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Seasonal variation in Textural Analysis of Coastal sediments Ratnagiri district, West Coast of Maharashtra, India: Implications on Depositional Sedimentary Environment

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ABSTRACT
The seasonal variations (pre and post-monsoon)in textural parameters were studied from Harnai to Kolthare coast, Ratnagiri district, West coast of Maharashtra, India. Textural analysis reveals the environmental and the dynamical processes that have acted on the collected sediment samples. It helps to understand the hydrodynamic conditions prevalent along the coastal areas. Seasonal characterization has been carried out on detrital sediments at the foreshore, backshore, raised marine terraces and coastal dunes. During pre-monsoon foreshore, backshore and raised marine terrace sub-environments are abundance of very fine to medium sand which is well sorted to poorly sorted which shows the prevalence of high energy conditions. The grains are fine to strongly coarse skewed and very platykurtic to very leptokurtic in nature. The raised marine terrace sediments are very platykurtic to mesokurtic. Majority of the sediments are very fine sand with well sorted grains in Harnai, Palande, Murud and Karde locations. In post-monsoon season foreshore sediments are fine to very fine sand which are well sorted to moderately well sorted. They are very fine to coarse skewed and are mesokurtic to leptokurtic in nature. The backshore sediments are very fine to coarse sand, being well sorted to poorly sortedindicates high wave energy condition of SW monsoon. During the SW monsoon, the west coast of India experiences high wave activity. The bivariate plots reveal the samples belong to the beach environment with limited mixing of riverine flux. Linear discriminant function (LDF) analysis of the samples indicates a beach and shallow marine deposition environment. CM diagram suggests that deposition takes place by few samples are mixtures of rolled grains and suspension process, while remaining samples are deposited by graded suspension no rolling. The sediment samples fall predominantly in the tractive current and beach environment from pre and post-monsoon season.The wave and currents operating along Harnai to Kolthare seems to be energized during SW monsoon and has dissipated its energy post-monsoon.The study will help in better management of the western coastal region of India.

***Keywords* -**Coastal sediments,CM plots, Statistical parameters, Sedimentary environment, Textural Analysis, West coast of India

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I. INTRODUCTION

Textural analysis can be used for depict depositional sedimentary environments, transport process, sediment provenance and wave energy conditions [1, 2, 3, 4]. The grain size in different sub-environments of a beach are indicative of different forces acting on the sediments, the statistical analysis of which helps to identify the sedimentary environments. Mean size, sorting and skewness are the most useful parameters to describe the sediments [1, 5]. The grain size statistics can also be used to delineate high and moderate energy environments [6]. The textural characteristics of beach sediment have been studied in the past by a number of researchers, especially along the east and west coast of India [7, 8, 9, 10, 11, 12, 13, 14]. According to [15], presented the textural characteristics of foreshore sediments along Karnataka coast, India. Textural analysis and depositional sedimentary environment of Holocene sediments from Kelshi to Anjarle creek, Maharashtra coast; the sediments are fine to very fine, moderately well sorted with strongly coarse skewed and very platykurtic to extremely leptokurtic in nature [16]. Textural characteristics and sedimentary environments of beach sediments of Karnataka coast, ranges from coarse to fine sand with moderately to well sorted character [17]. The longshore sediment transport along the west coast of India is towards south from January to May and

October [18]. The west coast of India the direction of waves from SW, WSW, W and WNW with periods ranging from 5 to 14 seconds [20]. The wave energy distribution along the coast and the direction function it provides information regarding longshore current which indicates the direction of the movement of beach sediments. The innershelf sediments off Kalpakkam, southeast coast of India [21]. He has been identified very poorly sorted, positively skewed sediments with very leptokurtic and platykurtic characteristics. The depositional environment in Kalbadevi, Mirya and Ratnagiri bays in central west coast of India, observed that well sorted sediments in Kalbadevi and Mirya bays, whereas, Ratnagiri bays are poorly sorted [19]. According to [22],reported three bays viz., Kalbadevi, Mirya and Ratnagiri bay suggested overlapping environments of beach/ dune barrier island in Kalbadevi and Mirya bays and river/lagoon type in Ratnagiri bay.

