	0.20	1.03	100	CS, VWSd, PSk, MK
16	Endada	0.55	0.38	-0.10	1.05	100	CS, WSd, SySk, MK
17	Thotlakonda	0.44	0.26	0.18	1.10	100	CS, VWSd, PSk, MK
18	Kothooru	0.67	0.38	0.08	1.11	100	CS, WSd, SySk, LK
19	Nerellavalasa	1.38	0.59	0.16	1.16	100	MS, MWSd, PSk, LK
20	Bheemili	1.66	0.53	0.30	1.15	100	MS, MWSd, PSk, LK
Dune							
21	Vuda park	0.96	0.30	0.30	1.24	100	CS, VWSd, PSk, LK
22	Jalaripeta	0.93	0.69	0.33	0.97	100	CS, MWSd, VPSk, MK
23	Appugar	1.47	0.49	0.12	1.19	100	MS, WSd, PSk, LK
24	Sagarnagar	1.17	0.47	0.10	1.20	100	MS, WSd, SySk, LK
25	Rushikonda	0.66	0.32	-0.05	1.23	100	CS, VWSd, SySk, LK
26	Endada	1.31	0.49	0.24	1.60	100	MS, WSd, PSk, VLK
27	Thotlakonda	0.80	0.42	0.09	0.88	100	CS, WSd, SySk, PK
28	Kothooru	2.03	0.65	0.04	0.74	100	FS, MWSd, SySk, PK
29	Nerellavalasa	2.09	0.49	-0.10	0.73	100	FS, WSd, SySk, PK
30	Bheemili	1.92	0.62	0.09	0.73	100	MS, MWSd, SySk, PK

Table 2.Grain size parameters of Coastal red sediments.

S. No.	Mz	SD	Sk	Kw	Sand (%)	Remarks
1	1.64	0.55	0.21	1.21	100	MS, MWSd, PSk, LK
2	1.95	0.59	0.21	0.94	100	MS, MWSd, PSk, MK
3	1.48	0.53	0.15	1.24	100	MS, MWSd, PSk, LK
4	1.84	0.63	0.23	0.92	100	MS, MWSd, PSk, MK
5	1.53	0.52	0.18	1.16	100	MS, MWSd, PSk, LK
6	1.60	0.60	0.23	1.30	100	MS, MWSd, PSk, LK
7	1.82	0.57	0.30	0.99	100	MS, MWSd, PSk, MK
8	1.51	0.51	0.29	1.20	100	MS, MWSd, PSk, LK
9	1.63	0.52	0.03	1.15	100	MS, MWSd, SySk, LK
10	1.79	0.62	0.21	1.03	100	MS, MWSd, PSk, MK
11	1.91	0.53	0.01	1.12	100	MS, MWSd, SySk, LK
12	1.23	0.63	0.20	1.14	100	MS, MWSd, PSk, LK
13	1.84	0.44	0.09	1.27	100	MS, WSd, SySk, LK
14	1.72	0.64	0.24	1.07	100	MS, MWSd, PSk, MK
15	1.68	0.50	0.23	1.18	100	MS, WSd, PSk, LK
16	1.51	0.52	0.17	1.22	100	MS, MWSd, PSk, LK
17	1.49	0.53	0.13	1.25	100	MS, MWSd, PSk, LK
18	1.69	0.58	-0.03	1.16	100	MS, MWSd, SySk, LK
19	1.69	0.58	0.22	1.18	100	MS, MWSd, PSk, LK
20	1.77	0.46	-0.04	1.23	100	MS, WSd, SySk, LK
21	1.55	0.44	0.27	1.25	100	MS, WSd, PSk, LK
22	1.79	0.58	0.30	1.17	100	MS, MWSd, PSk, LK
23	1.78	0.54	0.07	1.17	100	MS, MWSd, SySk, LK
24	1.73	0.53	0.25	1.15	100	MS, MWSd, PSk, LK
25	1.88	0.47	0.09	1.15	100	MS, WSd, SySk, LK
26	1.96	0.55	0.12	1.11	100	MS, MWSd, PSk, MK
27	1.65	0.58	0.24	1.18	100	MS, MWSd, PSk, LK
28	1.84	0.50	0.08	1.16	100	MS, MWSd, SySk, LK
29	1.73	0.55	0.19	1.17	100	MS, MWSd, PSk, LK
30	1.60	0.61	0.06	1.02	100	MS, MWSd, SySk, MK
31	1.53	0.59	0.23	1.24	100	MS, MWSd, PSk, LK
32	1.72	0.55	0.22	1.19	100	MS, MWSd, PSk, LK
33	1.68	0.56	0.25	1.24	100	MS, MWSd, PSk, LK
34	1.72	0.55	0.28	1.15	100	MS, MWSd, PSk, LK
35	1.73	0.54	0.27	1.21	100	MS, MWSd, PSk, LK
36	1.81	0.63	0.23	1.07	100	MS, MWSd, PSk, MK
37	1.79	0.60	0.27	1.14	100	MS, MWSd, PSk, LK
38	1.79	0.58	0.22	1.13	100	MS, MWSd, PSk, LK
39	1.49	0.93	-0.30	0.89	100	MS, MSd, VNSk, PK
40	2.95	0.68	-0.37	0.98	100	FS, MWSd, VNSk, MK
41	1.46	1.04	0.07	0.76	100	MS, PSd, SySk, PK

Table 2 Continued.

S. No.	Mz	SD	Sk	Kw	Sand (%)	Remarks
42	1.57	0.50	0.17	1.25	100	MS, WSd, PSk, LK
43	0.60	0.74	0.47	0.89	100	CS, MSd, VPSk, PK
44	1.84	0.66	-0.14	0.96	100	MS, MWSd, NSk, MK
45	1.64	0.62	-0.02	1.06	100	MS, MWSd, SySk, MK
46	1.35	0.81	-0.23	0.68	100	MS, MSd, NSk, PK
47	1.52	0.90	0.01	0.81	100	MS, MSd, SySk, PK
48	2.18	0.57	-0.13	0.90	100	FS, MWSd, NSk, PK
49	2.02	0.48	0.05	1.15	100	FS, WSd, SySk, LK

Table 3. Grain size parameters of Gosthani estuary sub-environments.

