DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 14 (2009) 197-207

# Studying the Morphologic Maturation of Aeolian Sand Grains During Transportation Process of Wind Erosion (Case study: Khartouran Erg)

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Received: 28 January 2009; Received in revised form: 23 June 2009; Accepted: 25 August 2009

**Abstract**

Wind, in the duration of its erosional process, affects considerable changes in a grain's morphology from its removal (detachment) step to sedimentation. In other word, a grain undergoes its gradual evolution during the transit process. In this project, the maturation of Aeolian sand grains had been studied upon as based on texture maturity indicator which includes: sorting, mean size grain, roundness as well as abrasion coefficient parameters. The study area is the transport region of Khartouran Erg sediments, which founded on the basis of ground index of wind erosion. According to these indicators, the direction of prevailing or strong winds is notably mentioned. In a later step, four transects are selected in different area in alignment with wind direction. Samples of sediment grains are taken at varied distances in any one of the transects. The samples were taken from the windward slope of Rebdou landform. The samples were evaluated to using granulometry and morphoscopy techniques. Grain size analysis of was done using dry sieve analysis while morphoscopy of grains carried out by studying the quartz grains of 150 to 300 µm diameter by using binocular microscope. Results indicate a gradual maturity (evolution) in sediment texture in all transects starting from the upper parts (near sand source) toward the lower parts (in transportation area).Also, results indicate that from among the four indicators of grain maturity namely: sorting, grain size, roundness and abrasion coefficient the respective factors of either " abrasion coefficient index" or" roundness index " in the first value and then" sorting" and finally "grain's mean size index" are the ones accounted for validation for determination of maturity.

*Keywords:* Khartouran Erg; Deflation; Abrasion; Wind erosion; Removal zone; Transit zone; Sand dunes; Wind erosion indicators

## 1. Introduction

The erosion, transport and subsequent deposition of sand dust by wind are the most significant geomorphic processes in many of the earth's arid regions. (Watson 1989). Aeolian transported grains evolutes considerable in the duration of wind erosion process. The closely relationship is between grain morphology and grain maturity. In fact, degree of maturation and morphology are closely related. Studying grain morphology indexes can be used for dating or distance of sediment from sediment sources. Degree of evolution or maturation of grain can be determinate with various methods. One of these methods are using of grain size, grain shape (roundness), surface features and sphericity indicators, which called under term of grain morphology. In this paper, indicators such as grains mean size, roundness, sorting and

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abrasion coefficient was used from for grain maturity.

Khartouran Erg with an area of about 170000 ha having complex sand dunes is result of wind on the area with 400000 ha as detachment and transit regions. The objective of this paper is to investigate grain morphology changes in the Rebdou geomorphological facies.

## 2. Materials and Methods

### *2.1. Study area*

The study area is on the southwestern of Sabzevar town in the eastern north of Iran with its boundary approximately in coordinates 56° 15´ to 57° 00´ eastern longitudes and 36°, 00´, 00″ to 36°, 24´, 36″ northern latitude (Figure 1). The area is about 5400 ha, its altitudes is varied from 770 (outlet of the basin) to 850 m above sea level, consequently the average elevation is 810m from sea level. The climate is arid with an average rainfall of 193mm. General slope of this area is less than 3%.

### *2.2. Materials*

The following data were used in the current study:

A- Topographic maps with scale of 1:250000 in order to prepare regional base map and boundary of wind activities. These maps include Sabzevar NJ 40-15, Miamei NJ 40-14, Kashmar NI 40-3 and Baghestan NI 40-2 sheets.

B- Topographical maps with scale of 1: 50000 These maps were used for more detailed studies and to obtain geographical coordinanate system of Universal Transverse Mercator(UTM), these maps include Abbas abad 7262-1, Astarband 7362-4, Davarzan 7362-1, Koh e Doshakh 7262 -2, Jonobe Astarband 7362 -3, Chubin 7362-2 sheets.

