

Texture of Dune Sands of Najaf Dunes Field, Iraq

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نسيج رمال الكثبان الرملية في حقل كثبان النجف، العراق

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Abstract

This study aims to define the texture properties and morphological features of the dune sands in the Najaf dune fields in southwestern Iraq. The field exhibits three major types of dunes, primarily barchan, longitudinal, and dome dunes, and different varieties such as Nabkha, Barchanoid ridges, and sand sheets. Based on geographical location, the study area was divided into three zones, from which a large number of samples were collected in the field. Sixty-seven surface samples were taken from typical dunes in windward, crest, and leeward locations. Statistical parameters were computed using the Folk and Ward technique, and grain-size distributions were ascertained by mechanical sieve analysis. Selected quartz grains from three size fractions (2 Ø, 3 Ø, and 4 Ø) were studied for roundness and sphericity using optical microscopy, and surface microtextures were investigated using scanning electron microscopy (SEM). The results show that medium to coarse sand fractions predominate in regions (B) and (C), and fine sand predominates in the dunes of area (A). Aeolian movement under fluctuating wind energy is indicated by mostly positive skewness values, which range from fairly well sorted to moderately sorted. Grain size and roundness have an inverse connection, according to roundness analysis, but sphericity values mostly fall into spherical to extremely spherical classes. A variety of microtextures, such as conchoidal cracks, V-shaped percussion imprints, bulbous edges, and varying surface relief, are revealed by SEM examinations. These features show that the Najaf dunes are comparatively young and are the result of both inherited river sediments and aeolian reworking, most likely from surrounding older strata and Euphrates floodplain deposits. The work offers fresh perspectives on dune formation in arid regions' transitional fluvial-aeolian ecosystems.

Keywords: Aeolian dunes, Grain size analysis, Iraq, Sand textures, SEM microtextures.

المخلص.

تهدف هذه الدراسة إلى تحديد خصائص نسيج وخصائص مورفولوجية رمال الكثبان الرملية في حقول كثبان النجف، جنوب غرب العراق. يضم الحقل ثلاثة أنواع رئيسية من الكثبان الرملية، هي: الكثبان الهلالية، والكثبان الطولية، والكثبان القُبيّة، بالإضافة إلى أنواع أخرى مثل: النخبة، والتلال الهلالية، والصفائح الرملية. قُسمت منطقة الدراسة إلى ثلاث مناطق وفقاً لموقعها الجغرافي، وجمعت عينات عديدة منها. أخذت سبع وستون عينة سطحية من كثبان رملية نموذجية في مواقع مواجهة للرياح، وقممها، ومواقع معاكسة لها. حُسبت المعايير الإحصائية باستخدام طريقة فولك وورد، وحُدد توزيع أحجام الحبيبات بتحليل المنخل الميكانيكي. دُرست حبيبات الكوارتز المختارة من ثلاثة أحجام (2، 3، و4) من حيث استدارتها وكرويتها باستخدام المجهر الضوئي، وفُحصت البنية المجهرية السطحية باستخدام المجهر الإلكتروني الماسح. تُظهر النتائج أن حبيبات الرمل متوسطة إلى خشنة الحجم هي السائدة في المنطقتين (ب) و(ج)، بينما يسود الرمل الناعم في كثبان المنطقة (أ). وتشير قيم الانحراف الموجبة في الغالب إلى حركة رملية بفعل الرياح المتغيرة، حيث تتراوح هذه القيم من جيدة الفرز إلى متوسطة الفرز. ووفقاً لتحليل الاستدارة، توجد علاقة عكسية بين حجم الحبيبات واستدارتها، إلا أن قيم الكروية تقع في الغالب ضمن فئات كروية إلى كروية للغاية. وقد كشفت فحوصات المجهر الإلكتروني الماسح عن مجموعة متنوعة من البنى المجهرية، مثل الشقوق الصدفية، وآثار الطرق على شكل حرف V، والحواف المننقخة، وتضاريس السطح المتفاوتة. وتشير هذه الخصائص إلى أن كثبان النجف حديثة نسبياً، وأنها ناتجة عن كلٍ من الرواسب النهرية

الموروثة وإعادة تشكيل بفعل الرياح، على الأرجح من الطبقات الأقدم المحيطة ورواسب سهل الفرات الفيضي. ويُقدم هذا العمل رؤى جديدة حول تكوين الكثبان الرملية في النظم البيئية الانتقالية بين الأنهار والرياح في المناطق القاحلة.

الكلمات المفتاحية: الكثبان الرملية الريحية، تحليل حجم الحبيبات، العراق، نسيج الرمال، صور مجهرية إلكترونية.

Introduction

Aeolian processes play a fundamental role in shaping the geomorphology of arid and semi-arid regions. The textural characteristics of dune sands provide critical insights into sediment provenance, transport history, and the aerodynamic energy of the depositional environment.

The three main characteristics of sedimentary rocks that make up their texture are grain size, grain shape (form, roundness, and surface texture [microrelief] of grains), and fabric (how the grains are packed and oriented). The grain shape and size are properties of individual grains. Fabric is a property of grain aggregates [1]. The texture of a clastic rock is a reflection largely of the depositional processes. Therefore, many modern types of sediments from different environments have been studied to determine their textural characteristics; this information is used as an aid to the interpretation of sedimentary rocks [2]. Several sediment characteristics affect particle entrainment, including density, textural variation, and shape [3]. As they are transported, grains are sorted according to a range of factors, including size, shape, and density, and may undergo changes in shape due to friction between particles or rolling along the Earth's surface. Therefore, it is essential to consider the physical properties of these grains and their impact on modifying the characteristics of grain groups during wind transport to understand and interpret the ancient environment of these sediments [4].

Locations of the study area

The study area is located in the western and southwestern parts of Najaf city center. The area is divided into three sites according to the presence of dunes. These locations are A, B, and C, as shown in Table 1 and Figure 1.

Table 1: Location coordinates of the Study Area.

Locations	No.	Latitude	Longitude
Area(A)	1	32°01'40" N	44°03'53" E
	2	32°02'15" N	44°05'27" E
	3	31°57'21" N	44°09'50" E
	4	31°56'42" N	44°08'02" E
Area(B)	1	31°53'41" N	44°14'48" E
	2	31°54'19" N	44°16'00" E
	3	31°50'36" N	44°18'49" E
	4	31°49'47" N	44°17'33" E
Area(C)	1	31°50'43" N	44°19'07" E
	2	31°51'13" N	44°19'59" E
	3	31°48'57" N	44°22'02" E
	4	31°48'23" N	44°21'06" E

Materials and Methods

Many visits were conducted; the first was an exploratory visit, in October, 2019 and continues field work to the January 2020. (Global Position System) (GPS), Brunton Compass, Tape and Ruler were used to indicate the exact points, in order to observe and measure the orientations of the sedimentary structures and to delineate the geometry of sand dune fields.

Accordingly, sampling was carried out for three localities; these are, as they are known locally: The first area is located next to the Al-Rahimiya village (I), the second area southren of Mazlum District (II), and the last area is in the northeast of (Khan Rahba) (III). The locations of samples were determined by a GPS device and by using (Earth Explorer software online) (Fig. 1).

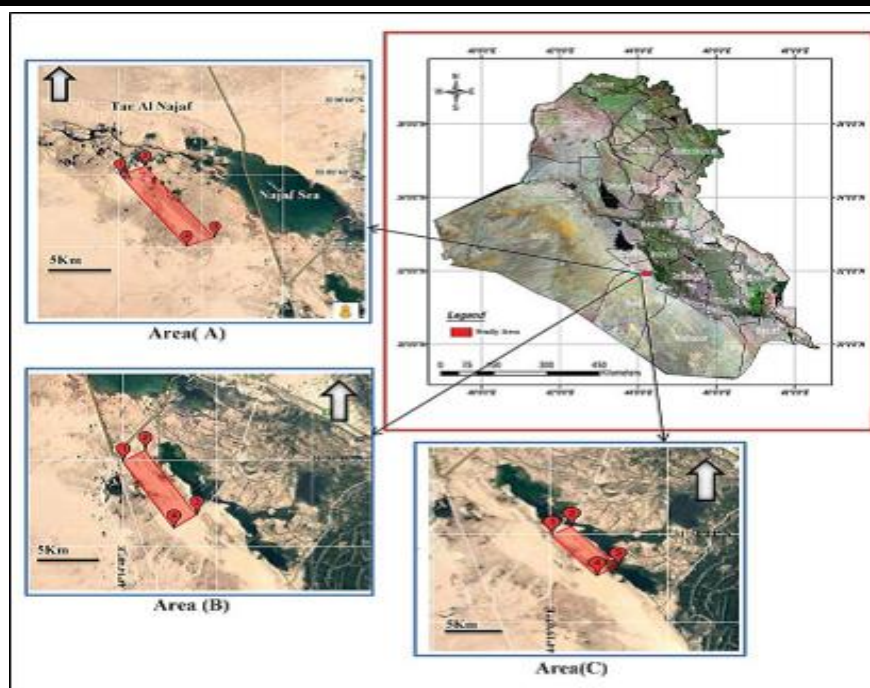


Fig 1: Satellite Image of the A, B and C zones which represent the Study Area

Sixty-seven representative samples from these localities were collected from (Windward, Crest, Leeward) of every individual sand dunes (mostly barchans), and collected samples from (East, West Flanks and Crest) of Longitudinal dunes with collected from all directions to the Dome dune, and one sample from (Sandsheet & Nabkha) dunes type. The collected samples were approximately along parallel orientation to prevailing wind direction NW-SE, and were taken from the uppermost 0-3 cm [5] to prevent mixing of material from different lamina.

