RESEARCH PAPER

Grain size characteristics of dune sands of the Grand Erg Oriental (Algeria)

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Abstract

The dunes of the Grand Erg Oriental sea occupy 120 000 km^2, about 12% of the Algerian Sahara surface. The grand erg oriental is composed two-thirds of sand dunes. The dunes are represented mainly by the linear-type with a northwestern to southeastern orientation. The textural characteristics of the sand forming the dunes are bimodal with a modal class in the fine sand size (2 ϕ and 2,64ϕ), well sorted (sorting < 0.5), positively skewed and very platykurtic. The dune sands are dominated by the rounded and well-rounded grains. The very fine sands are less rounded than the fine and medium sand. The grain size distribution and roundness characteristics reflect the high textural maturity of the studied sediments.

Keywords: grain size; dune sands; grand erg oriental; Algeria.

Caractéristiques granulométriques des sables dunaires du Grand Erg Oriental (Algérie)

Résumé

Le Grand Erg Oriental occupe 12% de la surface du Sahara algérien avec une superficie de 120 000 km². Il est composé des deux tiers de dunes de sable. Les dunes sont représentées principalement par le type linéaire avec une orientation Nord-Ouest à Sud-Est. Les caractéristiques granulométriques de sable formant les dunes montrent qu'ils sont bimodales avec une classe modale de sable fin (2 ϕ et 2,64ϕ), bien triés (écart type <0,5) avec une asymétrie positive et très platicurtique. Les sables dunaires sont dominées par les grains arrondis et très arrondis. Les sables très fins sont moins arrondis que les sables fins et moyens. La distribution de la taille des grains et des caractéristiques de rondeur reflètent la maturité texturale élevée des sédiments étudiés.

Mots-clés: *taille des grains; sable dunaire; Grand Erg Oriental; Algérie.*

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1. INTRODUCTION

The accumulations of windblown sand occur throughout the world, from coastal and lakeshore plains to arid desert regions. Sand dune areas are dynamic in nature, with the dunes changing their location, length or height, depending on the dune type (Tsoar, 2001). The Sahara desert is the largest arid region on Earth. It occupies nearly all of North Africa, extending in length for approximately 5600 km from the Atlantic coast to the shores of the Red Sea (Shao, 2008). In Algeria, The immense dunes and ergs are located in the lower topographic parts, shaped by the most regular winds, ergs form a parallel alignments dunes separated by corridors following to the prevailing wind direction. The dunes of the ergs can also have the form of the great pyramids, they often exceed 200 m high (Wilson, 1973). The dunes of the grand erg oriental occupy 12% of the Algerian Sahara surface (with 120 000 km^2), or 600 kilometers from East to West over 200 km from North to South. The two-thirds of the grand erg oriental are composed of sand dunes (Wilson, 1973). The highest of dune can reach 250 meters, and dotted with oases in its northern limits. The dunes are represented mainly by the linear-type (Sif) with a northwestern to southeastern trend according to the winds direction (McKee, 1979).

In sedimentology, granulometric analyzes hold a special place, linked to their development in different disciplines of earth science (geology, geomorphology, geo-archeology, soil science, for example: (Perriaux, 1972; Tricart and Mainguet, 1965; Miskovsky, 1974)). In paleo-environmental researchs, these statistical studies of particle size are an additional step observation and structural and textural interpretations made in a sedimentary formation (Foucault and Raoult, 2000). In fact, they determine the processes of transport and sedimentation inherited: power and dynamics of the past flows, transport (fluvial, marine, wind energy, etc.), accumulation mode and sedimentary rearrangement. Many studies have shown that the grain size distributions of dune sands are an important factor on the morphology and dynamic of dunes (Bagnold, 1937, Bagnold and Barndorff-Nielsen, 1980; Pye and Tsoar, 1990).

The granulometric and morphoscopic properties of aeolian sand particles of Grand Erg Oriental of Algeria is however not been investigated. Therefore, this study aims to fill this gap of knowledge in order to model sand transport for environmental planning purposes.