S. No	Mz (Ø)	SD	Sk	Kw	Sand (%)	Silt (%)	Remarks
Swash bar							
1	1.75	0.53	0.01	0.90	100	-	MS, MWSd, SySk, PK
2	1.93	0.51	0.00	0.93	100	-	MS, MWSd, SySk, MK
3	1.63	0.66	0.04	0.91	100	-	MS, MWSd, SySk, MK
4	0.74	0.42	-0.12	1.01	100	-	CS, WSd, NSk, MK
5	1.94	0.63	-0.05	0.84	100	-	MS, MWSd, SySk, PK
6	2.31	0.59	-0.48	1.09	100	-	FS, MWSd, VNSk, MK
7	1.36	0.64	0.11	1.18	100	-	MS, MWSd, PSk, LK
8	1.98	0.64	-0.05	0.76	100	-	MS, MWSd, SySk, PK
9	1.59	0.59	-0.01	0.98	100	-	MS, MWSd, SySk, MK
10	1.33	0.47	-0.02	0.95	100	-	MS, WSd, SySk, MK
11	1.35	0.48	-0.01	0.95	100	-	MS, WSd, SySk, MK
12	1.69	0.60	0.03	0.89	100	-	MS, MWSd, SySk, PK
13	1.69	0.54	0.02	0.89	100	-	MS, MWSd, SySk, PK
14	1.59	0.81	0.05	1.09	100	-	MS, MSd, SySk, MK
15	1.08	0.96	0.01	0.82	100	-	MS, MSd, SySk, PK
16	1.44	0.66	0.01	0.93	100	-	MS, MWSd, SySk, MK
17	2.02	0.67	-0.21	0.79	100	-	FS, MWSd, NSk, PK
18	1.55	0.57	0.14	1.10	100	-	MS, MWSd, PSk, MK
19	1.91	0.67	-0.02	0.76	100	-	MS, MWSd, SySk, PK
20	1.85	0.65	0.06	0.82	100	-	MS, MWSd, SySk, PK
21	1.49	0.51	0.20	1.26	100	-	MS, MWSd, PSk, LK
22	1.43	0.55	-0.02	1.01	100	-	MS, MWSd, SySk, MK

Table 3 Continued.

S. No	Mz (Ø)	SD	Sk	Kw	Sand (%)	Silt (%)	Remarks
Barrier bar							
23	1.30	0.44	0.09	1.50	100	-	MS, WSd, SySk, LK
24	1.40	0.55	0.01	0.94	100	-	MS, MWSd, SySk, MK
25	1.32	0.60	0.01	0.94	100	-	MS, MWSd, SySk, MK
26	1.50	0.57	-0.01	1.00	100	-	MS, MWSd, SySk, MK
27	1.43	0.59	0.02	0.94	100	-	MS, MWSd, SySk, MK
28	1.81	0.53	0.01	0.91	100	-	MS, MWSd, SySk, MK
29	1.43	0.79	0.09	0.95	100	-	MS, MSd, SySk, MK
30	1.24	0.65	-0.01	0.98	100	-	MS, MWSd, SySk, MK
31	1.72	0.87	0.04	0.90	100	-	MS, MSd, SySk, MK
32	0.94	0.58	0.05	0.91	100	-	CS, MWSd, SySk, MK
Estuary bar							
33	1.91	0.85	0.09	0.97	99.6	0.37	MS, MSd, SySk, MK
34	1.76	0.51	0.02	0.90	100	-	MS, MWSd, SySk, MK
35	1.66	0.66	0.14	0.98	99.1	0.91	MS, MWSd, PSk, MK
36	1.58	0.55	0.06	0.89	100	-	MS, MWSd, SySk, PK
37	2.01	0.63	0.25	0.81	99.6	0.35	FS, MWSd, PSk, PK
38	2.30	0.56	0.06	1.09	100	-	FS, MWSd, SySk, MK
39	1.65	0.52	0.04	0.89	100	-	MS, MWSd, SySk, PK
40	1.54	0.71	0.13	1.04	99.5	0.53	MS, MSd, PSk, MK
41	1.69	0.52	0.04	0.89	100	-	MS, MWSd, SySk, PK
42	1.76	0.53	0.03	0.91	100	-	MS, MWSd, SySk, MK
Back barrier							
43	2.40	0.70	-0.03	0.92	99.8	0.20	FS, MSd, SySk, MK
44	2.50	0.71	-0.07	0.98	99.6	0.42	FS, MSd, SySk, MK
45	1.82	0.62	0.05	0.90	100	-	MS, MWSd, SySk, MK
46	1.75	0.67	0.06	0.92	100	-	MS, MWSd, SySk, MK
47	1.40	0.59	0.09	1.33	100	-	MS, MWSd, SySk, LK
48	1.19	0.51	-0.02	0.96	100	-	MS, MWSd, SySk, MK
49	1.19	0.57	0.00	1.32	100	-	MS, MWSd, SySk, LK

50	1.44	0.64	0.16	1.24	100	-	MS, MWSd, PSk, LK

Mz: Mean size; SD: Standard deviation; SK: Skewness, Kw: Kurtosis; CS: Coarse Sand; MS: Medium Sand; FS: Fine Sand; VWSd: Very Well Sorted; MWSd: Moderately Well Sorted; MSd: Moderately Sorted; WSd: Well Sorted; VPSk: Positive Skewed; PSk: Positive Skewed; SySk: Symmetrical; NSk: Negative Skewed; VNSk: Very Negative Skewed; PK: Platykurtic; LK: Leptokurtic, MK: Mesokurtic; VLK: Very Leptokurtic

Table .4. Range and average values of grain size parameters of beach sub- environments, Coastal red sediments and Gosthani estuary sub-environment.

Environment	Range	Mean size	Standard Deviation	Skewness	Kurtosis
Foreshore	Min.	1.30	0.65	0.31	1.29
	Max.	0.20	0.30	-0.27	0.80
	Avg.	0.70	0.42	0.07	1.06
Backshore	Min.	1.66	0.59	0.30	1.25
	Max.	0.20	0.26	-0.10	0.88
	Avg.	0.77	0.38	0.14	1.11
Dune	Min.	2.09	0.69	0.33	1.60
	Max.	0.66	0.30	-0.10	0.73
	Avg.	1.33	0.49	0.12	1.05
Coastal red sediments	Min.	0.60	0.44	-0.37	0.68
	Max.	2.95	1.04	0.47	1.30
	Avg.	1.70	0.59	0.13	1.11
Swash bar	Min.	0.74	0.42	-0.48	0.76
	Max.	2.31	0.96	0.20	1.26
	Avg.	1.62	0.61	-0.02	0.95
Barrier bar	Min.	0.94	0.44	-0.01	0.90
	Max.	1.81	0.87	0.09	1.50
	Avg.	1.41	0.62	0.03	1.00
Estuary bar	Min.	1.54	0.51	0.02	0.81
	Max.	2.30	0.85	0.25	1.09
	Avg.	1.79	0.60	0.09	0.94
Back barrier	Min.	1.19	0.51	-0.07	0.90
	Max.	2.50	0.71	0.16	1.33
	Avg.	1.71	0.62	0.03	1.07

Distribution of sedimentary facies

The triangular diagram (Figs. 2 to 4)exhibits only one sedimentary facies for beach environments (foreshore, backshore, and dune), coastal red sediments and Gosthani estuary sub-environments (swash bar, barrier bar, estuary bar and back barrier) and all environments are composed of sandy sediments.