All samples were subjected to mechanical sieving analysis following the method suggested by Folk (1974). Weighting 100 grams per sample was sieved in a Ritsch Shaker for 15 minutes using a set of sieves at (1Phi) intervals from (-1 Phi) to (4Phi). The accumulation of mud size (Silt and Clay) in the pan position. The sieved fractions were collected and weighted; percent weights, cumulative percentage data were plotted against phi diameter by (Sigmaplot 14.0) software and the grain size parameters (sorting, mean, median, skewness, kurtosis) were estimated in accordance with (Folk and Ward) [6] formulae by using The (GRADISTAT) software [7].

Result and Discussion

Grain Size Distribution

Granulometric analysis serves as a fundamental tool for evaluating sediment transport behavior. Within desert systems, parameters such as sediment provenance, transport range, sand availability, and selective wind action collectively shape the particle size profiles of dune deposits [8] and [4]. Consequently, grain size characteristics are tightly linked to dune evolution, which is governed predominantly by eolian transport processes [9] and [10].

Displaying Grain-Size Data

The grain size data presented by two graphical procedures are; Histogram and Cumulative curve.

Histograms

Representing the data by plotting it as a percentage weight on the vertical axis and the phi value for each size category on the horizontal axis gives an impression of the nature of the data in the simplest way possible. pictorial representation of the grain-size distribution, but

their shape is affected by the phi size intervals selected for plotting [1]. The resulted histograms of studied dune samples are shown in (Fig. 2). The unimodal mode was observed to be the prominent type presents among the studied samples mostly in barchans dune samples, but in dome, longitudinal, nabkha, and sand sheet dunes samples show bimodal and polymodal. The reasons for these differences may be concerned with direction and speed of wind beside other factors such as relief, topography, presence of vegetation, and frequent dust storms deposited over the whole area.

The dome and longitudinal dunes samples show approximately high percentage of mud fraction (silt and clay) than barchan dunes, this is due to the fixed nature or slow movement of sand grains thus may trap sediment of dust storms sedimentation, while in barchans dunes the movement of these dunes prevents the accumulation of mud sizes sediments.

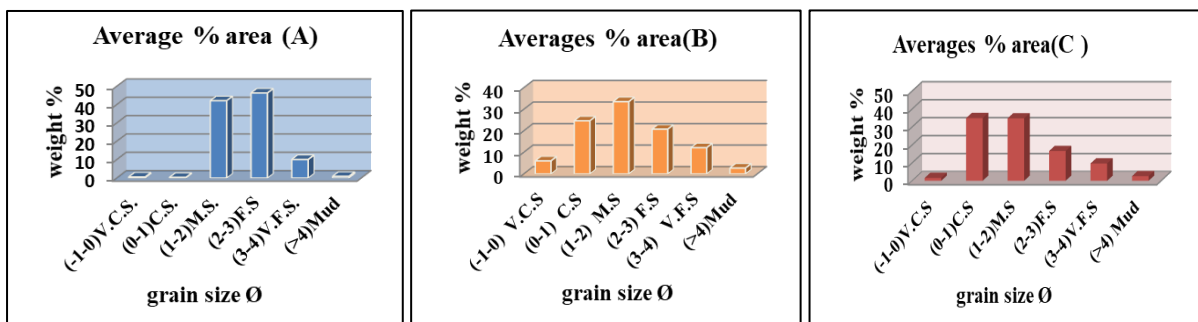


Fig 2: Show the histograms of the studies areas (A), (B), and (C).

Cumulative Frequency Curve:

These curves were first used by Fisher in 1969 in order to represent the cumulative distribution of grain size on a probability (orthogonal) sheet [11]. Cumulative frequency curves can often be divided into two, three, or four linear segments. Because the normal logarithmic distribution follows linear trends on the cumulative probability curve, each segment is considered a separate subset, whose characteristics are determined by the dynamics of transport: drag, jump, and suspension. Sediment from different environments (dune, fluvial, beach, tidal, and turbidities) can putatively be differentiated on the basis of the general shapes of the cumulative curves [12]. The results of the cumulative curve of the studied dune samples are shown in (Figure 3); the majority of samples represent a saltation population. The traction population is made up of a small amount of poorly sorted sediments, while the saltation population is made up of sediments that are better sorted than the fine-grained suspension population. The general trend of most sample curves was found to be similar to a dunes cumulative curve [13].

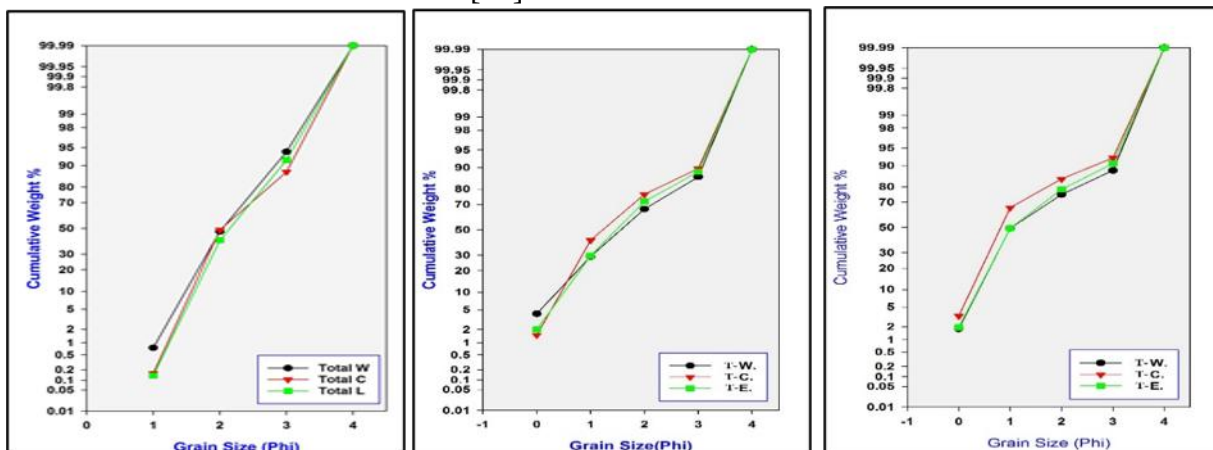


Fig3: Show the Cumulative Probability Curves for the study areas samples (A, B, and C).

Statistical Parameters

Quantitative assessments correlating natural granulometric profiles to lognormal distributions are achievable through the application of several statistical metrics[4]. Based on the equation proposed by Folkward, the statistical parameters for particle size were calculated [6].

The criteria used to describe particle size distribution are five groups, as follows: kurtosis, standard deviation, skewness, median, and mean. The calculated statistical parameters and descriptions are shown in Tables (3), (4), and (5). The range and average of statistical parameters, including of each studied areas in the dune field is given in Table (2).

Table (2): Shows the range and the Average of the statistical parameters for the studies areas (A), (B), and (C)

Statistical Parameters(Φ)	Area(A)		Area(B)		Area(C)	
	Range	Average	Range	Average	Range	Average
Mean size (Mz)	1.71 -2.69	2.34	1.04 -2.55	1.74	1.13-2.36	1.7
Median (MdZ)	1.66-2.71	2.35	0.69-2.60	1.61	0.85-2.48	1.49
Standard Deviation (σ I)	0.50-1.10	0.62	0.66-1.26	0.97	0.65-1.21	0.93
Skewness (SkI)	-0.41 - 0.60	0.08	-0.14-0.52	0.20	-0.06-0.72	0.38
Kurtosis (KG)	0.58-2.27	0.92	0.65-1.24	0.88	0.73-1.30	1.031

Table (3): Descriptive statistical analysis for the grain size of Study area (A).