C- Geologic maps with scale of 1:250000

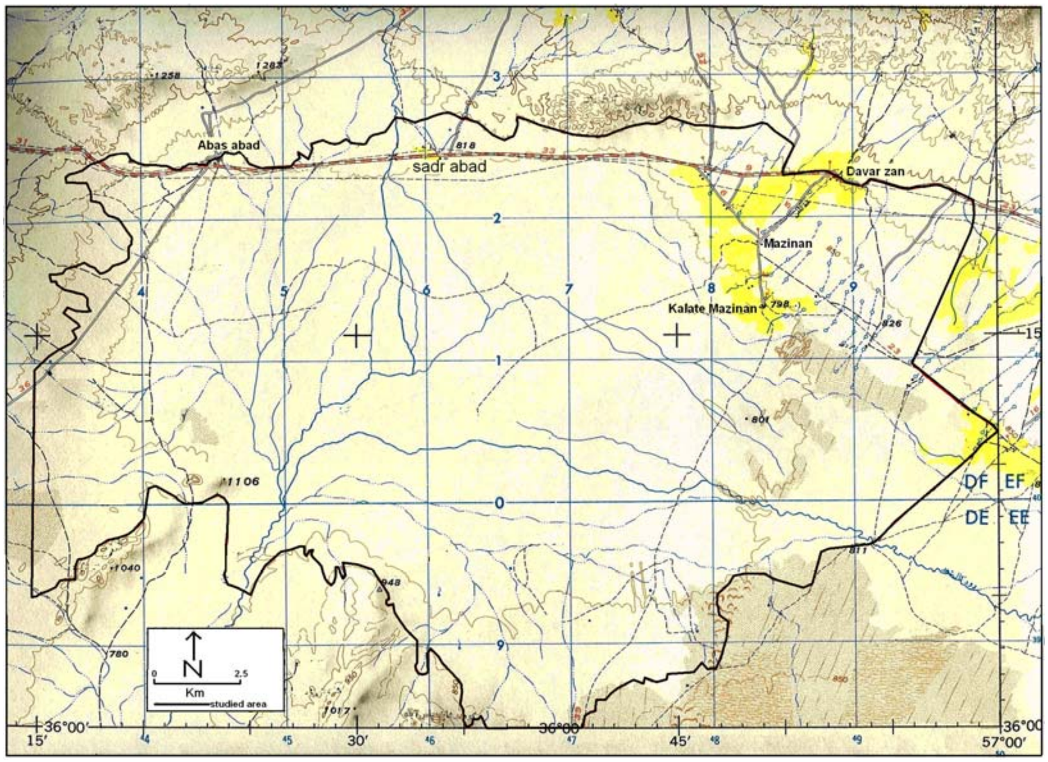



Fig. 1. Topographic map of the study area

These maps were used to determine the region lithology and include Sabzevar and Miamei sheets.

D- Aerial photographs 1:55000 in order to prepare geomorphologic characteristics of the region

E- Field observations to complete interpretation of aerial photographs, recording ground indicators of wind erosion and sampling.

F- Granulometry and morphoscopy of aeolian sand grains

### *2.3. Research methods*

On the basis of document and the following information research method can be stated as follow:

A - Determining the study area boundary on the basis of the wind function

To determine the boundary in which the wind functions and on the basis of its performance, at first a study was made on morphology of Khartouran erg sand dunes. This study was made on the basis of topographical maps 1:50000, aerial photographs 1:55000 and 1:20000 and satellite image. After studying morphology of sand dune, each of the forms of sand dunes, were analyzed in order to determine direction of prevailing and strong winds. This analysis was made on the basis of provided models which show the relation between morphology and direction of the wind. On the basis of obtained results from these studies, studied region was determined according to the lithology and topographical maps (Figure 2).

B - Determine sampling points

To following and studying point to point of wind effects on the ground surface and wind orientation, studied region (source and transport region) was networked. Provided network was square and was in distance of 3 kilometers on the earth. The network cross was coded after drawing the network on the map and so 214 points were determined.

C - Determine detachment, transportation areas and wind orientation

Detachment, transportation areas and wind orientation determined on the basis of ground indicator of wind erosion such as deflation, abrasion, accumulation.

D - Field sampling

Four transects determined in the various area within transport region and wind direction. In each transect 3to 4 samples were collected for analyses.

E - Samples analyses

Samples analyses were made with two methods: a; granulometry using dry sieves (sieve analysis) and GRADISTAT, EXCEL software and b: morphoscopy of grains using binocular microscope

