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Grain Size Analysis And Depositional Environment For Beach Sediments Along Abu Dhabi Coast, United Arab Emirates

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Abstract: The paper analysed the grain-size spectrum and textural parameters namely mean, sorting, skewness and kurtosis of Abu Dhabi coast in United Arab Emirates applying the ASTM sieves. For this purpose fifty seven samples were analysed. The results of the sieving analysis divulged that , samples of the study area range between -2.63 (pebble size) to 2-39 (Fine sands). The statistical analysis reveals that the sand is characteristically fine grained, moderately well sorted to extremely poorly sorted. The sand distribution is strongly coarse and leptokurtic in nature. Abundance of the medium sand to fine sand shows the prevalence of comparatively moderate- to low-energy condition in the study area. Linear discriminate function of the samples indicates an Aeolian, shallow marine deposition environment and less influence of fluvial (7 %) process.

Index Terms: Grain size distribution, Coast, ASTM sieves, Soil environment, Marine deposition,, Abu Dhabi, United Arab Emirates

1 INTRODUCTION

Soil is the natural growing medium for plants as it is rich in humus and organic matter. Different factors affect the type of soil, including weathering, climate conditions, fertilizers, humus parent material, agriculture, human activities, biological and bacterial activity and pH. The biological activity has a minor effect on soil in arid areas or in soil with low organic matter as in the UAE. The soil in the UAE is sandy, infertile and dominated by minerals such as quartz and carbonates. The big size of the particles in the sandy soil reduces the water-holding capacity of the soil, which can facilitate the erosion of soil with weathering conditions such as wind. Along the coast, however, soils contain high sodium chloride salt concentrations, and tend to be poorly drained. The coastal soils offering important information about the chemical and mineralogical accumulation meanwhile the geology of the origin rocks (Reinson, 1992; Barnhahdt et al. 1997), in addition the coastal soil provided information on the energetic conditions of transport and deposition of suspended and dissolved loads (Sahu, 1964; Pickrill, 1986; Kelley, 1987; Carter et al., 1990). The coastal soil particles sources and how it related to adjacent coastal rocks, and the precipitation from solution. The other coastal soil could be of biogenic or cosmic sources (Strorlazzi and Field, 2000).The interaction of both marine and terrestrial processes give the coastal soils their textural and compositional characteristics. The time, which these processes take it and their magnitude, consider to some extent, the dominant characteristics of the coastal soil deposits (Pickrill, 1986;). Grain size studies of beach sediments provide a wealth of information on the intrinsic properties of sediments and their depositional environment. Further, they help to delve into the nature and energy flux of the multifarious agents transporting the sediments.

Systematic granulometric studies of the In several locations in coasts of the United Arab Emirates, marine sediments were examined for the size of the grains (Abu-Hilal and Khordagui, 1992). The organic matter and mineralogical composition of Ras Al-Khaimah sediments was studied by El-Sammak (2000), and properties of sediments along Abu Dhabi and Dubai was studied by Al-Qubaisi (2001). The complex coastal processes operated in the past and operating today have left their imprints in the beach sediments. In this regard, the Sedimentology of beach sediments plays a vital role in documenting the depositional history of a region (Angusamy and Rajamanickam 2007). Sedimentalogists are particularly concerned with three aspects of particle size: (a) techniques for measuring grain size and expressing it in terms a grade scale, (b) methods for quantify- ing grain size data and presenting them in a graphical or statistical form and (c) the genetic significance of these data (Boggs 1995). Heavy minerals such as limonite, monazite, zircon, sillimanite and garnets are important economic resources as they are useful in many industries for various applications.. The placer deposits are considered economically viable deposits because of profitability and easy mine ability. Better profit and development of cost effective indigenous technology both in mining and processing are the main factors for its increasing importance over the years (Karikalan et al. 2001). The surface micro textural study of quartz grains with the help of scanning electron microscope (SEM) has proved to be an effective and useful tool in deciphering the depositional environments, the mode of transport and the digenetic processes of coastal, fluvial and glacial sediments. The different mechanical and chemical processes that affect quartz sand grains are apparent from the surface features (Al-Saleh and Khalaf 1982). These features are described and catalogued according to depositional environment (Krinsely and Doornkamp 1973)

2 STUDY AREA DESCRIPTION

Soil survey of Abu Dhabi Emirate was implemented by the Environment Agency. This implementation was done for the purpose of the identification and mapping of the Emirate's soil as well as for the determination of the soil suitability for different uses to assist with land management planning. The soils occur as extensive dune systems, sand sheets and tend to have low water holding and run – off capacity, high

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infiltration and low fertility. Due to the climate of the region, the desert of Abu Dhabi Emirate is highly prone to the crossing of the wind and degradation, increased salinization, water logging, human land use practices and overgrazing. The degradation of the soil leads to the reduction of the capacity of the soil to produce goods or services, influencing food security and the environment quality.