The aim of this work is to investigate the pre and post-monsoon seasons in textural characteristics and the hydrodynamic energy conditions along the west coast of India. The study will help to understand the West Coast dynamics by correlating the current processes operative in the study area with past geomorphic changes. Textural analysis for Maharashtra coast is studied by [19, 22, 23, 24], for Karnataka coast [15, 17, 25] have made significant contributions in differentiating the environments of beach and river sediments. However, information is lacking on the grain size characteristics of such sediments and on the processes operating along the west coast of India. The present study aims to fill this gap.

II. STUDY AREA

The study area lies between Harnai (Lat. 17^0 38′36.20’’E,Long 73^0 6′ 53.77’’N) and Kolthare (Lat.17^0 48′ 53.75”E, Long. 73^0 ,14′ 2.38” N) of Ratnagiri district, west coast of Maharashtra, India(Fig. 1). The area is covered in the survey of India topographic sheet number 47G/1 and 47G/2 (1:50,000 scale). The northern part of the area is marked by linear beaches at Harnai, Palande, Saldure, Murud andKarde, whereas the southern part shows the Ladghar and Kolthare bays. The bays have a crenulated coastline, within narrow sandy beaches. Seven seasonal streams, originating in the nearby basaltic hill, are steep gradient. Most of the area is covered by the basaltic lava flows of the Deccan Traps of upper Cretaceous to Eocene age. At the top part, laterite capping on basalt occur at various altitudes. All along the coast, deposition of recent sediments has resulted into formation of consolidated and unconsolidated sediments contain molluscan shells in varying proportions (Fig. 2). The coastal sands occur in different sub-environments, viz., foreshore, backshore, raised marine terrace and dune (Fig. 3a, b, c, d and e). The foreshore, exposed at low tide and submerged at high tide, while backshore, extending landward from the normal high tide limit. Various types of coastal landforms have been developed all along the coast due to marine processes. These includes sea-cliff, headland, wave cut platform, tombolo, linear beaches, sandbar, sandspit, marine terrace and sand dunes, which resulted due to sea levelfluctuations along with transgression and regression phases of sea during Late Quaternary.The sand bars are parallel to sub-parallel to the shoreline that have developed at Palande, Saldure and Murud extending for a distance of about 2 km having an average width of about 40-50 m. Sand dunes have developed on top of raised marine terraces along the shores at Palande, Murud and Ladghar. These are diagnostic features of past sea level fluctuations.

III. METHODOLOGY

The total ninety representative sediment samples were collected from Harnai, Palande, Murud, Karde, Ladghar and Kolthare bay, at an interval of about 1kmduring pre-monsoon and post-monsoon seasons2015. The sediment samples were seasonally collected with a plastic pipe from foreshore, backshore, raised beach and beach dunebrought to the laboratory for various textural analyses (Fig. 4). Determination of various aspects of coastal sediments has been carried out with the help of representative samples. All the sediment samples were reduced to 100 gm by coning and quartering. These representative samples were then washed with distilled water to remove salt content and further treated with 1:10 HCl to remove shell. In order to eliminate organic content, the sediment samples were treated with 30% H_2O_2 and$SnCl_2$[26]. Later these samples were washed with distilled water and oven dried at 65°C. After drying, the sediment samples were weighed again to calculate the loss of the organic content. Then the samples were sieved on Fritsch sieve shaker for 20 minutes using ASTM sieves on half phi intervals between mesh number 12 and 270. The grain size data obtained after sieving is processed using software packages such as Gradistat vs. 8.0 [27]. A Gradistat package was used to calculate all the statistical parameters such as graphic mean, inclusive graphic standard deviation, inclusive graphic skewness and graphic kurtosis [3]. Lineardiscriminant function by [28], was used for interpretation of depositional environments of the sediment. The C-M diagram was plotted through GStat software developed by [29], which is based on the hypothesis formulated by [30, 31].