## 3. Results

### *3.1. Meteorology and climate*

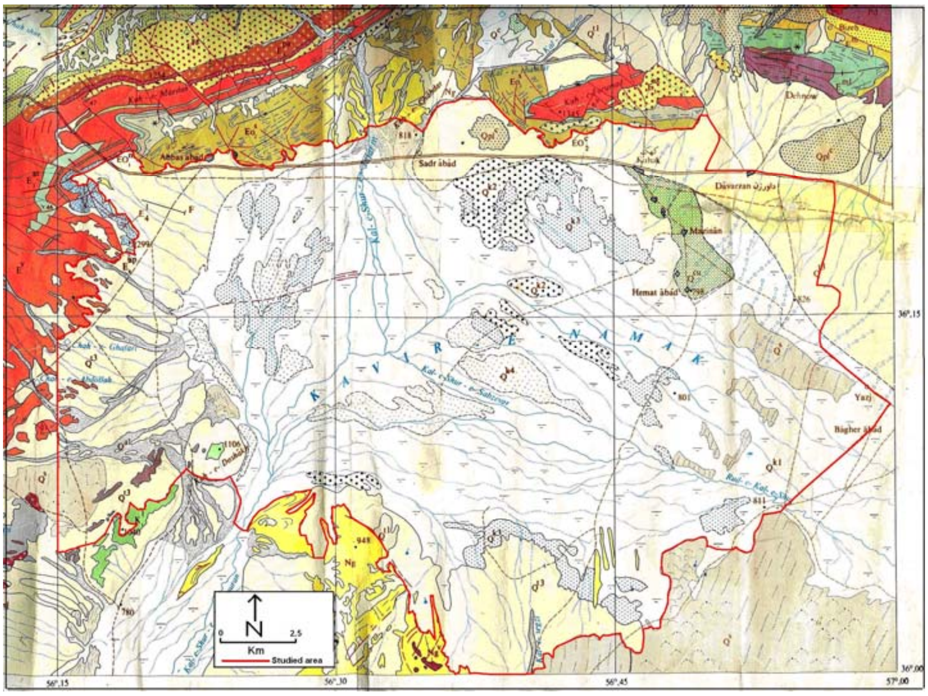
On the basis of analysis of two data series wes made the region's climate, Analysis of Sabzevar station data and the second analysis of adjacent stations data in Sabzevar basin and establishing the regression relation among usable parameters in climate. These studies showed that average annual precipitation is 193.2 mm and daily average of temperature is 16.9 °C. The climate of the region is arid, on the basis of De Martton method.

### *3.2. Geology*

The entire studied region is covered with alluvial depositions. These uncountinious depositions are not rough and have not distributed with different ticks in the region. Although whatever these depositions extend toward south and south-west, they have fine gains but they are clay deposits in sandy deposits, locally in west region and south-west. The most recent depositions are related to alluviums in rivers bed and the oldest of them are related to alluvial depositions of old terraces (Figure 2).

### *3.3. Study of morphology of Khrtouran erg sand dunes and determination of study area on the basis of wind performance*

The wind is the major element in shaping sandy landforms. Field studies and interpretation of aerial photographs of different shapes of sand dunes showed that the wind play a role in shaping them in two ways: first, the wind direction, a factor which determines the alignment of sand dunes. Prevailing winds or strong and local winds establish this alignment. Study of sand dune trend in Khartouran Erg showed that direction of dominant wind is northern and sometimes local or strong wind direction is from north-west to south-east. Majority of the sand dunes have regulated by northern dominant wind while irregular alignment in some regions are affected by local topography (like the existence of Kale-sabri in the middle of Erg and Kale-Hojaj and Sagzi beside it). Second, different wind regimes, is the factor which make different forms of sand dune. Under a uni-directional wind, regularly aligned crescent and barchanic dunes, under the influence of two winds blowing from opposite directions but with equal force, transverse dunes with symmetrical slopes will be formed. When the two winds cross obliquely at a lower angle, liner or seif dunes with one long wing will generally be formed. When two winds with equal force cross at right angles, longitudinal dunes will be produced. When wind from three of more directions meet, horn shaped dunes (Star dunes) will be formed.




$Q^{t1}$ : Older terraces and gravel fan

$Q^{t3}$ : Younger terraces and alluvial plain

$Q^{k4}$ : Moist and flat area, with soft puffy ground, dissected by numerous braided

$Q^{k3}$ : Dry and flat area, hard and smooth, with scattered soft puffy ground.

$Q^{k2}$ : Dry and flat area, hard and smooth, with widespread soft puffy ground.

$Q^{k1}$ : Dry, soft and puffy ground, containing local salt crusts and channels.

$Q^{cu}$ : Cultivated area

$Q^{s}$ : Various shaped Sans dunes

$Q^{c}$ : Clay flat

$Q^{al}$ : Alluvium in major streams

Fig. 2. Geologic map of the study area

*3.4. Study of ground indicator of wind erosion and to determine detachment and transportation areas*

In each sampling point, effects resulting from the wind performance on the basis of bench mark and ground indicator were studied and recorded. These include:

3.4.1. Deflation bench mark

Effect of wind action as deflation includes the following forms:

A: Desert pavement

B: Remaining soil in foot of plants

C: Remaining of stem and root of plant, outside of the soil (soil detachment)

3.4.2. Abrasion bench mark

Studies in the region showed the effects of wind performance as abrasion include the following features.