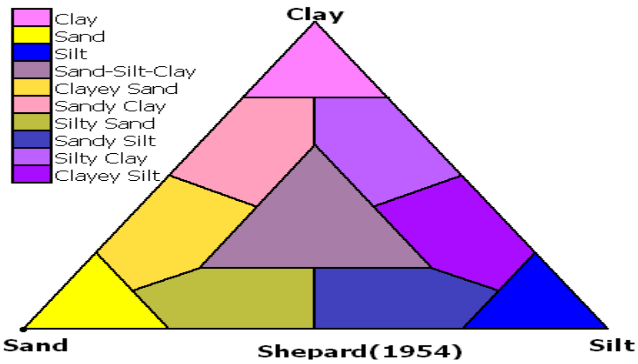

Fig.2. Sediment classification after Shepard (1954) with sand content for the beach environment (foreshore, backshore, and dune).

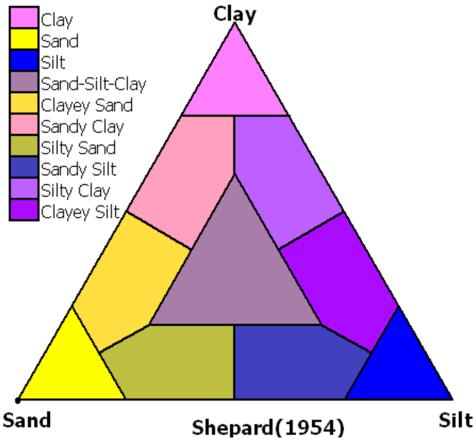

Fig. 3.Sediment classification after Shepard (1954) with sand content for the coastal red sediments.

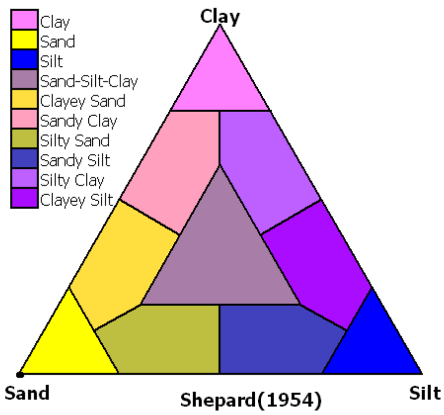

Fig. 4. Sediment classification after Shepard (1954) with sand content for Gosthani estuary sub-environments.

Grain size parameters of different sub-environments
Beach sub-environments

The most dynamics of all marine environments are at the intersection of sea and land – beaches [15]. Beaches are shaped and produced by wave processes. They constantly change at rates dependent upon individual waves, different tides, different seasons, and different years. Beach is an accumulation of unconsolidated sediments from mean low tide to a physiographic change, such as a dune field[15].Variation in beach profile that reflects these changing conditions.Distinguishes four zones within the near shore environments, from landward to seaward and are classified as backshore, foreshore, inshore and offshore[16].

Foreshore

The foreshore sediments comprise of coarse sand to medium sand (with mean size ranging from 0.20 to 1.30 Ø; av. 0.70Ø), which are very well sorted to moderately well sorted (the standard deviation values ranging from 0.30 to 0.65 Ø; av. 0.42 Ø), negative skewed to very positively skewed (skewness varies from-0.27 to 0.31 Ø; av. 0.07 Ø), and platykurtic to leptokurtic in nature (kurtosis values vary from 0.80 to 1.29 Ø; av. 1.06 Ø).The forshore sediments of Endada and Thotlakondashow the negative skewness and coarse sands. It is well known that the foreshore sands are more negatively skewed than that of the adjacent dunes and backshore. The continuous removal of the fine material from the foreshore either towards sea by waves and/or towards land by winds result in the negative skewness of the foreshore sediments. However, most of the sediments show positive skewness perhaps due to the less intense wave/wind action on such parts of the beach.

Backshore

The backshore is a part of the beach that is covered by water only during storms and thus is above normal high tide. The backshore sediments comprise of coarse sand to medium sand (with mean size ranging from 0.20 to 1.66 Ø; av. 0.77 Ø), which are very well sorted to moderately well sorted (the standard deviation values ranging from 0.26 to 0.59 Ø; av. 0.38 Ø), symmetrical to positive skewed (skewness varies from -0.10 to 0.30 Ø; av. 0.14 Ø), and platykurtic to leptokurtic in nature (kurtosis values vary from 0.88 to 1.25 Ø; av. 1.11

Ø).Backshore is the part of the beach that is exposed most of the time to the onshore winds. The winds regularly carry the finer sediments from the exposed parts of the foreshore during low tides to the backshore and from backshore to the inland areas to form sand dunes. The winds having velocities greater than the threshold velocity (9 m/h) are capable of initiating transport of sand size sediment and moving it while the winds stronger than 14.50 m/h move grains greater than 1 mm [17].Positive skewness of the backshore sands shows depositional tendency.

Dunes

Sand dunes are an accumulation of sand shaped by the wind usually in the form of a round hillock. Any mound or ridge of sand with a crest or definite summit is called a dune[18]. Dunes are most likely to develop in areas with strong winds. The classification of dunes can be understood as transverse, crescent and parabolic shaped[19]. The material for the formation of these dunes is essentially derived from the present day beach extending from foreshore to backshore. The most characteristic feature of these dunes is the vegetative cover.Thedune sediments comprise of coarse sand to fine sand (with mean size ranging from 0.66 to 2.09 Ø; av. 1.33 Ø), which are very well sorted to moderately well sorted (the standard deviation values ranging from 0.30 to 0.69Ø; av. 0.49 Ø), symmetrical to very positive skewed (Skewness varies from -0.10 to 0.33 Ø; av. 0.12 Ø), and platykurtic to very leptokurtic in nature (kurtosis values vary from 0.73 to 1.60 Ø; av. 1.05 Ø). The most of the dune sediments are medium sand, moderately well sorted, symmetrical skewed and mesokurtic nature. Fine sand and positive skewed nature is noticed at Kothooru and Nerellavalasa in dune sediments. This is expected as the dunes are formed due to the deposition of sands by prevailing wind action. The positive skewness of the sediments can be due to the addition of fine particles and/or removal of coarser particles[1].The positive skewness here is attributed to the addition of the fine particles.