IV. RESULTS AND DISCUSSION

4.1 Textural Analysis

One of the fundamental properties of sediment particles is the grain size, which influences their entrainment, erosion, transport and deposition. This analysis helps infer important processes related to sediment provenance, history of transport and conditions of deposition. Grain size distributions are generally described by their deviation from a set of ideal distribution in a bid to offer comparison of different sediments. These studies have been carried out on Harnai (3), Palande (1), Murud (3), Karde (4), Ladghar (2) and Kolthare (2) locations sediments each from foreshore and backshore zones.

4.1.1Mean Size

Mean size represents the average of the total distribution ofsediments and measure the nature as well as thedepositional environment of the sediments. It is the function of totalamount of sediments available, the amount of energy imparted to thesediments and nature of transporting agent. The energy of transportingagent includes the degree of turbulence and the role played by currentsand waves.Duringpre-monsoon season, foreshore, backshore and raised beachregion shows mean size ranges of very fine sand to medium sand. The dune sediments are fine sand to very fine sand. The average values of mean size from foreshore (3.04 phi), backshore (3.02 phi), raised beach (3.04 phi) and coastal dune (3.20 phi) are observed. In foreshore, backshore, raised beachand coastal dune are very fine sand 80%. The foreshore zone shows fine sand 13%, medium sand 7%, backshore zone fine sand 7%, medium sand 13%, raised beach show fine sand 10%, medium sand 10% and coastal dune, fine sand 20% are observed (Table 1,2,3 and 4).

In post-monsoon season, foreshore zone sediments range fromfine sand to very fine sand, backshore zone coarse sand to very fine sand, raised beach and dune sediments are very fine sand to medium sand.The average values of mean size from foreshore (3.15 phi), backshore (2.73 phi), raised beach (3.06 phi) and coastal dune (2.73 phi) are observed. In foreshore and coastal dune sedimentsshow fine sand to very fine sand 100%, backshore zone 87% and raised beach 90% are observed. The backshore zoneshows13% coarse sand and raised beach 10% medium sand are present. In pre and post-monsoon seasons dominance of fine sediments is probably due to the deposition by the fluvial system of reworked Late Quaternary sediments.According to [32], suggests that open coast beach sediments smaller than 0.150 mm (>2.75 phi) will be dispersed evenly in water column and be carried offshore in suspension mode of transport. According to [6],the bayside waves are largely locally generated therefore the effect of rapidly changing local wind conditions operating across limited fetch distances.

4.1.2Standard deviation

Standard deviation measures the sorting of a sediment and indicates the fluctuations in the kinetic energy (velocity) conditions of the depositing agent about its average velocity[28]. In pre-monsoon season, foreshore zone sorting were well sorted to moderately well sorted at Harnai, Planade, Murud andKarde location, but poorly sorted at Ladghar bay (SLAD2F).The average value of sorting from foreshore (0.53 phi), backshore (0.62 phi), raised beach (0.59 phi) and dune sediments (0.56 phi) are observed. In foreshore zone, well sorted 87%, moderately well sorted 6% and poorly sorted 7% sediments are observed. In backshore, raised beach and coastaldune sediments are 80% well sorted. The moderately well sorted 7% and poorly sorted 13% sediments arefound at backshore zone. The raised beach shows 10% each moderately sorted and poorly sorted, while coastal dune 20% poorly sorted sediments are found. The well sorted nature at Harnai, Planade, Murud andKarde locations like results in a place where there is a continuous, slow deposition of sediments. The foreshore sediments are under the influence of swash and backwash processes, giving rise to well sorted and negative skewness at midwater and low water levels [33]. The presence of minor amount of pebbles at Ladghar bay may be due to the deposition of the sands of varied sources with high velocity of the transporting agent.The moderately well sorting at Koltharebay in the southern sector is attributed to partial winnowing and addition of sediments in coastaldune environment by aeolian process. According to [1],fine sediments exhibit an improvement of sorting of the sediment.During pre-monsoon, the sorting is more at northern locations than the southern, whereas it seems to be evenly sorted post-monsoon at all the backshore locations, except Ladgharbay (Table 1, 2, 3 and 4).