A: Ventifacts index

B: Yardang index

3.4.3. Accumulation bench mark

These landforms classify two categories;

3.4.3. 1.Dunes related to topographic barriers

3.4.3.2. Dunes related to anchorage by vegetation

A: Isolated mounds (Nebka) index

B: Rebdou

3.4.4. Sand ripples

Transit area was determined on the basis of bench mark and ground indicators (figure 3).

*3.5. The azimuth of wind orientation on the earth based upon ground indicator of wind erosion*

Wind direction is important factor of wind characterize. However, wind orientations have no effect on the selecting grain, transport forms and sediment rate but influence on forming trajectory of erosion and accumulation landforms.

The marks of wind action on the ground resulting from sand-transporting winds, and reflect by the axes of the Nebka or Rebdou and by the striation of abrasion and deflation strips. These forms, parallel to the dominant wind, enable the wind trajectory in the diagnosis of aeolian trajectories (Mainguet and Canon 1976).It is evident that such shaped forms on the ground are criteria for diagnosing of the aeolian currents. The azimuth of wind orientation (Streamlines of wind) provided in each corner points of grid was determined based on these indicators (figure 4).

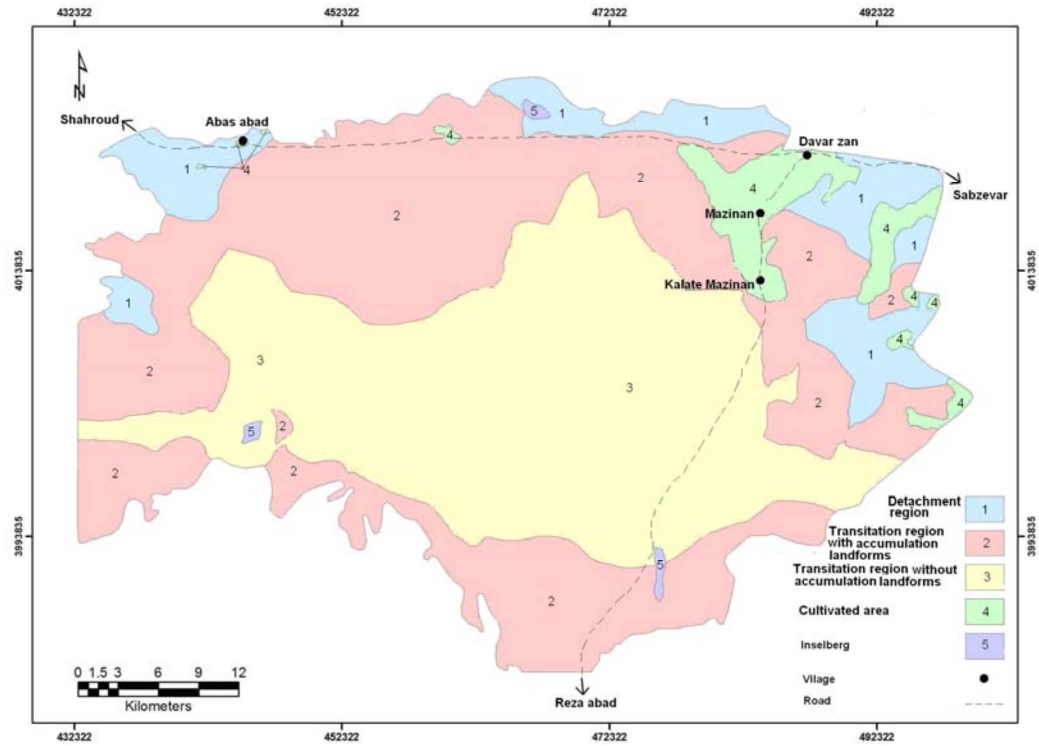



Fig. 3. Map of transportation region

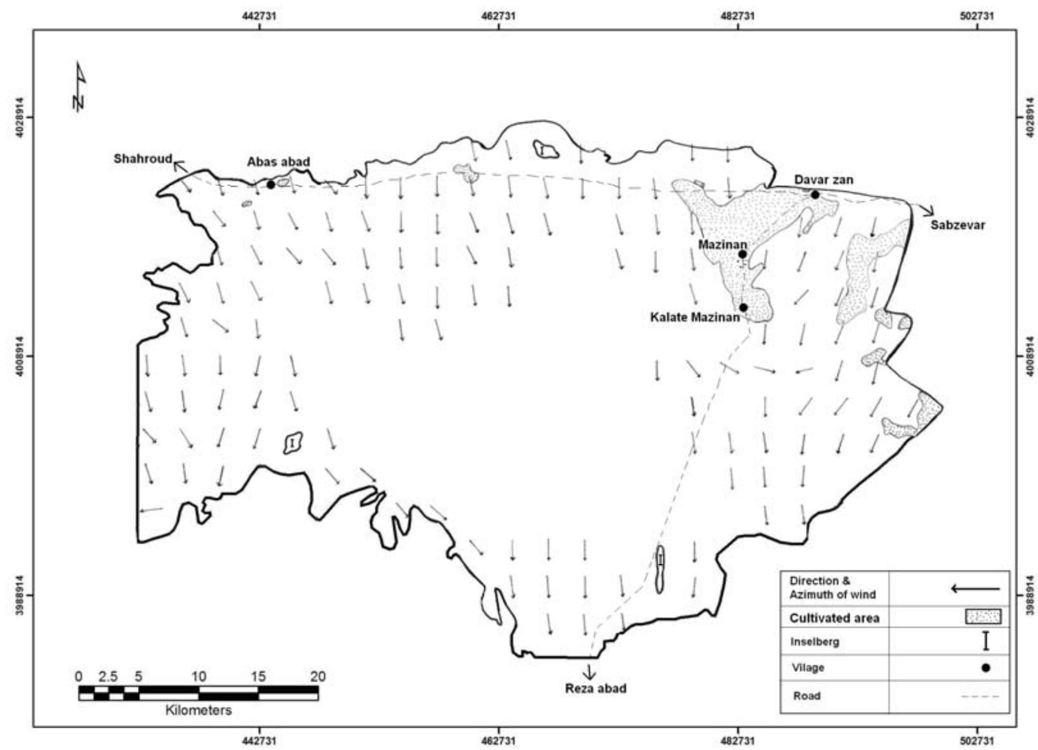



Fig. 4. Map of wind direction azimuth based upon ground indicators

*3.6- To determine the sampling points and field descriptions*

Based on incorporation of map of wind orientation (Figure4) and map of transportation region (Figure3) four transect selected in the various areas. Taken samples depended to transect length and rebdou position (Figure5).

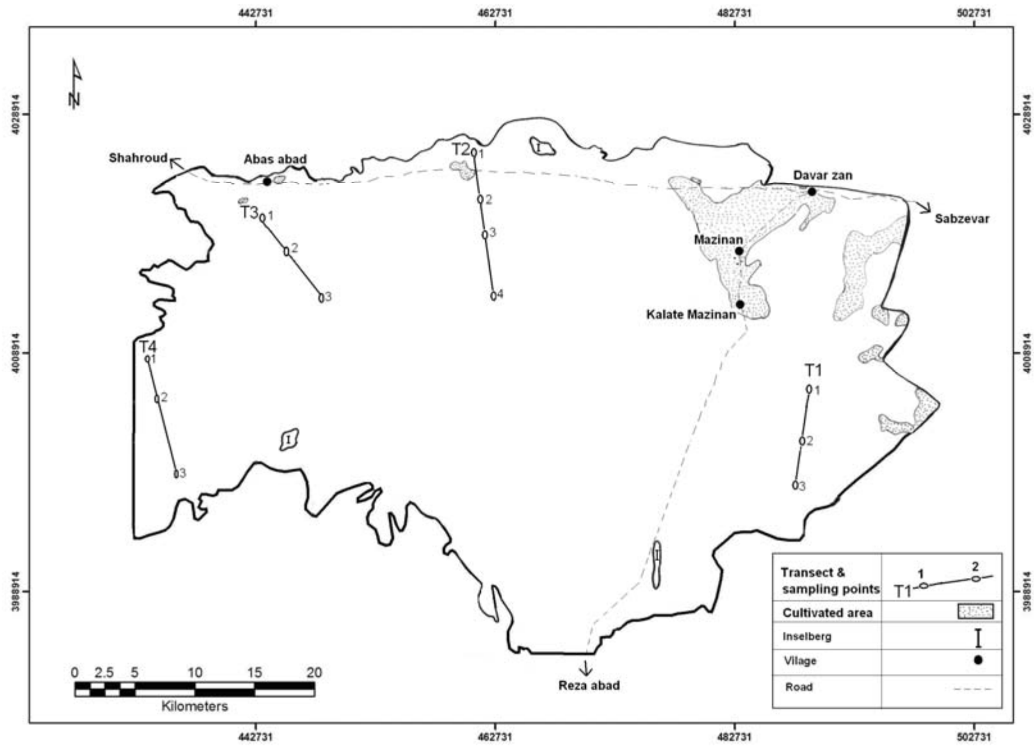



Fig. 5. Location of transects and sampling point

*3.7- Granulometry*

3.7.1- Dry sieve analysis

Approximately a 100 gram of each taken samples analyzed using dry sieves (Table 1).