2.1 Geology

The United Arab Emirates coast is mainly Holocene sediments accumulated on Neogenesedimentary rocks (Figure2). The Miocene substrate consists of a sequence of marls, sandstone, limestone, and the evaporation occurred with a southward gentle dip (Alsharhan & Kendall 2003). Along the coast these rocks crop out northeast – southwest escarpment with height more than 35m, paralleling the United Arab Emirates escarpment called by valleys that trend northwest – southeast. The valleys and ridges orientation is similar to that of many of local islands and lagoons, suggesting a combinable structural control and dominant wind blowing from the northwest. Distinguishing between these structural and wind controls is difficult. Banked up against the Neogene rocks and covering them are Quaternary Carbonate known locally as Miliolite (Kinsman 1964; Kirkham 1997). During the last major glacial eustatic changethe sedimentary rocks were deposited in the Arabian Gulf. These largely aeolian sands line the inner margins of the present – day salt flats or sabkhas and sometimes their festoon cross beds are exposed as wind-deflated surfaces(Kirkham1998). They underlie much of the Holocene carbonate evaporate complex and form the core barrier island and headlands. Walkenden and Williams (1998), however, argue that since The Arabian Gulf, where the study area is located, has been above sea level for over much of the past 2.5 Ma, and since it is in tectonic, eustatic and depositional disequilibrium it should not be considered a ramp. Despite this controversy, the Holocene sedimentary fill of the current Gulf has been and will continue to be used as a model for a carbonate ramp (Evans 1994).

3 METHODS

Samples were collected from the coastal sites under the condition (10-15 cm in length and 5.5 cm in diameter). Handling the soil samples followed the 1981 EPA/CE-81-1 protocol (Plumb, 1981). The collected samples were taken in polyethylene bags and transported in sample container 3-4 hours after collection for various analyses. Sample analyses were run out by the Geology workshop lab.-Geology Department-UAE University. The main purpose of the Sieve analysis of beach soil is to determine and understand their granulometric characteristics and textural properties. There are several techniques for the size analysis of soil: the most widely used are sieve analysis. The one used for sands and gravels. Fifty seven samples were analyzed for sieve analysis using ASTM Sieves, part of the samples were dried using dry oven while others used as reference samples, (Fig. 1).100 gm representing the original dry sample was taken using john splitter and poured in a set of sieves arranged from coarse to fine as follow (4,2,1,0.5,0.25,0.125,0.062 mm and pan).The set of sieves were fixed on a mechanical shaker .The sample were shake for about 15 minutes. The retained weights were recorded in a form sheet used for this purpose using a sensitive balance. The weight percentages and cumulative weight percentages were calculated for all samples and were then plotted on a ternary figure shown in the results section . The median (M_d), mean (Mz), sorting) (σ_1), skewness (SK_1), and kurtosis (KG_1) were calculated as follows:

The median (M_d)

$$M_d = \varphi_{50}$$ (Trask 1930) (eq1)

The mean (M_z)

$$M_z = \frac{\varphi_{16}+\varphi_{50}+\varphi_{84}}{3}$$ (Folk 1974) (eq2)

The graphic standard deviation (Sorting) (σ_1)

$$\sigma_1 = \frac{\varphi_{84}-\varphi_{16}}{4} + \frac{\varphi_{95}-\varphi_5}{6.6}$$ (Folk & Ward 1957) (eq3)

<Φ0.35 Very well sorted
Φ0.35 to Φ 0.5 Well sorted
Φ 0.50 to Φ0.71 Moderately well sorted
Φ0.71 to Φ1.0 Moderately sorted
Φ 1.0 to Φ 2.0 Poorly sorted
Φ 2.0 to Φ 4.0 Very poorly sorted
>Φ4.0 Extremely poorly sorted

The graphic skewness(SK_1)

$$S_{k1} = \frac{\varphi_{16}+\varphi_{16}-2\varphi_{50}}{2(\varphi_{84}-\varphi_{16})} + \frac{\varphi_{5}+\varphi_{95}-2\varphi_{50}}{2(\varphi_{95}-\varphi_5)}$$ (Folk & Ward 1957) (eq4)

Φ 1.0 to Φ 0.3 Very fine skewed
Φ 0.3 to Φ 0.1 Fine skewed
Φ 0.1 to Φ -0.1 Near symmetrical
Φ -0.1 to Φ -0.3 Coarse-skewed
Φ -0.3 to Φ -1.0 Very coarse skewed

The graphic kurtosis (KG_1)

$$K_G = \frac{\varphi_{95}-\varphi_5}{2.44(\varphi_{75}-\varphi_{25})}$$ (Folk & Ward 1957) (eq5)

<Φ 0.67 Very Platykurtic
Φ 0.67 to Φ 0.90 Platykurtic
Φ 0.90 to Φ 1.11 Mesokurtic
Φ 1.11 to Φ 1.50 Leptokurtic
Φ 1.50 to Φ 3.00 Very leptokurtic
>Φ 3.00 Extremely leptokurtic

The absolute numbers given in equation 1 through equation 5 represent the cumulative frequency percent by weight read from the curves at particular grain size unites measured by phi (ϕ). Attempts to discriminate between different depositional settings, via bivariant plots, are based on the assumption that these statistical parameters reliably reflect differences in the fluid-flow mechanisms of sediment transportation and deposition (Sutherland & Lee 1994). There is some covariance between mean grain size and sorting (Tucker 1990), and Griffiths(1967) explained that both mean grain size and sorting are hydraulically controlled, so that in all sedimentary environments the best sorted sediments have mean grain size in the fine sand size range. According to Edwards (2001) most sands are well sorted to moderately sorted. This energy-related universal relationship has been confirmed by many subsequent studies (Tucker1990). There is an obvious general trend for the sorting values to increase *(i.e.* for progressively poorer sorting) as mean grain size increases. Plotting of skewness against kurtosis is a powerful tool for interpreting the genesis of sediment, by quantifying the degree of normality of its size distribution (Folk 1974). Tucker (1990) said that among the relatively fine-grained unimodel deposits from many parts of the world, beach sands are well sorted and negatively skewed, while river sands are less well sorted and usually positively skewed. Dune sand typically has positive skewness, but is finer grained than beach sand. Generally most beach sediments are slightly negatively skewed because of the presence of a small proportion of coarse grains (coarse "tail") (Folk 1974). Friedman (1961) showed that most sands are leptokurtic and either positively or negatively skewed. This could be explained by the fact that most sands consist of two populations, one predominant, and the other very subordinate, coarse (leading to negative skewness), or fine (leading to positive skewness). The discriminate functions proposed by (Sahu 1964) were applied to the sediment grain size data from the collected sediment sample environments in order to test feasibility of these methods to characterize depositional setting. The following discriminate functions were used in the present work:

