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# Textural features and transportation mode of surface sediments along Al-Sanaouber coast-Latakia-Syria

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***Abstract***

*Detailed textural study of Alsanaouber area in the Syrian coast (35 ° 27` 50 "and 35 ° 27` 56": 35 ° 51` 56 "and 35 ° 51` 48") has been carried out to determine the sedimented nature, distribution, and transportation mode. The sediments are mainly coarse to fine sand, moderately sorted, very negatively skewed, and mesokurtic. The interrelationship of various parameters shows the bimodal nature of sediments dominating mainly medium to coarse sand. Based on the CM pattern, the sediment falls in the rolling and suspension field. These factors indicate that the wave energy conditions were high enough to disperse the sediments along the coast. Linear Discriminate Function analysis (LDF) of the samples indicates that the deposition of sediment is affected by both fluvial and marine processes.*

**Keywords —** *Grain size, Al-Sanoubег Coast, Sediments transportation mode, LDF.*

## I. INTRODUCTION

Coasts are unique geological environments in terms of their composition and the physical processes that affect them as a result of the continuous interaction between land and water. This reaction is in a highly dynamic and complex state, especially in the estuaries (Morris et al., 1995). The estuaries retain most of the coarse sediments, some of which may cross towards the open sea for later distribution due to coastal currents, which produces sand strips along the river estuaries on the internal pier (Raj and Prakash, 1989)). The interaction between land and water results in a group of factors that are active on the coast, including the process of erosion, erosion, and transport of marine sediments. The beaches and the adjacent areas are more affected by these processes, which makes them subject to changes that need to be known to rebuild old environmental conditions.

The study of the sediment transport mechanism is of great importance in sedimentology (Raj and Prakash, 1989), however, studies on the description and comparison of mechanisms responsible for the transport and distribution of sediments in various directions are few (Ghadeer & Macquaker, 2011). These studies initially relied on radioactive trace elements, but this method was relatively complex. Then, sediment physical properties such as texture, grain shape, isotope geochemistry, and metallic composition have been used. In later stages, simpler and reliable methods were used to trace sediment transport pathways through sediment distribution to guess the likely direction of sediment movement (Raj and Prakash, 1989). The primary assumption is that the processes that cause sediment transport will influence the textural parameters of the sediment in a predictable manner (McLaren and Beveridge, 2006).

Sediment transport operations are controlled by currents and waves and are therefore important and necessary to know the strength and direction of sedimentation velocities in that area and critical shear stress (Van Rijn, 1990). The differences in energy are related to different processes and sedimentation environment.

These fundamental aspects of the sound management of coastal areas have not been sufficiently assessed. There is a great interest globally in coastal zone management and study, such as sediment dynamics in the region (El Mekadem et al., 2011).

## II. REGIONAL SETTING AND STUDY AREA

The Syrian margin, which is located in a particular geodynamic context, is subject to tectonic regimes since the late Tertiary (Manla Al Dakhil, 2009). This passive margin is subject to a complex tectonic regime related to the proximity of major tectonic structures (Robertson, 1998). This situation supports the threat of disturbances of the geological substratum and its recent sedimentary cover including the original disturbance geomorphic shore and instabilities in the marine part of the Syrian coast.

The Syrian coast (183km) is characterized by a narrow continental shelf (<1--10km). The shoreline is generally straight, with very few estuaries. Most of the coastal rivers (e.g. Alkabeer aslhemaly and Alsanaouber rivers) flow from the western slope of the coastal mountains. Rivers often dry up in summer, producing low sedimentary loads. The study area (about 1000 meters) is located on the Syrian coast opposite to Alsanaouber area (Fig. 1). It extends between longitudes 35 ° 27` 50 "and 35 ° 27` 56" and latitudes 35 ° 51` 56 "and 35 ° 51` 48" (Table. 1).