During post-monsoon season, foreshore zone sorting ranging from well sorted (73%) to moderately sorted (27%), whereas backshore and raised beach sediments are well sortedto poorly sorted and coastal dune are moderately well sorted to poorly sorted. The average value of sorting from foreshore zone show (0.45 phi), backshore (0.65 phi), raised beach (0.78 phi) and dune sediments (0.99 phi) are observed. In backshore zone,well sorted (80%) and poorly sorted (20%) are found, while raised beach show well sorted (60%), moderately well sorted (20%) and poorly sorted (20%) are observed. Coastal dune sediments show 20% each from well sorted, moderately well sorted and moderately sorted, whereas, 40% poorly sorted sediments.In pre-monsoon(87%) and post-monsoon(73%) well sorted sediment are present, this well sorted nature of sediments can be mixing of sediments brought by waves and currents as well as addition to the inputs of palaeo-sediments from the major stream basin. This is the result of the mixing of sediments brought there by aeolian processes from the adjacent beach ridges which were formed as a consequence of sea level changes during the Late Quaternary period. In pre-monsoon Ladghar (SLAD2B) and Kolthare bay (SKOL1B) sediments samples are poorly sorted while in post-monsoon both Ladghar bay (SLAD1B andSLAD2B) sediment are poorly sorted. This is characterized by high energy wave action, the sediments could be due to the churning action of the waves, which facilities the deposition of a mixed type of sediments [34].

4.1.3 Skewness

Skewness is a measure of symmetry of grain size distribution. It is asignificant parameter in delineating environment, since it is sensitive to sub-population mixing.During pre-monsoon season foreshore, backshore and raised beach skewness valuesarefine skewed to strongly coarse skewed, whereas dunearenear symmetrical to strongly coarse skewed. The average value of skewness from foreshore (0.02), backshore (-0.01), raised beach (-0.04) and dune (-0.17) are observed. The positively skewed sediments infer the unidirectional (channel flow) transport in a sheltered low energy environment [35].According to [28], the skewness is negative, the sediments is coarsely-skewed, i.e. the mean is towards the coarser side of the median. When the skewness value is positive the sedimentshas finely-skewed. Skewness is a sensitive indicator of subpopulation mixing and the energy conditions prevailing in the depositional environment(Table 1, 2, 3 and 4).The foreshore zone shows fine skewed (47%), near symmetrical (27%) and coarse to strongly coarse skewed (26%), while in backshore, fine skewed (60%), near symmetrical (26%) and strongly coarse skewed (14%) are found. In raised beach region, 30% each from fine skewed, near symmetrical and coarse skewed and remaining 10% strongly coarse skewed. In coastal dune 40% each from symmetrical and coarse skewed, while in 20% are strongly coarse skewed.

During post-monsoon season,foreshore zone shows skewness ranges from near symmetrical to coarse skewed, while in backshore and raised beach region shows near symmetrical to strongly coarse skewed. The coastal dune sediments are fine skewed to coarse skewed.The average value of skewness from foreshore (0.08), backshore (0.16), raised beach (-0.12) and beach dune (-0.04) are found. The foreshore zone arefine skewed (60%), symmetrical (33%) and coarse skewed (7%), whereas in backshore zone shows fine skewed to strongly fine skewed (53%), symmetrical (40%) and strongly coarse skewed(7%) are observed. Symmetrical skewed sediment distribution on the Murud and Karde beach indicate slow rate of deposition. The raised beach shows20% each from fine skewed and near symmetrical 50% coarse skewed and 10% strongly coarse skewed.Coastal dune sediment shows 40% each from fine skewed and coarse skewed and 20% symmetrical.These trends in sediments signify fluctuatingenergy levels of the transportingmode (wave energydissipation by nearshore bars and several zones ofwave breaking). The positively skewed sediments indicate accumulations of fine sediments and prevalent low energy conditions, whereas negatively skewed sediments indicate winnowing of sediments and high energy condition, when the fines are removed by winnowing action of waves and currents [36].