1) For the discrimination between aeolian processes and littoral (Intertidal zone) environments, the following equation was used.

$$Y1 = -3.5688M_Z + 3.7016\delta I^2 - 2.0766SKI + 3.1135KG$$

Where:

Mz is the grain size mean,
δI is inclusive graphic standard deviation (sorting),
SKI is the skewness, and
KG is the graphic kurtosis.

When Y1 is less than -2.7411 Aeolian deposition is indicated whereas if it is greater than -2.7411 a beach environment is suggested.

2) For the discrimination between beach (back-shore) and shallow agitated marine environments (subtidal environment), the following equation was used.

$$Y_2 = 16.6534Mz + 65.7091\ \delta I^2 + 18.1071SKI + 18.5043KG$$

If the value of Y_2 is less than 65.3650 beach deposition is suggested whereas if it is greater than 65.3650 a shallow agitated marine environment is likely.

3) For the discrimination between shallow marine and the fluvial environments, the following equation was used.

$$Y_3 = 0.2852Mz - 8.7604\ \delta I^2 - 4.8932SKI + 0.0482KG$$

If $Y_3 < -7.419$ the sample is identified as a fluvial (deltaic) deposit, and if greater than -7.419 the sample is identified as a shallow marine deposit.

Plotting of the three discriminate functions (Y1, Y_2 and Y_3) as bivariant scatter plots has the potential to improve the success rate and refinement of the discrimination method in relation to depositions environment. Figure 8 shows the scatter graph of Y1 against Y2. Based on the classification of depositional environments using the discriminate function values of Y1 and Y2 , the graphs can be divided into four fields: Aeolian processes/Littoral environment, Beach and Littoral environment, Beach environment/Shallow marine agitated deposition and Aeolian process/Shallow agitated marine environment. According to a classification proposed by Sahu (1964) a graphical plot of Y2 vs. Y3 Figure 9 allows four fields of depositional environments to be distinguished. Group I represents Fluvial/Beach deposits, group II represents Fluvial/Shallow agitated marine environment deposits, group III represents Shallow marine/Beach deposits and group IV represents Shallow marine agitated deposits.

4 RESULTS:

The Trilinear plot in Figure 3 shows that most of the beach sediments are gravelly sand and the cumulative curves (Figure 4) were used to calculate the grain-size statistical parameters (Mz, σI ,Ski and K_G) through applying the equations of folk and Ward (1957).Figure 5 shows the relationship between mean grain size (ϕ) and sorting parameters. The collected samples are mostly within the medium to coarse sand range, and few samples are within the fine sand range, but also mainly lie in the range of moderately to poorly sorted sediments. Textural attributes of sediments, viz. mean (Mz), sorting (SD), skewness (Ski) and kurtosis (KG) are widely used to reconstruct the depositional environment of sediments (Angusamy and Rajamanickam, 2006)and are shown in Table 1.Correlation between size parameters and transport processes/depositional mechanisms of beach sediments has been established by exhaustive studies from many modern and ancient sedimentary environments (Anithamary, Ramkumar & Venkatramanan 2011; Asselman 1999;Folk & Ward 1957; Friedman 1967;Malvarez, Cooper & Jackson 2001;Mason & Folk1958; Ramamohanarao, Sairam, Venkateswararao, Nagamalleswararao & Viswanath 2003;Ramanathan, Rajkumar, Majumdar, Singh, Behera, Snatra & Chidambaram 2009;Suresh, Solai, Chandrasekaran & Rammohan 2008;Valia & Cameron 1977;Visher1969; Wang, Davis & Kraus 1998). Grain size analysis was carried out to construct trilinear plot and cumulative curves (Figures 3and4) and interpret the grain-size frequency distribution in the study of the beach samples. Moreover, cumulative curves were used to calculate the grain-size statistical parameters (Mz, σI, Ski and KG)by applying the equations of Folk and Ward (1957) as shown in Table 2. The measured mean values in the coastal samples of the study area range between -2.63 (pebble size) to 2.39 (fine sand)with an average value of 0.602 as shown in Table 2. Table 3a shows that almost half of the samples (47.4%) are sand gravel while 33.3% are sand. The standard deviation of the coastal samples along the study area (Table 2 and Figure 4) ranges between 0.51 (moderately well sorted) to 6.53 (extremely poorly sorted), i.e. from moderately well sorted to extremely poorly sorted, with an average value of 2.10. More than two-third of the beach sand are poorly to very poorly and extremely poorly sorted while the remaining are moderately or moderately well sorted as shown in Table 1. The lowest value of skewness in the beach samples is -0.86(very coarse skewed) while the highest value is 0.1 (near symmetry), *i.e* from very coarse skewed to near symmetrical (Table 2) with an average value of -0.36. Table 3a show that almost 90% of the beach samples are coarsely to strongly coarse – Skewed and the less abundant skewness class is the fine skewed with one sample (1.75%). The beach samples show kurtosis values ranging from 6.75 (extremely leptokurtic) to 0.79(playkurtic) with an average value of 1.33. According to the kurtosis scale, a third of the samples (33.3%) have mesokurtic curves of distribution while about quarter of the samples (28.1%) have leptokurtic curves (Table 2). The very leptokurtic and platykurtic samples make up 22.8% and 14% respectively as shown in Table 2. The extremely leptokurtic curves make up only 1.75% or one sample out of the fifty seven samples (Tables 1 and 2). Figures 5 to 9 show the relationship between the discriminate functions showing estimated environments. Figure 5 shows the relationship between mean grain size and sorting of the study area. Normally there is general trend for the sorting values to increase as mean grain size increases. Samples from Al Tawila (Yas Island) are mostly fine to medium sand and moderately sorted, while those from Abu Dhabi Island are coarse grain and poorly sorted. Figure 6 shows the relationship between sorting and skewness of the study area. Poorly sorted sediments are mostly from Abu Dhabi Island and plot in negatively symmetrical range *i.e.* skewed towards the coarse fractions, while sediments from Alwila (Yas Island) are moderately to well sorted cluster around near symmetrical range. Figure 7 shows the relationship between skewness and kurtosis. Most of the sediments plot in negatively skewed range and are in meso-to leptokurtic field. On the basis of Y1, linear discriminant function, values derived from calculations for the present study 94.7% of the samples were identified as beach sediments while only 5.3% were identified as aeolian deposits (Table 4 and Figure8). Values of Y2, linear discriminant function, calculated for the present sediments indicate that all of the collected sediments samples are derived from agitated marine environments (Table 4 and Figure 9). The collected sediment samples also show 68.4% are of fluvial deposits while 31.6% are of shallow marine deposits based on values calculated for Y3 (Table 4 and Figure 9).