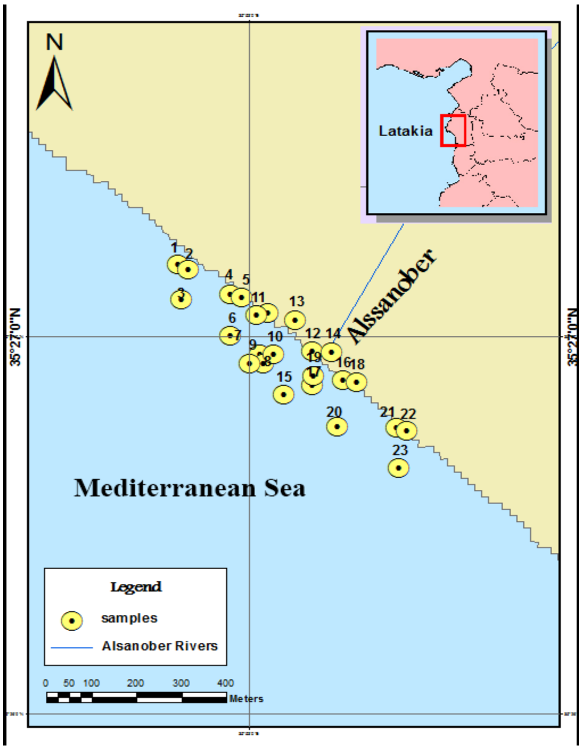


**Fig 1: Study area and sampling**

## III. RESEARCH METHODOLOGY

24 samples were collected from surface sediments along the inshore. Differential Global Positioning System (DGPS) was used to determine the coordinates of the sampling points. Samples were collected in August 2020 during low tide, as samples (from 1 to 9) represent the north area of Alsanaouber estuary and samples (from 10 to 18) represent the estuary, while the samples (from 19 to 24) represent the south area of the estuary. Approximately 1 Kg (wet weight) of sediments was collected at its site; samples were stored in plastic bags with lake water. The sediment samples were dried for at least 24 hours in an oven at 105 C o to remove the moisture before analysis. From the dried samples, 100 mg was taken by the coning and quartering method. The 100 mg of sample is then subjected to sieve analysis in ASTM sieves at one-phi intervals for about 20 minutes in EFL – 2000/1-sieve shaker. Hydrometer analysis was carried out to compute fine-grained material (>4 Φ). These data were then combined to produce complete grain size distributions. This basic data i.e. weight percentage frequency data is converted into cumulative weight percentage data, served as a basic tool for the generation of other statistical parameters such as mean grain size, sorting coefficient, and skewness using USGS GSSTAT and SEDPLOT (Poppe et al., 2004) described herein generates statistics to characterize sediment grain-size distributions and calculates the net sediment transport trend vectors (Gao and Collins, 1992). It is written in Microsoft Visual Basic 6.0 and provides a window to facilitate program execution. The input for the sediment fractions is weight percentages in whole-phi notation (Inman, 1952). LDF (Function Discriminate Liner) analyzes were performed to distinguish between the dominant processes in different sedimentation environments using the Sahu 1964 equations (Sahu,1964). C-M plotting is made after Passega and Byramjee to evaluate the hydrodynamic forces working during the deposition of the sediments.

## IV. RESEARCH RESULTS AND DISCUSSION

### *A. Cumulative curves of marine sediment*

The cumulative curve (S) represents the relationship between the particle size and the cumulative percentage corresponding to each Φ value. The cumulative curves show that the majority of the samples are medium sand while the rest are gravelly sand (Fig. 2; Table. 2).