Coastal red sediments

The coastal red sediments with bad land topography and an area comprising deeply gullied nature abundantly occur near to the INS Kalinga area. It is bounded by streams Chittigadda in the North-West and Peddagaddain the South-West.Today the coastal red sediments are one of the only three such existing formations in South East Asia, the other two being in Tamil Nadu (Teri Sands), India, and Sri Lanka. The rare natural wonder near INS Kalinga area, which took lot of time to produce these sediments, is about 10 km^2 from the backshore zone to 2.5 km inland and elevation is up to 90 m above Mean Sea Level (MSL).The coastal red sediments comprise of coarse sand to fine sand (with mean size ranging from 0.60 to 2.95 Ø; av. 1.70 Ø), well sorted to poorly sorted (the standard deviation values ranging from 0.44 to 1.04 Ø; av. 0.59 Ø), very negative skewed to very positive skewed (skewness varies from -0.37 to 0.47 Ø; av. 0.13 Ø),and platykurtic to leptokurtic in nature (kurtosis values vary from 0.68 to 1.30 Ø; av. 1.11 Ø). The negatively skewed grain size curves are indicative of areas of erosion or non-deposition, whereas positively skewed curves indicate deposition[20-21].The textural analysis reveals that the majority of the coastal red sediments are predominantly consists of medium size sand, moderately well sorted and positively skewed nature. In the light of skewness patterns, it is concluded that the coastal red sediments were laid down in a depositional environment.

Gosthani estuary sub-environments

An estuary has been defined as a semi-enclosedcoastal body of water freely connected to the ocean and within which sea water is measurably diluted with freshwater from the land[22]. Sources of estuarine sediment include rivers, the sea floor, and the adjacent shoreline. However, river sediment input is by far the most important source in most of the estuaries. Gosthani River is an East flowing young seasonal river which mainly flows in the rainy season the flow reduces gradually in the summer. The sea water intrusion at the river mouth is drastically changing due to discontinuous river flow. So river depth at the mouth is dominated by the tidal action. Due to pendulum effect, the river mouth is changing for every season. The Gosthani estuary consists of following sub-environments, swash bar, barrier bar, estuary bar and back barrier etc. Swash bars are low broad sandy bars formed by sediment in the surf and swash zones, separated by linear depressions, running parallel to the shore. The coastal wave dynamics and the seasonal changes in the position of swash bar in relation to the coast are important parameters to influence the textural characters. Barrier bars are exposed sandbars that may have formed during the period of the high-water level of a storm or during the high-tide season. During a period of lower mean sea level they become emergent and are built up by swash and wind-carried sand; this causes them to remain exposed. The estuary bar is open to sea throughout the year. The tapering of the estuary bar on both ends is the result of tidal and fluvial forces operating in opposite directions. The position of the estuary mouth changes due to sand bar formation and amount of flow of freshwater during monsoon months. Back barrier a narrow, elongate, intertidal, sloping landform that is generally parallel with the shoreline located on the lagoon or estuary side of the barrier island, or spit.

The **swash bar** sediments comprise of coarse sand to fine sand (with mean size ranging from 0.74 to 2.31 Ø; av. 1.62 Ø), which are well sorted to moderately sorted (the standard deviation values ranging from 0.42 to 0.96 Ø; av. 0.61 Ø), very negative skewed to positive skewed (skewness varies from -0.48 to 0.20 Ø, av. -0.02 Ø), platykurtic to leptokurtic in nature (kurtosis values vary from 0.76 to 1.26 Ø, av. 0.95 Ø).The above grain size parameters clearly indicate that negative skewness has relationship with the intensity and duration of high energy depositional agent through a removal of fines (swash and backwash) of a high energy conditions. However, positive skewness perhaps due to the less intense wave action/wind on such parts of the swash bar.

The **barrier bar** sediments comprise of coarse sand to medium sand (with mean size ranging from 0.94 to 1.81 Ø; av. 1.41 Ø), which are well sorted to moderately sorted (the standard deviation values ranging from 0.44 to 0.87; av. 0.62 Ø), symmetrical skewed (skewness varies from -0.01 to 0.09 Ø, av.0.03 Ø), mesokurtic to leptokurtic in nature (kurtosis values vary from 0.90 to 1.50 Ø, av. 1.00 Ø).The majority of the barrier bar sediments are medium sand, moderately well sorted and symmetrical Skewness, it indicate that the deposited at a moderate energy conditions. The kurtosis value indicates that the sediments are meso to leptokurtic nature. This indicates the concentration of one dominant and other subordinate population.

The **estuary bar** sediments comprise of medium sand to fine sand (with mean size ranging from 1.54 to 2.30 Ø; av. 1.79 Ø), which are moderately well sorted to moderately sorted (the standard deviation values ranging from 0.51 to 0.85 Ø; av. 0.60 Ø), symmetrical to positive skewed (skewness varies from 0.02 to 0.25; av. 0.09 Ø), platykurtic to mesokurtic (kurtosis values vary from 0.81 to 1.09 Ø; av. 0.94 Ø) in nature.

The **back barrier** comprise of medium sand to fine sand (with mean size ranging from 1.19 to 2.50 Ø; av. 1.71 Ø), which are moderately well sorted to moderately sorted (the standard deviation values ranging from 0.51 to 0.71 av. 0.62 Ø), symmetrical to positive skewed (skewness varies from -0.07 to 0.16; av. 0.03 Ø), mesokurtic to leptokurtic in nature (kurtosis values vary from 0.90 to 1.33; av. 1.07 Ø).

The estuary bar and back barrier sediments are medium to fine sands. These sediments are better sorted than very fine sediments[1]. A moderately well sorted and symmetrical skewness of estuarine bar sediments shows that there is a fair amount of variability among the diameters of their particles. This means that the sediments are matured to a reasonable extent and the particles have been transported quite far away from its source. Few sediment samples of estuary bar and back barrier environments shows positive Skewness,it indicates that the unidirectional transport (channel) or the deposition of sediments in sheltered low energy environment[23-25]. These sediments were generally mesokurtic close to the mouth.

The average grain size is higher in foreshore (0.70 Ø), and backshore (0.77Ø) sediments are coarse sand when compared to dune (1.334 Ø), barrier bar (1.409 Ø), swash bar (1.620 Ø), coastal red sediments (1.698 Ø), back barrier (1.709 Ø), and estuary bar (1.786 Ø) are medium sand.

Backshore (0.38Ø), foreshore (0.42Ø) and dune (0.49Ø) sediments are better sorted (well sorted) than the coastal red sediments (0.59Ø), estuary bar (0.60Ø), swash bar (0.61Ø), barrier bar (0.62Ø), and back barrier (0.62Ø) sediments (Moderately well sorted).

Swash bar (-0.02Ø), barrier bar (0.03Ø), back barrier (0.03Ø), foreshore (0.07Ø), and estuary bar (0.09Ø) shows near symmetrical while dune (0.12Ø), coastal red sediments (0.13Ø) and backshore (0.14Ø) show positively skewness.