Dune Type& No.	Sample No.	MEAN (MZ)		MEDIAN (MdZ)	SORTING (ϕ I)		SKEWNESS (SKI)		KURTOSIS (KG)	
		Values	Description	Values	Values	Description	Values	Description	Values	Description
Barachan 1	A-1W	2.422	Fine Sand	2.616	0.614	Moderately Well Sorted	-0.249	Coarse Skewed	0.871	Platykurtic
	A-1C	2.374	Fine Sand	2.526	0.641	Moderately Well Sorted	-0.134	Coarse Skewed	0.848	Platykurtic
	A-1L	2.335	Fine Sand	2.478	0.524	Moderately Well Sorted	-0.318	Very Coarse Skewed	0.585	Very Platykurtic
Barachan 2	A-2W	2.080	Fine Sand	1.870	0.505	Moderately Well Sorted	0.526	Very Fine Skewed	0.623	Very Platykurtic
	A-2C	2.185	Fine Sand	1.985	0.650	Moderately Well Sorted	0.534	Very Fine Skewed	0.850	Platykurtic
	A-2L	2.207	Fine Sand	1.995	0.673	Moderately Well Sorted	0.541	Very Fine Skewed	0.848	Platykurtic
Barachan 3	A-3W	2.401	Fine Sand	2.589	0.607	Moderately Well Sorted	-0.245	Coarse Skewed	0.831	Platykurtic
	A-3C	2.175	Fine Sand	1.941	0.669	Moderately Well Sorted	0.588	Very Fine Skewed	0.859	Platykurtic
	A-3L	2.373	Fine Sand	2.550	0.518	Moderately Well Sorted	-0.415	Very Coarse Skewed	0.588	Very Platykurtic
Barachan 4	A-4W	2.332	Fine Sand	2.482	0.526	Moderately Well Sorted	-0.335	Very Coarse Skewed	0.585	Very Platykurtic
	A-4C	2.162	Fine Sand	1.959	0.633	Moderately Well Sorted	0.547	Very Fine Skewed	0.840	Platykurtic
	A-4L	2.489	Fine Sand	2.680	0.583	Moderately Well Sorted	-0.289	Coarse Skewed	2.223	Very Leptokurtic

Barachan 5	A-5W	2.150	Fine Sand	1.919	0.657	Moderately Well Sorted	0.595	Very Fine Skewed	0.869	Platykurtic
	A-5C	2.619	Fine Sand	2.647	0.777	Moderately Sorted	-0.002	Symmetrical	0.896	Platykurtic
	A-5L	2.425	Fine Sand	2.612	0.635	Moderately Well Sorted	-0.212	Coarse Skewed	0.882	Platykurtic
Barachan 6	A-6W	2.364	Fine Sand	2.530	0.602	Moderately Well Sorted	-0.202	Coarse Skewed	0.793	Platykurtic
	A-6C	2.172	Fine Sand	1.923	0.677	Moderately Well Sorted	0.609	Very Fine Skewed	0.862	Platykurtic
	A-6L	2.144	Fine Sand	1.955	0.516	Moderately Well Sorted	0.446	Very Fine Skewed	0.587	Very Platykurtic
Barachan 7	A-7W	2.385	Fine Sand	2.566	0.603	Moderately Well Sorted	-0.237	Coarse Skewed	0.807	Platykurtic
	A-7C	2.592	Fine Sand	2.584	0.799	Moderately Sorted	0.055	Symmetrical	0.852	Platykurtic
	A-7L	2.476	Fine Sand	2.671	0.634	Moderately Well Sorted	-0.235	Coarse Skewed	0.952	Mesokurtic
Nabakaha	A-1Nab.	2.530	Fine Sand	2.710	0.596	Moderately Well Sorted	-0.255	Coarse Skewed	2.278	Very Leptokurtic
	A-2Nab.	2.697	Fine Sand	2.708	0.790	Moderately Sorted	-0.002	Symmetrical	0.955	Mesokurtic
	A-3Nab.	2.135	Fine Sand	1.903	0.648	Moderately Well Sorted	0.603	Very Fine Skewed	0.877	Platykurtic
Sand Sheet	A-1S.Sh.	1.871	Medium Sand	1.817	0.969	Moderately Sorted	0.155	Fine Skewed	1.182	Leptokurtic
	A-2S.Sh.	1.710	Medium Sand	1.668	1.122	Poorly Sorted	0.069	Symmetrical	0.919	Mesokurtic

Table (4): Descriptive statistical analysis for the grain size of Study area (B).

Dune Type& No.	Sample No.	MEAN(MZ)		MEDIAN (Mdz)	SORTING (δI)		SKEWNESS (SKI)		KURTOSIS(KG)	
		Values	Description		Values	Description	Values	Description	Values	Description
B-1Dome	B-1SD	1.172	Medium Sand	0.862	1.124	Poorly Sorted	0.352	Very Fine Skewed	0.670	Platykurtic
	B-1ED	1.209	Medium Sand	0.883	1.269	Poorly Sorted	0.357	Very Fine Skewed	0.821	Platykurtic
	B-1CD	1.102	Medium Sand	0.740	1.001	Poorly Sorted	0.398	Very Fine Skewed	0.652	Very Platykurtic
	B-1ND	1.192	Medium Sand	0.910	1.208	Poorly Sorted	0.331	Very Fine Skewed	0.852	Platykurtic
	B-1WD	1.047	Medium Sand	0.698	1.178	Poorly Sorted	0.406	Very Fine Skewed	0.873	Platykurtic
B-2long.	B-2WF	1.776	Medium Sand	1.734	0.890	Moderately Sorted	0.157	Fine Skewed	0.804	Platykurtic
	B-2C	1.720	Medium Sand	1.660	0.921	Moderately Sorted	0.082	Symmetrical	0.866	Platykurtic
	B-2EF	1.778	Medium Sand	1.742	0.901	Moderately Sorted	0.148	Fine Skewed	0.776	Platykurtic
B-3long.	B-3WF	1.817	Medium Sand	1.776	1.050	Poorly Sorted	0.143	Fine Skewed	0.757	Platykurtic
	B-3C	1.687	Medium Sand	1.615	1.008	Poorly Sorted	0.215	Fine Skewed	1.110	Mesokurtic
	B-3EF	1.781	Medium Sand	1.737	1.014	Poorly Sorted	0.163	Fine Skewed	0.797	Platykurtic
B-4long.	B-4WF	2.557	Fine Sand	2.606	0.966	Moderately Sorted	-0.148	Coarse Skewed	1.106	Mesokurtic
	B-4C	1.770	Medium Sand	1.700	1.040	Poorly Sorted	0.192	Fine Skewed	0.766	Platykurtic
	B-4EF	1.788	Medium Sand	1.731	1.015	Poorly Sorted	0.179	Fine Skewed	0.799	Platykurtic
B-5long.	B-5WF	1.795	Medium Sand	1.733	1.083	Poorly Sorted	0.170	Fine Skewed	0.687	Platykurtic
	B-5C	1.451	Medium Sand	0.961	1.176	Poorly Sorted	0.521	Very Fine Skewed	0.892	Platykurtic

	B-5EF	2.510	Fine Sand	2.503	0.983	Moderately Sorted	-0.077	Symmetrical	1.062	Mesokurtic
B-6long.	B-6WF	1.806	Medium Sand	1.785	0.797	Moderately Sorted	0.128	Fine Skewed	0.753	Platykurtic
	B-6C	1.679	Medium Sand	1.580	0.832	Moderately Sorted	0.141	Fine Skewed	0.875	Platykurtic
	B-6EF	1.902	Medium Sand	1.806	0.956	Moderately Sorted	0.206	Fine Skewed	1.247	Leptokurtic
B-Sand Sheet	B-S.Sh.	1.775	Medium Sand	1.744	0.967	Moderately Sorted	0.151	Fine Skewed	0.843	Platykurtic
B-Nabkaha	B-1Nab.	2.112	Fine Sand	1.861	0.658	Moderately Well Sorted	0.458	Very Fine Skewed	1.137	Leptokurtic
	B-2Nab.	2.090	Fine Sand	1.848	0.686	Moderately well Sorted	0.407	Very Fine Skewed	1.191	Leptokurtic
	B-3Nab.	2.397	Fine Sand	2.557	0.665	Moderately Well Sorted	-0.137	Coarse Skewed	0.858	Platykurtic

Table (5): Descriptive statistical analysis for the grain size of the study area (C).