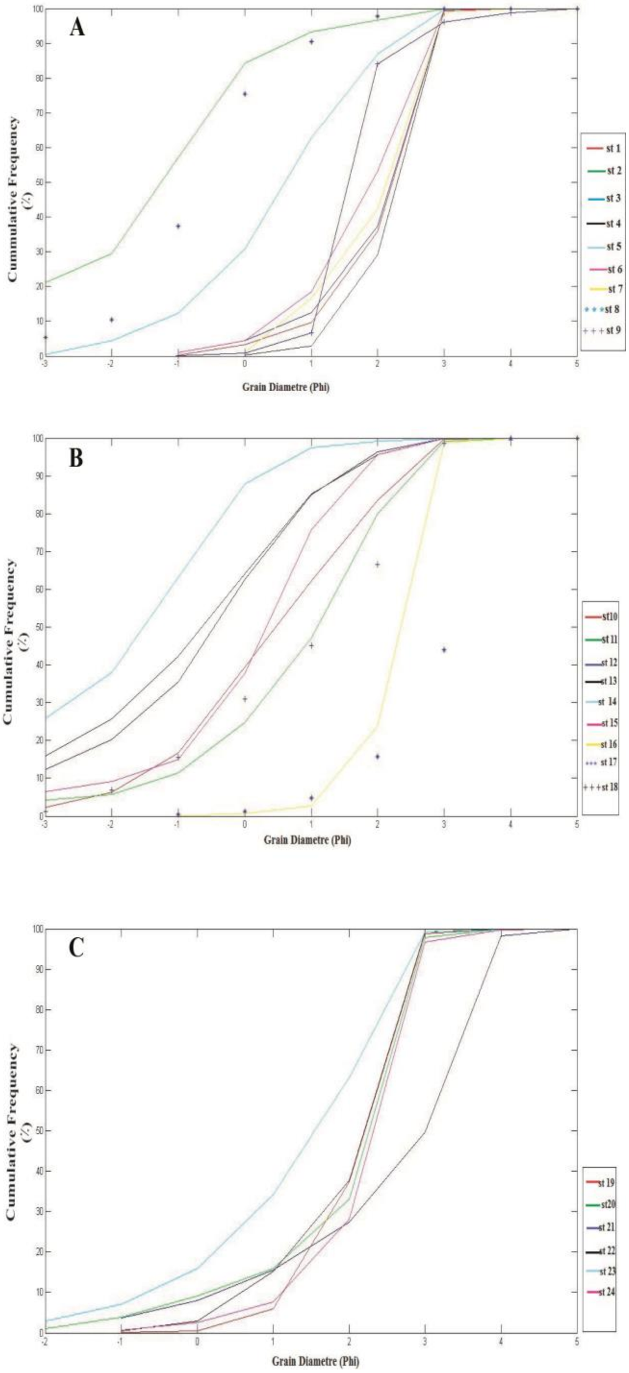


**Fig 2: Cumulative curves showing the trends of all the samples along the study area.**

**TABLE 1: Sampling sites and coordinates**

| Location | Sample number | longitude | latitude | Water Depth (m) | Distance from the beach (m) |
|---|---|---|---|---|---|
| Alsanaouber | 1 | 35° 27` 56" | 35° 51` 48" | 0.5 | 5m |
| Alsanaouber | 2 | 35° 27` 56" | 35° 51` 48" | 0 | 0 |
| Alsanaouber | 3 | 35° 27` 55" | 35° 51` 48" | 1 | 30m |
| Alsanaouber | 4 | 35° 27` 55" | 35° 51` 50" | 0.5 | 5m |
| Alsanaouber | 5 | 35° 27` 55" | 35° 51` 50" | 0 | 0 |
| Alsanaouber | 6 | 35° 27` 54" | 35° 51` 50" | 1 | 24m |
| Alsanaouber | 7 | 35° 27` 54" | 35° 51` 51" | 1 | 10m |
| Alsanaouber | 8 | 35° 27` 53" | 35° 51` 51" | 0 | 0 |
| Alsanaouber | 9 | 35° 27` 53" | 35° 51` 51" | 1 | 22m |
| Alsanaouber | 10 | 35° 27` 53" | 35° 51`51.01" | 0.5 | 1 |
| Alsanaouber | 11 | 35° 27` 54" | 35° 51` 51" | 1 | 70m |
| Alsanaouber | 12 | 35° 27` 54" | 35° 51` 52" | 1 | 55m |
| Alsanaouber | 13 | 35° 27` 53" | 35° 51` 52" | 1 | 40m |
| Alsanaouber | 14 | 35° 27` 53" | 35° 51` 52" | 1 | 30m |
| Alsanaouber | 15 | 35° 27` 53" | 35° 51` 53" | 0.5 | 0 |
| Alsanaouber | 16 | 35° 27` 52" | 35° 51` 52" | 0.5 | 10m |
| Alsanaouber | 17 | 35° 27` 52" | 35° 51` 53" | 1 | 25m |
| Alsanaouber | 18 | 35° 27` 52" | 35° 51` 53" | 0 | 0 |
| Alsanaouber | 19 | 35° 27` 52" | 35° 51` 54" | 0.5 | 5m |
| Alsanaouber | 20 | 35° 27` 52" | 35° 51` 54" | 0 | 0 |
| Alsanaouber | 21 | 35° 27` 51" | 35° 51` 54" | 1 | 15m |
| Alsanaouber | 22 | 35° 27` 51" | 35° 51` 56" | 0.5 | 5m |
| Alsanaouber | 23 | 35° 27` 51" | 35° 51` 56" | 0 | 0 |
| Alsanaouber | 24 | 35° 27` 50" | 35° 51` 56" | 1 | 15m |