Estuary bar (0.94Ø), swash bar (0.95Ø), barrier bar (1.00Ø), dune (1.05Ø), foreshore (1.06Ø), back barrier (1.07Ø), backshore (1.11Ø) and coastal red sediments (1.11Ø) shows mesokurtic nature.

C-M Diagrams of different sub-environment

The C-M diagrams (Fig. 5 and 6) of **foreshore** sediments show two fields created by two different depositional conditions. Field I correspond mostly with basic C-M pattern III[26]. This field represent the tractive current deposition and most of these sediments deposited by rolling whereas at Appugar sediments are transported by bottom suspension and rolling; The C-M diagrams (Fig. 7 and 8) of **backshore** sediments are deposited by rolling whereas at Bheemili and Nerellavalasa sediments are deposited by bottom suspension and rolling ; The C-M diagrams (Fig. 9 and 10) of **dune** sediments are deposited by graded suspension and no rolling at Nerellavalasa, Kothooru and Bheemili. Whereas at Appugar, Endada and Sagarnagar dune sediments are deposited by bottom suspension and rolling.

The C-M diagrams (Fig.11 and 12) of most of the **coastal red sediments** are deposited by graded suspension and bottom suspension and rolling, except sample no. 43 transported by rolling mechanism.

The C-M diagrams (Fig.13to16) of **Gosthani estuary sub-environments** of swash bar, barrier bar, back barrier, and estuary bar sediments are deposited by bottom suspension and rolling, few sediment samples fall under graded suspension and no rolling.

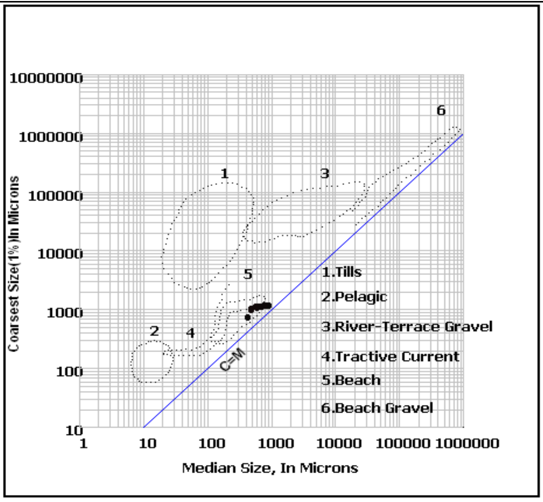

Fig. 5. CM pattern of foreshore.

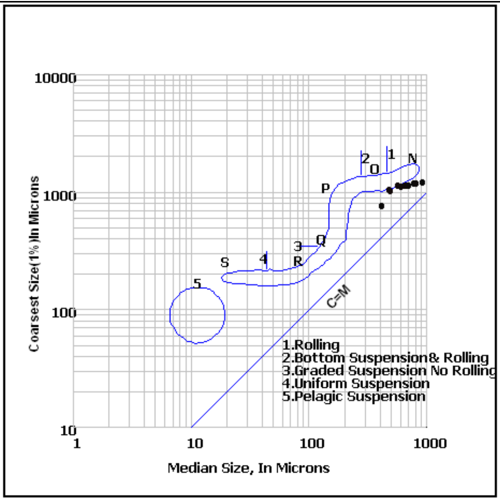

Fig. 6. Complete CM pattern of tractive current deposits of foreshore.

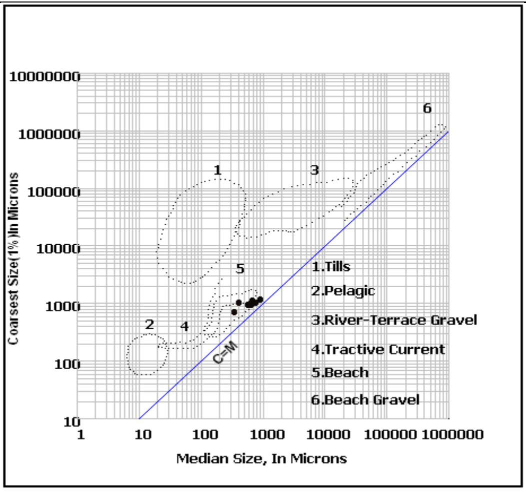

Fig. 7. CM pattern of backshore.

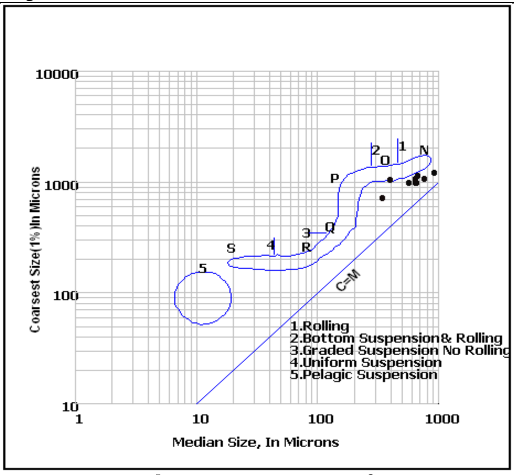

Fig. 8. Complete CM pattern of tractive current deposits of backshore.

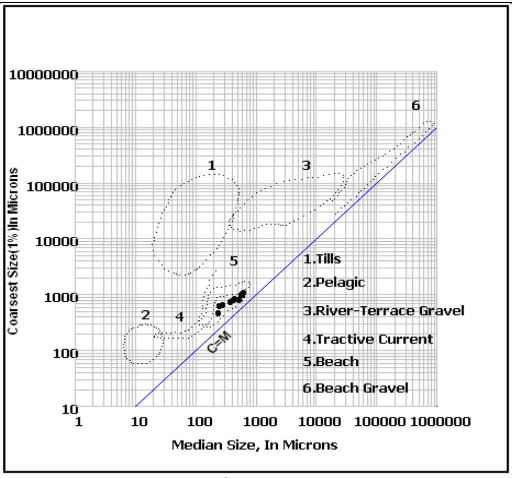

Fig. 9. CM pattern of dune.

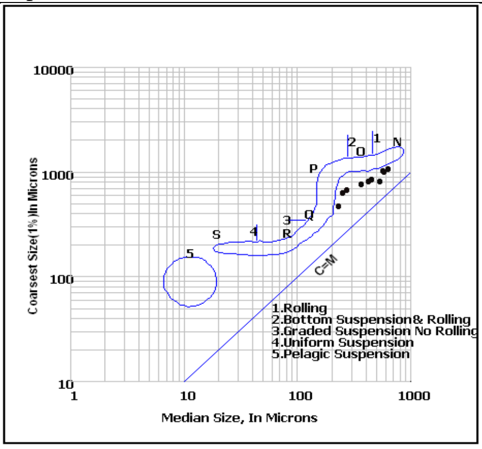

Fig. 10. Complete CM pattern of tractive current deposits of dune.