Dune Type& No.	Sample No.	MEAN(Mz)		MEDIAN (Mdz)	SORTING (GI)		SKEWNESS (SKI)		KURTOSIS(KG)	
		Values	Description		Values	Description	Values	Description	Values	Description
C-1long.	C-1 WF	1.420	Medium Sand	0.929	1.009	Poorly Sorted	0.721	Very Fine Skewed	1.074	Mesokurtic
	C-1 C	1.471	Medium Sand	0.966	1.030	Poorly Sorted	0.712	Very Fine Skewed	0.734	Platykurtic
	C-1EF	1.826	Medium Sand	1.789	0.954	Moderately Sorted	0.147	Fine Skewed	1.200	Leptokurtic
C-2long.	C-2 WF	1.773	Medium Sand	1.711	1.023	Poorly Sorted	0.187	Fine Skewed	0.779	Platykurtic
	C-2 C	1.912	Medium Sand	1.557	1.216	Poorly Sorted	0.378	Very Fine Skewed	0.732	Platykurtic
	C-2EF	1.634	Medium Sand	1.651	0.822	Moderately Sorted	0.038	Symmetrical	0.935	Mesokurtic
C-3long.	C-3 WF	1.137	Medium Sand	0.859	0.823	Moderately Sorted	0.691	Very Fine Skewed	1.245	Leptokurtic
	C-3 C	1.391	Medium Sand	0.902	1.091	Poorly Sorted	0.608	Very Fine Skewed	1.301	Leptokurtic
	C-3 EF	1.678	Medium Sand	1.538	1.043	Poorly Sorted	0.284	Fine Skewed	0.767	Platykurtic
C-4long.	C-4 WF	1.662	Medium Sand	1.508	1.038	Poorly Sorted	0.304	Very Fine Skewed	1.060	Mesokurtic
	C-4 C	1.154	Medium Sand	0.871	0.825	Moderately Sorted	0.687	Very Fine Skewed	1.195	Leptokurtic
	C-4 EF	1.621	Medium Sand	1.507	0.999	Moderately Sorted	0.275	Fine Skewed	1.089	Mesokurtic
C-Sand Sheet	C-S.Sh.	2.131	Fine Sand	1.935	0.841	Moderately Sorted	0.287	Fine Skewed	1.103	Mesokurtic
Nabakha	C-1Nab.	2.360	Fine Sand	2.484	0.669	Moderately Well Sorted	-0.066	Symmetrical	0.850	Platykurtic
	C-2Nab.	2.081	Fine Sand	1.827	0.804	Moderately Sorted	0.415	Very Fine Skewed	1.236	Leptokurtic
	C-3Nab.	2.083	Fine Sand	1.845	0.767	Moderately Sorted	0.416	Very Fine Skewed	1.200	Leptokurtic

The general features and properties of statistical parameters are shown:

Mean Size (Mz)

The mean size is the average of all the particle sizes in a sample [1]. The geometric mean size is a parameter that associates to the overall grain size. It is the average size of the sediment, epitomized by (Phi) mean size, and the significance of the index of energy environments [14]. The average percentages of mean values of dune samples from area (A) was mostly in fine sand fraction especially of Barchan and Nabkha dunes, while the mean size average value of areas(B)and (C) dune samples represent a medium sand from Dome, longitudinal, and Sand Sheet Dunes where the Nabkha in these areas have mean size fine sand(Fig.4). The area(A) Shows high percentages of fine sand fractions that indicated formed under high wind regime [15].while the areas(B),(C) are has high percentage of medium sand fractions.

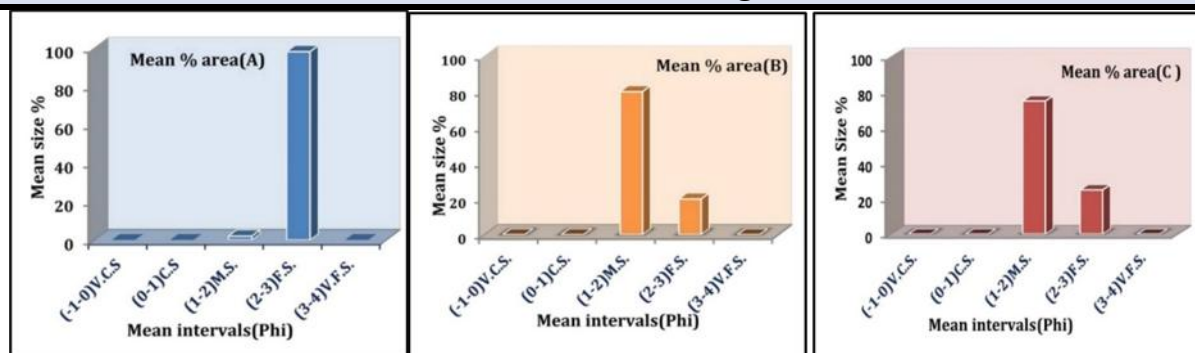


Fig 4: The Mean size percentage of dunes samples from three studies areas (A), (B), and(C).

Median (Md_z)

From the cumulative distribution curve, the particle size can be determined from the 50% line, where it is observed that half of the particles are coarse and the other half are finer than the average diameter [16]. The average percentages of median in area(A) fine sand interval, while areas (B)and(C) are for the dune medium sand interval. Where the area (A) has the 58% in fine sand and 42% medium sand interval, while the percentage of area(B) show 25% in coarse sand interval, 63% in medium sand, and 12% in fine sand interval, finally the area(C) has the 31% median coarse sand and 69% in medium sand interval (Fig. 5).

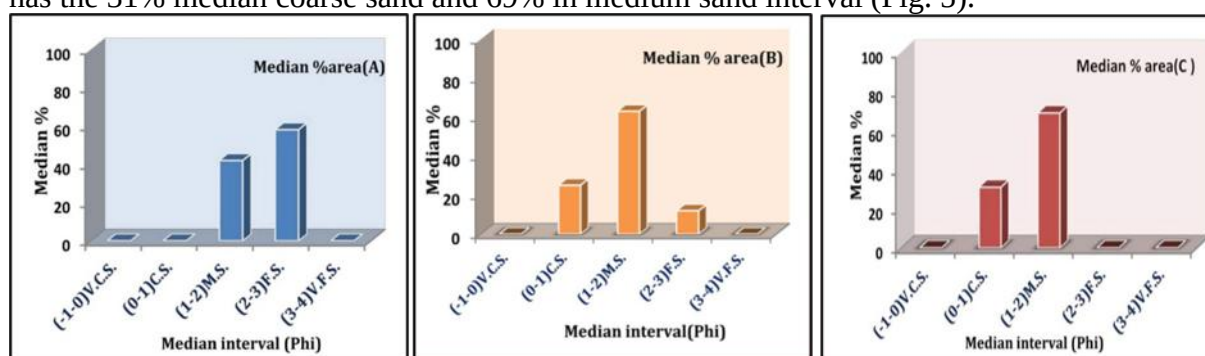


Fig 5: Bar charts of median of studies areas (A), (B), and(C).

Standard Deviation (Sorting_σ)

It can be used to measure the homogeneity and uniformity of particle size distribution. It also serves as an indicator of fluctuations in the dynamic energy characteristics of the depositional environment [17].

The inclusive graphic standard deviation values average 0.62 ϕ (Moderately well sorted) in area (A), 0.97 ϕ (Moderately sorted) in area(B), and 0.93 ϕ (Moderately sorted) in area(C) (Table 4). The study area (A) have the (81%) from samples moderately well sorted and (19%) moderately sorted, While the area(B) have (50%) poorly sorted a, (38%) moderately sorted, and (12%) Moderately well sorted, and area(C) have (43%, 50%, and 7%) poorly sorted, moderately sorted, and moderately well sorted, respectively (Fig.6). The moderately sorted and moderately well sorted nature of the sediment could be due to partial winnowing action as well as the addition of previously sorted sediments [18]. The bad sorting can be explained by the fact that the former come mostly from sediments or weathered rock that weren't sorted well and haven't been moved very far from where they came from [4], and may be the size, shape, and closeness of the source area [19].

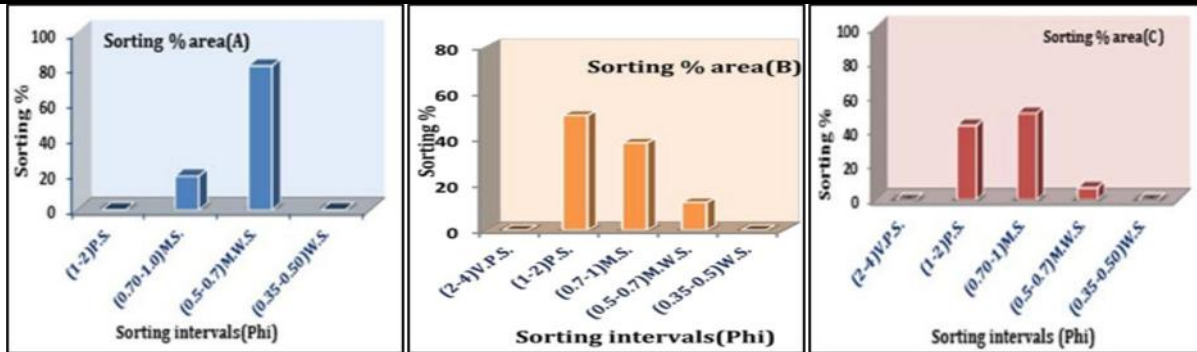


Fig 6: Bar Charts of standard deviation (Sorting %) in studies areas (A), (B), and (C).