### *B. Grain size analysis*

Sediment type varies depending on sampling sites. Also, depth controls the sediment type. The results revealed that the sediments of the studied coast are generally sand (ranged from fine sand to very coarse sand), even though coarser fractions; gravel fraction; are distributed in rare sites. It is represented in some samples as shells and shell fragments. Gravel size reaching to 37.95 % at the mouse of Alsanaouber river. The sand fractions were the dominant fraction. Sand sizes varied between (62.02–99.90%) (site 14 (front of Alsanaouber estuary) and site 7 (in the north area of the estuary), respectively). Predominantly, 50% of the samples exhibit medium sand and 16.66% of the samples fall under the gravelly sand category (Fig. 2, Table 2). The mud fraction (silt and clay) of the surficial sediments of the investigated area represented less than 1% at all studied sites (Fig. 3, Table 2).

### *C. Textural Parameters*

The mean size of the sediments are influenced by the source of supply, transporting medium, and the energy conditions of the depositional environment (Sahu, 1964). The mean grain size of the study area sediments varies from-3.02 ϕ to 2.56 ϕ (Table 2) with an average of 0.63 ϕ and thus falls in the Coarse Sand category. The variation in mean size is a reflection of the changes in the energy condition of the depositing media and indicates the average kinetic energy of the depositing agent (Sahu, 1964). The mean size indicates that the coarse sand was deposited in high energy conditions and the medium sands were deposited in moderate energy conditions.

Standard deviation is the measure of sorting or uniformity of particle size distribution. It indicates the difference in kinetic energy associated with the mode of deposition. It is an important parameter in sediment analysis because it reflects the energy conditions of the depositional environment but it does not necessarily measure the degree to which the sediment has been mixed (Joseph, et.al., 1997). Sorting has an inverse relation with the standard deviation. The standard deviation of the study area sediments varies from very well sorted to poorly sorted (0.31 Φ to 1.71 Φ) (Table 2) with an average of 0.83 Φ and falls in the moderately sorted category. The variations in the sorting values are likely due to the continuous addition of coarser or finer materials in differential proportions. The dominance of moderately sorted character is attributed to the improvement of uniformity in grain size by strong wave energy.