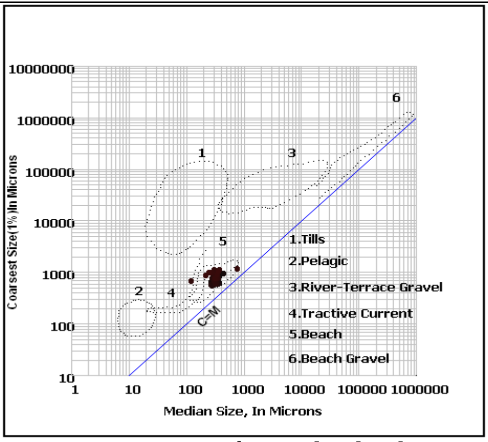

Fig. 11. CM pattern of coastal red sediments.

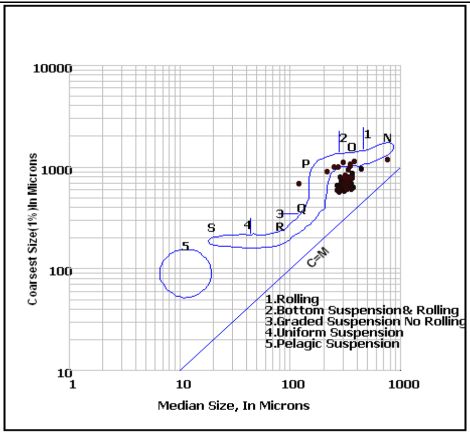

Fig. 12. Complete CM pattern of tractive current deposits of coastal red sediments.

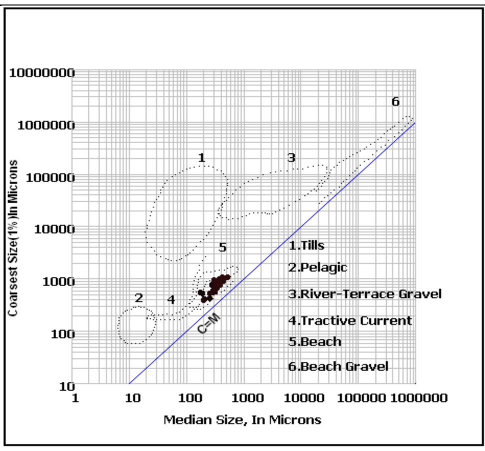

Fig. 13. CM pattern for mixed sediment of Gosthani estuary sub-environments.

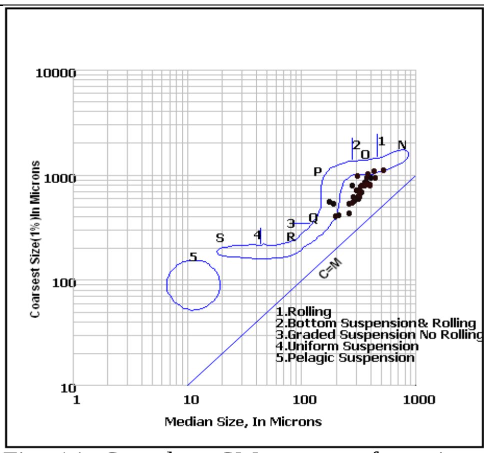

Fig. 14. Complete CM pattern of tractive current deposit for mixed sediments of Gosthani estuary sub-environments.

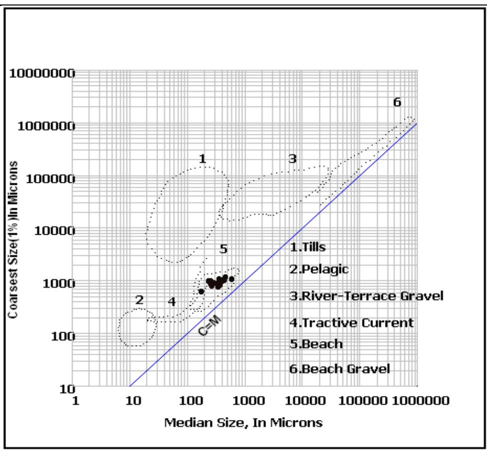

Fig. 15. CM pattern for sandy sediments of Gosthani estuary sub-environments.

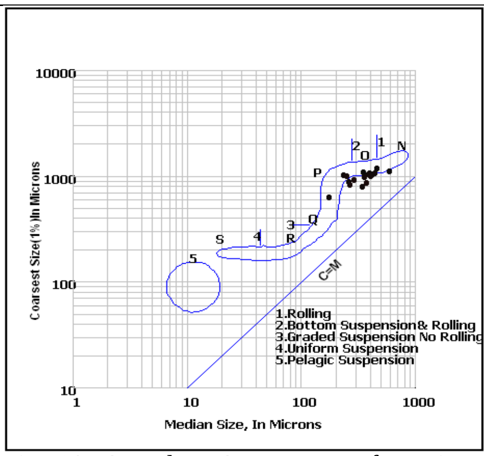

Fig. 16. Complete CM pattern of tractive current deposit for sandy sediment of Gosthani estuary sub-environments.

Factor Analysis

Factor analysis is a process of grouping empirical data into meaningful facies or factors, which can then be interpreted in their geological context. The chief advantages of factor analysis are the objectivity with which the facies or factors are derived and the speed with which a large mass of data can be treated.Table 5 shows the eigen values, the percentage of total variance, cumulative eigen value and cumulative percentage obtained from Q-mode analysis of one hundred and twenty-ninesamples.First three factors account for 100 % of the information; hence these three factors were selected to describe adequately the grain size variations in these samples. The rotated factor matrix of factor loadings of 129 samples, their communalities and the normalized data of each factor is calculated. Most of the samples have very high communality indicating a good description of them by the use of only three factors.

Table 5. Eigen value, Percept of total variance, cumulative eigen value and cumulative percentage of grain size data - Q-mode analysis.

Value	Eigen value	% Total Variance	Cumulative Eigen value	Cumulative %
1	88.40851	68.53373	88.4085	68.5337
2	33.71191	26.13327	122.1204	94.667
3	6.87958	5.33301	129	100

Figures 17 and 18 show normalized factor components and the statistical parameters of some of the samples. As many samples fall in the corner representing Factor I, II & III (Fig. 17), only a few are shown in figure 18 for clarity. The diagram shows predominantly samples fall at the corner of Factor I, and next followed by Factor II, A number of samples fall along the edges between the Factors I and III and very few samples fall along the edges between Factors II and III.The samples occurring nearest to the corners are “end member” samples and the samples occurring in between them can be considered as mixtures of these end member samples, which indicate that there are three different situations in the study area in which many samples occur while some others show the mixing or transition from one to the other.