4.1.4 Kurtosis

Kurtosis is a measure of ratio between the sorting in the tails of thecurve and the sorting in the central portion.During pre-monsoon season, foreshore zone shows kurtosis values range from very platykurtic to very leptokurtic, backshore zone platykurtic to very leptokurtic, raised beach region very platykurtic to mesokurtic and coastal dune sediments shows platykurtic to very leptokurtic in nature. The average value of kurtosis from foreshore (1.06), backshore (0.99), raised beach (0.91) and coastal dune (1.23) are found.Kolthare bay sediments (SKOL2F) are very leptokurtic because of the mixing of the fluvial sediments (Table 1, 2, 3 and 4).

The foreshore zone showsmesokurtic (47%), leptokurtic (33%) and very platykurtic (20%), backshore zone platykurtic to very platykurtic (47%), mesokurtic (33%) and leptokurtic to very leptokurtic (20%). The raised beach region showsmesokurtic (70%), platykurtic (20%) andvery leptokurtic (20%) whereas coastal dune kurtosis values range from platykurtic (40%) and 20% each from leptokurtic,very leptokurtic and mesokurtic class limits of Folk and Ward (1957).

During post-monsoon season, foreshore zone shows kurtosis values range from mesokurtic to leptokurtic, backshore and raised beach shows very platykurticto very leptokurtic whereas, coastal dune shows platykurticto very leptokurtic. The average value of kurtosis from foreshore (1.08), backshore (1.07), raised beach and coastal dune (1.14) are observed.The foreshore zone, shows mesokurtic (67%), leptokurtic (33%), backshore zone, mesokurtic (47%), very platykurtic to platykurtic(40%), leptokurtic to very leptokurtic (13%), raised beach shows mesokurtic (30%), platykurtic(30%), very leptokurtic (30%) and very platykurtic (10%). The coastal dune shows platykurtic (40%), leptokurtic (40%) and very leptokurtic (20%). Kurtosis values are higher on the Ladghar and Kolthare bay than on the sea-side beaches, caused by lag gravel deposits. The effect of small amounts of gravel to the sand mode [3]. Variation in the kurtosis values reflects the flow characteristic of the depositing medium, and the dominance of finer size of platykurtic nature of sediments reflects the maturity of the sand(Table 1, 2, 3 and 4).

4.2 Frequency curves

The frequency distribution curves for the pre and postmonsoon seasons show a bimodal to polymodal class of foreshore, backshore, raised beach and coastaldune sediments (Fig.5 and 6). The foreshore zone sediments display bimodal class for pre and post-monsoon sediments, where the primary mode between 2.0 to 3.0 phiand secondary one 3.0 to 4.0 phi size class. The secondary mode contains Kolthare and Ladghar bay samples (Fig.5). The backshore zone sediments display bimodal class for pre and post-monsoon seasons with the primary mode between 2.5 to 3.5 phiand secondary one 3.0 to 4.0 phi size class.

The raised beach sediments from pre and post-monsoon seasons are seen to be polymodal, where the primary mode between 3.0 to 4.0 phi, secondary at 2.0 to 3.0 phi and weak third mode between 1.0 to 2.0 phi in pre-monsoon. Post-monsoon seasons the primary mode between 3.5 to4.5 phi, secondary mode between 2.5 to 3.5 phi and weak third mode between 1.0 to 2.0 phi. The coastal dune sedimentsfrom pre and postmonsoon seasons are unimodal class, the primary mode between 3.0 to 4.0 phi (Fig.6).

4.3 Bivariate Plots

Bivariate plots are very helpful to understand the various depositional environments.The relationship between the graphic mean size, graphic standard deviation, graphic skewness and graphic kurtosis parameters can be well understood by plotting them against each other as scatter diagrams.The bivariate plots for understanding the geological significance of these four size parameters successfully used [2, 37].

4.3.1 Graphic standard deviation vs Graphic mean size

Pre-monsoon graphic mean size vs graphic standard deviation reveals most of the sediments are well sorted and only a few from foreshore and backshore are moderately sorted. The superimposed bivariate plots of [2], indicate that, most of the samples fall within beachenvironment and few samples fall mainly in the river zone (Fig.7a).