**TABLE 2: Grain size parameter for Alsanaouber sediment samples.**

| Sample Number | Sediment Type | Mean (Mz) | Sorting (Std. dev) | Skewness ($S_k$) | Kurtosis ($K_G$) | DF (Function Discriminate Liner) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $Y_{1(A:B)}$ | $Y_{2(B:SM)}$ | $Y_{3(SM:F)}$ | $Y_{4(F:Tur)}$ |
| 1 | Sand | 1.85 MS | 0.67 MWS | -0.46 $VNS_k$ | 1.07 $MK_G$ | Beach | Shallow marine | Shallow marine | Turbidity |
| 2 | Gravelly Sand | -3.02 G | 0.85 MS | -0.32 $VNS_k$ | 0.78 $PK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 3 | Sand | 1.72 MS | 0.47 WS | -0.74 $VNS_k$ | 1.04 $LK_G$ | Beach | Shallow marine | Shallow marine | Turbidity |
| 4 | Sand | 1.59 MS | 0.31 VWS | -0.21 $NS_k$ | 0.87 $PK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 5 | Sand | -0.13 VCS | 0.84 MWS | -0.38 $VNS_k$ | 0.97 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 6 | Sand | 1.46 MS | 0.69 MWS | -0.36 $VNS_k$ | 0.98 $MK_G$ | Beach | Shallow marine | Shallow marine | Turbidity |
| 7 | Slightly Gravelly Sand | 1.69 MS | 0.65 MWS | -0.38 $VNS_k$ | 0.87 $PK_G$ | Beach | Shallow marine | Shallow marine | Turbidity |
| 8 | Sand | -1.19 G | 0.76 MS | -0.39 $VNS_k$ | 1.08 $MK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 9 | Sand | 1.57 MS | 0.37 WS | -0.26 $NS_k$ | 0.97 $MK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 10 | Sand | -0.46 VCS | 0.90 MS | -0.35 $VNS_k$ | 1.02 $MK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 11 | Sand | 0.15 CS | 1.15 PS | -0.43 $VNS_k$ | 1.07 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 12 | Sand | 1.64 MS | 0.98 MS | -0.34 $VNS_k$ | 0.86 $PK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 13 | Sand | -1.92 G | 0.93 MS | -0.28 $NS_k$ | 0.83 $PK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 14 | Gravelly Sand | -2.43 G | 0.78 MS | -0.24 $NS_k$ | 0.77 $PK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 15 | Sand | -0.7 VCS | 1.10 PS | -0.49 $VNS_k$ | 1.06 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 16 | Sand | 2.21 FS | 0.48 WS | -0.40 $VNS_k$ | 1.10 $MK_G$ | Aeolian | Beach | Shallow marine | Turbidity |

| Sample Number $Y_{2(B:SM)}$ | Sediment Type $Y_{3(SM:F)}$ | Mean (Mz) $Y_{4(F: Tur)}$ | Sorting (Std. dev) | Skewness ($S_k$) | Kurtosis ($K_G$) | LDF (Function Discriminate Liner) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $Y_{1(A:B)}$ | $Y_{2(B:SM)}$ | $Y_{3(SM:F)}$ | $Y_{4(F:Tur)}$ |
| 17 | Sand | 2.56 FS | 0.76 MS | -0.43 $VNS_k$ | 1.02 $MK_G$ | Aeolian | Shallow marine | Shallow marine | Turbidity |
| 18 | Sand | -0.28 VCS | 1.02 PS | -0.29 $NS_k$ | 0.92 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 19 | Gravelly Sand | 1.98 MS | 0.53 MWS | -0.36 $VNS_k$ | 0.93 $LK_G$ | Beach | Beach | Shallow marine | Turbidity |
| 20 | Sand | 1.38 MS | 1.05 PS | -0.53 $VNS_k$ | 0.93 $MK_G$ | Beach | Shallow marine | Shallow marine | Turbidity |
| 21 | Sand | 1.63 MS | 1.13 PS | -0.39 $VNS_k$ | 0.94 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 22 | Sand | 1.71 MS | 1.71 PS | -0.44 $VNS_k$ | 0.92 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 23 | Sand | 0.26 CS | 1.24 PS | -0.47 $NS_k$ | 1.09 $MK_G$ | Beach | Shallow marine | River | Turbidity |
| 24 | Sand | 1.99 MS | 0.66 MWS | -0.50 $VNS_k$ | 1.16 $LK_G$ | Beach | Shallow marine | Shallow marine | Turbidity |

Note G -Gravel, VCS-Very Coarse Sand, FS-Fine Sand, CS-Coarse Sand, MS-Medium Sand, MS Medium Sorted, MWS-Moderately Well Sorted, PS-Poorly Sorted, WS-Well Sorted, VWS-Very Well Sorted, $NS_k$-Negatively Skewed, $VNS_k$-Very Negatively Skewed, MKg-Mesokurtic, PKg-Platykurtic, LKg-Leptokurtic.