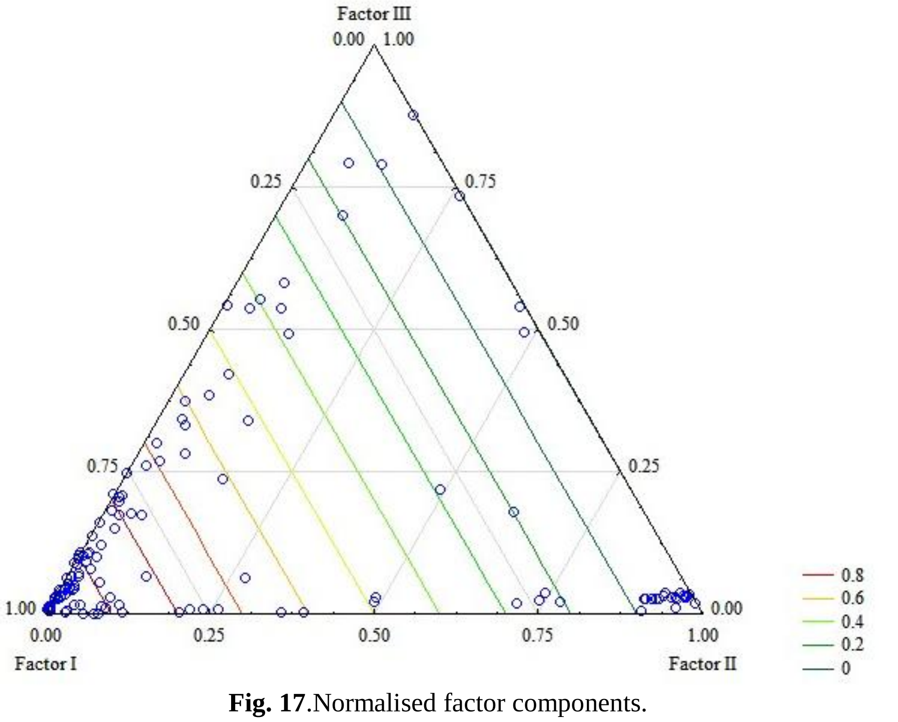

Fig. 17.Normalised factor components.

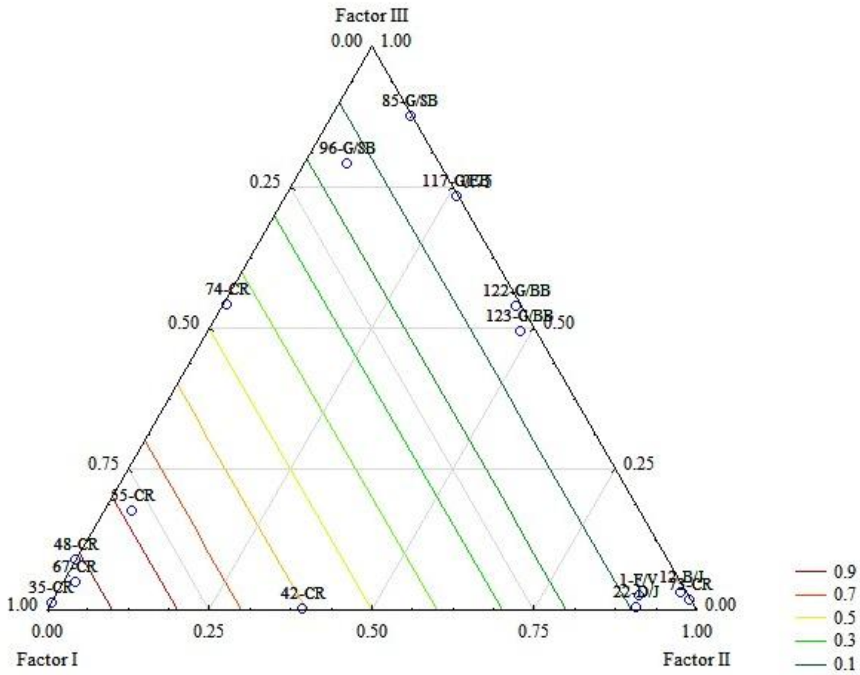

Fig. 18.Normalised factor components and the associated grain size parameters

The study of grain size statistical parameters and size frequency curves drawn on probability paper.**From Factor I to II** (Fig. 19) the end member sample no.35-CR is medium sand with moderately sorted and positively skewed and another end member sample no. 73-CR is coarse sand with moderately sorted and very positively skewed. While middle members sample no. 128-G/BB is medium sand and moderately well sorted with symmetrical nature, sample no.42-CR is medium sand with moderately well sorted and positive skewed and sample no. 76-CR is medium sand and moderately sorted with negative skewed.

From Factor II to III (Fig. 20) the end member sample no. 73-CR is coarse sand with moderately sorted and very positively skewed and another end member sample no. 85-G/SB is fine sand with moderately well sorted and very negative skewed. While middle members sample no.12-B/J is coarse sand with well sorted and positive skewed, sample no.122-G/BB is fine sand with moderately sorted and symmetrical, and sample no. 117-G/EB is fine sand with moderately well sorted and symmetrical.

From Factor I to III (Fig. 21) the end member sample no. 35-CR is medium sand with moderately sorted and positively skewed and another end member sample no. 85-G/SB is fine sand with moderately well sorted and very negative skewed. While middle members sample no. 125-G/BB shows medium sand with moderately well sorted and symmetrical, sample no. 74-CR shows medium sand and moderately well sorted with negative skewed, and sample no. 96-G/SB shows fine sand and moderately well sorted with negative skewed.

The trends observed on the factor plots are simply the end results of a data reducing techniques. Their orderliness is illustrated by systematic variations of the grain size frequency curves and suggests some underlying casual influences which are responsible for the pattern.

Factor I predominantly consists of medium sizes sand samples, Factor II consists of coarse sand samples and Factor III consists of fine sand samples. This indicate that there are three different energy conditions in the study area in which many samples occur while some others show the mixing or transition from one to the other.The majority of the Factor I sediment samples are predominantly consists of medium size sand, moderately well sorted and positively skewed nature. In the light of skewness patterns, it is concluded that these sediments were laid down in a depositional environment. The positive skewness of sediments indicates deposition was either by wind or river agents**[25].**Factor II samples are coarser (lower Ø values), better sorted, negative skewed to positive skewed and mesokurtic to leptokurtic, which indicates that they were deposited in a high energy environment where there is a reworking and winnowing fine. It can probably be expected that surf zone of a beach would produce such a distribution. Then factor II represents current energy.Few samples fall at the Factor III and these are medium to fine size sand samples, moderately well sorted and symmetrical to positively skewed. Factor III has medium to low energy environment compare than Factor I and Factor II.