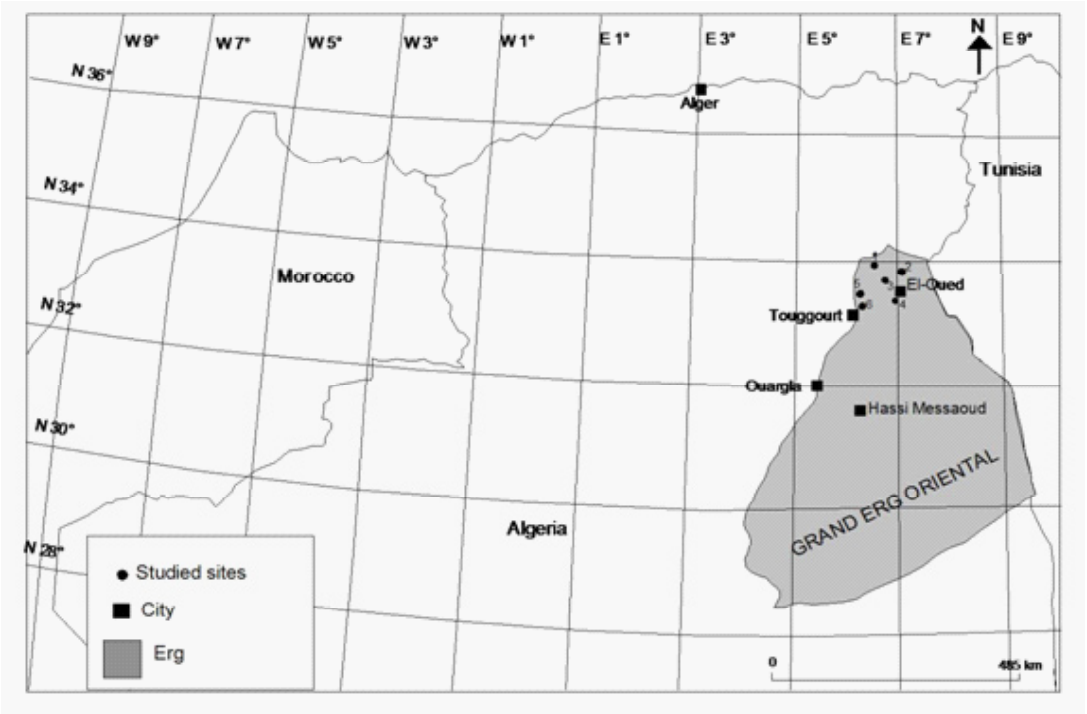

Figure 01. Location of the studied sites (1: Meghaïr, 2: Hassi Khalifa, 3:Reghuiba, 4:Sidi Abdellah, 5:Sidi Rached, 6:Sidi Slimane).

2. MATERIALS AND METHODS

2.1. Study area

The study area is located in the grand erg oriental which includes an area of about 192.000 km^2, and about 70% of its surface is covered by sands (Wilson, 1973). It is located in the North eastern Sahara of Algeria (between 28° to 34° North and 4° to 10° East) (Fig. 01). Low and fine dunes are located in the north of the grand erg oriental of Algeria (Wilson, 1973). The study area is characterized by low and irregular rainfall with a considerable annual variability (Dubief, 1963; Ozenda, 1991). Rainfalls are characterized by their low quantitative importance and torrential rains are rare. They are linked to Sudano-Saharan or Saharan disturbances (Dubief, 1963). The lack of Saharan rains accompanied by a very irregular rainfall regime and considerable inter-annual variability; which accentuates drought (Ozenda, 1991). The average annual rainfall does not exceed 70 mm (1975–2013). The average annual temperature is 23 °C with a minimum of 11 °C in January and a maximum of 35°C in July. The average annual relative humidity ranges around 45%. The average annual wind speed is 3.2m/s.