Skewness measures the asymmetry of frequency distribution and marks the position of mean concerning median. The positive value represents more fine material in the fine tail i.e., fine-skewed, whereas, the negative value denotes coarser material in coarser-tail i.e., coarse skewed. Skewness value ranges in between -0.74 (very negatively skewed) to -0.21 (Negatively Skewed ) (Table 2) with an average of -0.39 (very negatively skewed). Very negatively skewed sediments indicate deposition at high-energy environments and winnowing action of waves and currents (Reddy et al., 2008).

Kurtosis is the qualitative measure of the part of sediments already sorted elsewhere in a high energy environment (Folk and Ward, 1957). If the tails are better sorted than the central portion, then it is termed as leptokurtic, whereas, it is platykurtic in the opposite case. If both are equally sorted then mesokurtic condition prevails. The kurtosis value of the study area sediments ranges from 0.77 (platykurtic) to 1.16 (leptokurtic) (Table 2) with an average of 0.96 (mesokurtic). The majority of the samples fall under the mesokurtic type. Of the total samples analyzed, 62.5% represent mesokurtic, 25% of the samples fall under platykurtic, 12.5% are leptokurtic (Table 2). The dominant mesokurtic to leptokurtic nature of sediments refers to the continuous addition of finer or coarser materials after the winnowing action and retention of their original characters during deposition.

### *D. Triangular diagram*

One of the most common methods used by sedimentologists is to plot the basic gravel, sand, silt, and clay percentages on triangular diagrams. Sedimentological data are typically large and pure numerical information is difficult to understand and interpret. Thus, the presenting data will be simple and facilitates quick classification of sediments and comparison of samples (Poppe and Eliason, 2008). This study reveals that most of the coastal sediments of the study area fall in the sand category (Fig. 3). This means that the wave energy conditions were high enough to disperse the sediments along the coast.

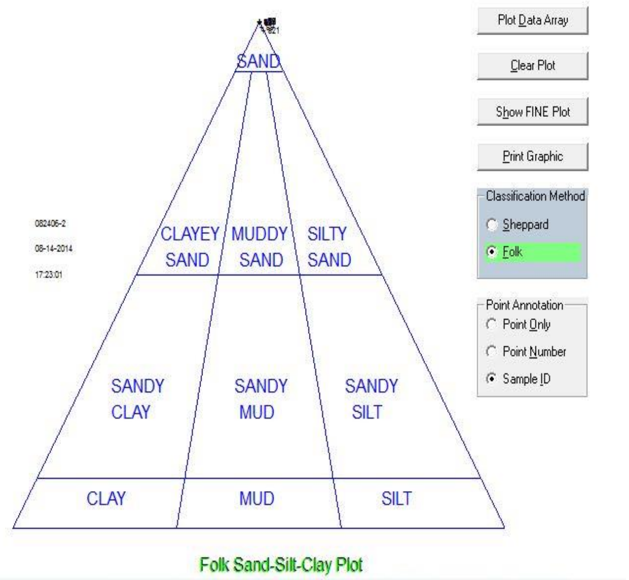


**Fig 3: Triangular diagram showing the distribution of study area sediments.**

### *E. Application of the CM diagram*

The CM patterns of the sedimentary environment are used to determine processes that are responsible for the formation of clastic deposits. It also helps to distinguish between sediments of different depositional environments concerning size and energy level of transportation. Passega (1957) introduced a C-M plot to evaluate the hydrodynamic forces working during the deposition of the sediments by plotting the coarsest first percentile grain size (C) and the median size (M) of sediment samples (Fig. 4). The majority of the samples of the study area scattered within class IV while the rest fall in the V class. This means that the load type of studied samples can be designated as rolling for the samples of class IV, suspension, and rolling for the samples of class V.