Skewness (SkI)

The average Skewness value of study area (A) from dune field sample is 0.08 Ø (Symmetrical), area (B) dune sample is 0.20Ø (Fine Skewed), and study area(C) is 0.38 Ø (Very Fine Skewed) (Table 2). The calculated skewness of the studied samples shows that most of these samples have positive values with a few negative values; this result indicates a higher percentage of the finer sizes in the studied dune samples (Figure 7). The predominance of positive values of skewness is common in dune sand [20] and [21]. Positive skewed dune sands can be attributed to the fact that wind competency limits the largest carried size, whereas no such limitation affects the fine particles in transport [20]. Also, the wide distribution of skewness values may be due to the mixing of fine and coarse grains, which is a result of wind direction changes that can happen during some days of the year [6].

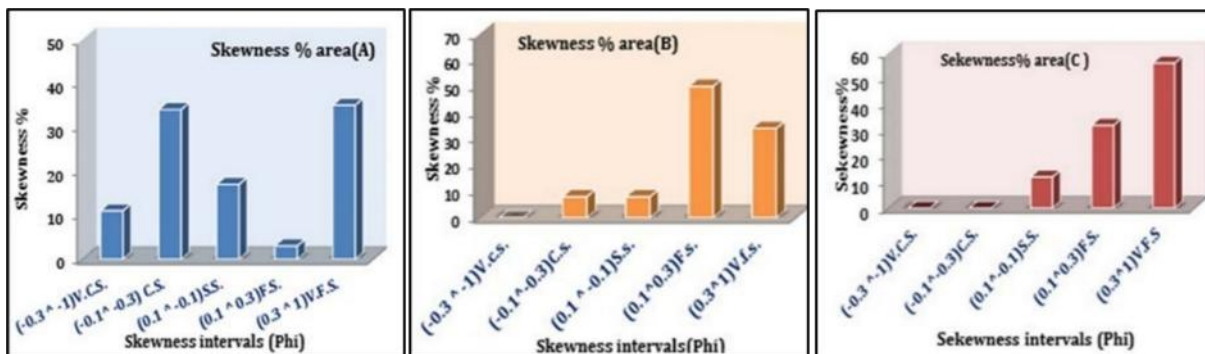


Fig 7: Bar charts of skewness of study areas (A), (B), and (C).

Kurtosis (KG)

The average kurtosis value of the study area (A) samples is 0.92Ø (Mesokurtic), area (B) dune is 0.88Ø (Platykurtic), and area(C) dune samples are 1.03Ø (Mesokurtic) (Table 2). The percentage of different values has area (A), where 58% (Platykurtic), 19% (Very Platykurtic), 10% (Very Leptokurtic), and 13% (Mesokurtic). The kurtosis of area (B) has the 75% (Platykurtic), 13% (Mesokurtic), and 12% (Leptokurtic).while the area (C) has 38% (Leptokurtic), 31% (Platykurtic), and 31% (Mesokurtic)(Fig.8). These variation in kurtosis may be due to the different source area of these dune field, such as the flood plain of Euphrates Rivers and outcrops of old formation in the east, west, and southwest of dune field.

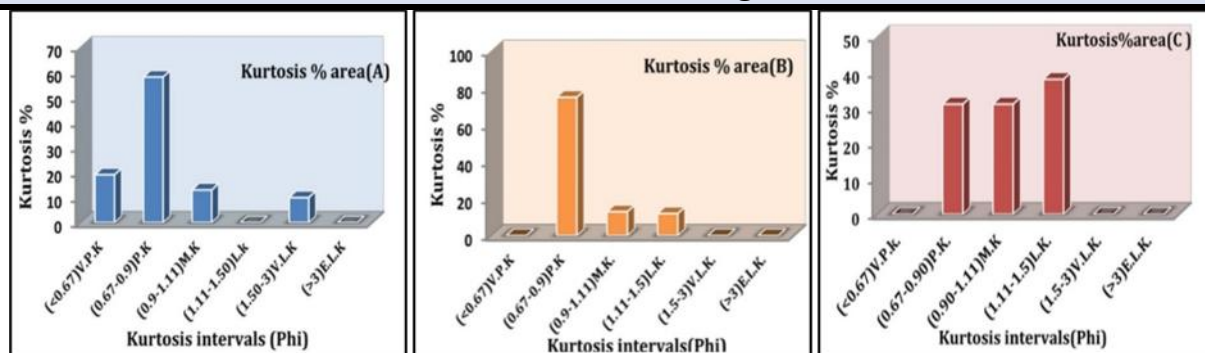


Fig 8: Bar charts of kurtosis of study areas (A), (B), and(C).

Bivariate Plots

Bivariate plots between the different delicate textural parameters throw light on information concerning the depositional environment of sedimentation and demarcate the fields of overlapping of closely related depositional environments [22].

Most of the studied samples have positive values of skewness and moderate values of standard deviation (Figure 9); such cases may indicate that these samples show the inherent effect of the ancient environment (river and beach), in addition to near-distance transportation. The samples area (A) located in transition between river and dunes and other samples especially areas (B) and (C) have positive values of skewness and high values of standard deviation, these samples are usually located within areas characteristics of inherent effect at river, and possibility that the dunes in Najaf field are immature dunes such as the great deserts do not have the characteristics of the desert dunes, but the inherent from the sediments of the source.

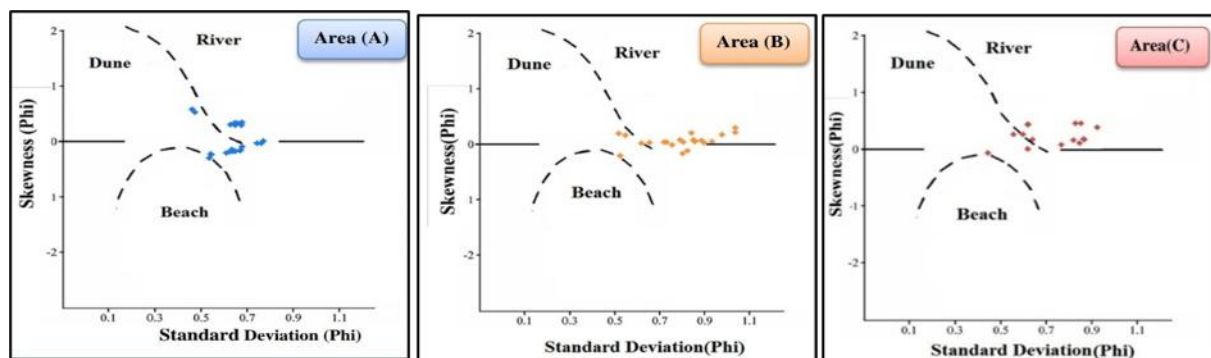


Fig 9: Bivariate plot of Standard Deviation versus Skewness for study areas (A), (B), and(C) [23]

Shape Characteristics of Dune Sands

Nine representative samples from all studied dune field, where chosen three samples for each area (A), (B), and (C), with grain size (2 ϕ , 3 ϕ , and 4 ϕ) to these samples. Were examined and compared under the polarizing and binocular microscopes to the chart suggested by [13].

Roundness

The results of roundness intervals are listed in (Table 6), and show variations with grain size in Figure (11). A clear inverse relationship between grain size and roundness averages percentage, where the studied samples as the roundness of medium sand are higher than those of fine and very fine sand. Roundness averages of the studied samples show that there is a wide range of values from angular to rounded; such results may be attributed to the source of sediments and the distance of transportation. The presence of angular and sub angular values refers to the moderate and short distance of transportation, and this could be due to the partial stabilization of the dunes by vegetation cover, which leads to the transport of grains to distances close to their original location. While the sub-rounded and rounded values refer to the long distance of transportation.

Table 6: Roundness intervals percentage with the grain size in the areas (A), (B), and (C).