5 DISCUSSION

In the following the results are discussed and compared to the literature about beach sediment grain size and their depositional environment in Abu Dhabi, United Arabic Emirates.

5.1 Grain size distribution

The Trilinear plot in Figure 3 shows that most of the beach sediments are gravelly sand and the cumulative curves (Figure 4) were used to calculate the grain-size statistical parameters (**Mz** , σI ,Ski and K_G) through applying the equations of folk and Ward (1957). The mean (Mz) reflects the overall average size of the beach samples which is influenced by sample source, mode of transportation and environment of deposition (Folk, 1966; Udden, 1914). The grain size of the beach sediments controls the mode and points the distance of transportation: the finer the size, the greater the distance. Most of the beach sediments are gravel sand to sand, Table 3a. This suggests that the sediments were deposited under high energy condition, as sediments usually become coarser with increase in energy of the transporting medium (Folk, 1974 The inclusive standard deviation is a measure of the uniformity of grain-size distribution within the beach samples. It depends on the size range in the source rock, extent of weathering, distance of transportation and the energy variation of the depositing medium (Amaral and Prayor, 1977; Folk and Ward , 1957). Table 3a show that More than two-third of the beach sand are poorly to very poorly and extremely poorly sorted. A poor sorting indicates that little selection of grains has taken place during transport or deposition. This might be explain as the result of highly variable energy, turbulent conditions, and lack of constant energy in any one direction. Table 1 show that almost 90% of the beach samples are coarse to strongly coarse – Skewed. Thus, indicating the dominance of coarse fraction in Abu Dhabi beach sediments. The positive values indicate skewness towards the finer grain sizes and the negative values indicating skewness towards the coarser grain sizes. The analysed samples are skewed towards the coarser grain sizes, indicating marine biogenic sediments. More than half of Abu Dhabi beach sand samples are leptokurtic to very leptokurtic , that is, the central portions are better sorted at the tails. This strongly suggests a fluvial or tidal environment, confirming that the sands are river deposited.

5.2 Bivariant Scatter Graphs of Grain Size Parameters

Figure 5 shows the relationship between mean grain size and sorting of the collected samples that are mostly medium to coarse sand range, and few samples are within the fine sand range, but also mainly lie in the range of moderately to poorly sorted sediments. Normally mean grain size and sorting are hydraulically controlled, so that all sedimentary environments the best sorted sediments have mean size in finer fraction. Abu Dhabi beach sediment samples confirm this trend Figure 5. The relationship between skewness and sorting of the collected samples range mainly from moderately to poorly sorted sediments and most of the samples have negative skewness values with few samples near symmetrical (Figure 6). The coarse fractions may be due to the presence of shell and rock fragments. Plotting of skewness against kurtosis is a powerful tool for interpreting the genesis of sediment, by quantifying the degree of normality of its size distribution (Folk.R.L.1966). It is clear from plotting relationship between Skewness and Kurtosis that most of the sediments from the collected samples lay within the negative Skewness and Kurtosis range of mesokurtic to leptokurtic field with few samples lying in the platykurticrange (Figure 7). This suggests the dominance of a sand population with the presence of a subordinate population of coarse-grained particles.

5.3 Determination of the Mechanisms and Environments of Deposition

The process and environment of deposition were decoded by Sahu's(1964) linear discriminate functions of Y1 (Aeolian,beach), Y2 (Beach, shallow agitated water) and Y3 (Shallow marine, fluvial). Scatter plot of Y1 and Y2 shows that majority of the beach sediment fall in Beach/shallow agitated (Figure 8), while few samples fall in the Aeolian/shallow agitated. The scatter plot of Y2 and Y3 (Figure 9), indicate that almost 50% of the samples are deposited in Shallow marine agitated, while the other 50% are fluvial agitated.