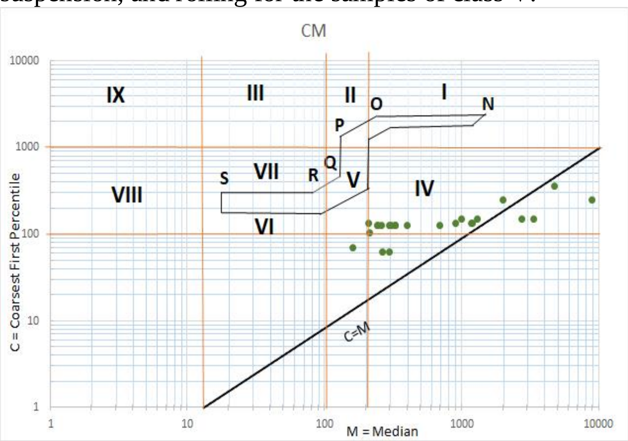


**Fig 4: C-M plot showing the distribution of sediment samples. Samples fall in IV and V sectors.**

### *F. Linear Discriminate Function*

Sahu (1964) introduced the linear discriminate analysis for environmental interpretation. Sahu's linear discriminate functions of Y1 (Aeolian: beach), Y2 (Shallow marine: Beach), Y3 (shallow marine: river), and Y4 (Turbidity: river) were used to decipher the process and environment of deposition. From the values of Y1 Concerning the values obtained from Sahu’s linear discriminate functions (Table 2), Y1 values exhibit 91% samples by Beach process while the rest deposited under Aeolian conditions. Concerning Y2 values, 58% by Shallow marine, 42% by beach processes. Y3 values indicate that 70.83% of sediments are deposited in shallow marine environments, the rest of the samples are deposited under condition river. Y4 values referred to 100% of the samples fall in the turbidity category of deposition. The results indicate that the deposition of sediment in this area is affected by both fluvial and marine processes.

### *G. Bivariate Plots*

Scatter plots between certain parameters are also helpful to interpret various aspects of the depositional environment such as energy conditions, the medium of transportation, mode of deposition, etc (Folk and Ward, 1957; Passega, 1957; Friedman, 1967). Passega (1957), Friedman (1967), and others described that the trend and interrelationship exhibited in the bivariate plots might indicate the mode of deposition and in turn aid in identifying the environments.

The scatter plot between mean size and standard deviation shows (Fig. 5A) that sorting increases as the mean size increases. Griffiths, 1967 explained that the average grain size and sorting are controlled hydraulically, as in all sedimentary environments well-sorted sediments have a medium size within the fine sand category (Griffiths, 1967).

The bivariate plot between Mean size and Skewness (Fig.5B) brings out the values, which fall mostly in the very negatively-skewed area, with a mean size range from Gravel to fine sand. Sediments of negative skewness occur in high energy environments.

The relation between mean-size and kurtosis is a bit complex (Folk and Ward 1957). The plotting model of Folk and Ward (1957) denotes the mixing of many size classes of sediments, which fundamentally affects the sorting in peak and tails. The plot between mean-size versus kurtosis exhibits a decrease in grain size with an increase in kurtosis value (Fig. 5C). This indicates fluctuation in energy conditions in the site of deposition.

The plot between Standard deviation and Skewness (Fig.5D) shows a trend as the standard deviation decreases, skewness becomes less negative. It may be due to two conditions i.e. either unimodal samples with good sorting or an equal mixture of two modes.

The plot between standard deviation and kurtosis shows most of the samples fall in mesokurtic to platykurtic and moderately well sorted to poorly sorted because of the dominance of medium to coarse sand-size sediments (Fig.5E).