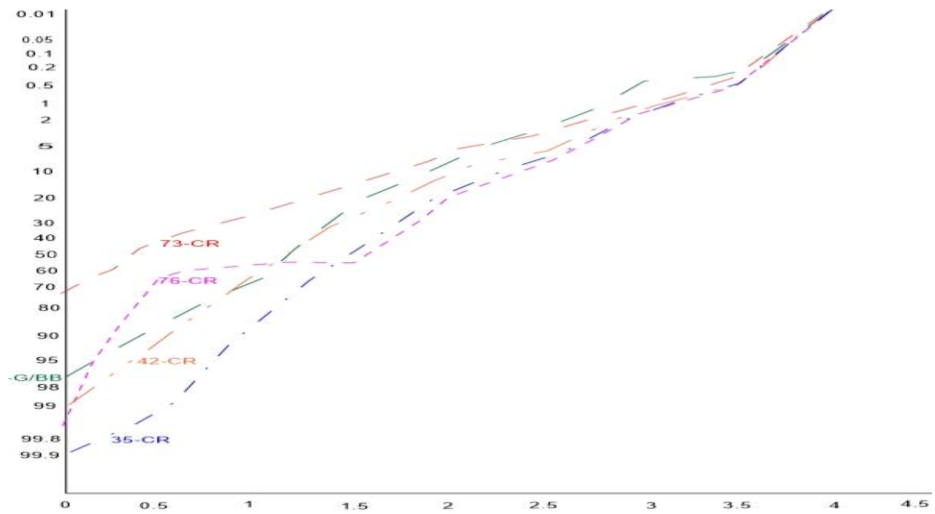

Fig. 19. Grain size distribution curves for samples on trend from sample 35-CR to 73- CR.

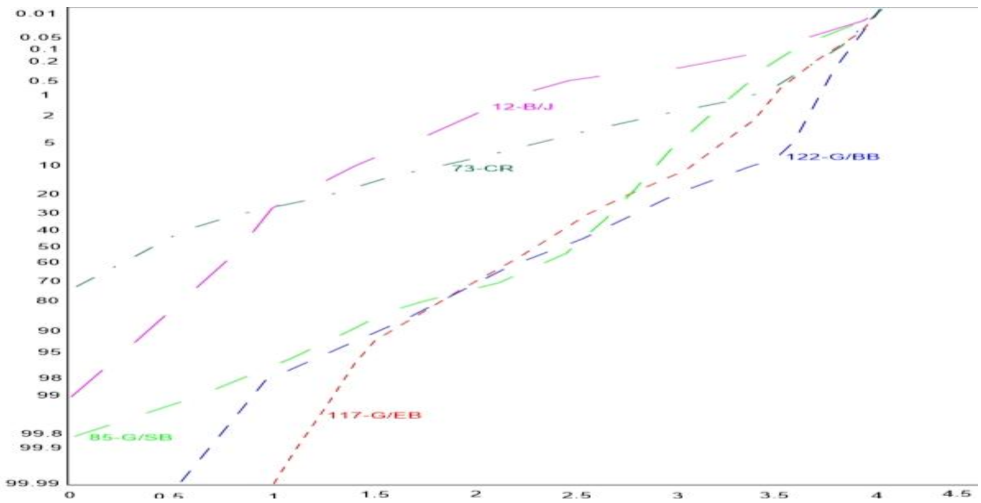

Fig.20. Grain size distribution curves for samples on trend from sample 73-CR to 85- G/SB.

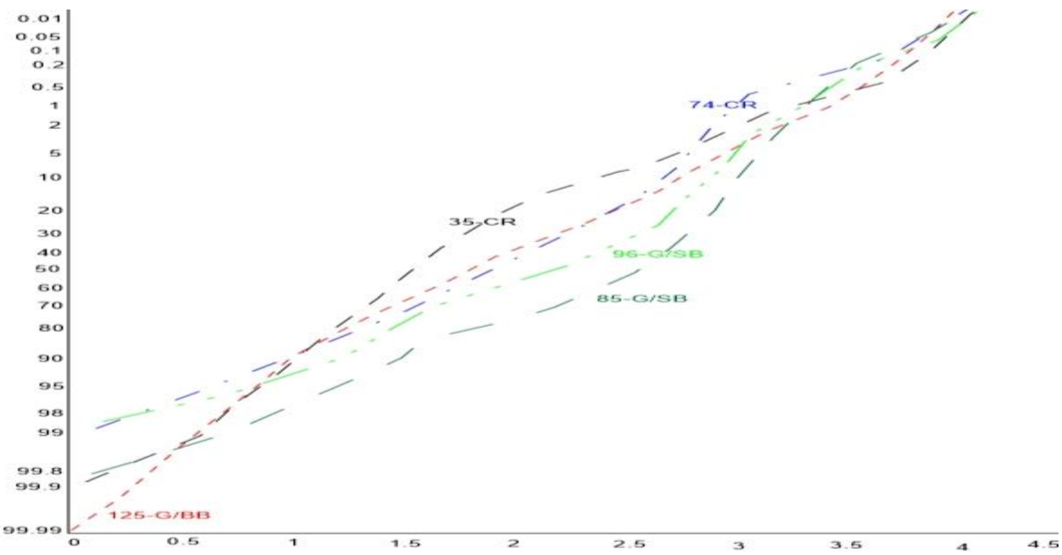

Fig. 21. Grain size distribution curves for samples on trend from sample 35-CR to 85- G/SB.

IV. Conclusions

Coarser grain size and negative skewness indicates relatively the higher energy while finer grain size and positive skewness indicates the low energy of the environment of deposition. Well sorting of the sediments indicate uniform and continuous energy of the environment acting on the sediments. Q-mode factor analysis of grain size data it is concluded that the sediments of the area are deposited under three different energy conditions. The three factors correspond well with coastal red sediments, beach sediments, Gosthani estuary sediments which corresponds to relatively three different energies of the environments viz., moderate, current energy and medium to low energy environments respectively.

Acknowledgement

We are thankful to Prof. C.V. Raman, former Director, Delta Studies Institute and former principal, College of Science and Technology, Andhra University for guidance and extending the lab facilities to carry out this research work.

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G. APPA RAO "Grain Size Studies of Coastal Sediments of Visakhapatnam to Bheemunipatnam, East Coast of India – Statistical Approach"International Journal of Engineering Science Invention (IJESI), vol. 07, no. 03, 2018, pp62-75