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6 CONCLUSION

Grain size analysis of 57 sediment samples from coastal area of Abu Dhabi was performed in this study. The sediments are generally coarse grained, poorly sorted, negatively symmetrical and mostly leptokurtic in nature. The energy process discriminant functions of the sediments indicated that they were deposited predominantly by Aeolian, shallow marine deposition environment and with influence of fluvial process. A further study on the composition of the different grain size sediments is recommended.

7 APPENDICES

Fig.1 *Location map of sampling sites at the study area.*

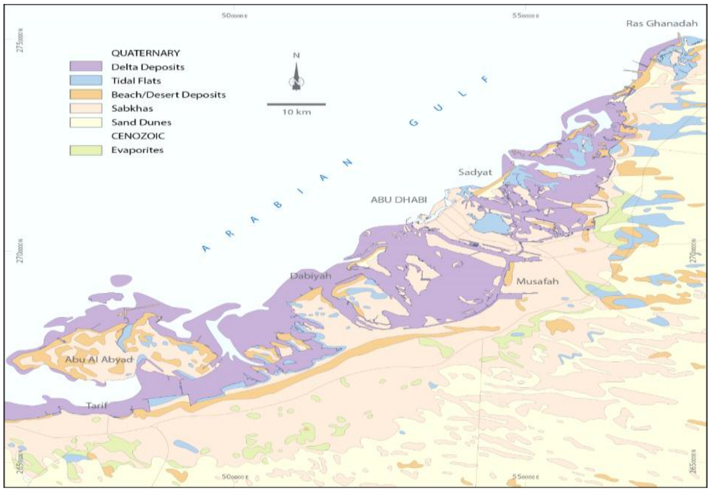

Fig. 2. *Geological map of the study area (Simplified from EAD, 2012).*

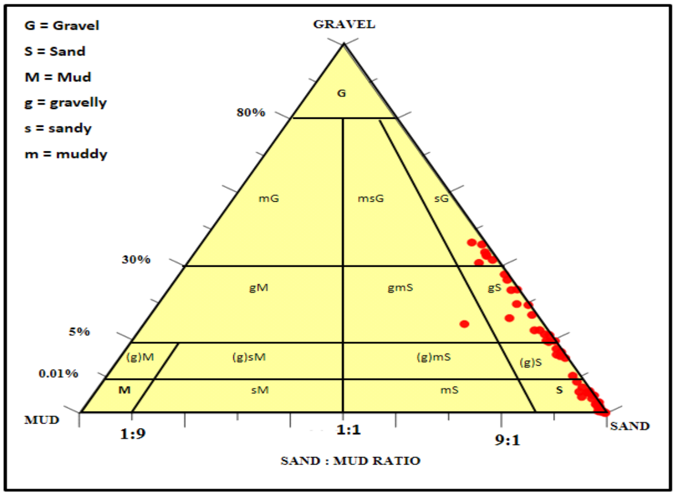

Fig. 3. *Trilinear plot sieve analysis (After Folk, 1974)*

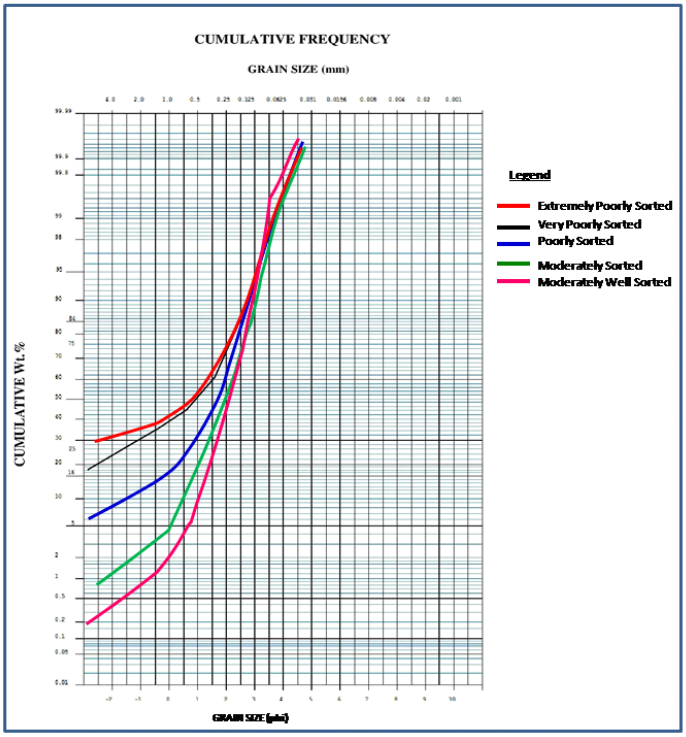

Fig. 4. *Shows the average cumulative curves classified according to sorting values as the following: Extremely Poorly Sorted (29, 32, 33, 35, 44, 47, 57). Very Poorly Sorted (3, 8, 13, 17, 19, 20, 21, 22, 23, 26, 27, 28, 30, 36, 37, 42, 43, 45, 46, 49, 52, 56). Poorly Sorted (4, 6, 10, 12, 18, 25, 31, 38, 39, 51). Moderately Sorted (1, 2, 5, 7, 11, 15, 24, 34, 48, 50, 54). Moderately Well Sorted (9, 14, 16, 40, 41, 53, 55)*