Studies Areas	Roundness intervals	Samples Number Medium size area(A)			Average %	Samples Number fine Size area(A)			Average %	Samples Number Very Fine Size area(A)			Average %
		A-7W	A-7C	A-7L		A-7W	A-7C	A-7L		A-7W	A-7C	A-7L	
Area (A)	Angular	1.3	1	1.1	1.13333	14.2	12.1	9.9	12.06667	30.7	29.6	28.7	29.66667
	SubAngular	6.3	5.4	4.9	5.53333	41.4	35.6	29.4	35.46667	41.4	40.3	39.2	40.3
	SubRounded	34.1	36.3	35.4	35.26667	33	36.4	40.7	36.7	20.2	21.7	23	21.63333
	Rounded	41.9	42.2	40.3	41.46667	10.1	12.1	16	12.73333	6.7	6.9	7.2	6.93333
	Well Rounded	16.4	15.1	18.3	16.6	1.3	3.8	4	3.03333	1	1.5	1.9	1.46667
	Roundness intervals	Samples NumberMedium size area(B)			Average %	Samples Number Fine size area(B)			Average %	Samples Number Very Fine Size area(B)			Average %
		B-6WF.	B-6C	B-6EF		B-6WF.	B-6C	B-6EF		B-6WF.	B-6C	B-6EF	
Area(B)	Angular	1.3	1.8	2.1	1.73333	13.3	17.6	15.8	15.56667	30.3	26.9	29.7	28.96667
	SubAngular	8.3	7	9.7	8.33333	39.4	41.7	38.9	40	43.4	45	39.9	42.76667
	SubRounded	32.1	33.3	35.4	33.6	32.1	27.3	29.4	29.6	19.6	20.3	21	20.3
	Rounded	39.9	41.7	40.2	40.6	13.5	11.4	13.8	12.9	5.6	6.4	7.3	6.43333
	Well Rounded	18.4	16.2	12.6	15.73333	1.7	2	2.1	1.93333	1.1	1.4	2.1	1.53333
	Roundness intervals	Samples Number Medium Size area(C)			Average%	Samples Number Fine size area(C)			Average%	Samples Number Very Fine Size area(C)			Average%
		C-2WF.	C-2C	C-2EF.		C-2WF.	C-2C	C-2EF.		C-2WF.	C-2C	C-2EF.	
Area(C)	Angular	1.6	0.9	1.9	1.46667	15	13	12	13.33333	31.6	30.2	32.3	31.36667
	SubAngular	9.4	12.2	9.1	10.23333	40.2	39.7	38.9	39.6	45.2	48.3	50.1	47.86667
	SubRounded	30.1	29	31.3	30.13333	28.4	29.4	30.1	29.3	13.1	11	13.4	12.5
	Rounded	39.2	39.7	38.6	39.16667	15.3	16.5	17	16.26667	8.3	9.4	3.2	6.96667
	Well Rounded	19.7	18.2	19.1	19	1.1	1.4	2	1.5	1.8	1.1	1	1.3

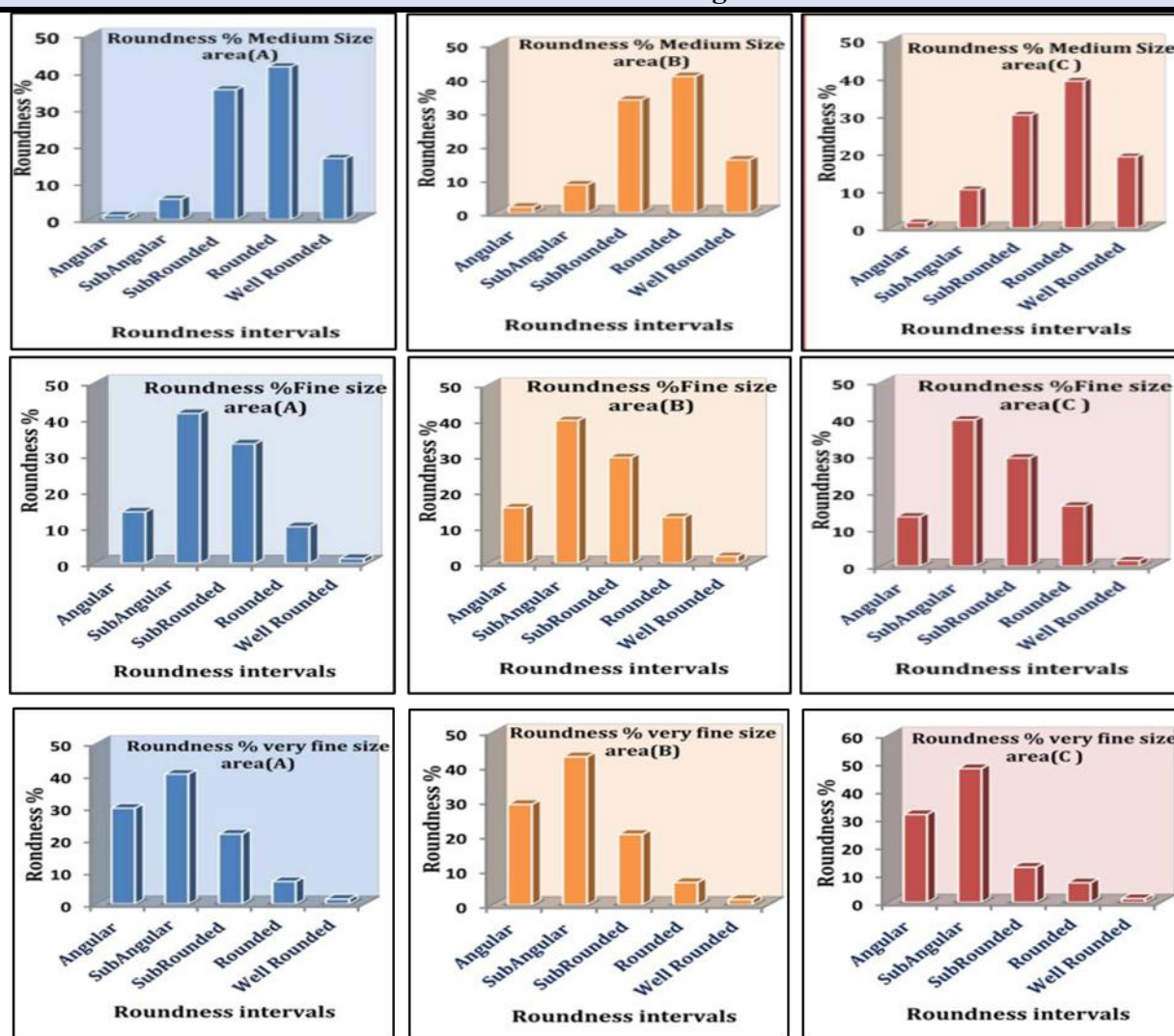


Fig 11: Bar charts of roundness interval percentages with grain size of study areas (A), (B), and(C).

Sphericity

The result of sphericity intervals is listed in (Table 7), and summarized in (Fig.12). The studied dune sand samples have a degree of average sphericity within spherical and high spherical interval, this high values can be related to the wind action which caused the spherical grains to be sorted during transportation [24], and may be attributed to the two-dimensional nature of the visual comparison method [13] which has exaggerated the sphericity value [24] and [25]. Other factor may be related to the nature of the quartz grains themselves, as there is relative high hardness, no cleavage surfaces and no elongation, furthermore sediment of the source area may also play a considerable role.

Table 7: Sphericity intervals percentage with the grain size in the study areas (A), (B), and (C).

Sphericity intervals	Samples Number Medium size area(A)			Average%	Samples Number Fine Size area(A)			Average%	Samples Number Very fine Size(A)			Average%
	A-7W	A-7C	A-7L		A-7W	A-7C	A-7L		A-7W	A-7C	A-7L	
Low Spherical	2.1	1.8	1.6	1.8	3.6	5.4	7.3	5.4	6.3	4.5	5.2	5.3
Moderately Spherical	20.7	18	16.5	18.4	22.4	17.8	16.7	18.9	21.2	19.8	20.7	20.5
Spherical	37.3	37.8	40.3	38.4	34.3	37.8	35.3	35.8	30.3	31.8	32.5	31.5
High Spherical	39.9	42.4	41.7	41.3	39.7	39	40.7	39.8	42.2	43.9	41.6	42.5

Sphericity intervals	Samples Number Medium size area(B)			Average%	Samples Number Fine Size area(B)			Average%	Samples Number Very fine size(B)			Average%
	B-6WF	B-6C	B-6EF		B-6WF	B-6C	B-6EF		B-6WF	B-6C	B-6EF	
Low Spherical	1	1.2	1.5	1.23	6.7	2.7	8.2	5.8	2.4	3.1	4	3.1
Moderately Spherical	15.1	17.3	19.2	17.2	23.6	26.5	19.9	23.3	26.2	22.3	24	24.1
Spherical	41	40.2	38.6	39.9	30.2	27	34.5	30.5	32.6	35.4	34.2	34.0
High Spherical	42.9	41.3	40.7	41.6	39.5	43.8	37.4	40.2	38.8	39.2	37.8	38.6
Sphericity intervals	Samples Number Medium size area(C)			Average%	Samples Number Fine size (C)			Average%	Samples Number Very fine size (C)			Average%
	C-2WF	C-2C	C-2EF		C-2WF	C-2C	C-2EF		C-2WF	C-2C	C-2EF	
Low Spherical	1	1.2	0.5	0.9	7.3	6.5	7.8	7.2	4.3	2.1	3.4	3.26
Moderately Spherical	17.6	19.3	13.2	16.7	20.2	19.3	22.3	20.6	20.2	20.3	22.8	21.1
Spherical	36.5	37.2	38.6	37.4	34.7	37.6	37.4	36.5	37.7	39.4	36.3	37.8
High Spherical	44.9	42.3	47.7	44.9	37.8	36.6	32.5	35.6	37.8	38.2	37.5	37.8