In post-monsoon season, most of the samples are well sorted to moderately well sorted and fall within the area of beach environment. The few samples mark the prevalence of river environment probably associated with mainly Murud, Karde, Ladghar bay and Kolthare bay. The Ladghar bay (backshore) samples are coarse sand and poorly sorted (Fig.8a). The fluvial interference was observed during postmonsoon season. According to [38], both mean grain size and sorting are hydraulically controlled, so that in all sedimentary environments the best sorted sediments have mean size in the fine sand size range. The study area reveals presence of dominantly beach and the mixing of riverine environments. The plot shows most of the samples fall in beach process field, which suggests thepossibility of wave (marine) action in deposition of beach sediments.

4.3.2 Graphic mean size vs graphic Skewness

The bivariate plots of graphic mean vs graphic skewness has been used for differentiating between dune and beach environment [37]. This plot reveals pre and post-monsoon seasons samples belong to beach and dune depositional environment. The samples were primarily collected from these two sub-environments (Fig.7b and 8b). The increase in mean size valueexhibits negative skewness. In pre and post-monsoonseason foreshore zone Harnai, Murud and Kardeshows negative skewness which indicates that sediments were subjected to high wave energy conditions.

4.3.3 Graphic skewness vs graphic Kurtosis

The superimposed bivariate plots of [2], for the pre-monsoon season majority of the samples fall within the beach environment and few are in the riverine environment (Fig. 7c), whereas post-monsoon season show most of the samples fall in beach environment (Fig.8c).Harnai, Murud and Karde location shows negatively skewed/ very platykurtic to very leptokurtic range (Fig.7c), suggests that the dominance of fine grain size populations and the subordinate medium grain size which gives negative skewness.

4.3.4 Graphic standard deviation vs graphic skewness

The pre-monsoon seasons, the superimposed bivariate plots of [2, 37],indicate that; most of the samples fall within the beach environment and four samples fall in the riverine environment (Fig.7d). During post-monsoon, majority of the samples fall within the beach realm, and few samples from foreshore and backshore fall within the riverine environment (Fig.8d).

4.4 CM-Diagram

The plot of CM diagram of coarsest one percentile of grain size (C) against the median grain size (M) following the procedures of [30, 31], depicts various modes of sediment transport as well as provides information on the source of sediment origin.The CM diagram has sub-divided into five segments depending upon the mode of transport and deposition as follows [30]: NO-deposit of rolled grains, OP-mixtures of rolled grains and suspension sediments, PQ-suspension, QR-Graded suspension no rolling and RS-uniform suspension. The sediment samples fall predominantly in the tractive current and beach environment from pre and post-monsoonseason (Fig.9a and b).

In pre-monsoon season Harnai (SHAR1F, 2F), Ladghar (SLAD1F, 2F) and Kolthare (SKOL1F, 2F) samples fall in OP and PQ segments indicates that the sediments are deposited by mixtures of rolled grains and suspension process indicative of high wave energy condition. The remaining all samples fall in QR segments, the sediments are deposited by graded suspension no rolling (Fig. 9c).

In post-monsoon season, Kolthare bay (SKOL1F) samples fall in NO segments, Ladghar bay (SLAD1F and 2F) samples fall in OP segments and two samples fall in PQ segments, indicates that the sediment are deposited by rolled grains, mixtures of rolled grains and suspension mechanism process. The remaining all samples fall in QR segments, the sediments are deposited by graded suspension no rolling (Fig. 9d).

4.5 Linear Discriminant Analysis (LDA)

The LDA function of [28], has been used for multivariate analysis of beach sediments. This statistical method of analysis, to interpret variations in the energy and fluidity factors, has excellent correlation with different processes and environment of deposition.

To distinguish environment of deposition between aeolian and beach, the following equation has been applied

$Y1_{\text{Aeolian: Beach}} = -3.5688M + 3.7016r^2 - 2.0766SK + 3.1135KG$ (1)

Where, if Y is ≥ -2.7411, environment of deposition is beach and if Y is ≤ -2.7411, environment of deposition is aeolian. (M= mean, r = standard deviation, SK= skewness and KG= kurtosis)

To delineate and to confirm the environment of deposition between beach and shallow marine, the following equation has been applied

$Y2_{\text{Beach: Shallow marine}} = 15.6534M + 65.7091r^2 + 18.1071SK + 18.5043KG$ (2)

Where, if Y is ≥ 63.3650, environment of deposition is shallow marine and if Y is ≤ 63.3650, environment of deposition is beach.