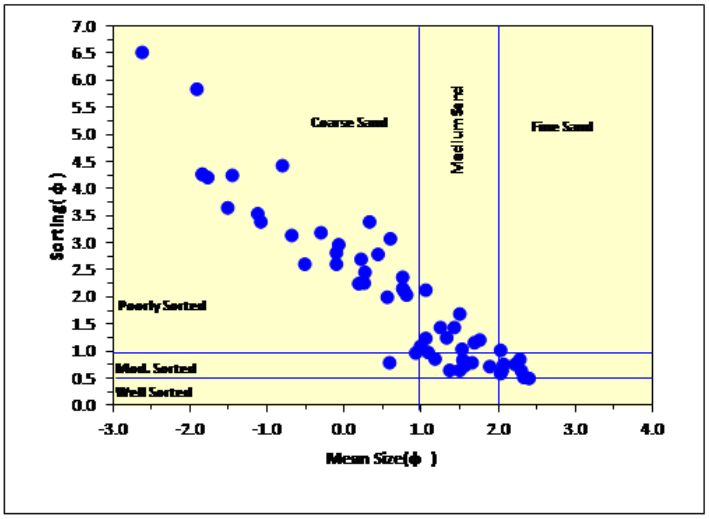

Fig.(5) *Sector Plot showing the bivariant relationship between Grain size(ϕ) and Sorting*

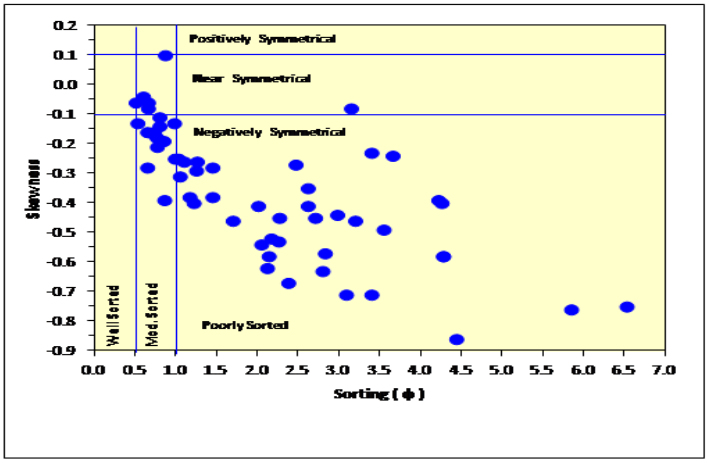

Fig. (6) *Sector Plot showing the bivariant relationship between Skewness and Sorting*

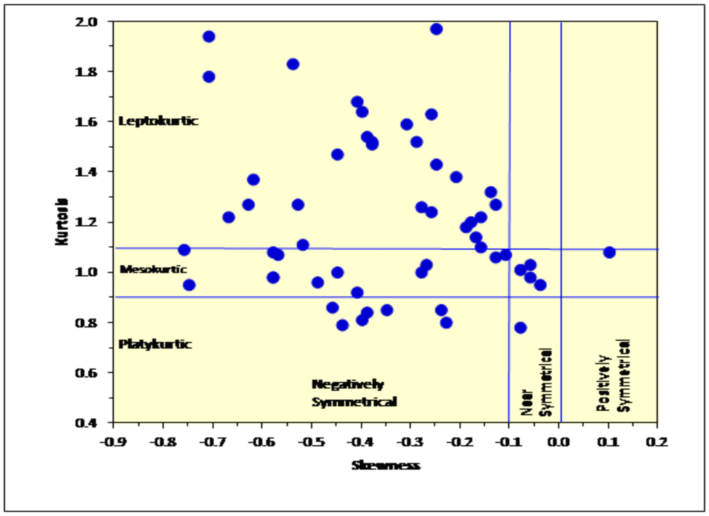

Fig. (7) *Sector Plot showing the bivariant relationship between Skewness and Kurtosis.*

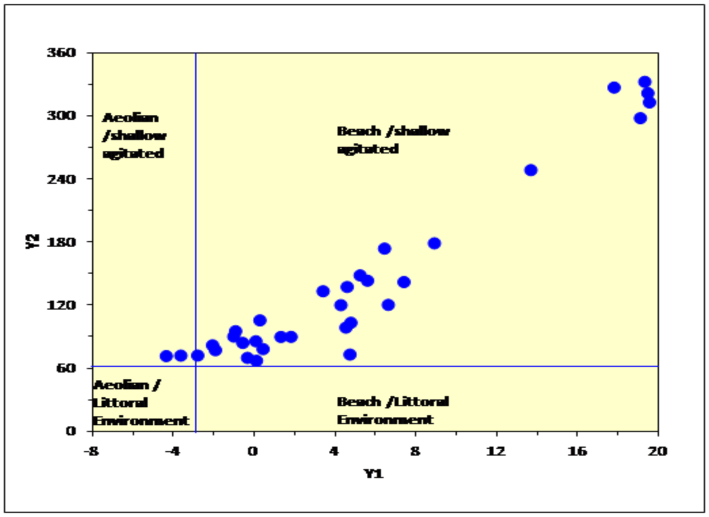

Fig (8) *Relationship between the discriminate functions Y1 and Y2 showing estimated environments.*

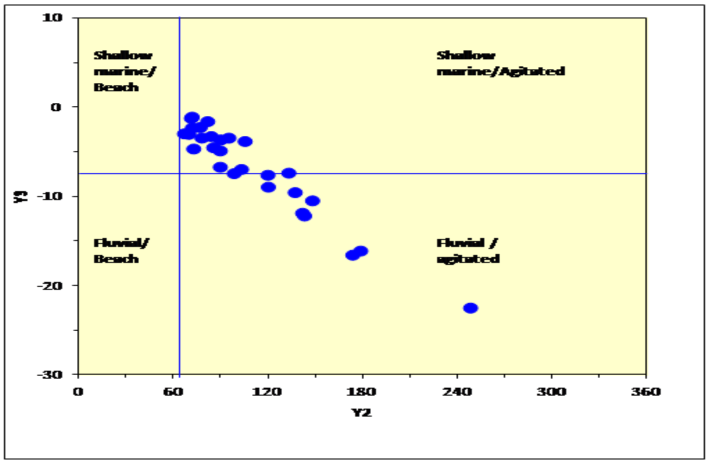

Fig. (9) *Relationship between the discriminate functions Y2 and Y3 showing estimated environments.*