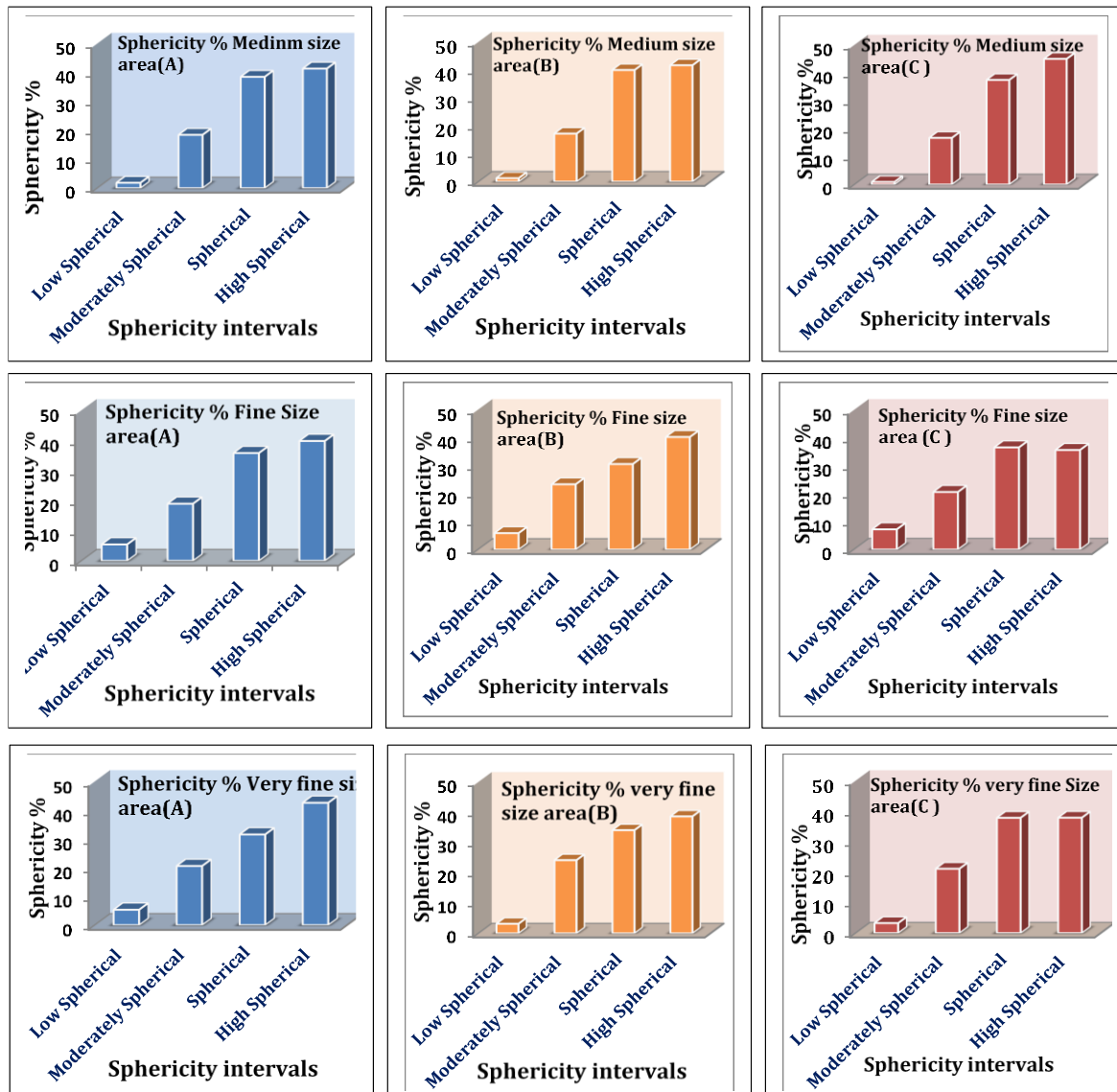


Fig 12: Bar charts of sphericity interval ratios with grain size of the study zones (A), (B), and (C).

Surface Texture

The six samples were studied under an SEM microscope, and many surface features were observed in the studied samples. Some of these features are caused by wind action, such as conchoidal fractures, Bulbous edges, and shape (roundness and sphericity). Additionally, other characteristics of various sedimentation and transportation modes, such as the existence of mechanical surface features such as conchoidal fractures and smooth surfaces characteristic of aeolian transport and fluvial environments, respectively [26].

The most prominent surface features observed in the studied samples can be described as follow:

1- Conchoidal fracture feature: this feature is observed in area (A) dune (Fig. 13). The size of conchoidal fractures on littoral and eolian grains is more uniform in [27]. On eolian grains, the fracture edges are dish-shaped and somewhat curved [28] and [27]. One of the traits of mechanical processes is this attribute. (Reineck and Singh, 1980).

2- V-Shape percussion cracks (triangular shaped depressions): The underlying cleavage plane edges are expressed by the triangle shape [29]. The v-shaped percussion cracks are usually oriented randomly, reflecting the grain collisions that happen at random. Percussion fractures with a V form are frequently inherited from earlier sedimentary cycles [30] (Fig.14).

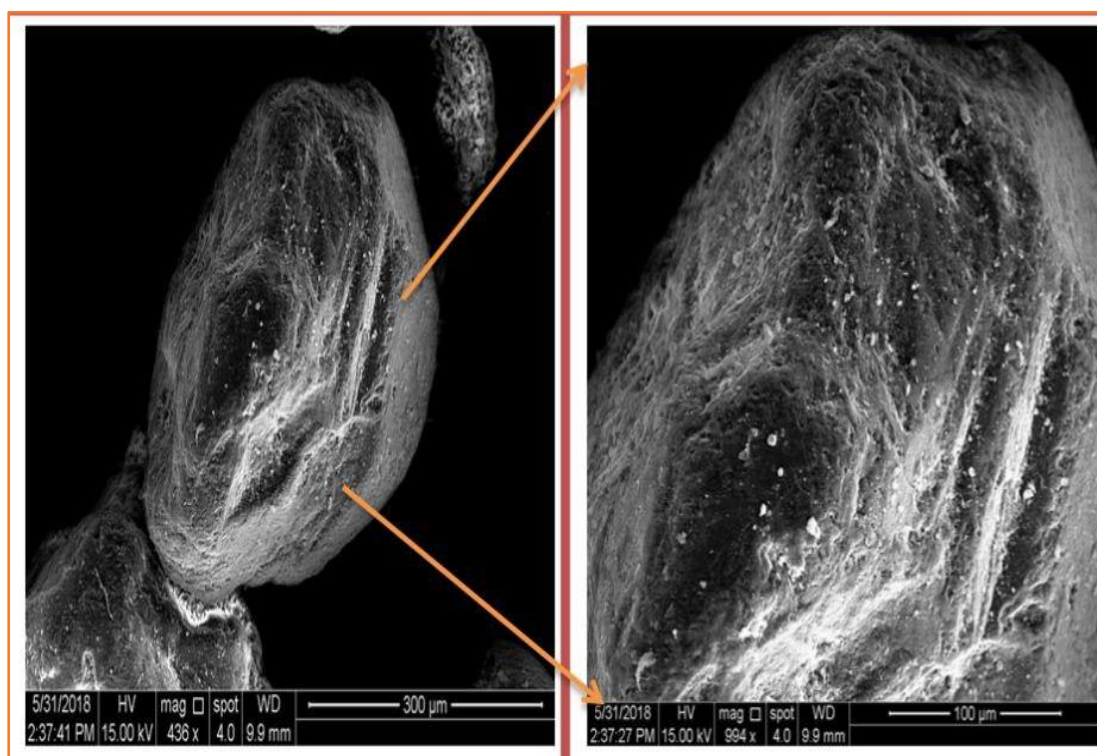


Fig 13: Conchoidal fractures planes straight in quartz grain, from area (A), S.No.A-7W.