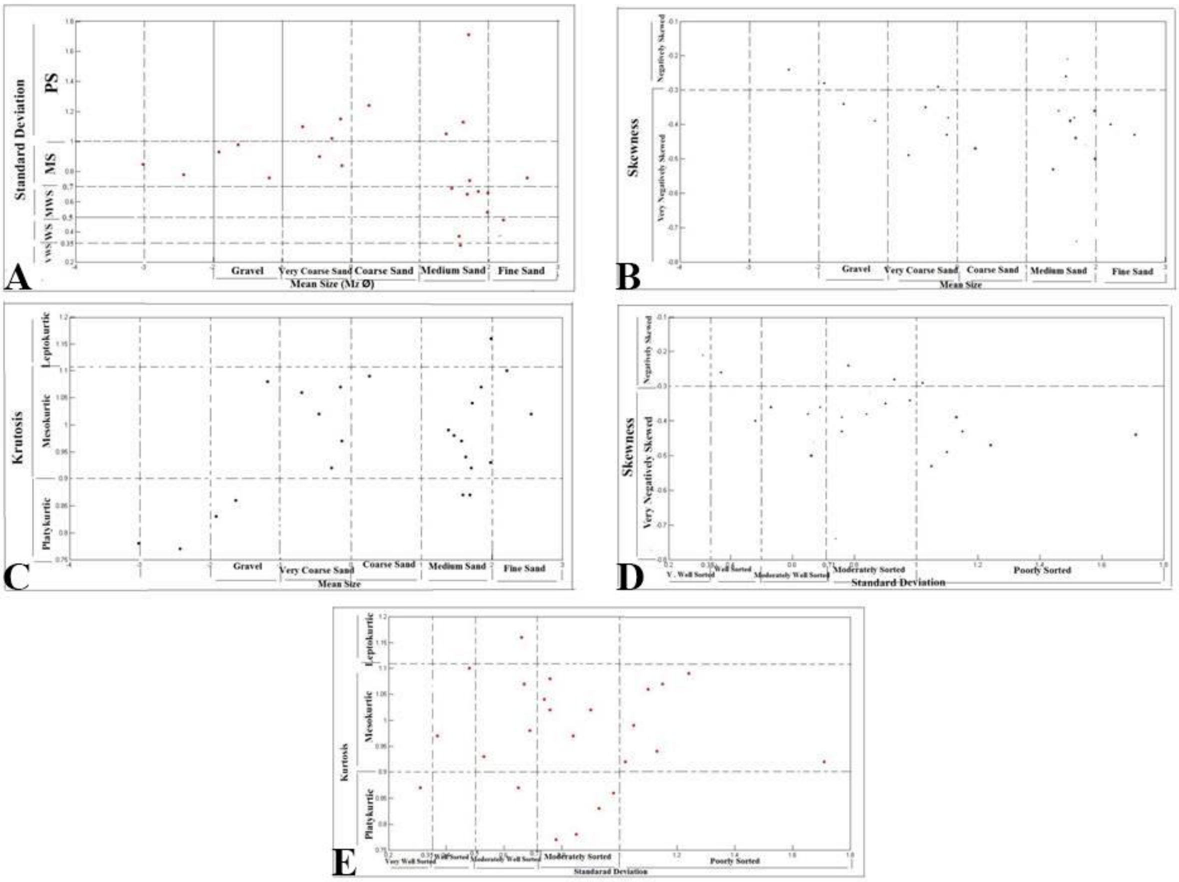


**Fig 5: Bivariate plots between certain parameters in the studied area.**

## V. CONCLUSIONS

The following conclusions are made:

- The textural parameters indicate that the sediments are coarse to fine sand, moderately sorted, very negatively skewed, and mesokurtic. and deposited under relatively high energy conditions with dominant rolling and suspension mechanisms.
- The variations in the mean size indicates that the coarse sand was deposited in high energy conditions and the medium sands were deposited in moderate energy conditions. Whereas, the variation in the sorting values is likely due to the continuous addition of coarser or finer materials in differential proportions.
- Cumulative Curves and bivariate plots were drawn between different textural parameters established that the sediments are mostly bimodal and composed of medium sand and gravelly sand.
- Various bivariate plots between mean, skewness, kurtosis, and standard deviation explain the dynamic process operating in the region together with the influence of climatic changes.
- Triangular diagram reveals that most of the coastal sediments of the study area fall in the sand category.
- The CM plots indicate that the Latakia coast sediments underwent the rolling and suspension under tractive current.
- Linear Discriminate Function analysis (LDF) of the samples indicates that the deposition of sediment is affected by both fluvial and marine processes.

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