3.7.2- Grain size analysis

The various techniques employ in grain size analysis include arithmetically and geometrically (in metric units) and logarithmically (in phi units) using moment and Folk and Ward graphical methods. Generally, grain size distributions have frequently been described by their deviation from a prescribed ideal distribution. Regardless of the methods employed to determine the distribution of the size of the grains making up a sand population, the same statistical parameters are used to describe the distribution. Those measuring;

- The mean size
- The skewness, the symmetry or preferential spread to one side the average.
- The sorting, the spread of size around the average. It is calculated from standard deviation.
- The mode, the size range within which most of the sand falls.
- The median, the diameter at which 50 per cent of the population of grain are coarser and 50 per cent are finer.
- The kurtosis, the degree of concentration of the grains relative to the average.

In this project is used from a computer program called GRADISTAT and EXCEL. Output statistical parameters of this program are shown in Figure 6.

Table 1. Dry sieve analysis of sampling point within each transect

| Transect | Samples | 3350 µm | 1700 µm | 1190 µm | 700 µm | 300 µm | 150 µm | 75 µm | 63 µm | Pan µm | Total % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 1 | 37.3 | 7.9 | 2.8 | 5.8 | 13.4 | 21.3 | 10 | 1.1 | 0.2 | 100 |
| | 2 | 19.4 | 3.2 | 1.2 | 5.2 | 27.1 | 30.6 | 11.6 | 1.2 | 0.5 | 100 |
| | 3 | 32 | 4.9 | 0.6 | 1.3 | 4.6 | 20.1 | 31.7 | 3.3 | 1.5 | 100 |
| $T_2$ | 1 | 15.5 | 7.4 | 2.6 | 4.5 | 11.1 | 27.7 | 25.4 | 4.0 | 1.8 | 100 |
| | 2 | 5.7 | 1.7 | 1.0 | 3.2 | 14.7 | 44.4 | 26.1 | 2.2 | 1.0 | 100 |
| | 3 | 23.6 | 7.7 | 4.1 | 13.6 | 27.8 | 16.6 | 5.8 | 0.5 | 0.3 | 100 |
| | 4 | - | - | - | 1.2 | 30.8 | 51.6 | 14.9 | 0.8 | 0.7 | 100 |
| $T_3$ | 1 | - | 4.2 | 1.5 | 3.7 | 14.5 | 47.4 | 23.7 | 2.8 | 2.2 | 100 |
| | 2 | 27.7 | 5.2 | 1.5 | 2.6 | 3.8 | 7.7 | 33.2 | 14.0 | 4.3 | 100 |
| | 3 | 15.1 | 10 | 12.4 | 15.6 | 11.7 | 13.8 | 16.0 | 4.4 | 0.9 | 100 |
| $T_4$ | 1 | 9.7 | 6 | 1.8 | 8.7 | 32.6 | 25.8 | 11.5 | 2.4 | 1.5 | 100 |
| | 2 | 0.6 | 0.6 | 0.4 | 1.6 | 14.8 | 47.0 | 28.5 | 4.1 | 2.4 | 100 |
| | 3 | - | - | 1.1 | 4.2 | 19.0 | 47.3 | 23.3 | 3.1 | 2 | 100 |

**SAMPLE STATISTICS**

SIEVING ERROR: 0.0%
SAMPLE IDENTITY: **T1-2**
ANALYST & DATE: ,
SAMPLE TYPE: Unimodal, Poorly Sorted
TEXTURAL GROUP: Gravelly Sand
SEDIMENT NAME: Very Fine Gravelly Fine Sand

| | µm | φ |
|---|---|---|
| MODE 1: | 225.0 | 2.237 |
| MODE 2: | | |
| MODE 3: | | |
| $D_{10}$: | 123.2 | -2.370 |
| MEDIAN or $D_{50}$: | 363.0 | 1.462 |
| $D_{90}$: | 5169.6 | 3.021 |
| $(D_{90} / D_{10})$: | 41.98 | -1.275 |
| $(D_{90} - D_{10})$: | 5046.4 | 5.392 |
| $(D_{75} / D_{25})$: | 5.385 | -31.691 |
| $(D_{75} - D_{25})$: | 857.3 | 2.429 |