To distinguish environment of deposition between shallow marine and fluvial, the following equation has been applied

$Y3_{\text{Shallow marine: Fluvial}} = 0.2852M - 8.7604\, r^2 - 4.8932SK + 0.0428KG$ (3)

Where, if Y is ≥ -7.4190, environment of deposition is shallow marine and if Y is ≤ -7.4190,

Linear discriminant functions (LDF) for environmental interpretation,and the method was in combination of all the four size parameters into asingle linear equation [28]. Y1 (Aeolian; Beach), Y2 (Beach; Shallow AgitatedWater) and Y3 (Shallow marine; Fluvial (deltaic) were used to decipher the processes and environment of deposition.Sediments from foreshore, backshore and raised beach in pre and post-monsoon seasons exhibit 100% samples as beach process for Y1. As far as Y2 concerned, 100% samples under shallow agitated water process fromforeshore, backshore, raised beach and coastal dune in pre and post-monsoon season. With reference to Y3 values 96% depositedunder shallow marine and 4% under fluvialenvironments (Fig.10a and b). The fluvial interference was observed during postmonsoon season.

The morphological framework of the grains can help in understanding the natural processes and mechanisms that are operative during transportation and deposition, and the distance they travel. In the study area, the southwest monsoon (June to September) is seen to greatly influence the coastal processes, impacting the textural variations. Apart from the monsoonal influence, these sediments are also affected by the presence of wind, tide and current patterns in the Arabian sea and the longshore currents. The frequency curves are dominantly indicative of overall fine, and to some extent, medium to coarse grains are prevalent from Harnai to Kolthare. The graphic mean values indicate the dominance of fine particles. The sediments, in general, show fine sorting and are dominantly fine-skewed to symmetrical in nature. In majority of the cases, both peak and tails are positively sorted giving rise to platykurtic to leptokurtic condition. The interpretation of various bivariate plots between graphic mean, graphic standard deviation, graphic skewness and kurtosis are indicative of beach and riverine environment. Standard deviation versus mean and standard deviation versus skewness indicates a beach and riverine environment of deposition as proposed by [2, 37]. The sediments are mostly graded suspension and deposited by traction currents. However, there are few samples that show rolled and suspension mode, probably because the sediments contain copious amount of fine-grained material.

The mean grain size along the study area at the foreshore is almost uniform during pre-monsoon, except one sampling location at Ladghar bay while in postmonsoon the scatter is comparatively less than observed pre-monsoon. The wave and currents operating along this stretch seems to be energized during the monsoon and has dissipated its energy postmonsoon. The wind energy must have picked up pre-monsoon, the effect of which can be seen at Ladghar bay. The decrease in grain size from Kolthare (south) to Harnai (north) due to NW; which is northerly sediment movement, probably due to the onshore transport of finer size particles from the offshore through wave and current action after the cessation of monsoon. The backshore region, the sediments are very fine indicating the influence of aeolian activities in transporting fine sediments in saltation and suspension from the adjoining beach [34]. The study will help in better management of the Western coastal region of India.

V. CONCLUSIONS

During pre-monsoon, predominant grain size at Harnai, Palande, Murud and Karde is very fine sand which is well sorted indicating the grains travelled a long distance.In post-monsoon samples are comparatively coarse and moderately sorted indicating the influence of SW monsoon in reworking the sediments at these four sampling locations. Gradual decrease in mean grain size from south to north indicates the direction of movements of sediments towards north.The bivariate plots and LDA unravel the presence of beach facies of these samples having a limited role of mixing of riverine flux. This indicates dominance of shallow marine environment of deposition for pre and postmonsoon season. The CM diagram shows sediment samples fall predominantly in the tractive current and beach environment of deposition.The presence of natural barriers like the Burondi headlands and Kolthare headlands contribute appreciably to restricting the littoral sediment movement among the Ladghar and Kolthare bays.

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