2.2. Granulometric analyzis

A total of 16 sand samples were randomly collected from top 5cm of the surface of summit of sands dune of the northern part of the Grand Erg Oriental in April 2014. The sampling locations (Fig.01) were determined using a Global Positioning System (GARMIN). Granulometric analyses were executed by the dry-sieving method (Carver, 1971), and the textural classes of the samples were determined according to (Folk, 1974). There are 4 statistical size parameters calculated from granulometric analyses which are mean size, sorting, skewness and kurtosis.

For grain roundness study, samples were dry-sieved and a representative portion of three sizes fractions were examined under a binocular microscope. These size fractions were medium sand (1-2ϕ), fine sand (2-3 ϕ) and very fine sand (3-4 ϕ). Grains were washed in cold 10% HCl to clean them from carbonate-clayey and ferruginous contamination, then in water and subsequently dried. The roundness classes (rounded, sub-rounded and angular) of 100 quartz grains in each size fraction were determined.

3. RESULTS

3.1. Grain size distribution

The curves of the average grain size distribution of each studied locations were drawn (Fig. 02). It can be seen that dune sands in all the locations are similar in being bimodal with a modal class in the fine sand size (2,64ϕ in Sidi Abdellah and 2 ϕ in the other sites). They also have a narrow range of grain size in which the fine sand fraction ranges from 74 to 94%. The curves of cumulative frequencies (Fig. 03) are

Table 01: Average grain size parameters for the dune sands (units ϕ)

Locations	Number of samples	Coordinates	Mz (mean)	Standard deviation (sorting)	Skewness SKi	Kurtosis
Meghaïr	03	33°53'24.97" N 006°09'18.04" E	2,03	0,34	0,43	SK
Reguiba	03	33°39'17.09" N 006°40'14.51" E	1,90	0,27	0,29	0,25
Hassi Khalifa	02	33°47'11.11" N 006°56'44.30" E	2,14	0,42	0,64	0,11
Sidi Abdellah	02	33°21'6.66" N 006°48'31.45" E	2,36	0,36	0,07	0,42
Sidi Rached	04	33°27'22.15" N 006°06'47.44" E	2,01	0,37	0,55	0,30
Sidi Slimane	02	33°19'59.19" N 006°09'22.89" E	2,02	0,35	0,29	0,25

divided into three segments, which indicate three populations of the analyzed sand grains.

3.2. Size parameters

The average values of the four statistical size parameters for the various studied localities are given in Table 1. Averages mean size of dune sands range from 1.9 to 2.36 ϕ (fine sand). The swhich is defined by the standard deviation identifies the level of classification of the sediment. According to (Folk, 1965), all samples are well sorted (sorting < 0.5 ϕ), with an average of 0.35ϕ. Skewness of dune sands in the present study varies from 0.29 to 0.64 ϕ (positively skewed). So they are very asymmetrical to fins fractions. The sample of Sidi Abdellah presents a skewness of 0.07. It is almost symmetrical. The average sorting in the grand erg oriental of Algeria is 0.38 ϕ. Finally, kurtosis of the present study is lower to 0.67 ϕ. They are classified as very platykurtic.

3.3. Grain Roundness

The dune sands in the study area are dominated by the rounded (averages 28.5-35.7%) and well-rounded grains (averages 29.2-54.1%) (Table 02). The results showed that the very fine sands (50-89% of rounded and well rounded grains) are less rounded than the fine and medium sand (successively with 62-89% and 65-85% of rounded and well rounded grains).