GRAIN SIZE DISTRIBUTION

| | | | |
|---|---|---|---|
| GRAVEL: | 21.8% | COARSE SAND: | 14.3% |
| SAND: | 77.7% | MEDIUM SAND: | 24.4% |
| MUD: | 0.5% | FINE SAND: | 25.6% |
| | | V FINE SAND: | 9.7% |
| V COARSE GRAVEL: | 0.0% | V COARSE SILT: | 0.1% |
| COARSE GRAVEL: | 0.0% | COARSE SILT: | 0.1% |
| MEDIUM GRAVEL: | 0.0% | MEDIUM SILT: | 0.1% |
| FINE GRAVEL: | 0.0% | FINE SILT: | 0.1% |
| V FINE GRAVEL: | 21.8% | V FINE SILT: | 0.1% |
| V COARSE SAND: | 3.7% | CLAY: | 0.1% |

| | METHOD OF MOMENTS | | | FOLK & WARD METHOD | | |
|---|---|---|---|---|---|---|
| | Arithmetic µm | Geometric µm | Logarithmic φ | Geometric µm | Logarithmic φ | Description |
| MEAN ($\bar{x}$): | 365.7 | 98.73 | 1.407 | 539.4 | 0.891 | Coarse Sand |
| SORTING ($\sigma$): | 476.0 | 10.68 | 1.260 | 3.059 | 1.613 | Poorly Sorted |
| SKEWNESS ($Sk$): | 3.109 | -1.198 | 0.296 | 0.199 | -0.199 | Coarse Skewed |
| KURTOSIS ($K$): | 14.07 | 2.963 | 3.734 | 0.658 | 0.658 | Very Platykurtic |

Fig. 6. The statistical parameters calculated by GRADISTAT (e.g. Transect1, sample 2)

The results of statistic analysis of samples based upon Folk and Ward (1957) method summarized in the Table2.

Table 2. Statistic analysis of samples (Folk and Ward method)

| Transect | Samples | Median (µm) | Mean (µm) | Sorting | Skewness | Kurtosis | Grain description |
|---|---|---|---|---|---|---|---|
| $T_1$ | 1 | 1000.1 | 664.2 | Poorly | Very fine | Very platykurtic | Coarse sand |
| | 2 | 363.0 | 539.4 | Poorly | coarse | Very platykurtic | Coarse sand |
| | 3 | 238.9 | 347.3 | Poorly | coarse | Very platykurtic | Medium sand |
| $T_2$ | 1 | 240.1 | 423.8 | Poorly | Very coarse | Very platykurtic | Medium sand |
| | 2 | 207.2 | 328.0 | Poorly | Very coarse | Very leptokurtic | Fine sand |
| | 3 | 679.0 | 699.8 | Poorly | fine | Very leptokurtic | Coarse sand |
| | 4 | 235.6 | 252.8 | Medium | Symmetrical | Mesokurtic | Medium sand |
| $T_3$ | 1 | 204.8 | 216.1 | Poorly | coarse | Very leptokurtic | Fine sand |
| | 2 | 145.4 | 277.2 | Poorly | Very coarse | Very platykurtic | Medium sand |
| | 3 | 779.2 | 664.1 | Poorly | Very fine | Very platykurtic | Coarse sand |
| $T_4$ | 1 | 377.1 | 451.6 | Poorly | coarse | Mesokurtic | Medium sand |
| | 2 | 187.1 | 181.2 | Medium | Symmetrical | Mesokurtic | Fine sand |
| | 3 | 205.9 | 210.1 | Poorly | Symmetrical | leptokurtic | Fine sand |

### *3.8- Grain morphology*

The interpretation of a sediment sample on the basis of the size variation within a large population of sand grain is prone to inaccuracies largely because it is known that another characterizes of grain also affected their mobility. Generally, three index, roundness, surface features and sphericity are studied as grain morphology.

3.8.1. Roundness (grain shape)

In additional to influencing size analyses, it is known that grain shape also affects their mobility. It is also known that natural sand grains do not behave in the same way as spherical particles (Cui et al.1983). therefore, some measure of grain shape should be incorporated in predictive formulae of the rate of sand transport.

Roundness or degree of abrasion of a clastic particle is shown by the sharpness of its edges and corners. Various methods have been adopted for describing the roundness of sand grains; Wadell's ratio as the ratio of the average radius of curvature of the several edges or corners of the particle to the radius of curvature of the maximum inscribed sphere (or to one-half the nominal diameter of the particle).

Another method assigning quality coefficient to each grain based upon a visual impression of the grain. for example, Powers' shape coefficient (powers 1953). This method employs values corresponding to a range from very angular to well round (figure 7). These values are; very angular, angular, sub- angular, sub-rounded, rounded, well rounded that are into two category high sphericity and low sphericity, and the third technique for measuring roundness involves the use of quantity coefficient. One of these coefficients is Pettijohn coefficient (Pettijohn 1957).