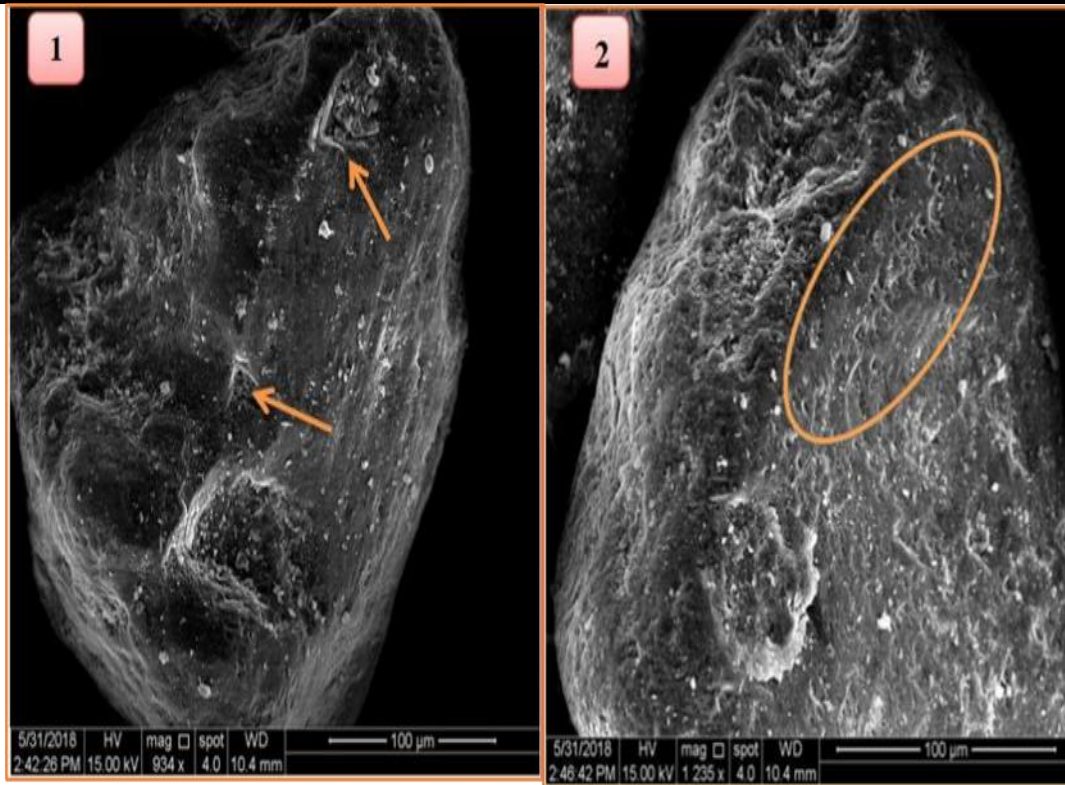


Fig 14: V-shaped percussion cracks (1) irregular outline and size, (2) regularly oriented etch triangles in area (A), S.No. A-5C.

3- Relief refers to the microscopic level of surface roughness or smoothness of the grains. It is classified into two categories: low relief, which is characterized by practically smooth surfaces devoid of topographic imperfections, and medium relief, which is characterized by semi-smooth surfaces with some topographic irregularities. The imperfections are either the result of modification processes or collisions with other grains [31] (Fig.15).

4- Grain outline describes the roundness or angularity of each grain on a microscopic scale. It is separated into three categories: rounded grains with smooth edges, subangular grains with somewhat blunt edges, and angular grains with sharp edges. (Fig.16). The grain outline relates mainly to the transportation mode, distance and time, and to the size of the particle, but is equally a function of the original grain shape of the particle in the source rock [32]; [33] and [34].

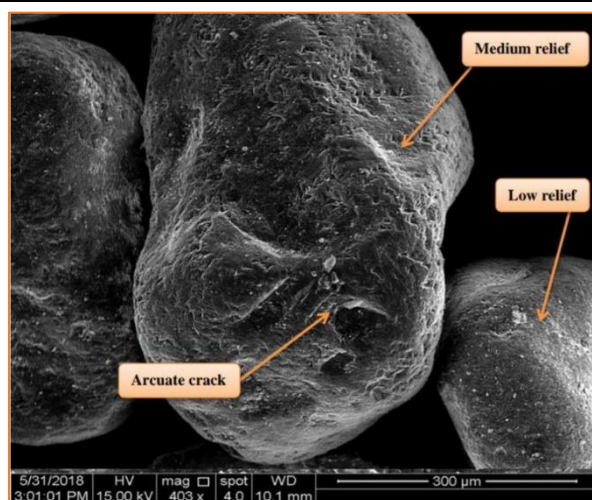


Fig 15: low relief and medium relief of quartz grains in area (B), S.No. B-5C

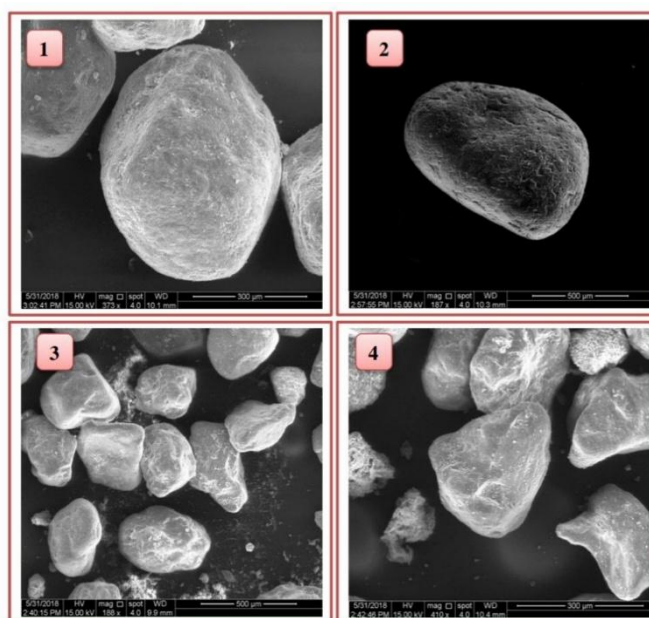


Fig 16: Grain outline (1) and (2) Rounded and well-rounded in area(C), C-4WF.medium sand, (3) and (4) Angular and subangular grains in area (A), A-4W fine

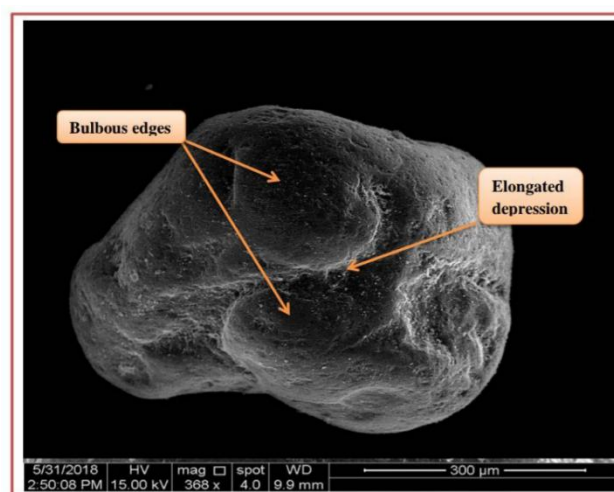


Fig 16: Rounded grain bulbous edges and in the center of the grain, elongated depression from area(C), S.No.C-4WF.

5- The term "bulbous edges" refers to noticeable, rounded, and projecting grain edges that resemble parabolic curves [35](Fig.16). The rotation of saltating grains is responsible for the rounding of the edges and protrusions; bulbous edges are indicative of eolian transportation phases [29]; [35] and [34].

Conclusion

The texture of the dune sediments shows different textural parameters such as grain size, grain shape, and surface texture: Fine sand size represents the main size fractions of area (A) dune, while the area (B) and (C) dunes have coarse and medium sand fractions. These differences are related to the higher wind energy that accumulated these sands; this is supported by the statistical parameters.

The sorting average of (0.62 ϕ) (moderately well sorted) in area (A), (0.97 ϕ) (moderately sorted) in area (B), while area (C) has (0.93 ϕ) (moderately sorted). However, the poorer sorting of the studied sediments may be attributed to the size, shape and nearness of the source area, and may indicate different wind energy.

The skewness average value in area (A) of the samples is (0.08 ϕ) (symmetrical), in area (B) is (0.20 ϕ) (fine skewed), and (0.38 ϕ) (very fine skewed) in area (C). The samples of the study area tend to have more positive than negative values; thus, ideal values of aeolian deposits usually have positive skewness.

Kurtosis of the studied dune sands shows that these have different degrees of kurtosis ranging from mesokurtic to platykurtic. Where area (A) has (0.92 ϕ) (Mesokurtic), area (B) has (0.88 ϕ) (platykurtic), and area (C) has (1.03 ϕ) (mesokurtic). The ideal type of sand dunes is platykurtic.

The result of roundness shows variations with grain size. A clear inverse relationship between the grain size and roundness averages percentage, where the studied samples as the roundness of medium sand are higher than the fine and very fine sand, results may be attributed to the source of sediments and the distance of transportation.

The studied dune sand samples have a degree of average sphericity within the spherical and high spherical interval, this high values can be related to wind action, which caused the spherical grains to be sorted during transportation. can be caused by the presence of recycled quartz grains derived from the older sedimentary rocks.

Many surface textures are observed by the SEM technique, such as conchoidal fracture, V-shape texture, Relief (smoothness and roughness), Grain outline (roundness and angularity), and Bulbous edges. These surface textures reflect the combined action of aeolian and fluvial processes, indicating inherent effects of the source rocks.

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