4. DISCUSSION AND CONCLUSION

The study of size of dune sands of the grand erg oriental showed that the sands are fine with mean size of

Table 02: Relative frequency percentages of the roundness classes in the various size fractions of the studied dune sands

Locations	Sand size	V.A	A	S.A	S.R	R	W.R
Meghaïr	Very fine	0,4	4,9	14,9	19,9	36,9	22,9
	Fine	0,5	3,9	10,9	21,9	27,9	34,9
	medium	4,9	3,2	11,9	14,9	34,9	29,9
	Average	1,9	4	12, 6	18,9	33,2	29,2
Sidi Abdellah	Very fine	0,7	2,9	6,9	20, 0	44,9	44,5
	Fine	0,5	2	5,9	11,9	39,5	39,9
	medium	0,6	3	3,9	9,9	22,9	59,6
	Average	0,6	2,6	5,5	10,9	35,7	48
Reguiba	Very fine	0	0,6	5	9,9	34,4	49,9
	Fine	0,8	1,2	3,9	4,9	19,9	69,2
	medium	0,5	2	5,9	14,5	33,9	43,1
	Average	0,4	1,2	4,9	9,7	29,4	54,1
Hassi Khalifa	Very fine	2,9	6,9	14,9	19,9	34,9	20,2
	Fine	0	0,8	4,6	9,7	34,9	49,9
	medium	0	0,5	4,9	9,5	19,9	64,9
	Average	0,9	2,7	8,1	13,0	29,9	45
Sidi Rached	Very fine	3,9	10,3	14,9	19,9	37,9	12,9
	Fine	0	2,9	12,1	14,9	24,9	45
	medium	0	1,5	6,9	9,9	22,9	58,6
	Average	1,3	4,9	11,3	14,9	28,5	38,8
Sidi Slimane	Very fine	1,1	9,9	16,8	20,1	39,9	12
	Fine	1	2,2	7,5	19,9	34,6	34,5
	medium	3	3,9	6,1	12,9	23,7	49,9
	Average	1,7	5,3	10,1	17,6	32,7	32,1

V.A: very angular, A: angular, S.A: sub-angular, S.R: sub-rounded, R: rounded, W.R: well rounded.