Table 1 *Size Parameter Values (Folk and Ward (1957)*

S.No.	Mean	Sorting	Skewness	Kurtosis
1	Medium Sand	Moderately Sorted	Coarsely Skewed	Mesokurtic
2	Medium Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
3	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Leptokurtic
4	Medium Sand	Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
5	Coarse Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
6	Medium Sand	Poorly Sorted	StronglyCoarse Skewed	Very Leptokurtic
7	Fine Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
8	Very Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
9	Fine Sand	Moderately Well Sorted	Coarsely Skewed	Leptokurtic
10	Medium Sand	Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
11	Coarse Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
12	Medium Sand	Poorly Sorted	Coarsely Skewed	Mesokurtic
13	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Leptokurtic
14	Fine Sand	Moderately Well Sorted	Coarsely Skewed	Mesokurtic
15	Fine Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
16	Fine Sand	Moderately Well Sorted	Nearly Symmetrical	Mesokurtic
17	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Leptokurtic
18	Fine Sand	Poorly Sorted	Coarsely Skewed	Very Leptokurtic
19	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
20	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Leptokurtic
21	Very	Very Poorly	Strongly	Platykurtic

	Coarse Sand	Sorted	Coarse - Skewed	
22	Medium Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
23	Granule	Very Poorly Sorted	Coarsely Skewed	Platykurtic
24	Medium Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
25	Medium Sand	Poorly Sorted	Coarsely Skewed	Very Leptokurtic
26	Very Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
27	Granule	Very Poorly Sorted	Coarsely Skewed	Platykurtic
28	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
29	Granule	Extremely Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
30	Very Coarse Sand	Very Poorly Sorted	Nearly Symmetrical	Platykurtic
31	Medium Sand	Poorly Sorted	Coarsely Skewed	Leptokurtic
32	Granule	Extremely Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
33	Pebble	Extremely Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
34	Fine Sand	Moderately Sorted	Strongly Coarse - Skewed	Very Leptokurtic
35	Granule	Extremely Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
36	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Leptokurtic
37	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
38	Coarse Sand	Poorly Sorted	Coarsely Skewed	Very Leptokurtic
39	Medium Sand	Poorly Sorted	Strongly Coarse Skewed	Very Leptokurtic
40	Medium Sand	Moderately Well Sorted	Nearly Symmetrical	Mesokurtic
41	Medium Sand	Moderately Well Sorted	Nearly Symmetrical	Mesokurtic
42	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
43	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Leptokurtic
44	Granule	Extremely Poorly Sorted	Strongly Coarse - Skewed	Platykurtic
45	Coarse Sand	Very Poorly Sorted	Coarsely Skewed	Mesokurtic
46	Very Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Platykurtic
47	Granule	Extremely Poorly Sorted	Strongly Coarse - Skewed	Platykurtic
48	Medium Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
49	Granule	Very Poorly Sorted	Strongly Coarse - Skewed	Mesokurtic
50	Medium Sand	Moderately Sorted	Coarsely Skewed	Leptokurtic
51	Medium Sand	Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
52	Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Very Leptokurtic
53	Fine Sand	Moderately Well Sorted	Nearly Symmetrical	Mesokurtic
54	Medium Sand	Moderately Sorted	Fine Skewed	Mesokurtic
55	Fine Sand	Moderately Well Sorted	Coarsely Skewed	Mesokurtic
56	Very Coarse Sand	Very Poorly Sorted	Strongly Coarse - Skewed	Platykurtic
57	Very Coarse Sand	Extremely Poorly Sorted	Strongly Coarse - Skewed	Extremely Leptokurtic

***Table 2** Grain size characteristics of beach soil environment along Abu Dhabi coast, United Arab Emirates.*

S.No.	Median	Mean (Mz)	Sorting (σI)	Skewness (SkI)	Kurtosis (KG)
1	1.70	1.65	0.80	-0.11	1.07
2	1.62	1.55	0.74	-0.17	1.14
3	1.54	0.77	2.12	-0.62	1.37
4	1.94	1.75	1.22	-0.40	1.64
5	0.96	0.92	0.98	-0.13	1.27
6	1.50	1.24	1.45	-0.38	1.52
7	2.11	2.06	0.77	-0.18	1.20
8	0.88	-0.11	2.83	-0.57	1.07
9	2.36	2.29	0.65	-0.28	1.26
10	1.60	1.52	1.05	-0.31	1.59
11	0.60	0.58	0.80	-0.14	1.32
12	1.62	1.42	1.45	-0.28	1.00
13	0.87	0.18	2.26	-0.53	1.27
14	2.07	2.04	0.65	-0.16	1.10
15	2.23	2.21	0.77	-0.21	1.38
16	2.03	2.02	0.60	-0.04	0.95
17	1.71	0.75	2.38	-0.67	1.22
18	2.06	2.02	1.03	-0.25	1.97
19	1.02	0.21	2.71	-0.45	1.00
20	1.41	0.75	2.17	-0.52	1.11
21	0.62	-0.31	3.20	-0.46	0.86
22	1.81	1.05	2.14	-0.58	1.08
23	-1.04	-1.52	3.66	-0.24	0.85
24	1.17	1.08	0.99	-0.25	1.43
25	1.20	1.05	1.25	-0.29	1.52
26	0.59	-0.11	2.62	-0.41	0.92
27	-0.72	-1.09	3.40	-0.23	0.80
28	1.62	0.32	3.40	-0.71	1.78
29	0.85	-1.92	5.85	-0.76	1.09
30	-0.68	-0.69	3.15	-0.08	0.78
31	1.46	1.32	1.26	-0.26	1.24
32	-0.24	-1.85	4.28	-0.58	0.98
33	0.55	-2.63	6.53	-0.75	0.95
34	2.37	2.27	0.86	-0.39	1.54
35	-0.24	-1.85	4.28	-0.58	0.98
36	0.81	0.25	2.27	-0.45	1.47
37	0.90	0.55	2.01	-0.41	1.68
38	1.05	0.98	1.10	-0.26	1.63
39	1.68	1.49	1.70	-0.46	2.35
40	1.38	1.36	0.66	-0.08	1.01
41	1.51	1.49	0.66	-0.06	1.03
42	1.74	0.59	3.09	-0.71	1.94
43	1.50	0.43	2.80	-0.63	1.27
44	-0.81	-1.78	4.22	-0.39	0.84
45	0.54	0.26	2.47	-0.27	1.03