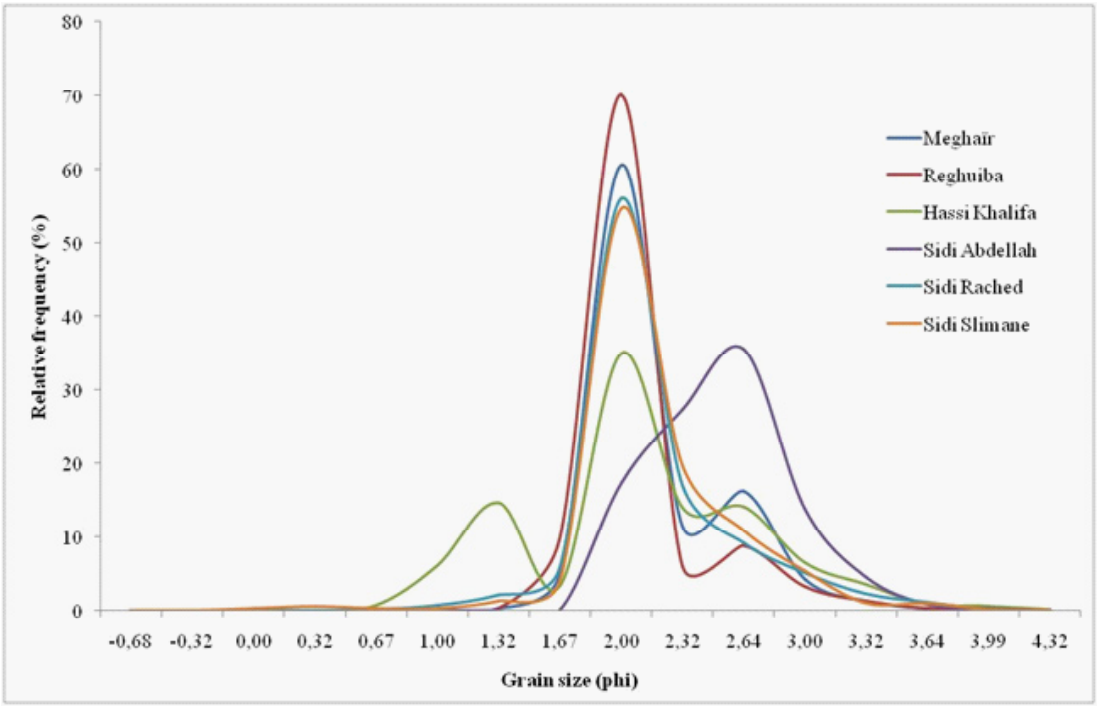

Figure 02. Curves of the cumulative frequency of grain size of the dune sands (North of grand erg oriental).

1.9 to 2.36 ϕ. Wilson (1973) indicated, by satellite image, that the highs dunes of the Grand Erg Oriental contain mixed sand sizes; the rest of the sand sea is composed of sand having a modal size of about 2.64 ϕ (fine sand). Ballais and Benazzouz (1987) indicated that the grand erg oriental is an immense accumulation of fine sand that the wind deposited in depressions. The origin of its sands is the dried alluvial deposits which transported by the southern and western winds. The obtained results are comparable with the world average (2.23 ϕ) mean grain size (Goudie et al. 1987). Abu-Zeid et al. (2001) indicated that the average mean size values (2.50 to 2.71ϕ) represent fine sands in United Arab Emirates. Whereas the aeolian sediments of the Toshka area (Egypt) are represented mainly by medium to fine grained sands with an average value varying between 0.78 and 2.52 ϕ (Hamdan et al. 2014). Alali et al. (2014) indicated that the dune sands of Tafilalet (Morocco) are characterized by fine to medium sand size (mean size: 1.31-2.44 ϕ). The curves of cumulative frequencies (Figure 3) indicate the existence of three populations of the analyzed sands grain, these reflecting a particular transport mode depending on the size of sand grains. So, according to Moss (1962, 1963) and Vischer (1969), saltation is the dominate mode of transport; although rolling and suspension affect only a small number of the grains. The sand of the Grand Erg Oriental is well sorted; this indicates that sands are exposed to regular current transport. The average sorting in the grand erg oriental of Algeria is 0.38 ϕ, which is comparatively better sorted than many other localities such as UAE (0.43 ϕ) (El-Sayed, 1999), Kuwait (0.80 ϕ) (Khalaf, 1989) and Gebel El-Asfer of Egypt (0.84 ϕ) (El-Sayed, 1994). The world average value of the sorting is 0.53 ϕ (Goudie et al., 1987); it ranges between 0.22 ϕ in Oman (Glennie, 1970) to 0.87 ϕ in Saudi Arabia (Goudie et al., 1987).

The dune sands are fine skewed; therefore the sediments were deposited in the environment by decantation (Folk, 1965). The results of kurtosis show that sands are very platykurtic. Our results are similar to that of Ashour (1985) for the sand dunes in Qatar and Alali et al. (2014) for the sand of Tafilalet in Morocco. Quartz grains of aeolian sand of grand erg oriental are rounded and well rounded (Table 02). Generally, the grain-size characteristics of the studied dunes resemble those previously reported for dunes in other localities. Abu-Zeid et al. (2001) indicated that the sand dune in United Arab Emirates dominated by well rounded (37%) and rounded (34%) grains. Alali et al. (2014) have founded the abundance of rounded grains sand (49-70%) in Tafilalet (Morocco). The similarity of results from the morphoscopic analysis, of the various dunes sand grains, indicates that they have the same mode and rate of transport (Kuenen, 1960; Reineck and Singh, 1980). Previous studies have shown