46	0.75	-0.08	2.98	-0.44	0.79
47	-0.50	-1.46	4.26	-0.40	0.81
48	1.59	1.53	0.85	-0.19	1.18
49	-0.05	-1.13	3.55	-0.49	0.96
50	1.93	1.88	0.73	-0.16	1.22
51	1.85	1.68	1.17	-0.38	1.51
52	1.28	0.80	2.05	-0.54	1.83
53	2.41	2.39	0.51	-0.06	0.98
54	1.12	1.17	0.87	0.10	1.08
55	2.35	2.32	0.53	-0.13	1.06
56	0.02	-0.52	2.62	-0.35	0.85
57	0.68	-0.81	4.44	-0.86	6.75

Table 3 *Grain size distribution and Texture*

Sample no.	Gravel%	sand%	mud%	Texture
1	0.98	98.39	0.63	Sand
2	1.07	97.93	1.00	Sand
3	16.62	83.03	0.33	Gravelly Sand
4	5.58	93.46	0.94	Gravelly Sand
5	2.94	96.93	0.00	Sand
6	8.52	89.98	1.40	Gravelly Sand
7	2.41	96.60	0.93	Sand
8	26.70	72.44	0.83	Gravelly Sand
9	1.82	97.69	0.45	Sand
10	5.06	94.67	0.27	Gravelly Sand
11	4.78	95.22	0.00	Sand
12	5.80	91.83	2.34	Gravelly Sand
13	21.23	78.49	0.26	Gravelly Sand
14	0.15	99.65	0.20	Sand
15	0.55	98.09	1.34	Sand
16	0.00	99.65	0.28	Sand
17	18.75	81.06	0.00	Gravelly Sand
18	4.40	92.92	2.55	Sand
19	25.81	68.56	5.54	Gravelly Sand
20	17.47	81.67	0.80	Gravelly Sand
21	23.68	59.51	14.55	Gravelly Sand
22	15.90	82.48	1.56	Gravelly Sand
23	46.37	51.17	2.39	Sandy Gravel
24	4.00	95.06	0.85	Sand
25	7.02	91.84	1.14	Gravelly Sand
26	29.65	68.06	2.24	Gravelly Sand
27	42.74	55.73	1.42	Sandy Gravel
28	21.44	77.48	1.07	Gravelly Sand
29	36.24	63.01	0.75	Sandy Gravel
30	40.84	55.31	3.81	Sandy Gravel
31	25.77	61.74	0.16	Gravelly Sand
32	5.54	93.81	0.65	Gravelly Sand
33	43.05	55.48	1.30	Sandy Gravel
34	2.28	96.87	0.78	Sand
35	41.59	57.39	0.82	Sandy Gravel
36	19.66	78.59	1.60	Gravelly Sand
37	15.48	83.35	1.08	Gravelly Sand
38	6.01	93.61	0.27	Gravelly Sand
39	10.15	88.39	1.38	Gravelly Sand
40	0.12	99.61	0.26	Sand
41	0.15	99.33	0.50	Sand
42	19.34	79.25	1.33	Gravelly Sand
43	22.53	75.01	2.46	Gravelly Sand
44	45.83	53.36	0.75	Sandy Gravel
45	22.56	75.97	1.45	Gravelly Sand
46	33.44	65.09	1.39	Sandy Gravel
47	43.74	55.02	1.22	Sandy Gravel
48	2.69	97.00	0.27	Sand
49	37.70	61.73	0.52	Sandy Gravel
50	2.61	96.97	0.36	Sand
51	5.19	94.21	0.45	Gravelly Sand
52	14.97	84.56	0.40	Gravelly Sand
53	1.51	97.44	0.89	Sand
54	0.35	98.62	0.98	Sand
55	0.53	98.98	0.47	Sand
56	33.58	66.10	0.20	Sandy Gravel
57	19.59	80.37	0.03	Gravelly Sand

Table(4) *summary of the environment using the discriminate functions of the collected samples*

Samples	Area	Y1 (%)		Y2 (%)		Y3 (%)	
		Aeolian	Beach	Beach	Agitated	Fluvial	Shallow Marine
Number of samples	57	3	54	0	57	39	18
Percentage of samples	57	5.3	94.7	0.0	100.0	68.4	31.6

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