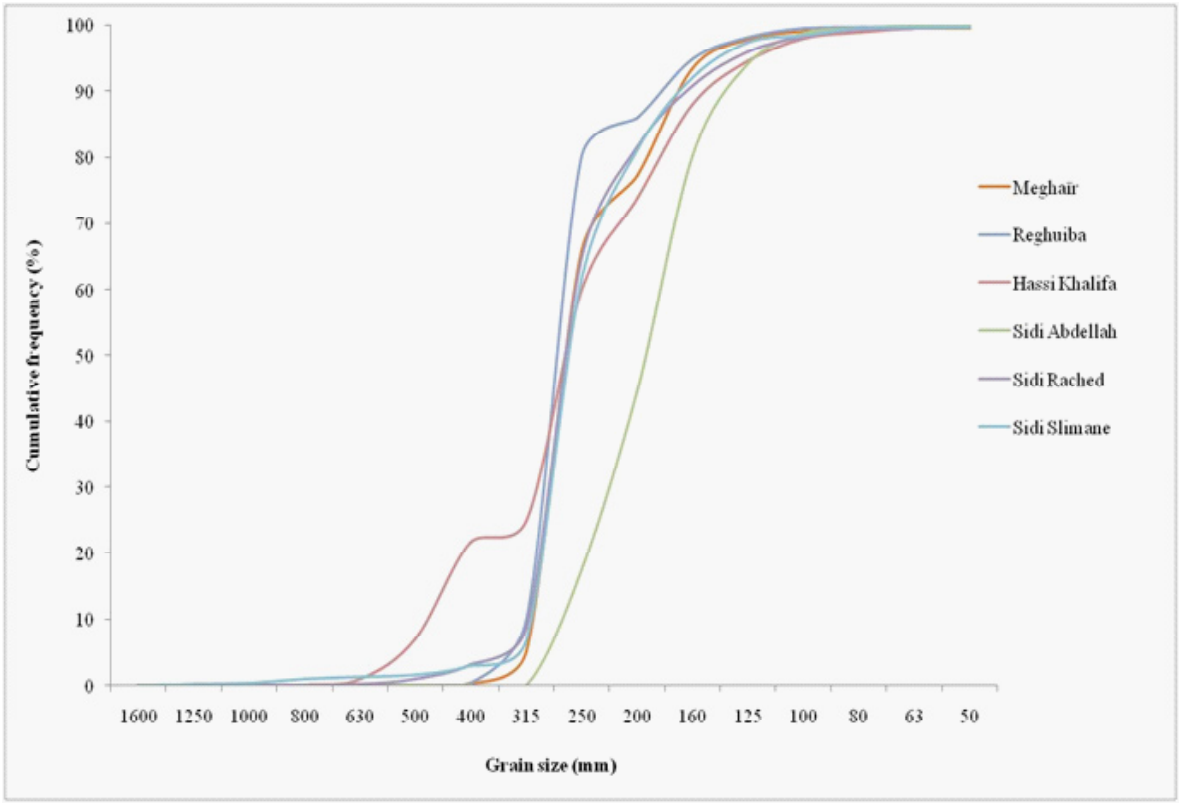

Figure 03. Curves of the average grain size distribution of the dune sands in the North of grand erg oriental.

that aeolian action rounds sand more effectively than aqueous transport (Thoulet, 1881; Mackie, 1897; Twenhofet, 1932; Kuenen, 1959; Kuenen, 1960). The grain size distribution and roundness characteristics reflect the high textural maturity of the studied sediments. Several authors Bagnold (1941), Twenhofel (1945) and Kukal (1971) indicated that dune sediments are relatively more rounded and compositionally mature than sediments of most other depositional environments. In the grand erg oriental, the very fine sands are less rounded than the fine and medium sand. Our results are similar to those of Abu-Zeid et al. (2001) for the sand of United Arab Emirates. Kuenen (1960) have found that rounding increased with size. Pettijohn (1987) indicated a linear positive correlation between size and roundness of sand grains as an indication of the maturity of sediment. In Algeria, there are only few studies that have been performed in this field. Our results are very important in the protection of the infrastructure against aeolian deposit, because, the grain size characteristics are strongly related to factors such as dynamic processes of the dunes, sand availability and the transportation distances from the source zones.

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