Angular, with roundness value between 0.00 – 0.15

Sub- angular, with roundness value between 0.15 – 0.25

Sub-rounded, with roundness value between 0.25 – 0.4

Rounded, with roundness value between 0.4 – 0.6

Very rounded, with roundness value between 0.6 – 1

In this paper, roundness index was described according to the Powers's scale and also abrasion coefficient was used based on Pettijohn's values ,Therefore to harmony these was done following modification;

- To create the abrasion coefficient 0.0-0.05 at the Pettijohn's values against very angular in the Powers's scale.
- To change the Pettijohn's values based on 10 for values comparison with available values in Iran (table3).

Table 3. Modifications of Pettijohn's values base on Powers's scale

| Roundness values | Pettijohn's values (modified) | Max.values with implementation of coefficient of ten |
|---|---|---|
| very angular | 0.00 - 0.05 | 0.5 |
| angular | 0.05 – 0.15 | 1.5 |
| sub- angular | 0.15 – 0.25 | 2.5 |
| sub-rounded | 0.25 – 0.4 | 4 |
| rounded | 0.4 – 0.6 | 6 |
| well rounded | 0.6 - 1 | 10 |

3.8.2 . Surface features

The process of roundness results in damage to the surface of a grain. Surface damage or surface texture (Mazzullo, 1987) can be result from differential weathering, transport and deposit by either river or a glacier and the action of wind. Surface features evaluate at 6 type, which based upon process of damage include; physical and chemical weathering (Percussion mark, Differential weathering, Striation grains), water erosion (Polish, Impression mark grains) and wind erosion (Frosting grains).

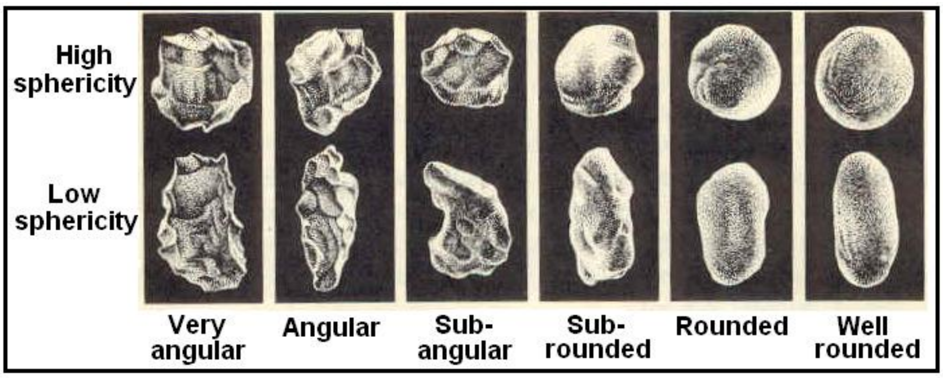



Fig. 7. Powers's scale for grain shape classification (modified Powers 1953)

3.8.3. Morphoscopy study

In this project, morphology investigation of collected samples were described according to roundness degrees (incorporation of Powers & Pettijohn, 1957) and Surface features (Ahmadi, 2008).A sample of morphology study illustrated in table4.

The abrasion coefficients of samples were summarized in table 5.

Table 4. Sand grain morphology according to roundness and surface features (reference, Powers1953, Pettijohn 1957, Ahmadi 2007, and Mashhadi 2008)

Geomorphologic facies: Rebdou Transect No.: 1 Sample No.:2

Mineral: Quartz diameter grain: 150-300 µm

| Surface features | Type of weathering and erosion | Percentage | Roundness | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Very angular 0.5× | Angular 1.5× | Sub-angular 2.5× | Sub-rounded 4× | Rounded 6× | Well rounded 10× |
| Percussion mark | physic and chemical weathering | 4 | --- | --- | * | *** | --- | --- |
| Differential weathering | | 7 | --- | --- | ** | ***** | --- | --- |
| Striation | | 6 | --- | --- | ** | **** | --- | --- |
| Polish | wives | - - - | --- | --- | - - - | - - - | --- | --- |
| Impression mark | river erosion | 1 | --- | --- | * | - - - | --- | --- |
| Frosting | wind erosion | 7 | --- | --- | ** | ***** | --- | --- |
| Total | 25 | 25 | --- | --- | 8 | 17 | --- | --- |
| Percentage | 100 | 100 | --- | --- | 32 | 68 | --- | --- |
| Abrasion coefficient | -------- | | --- | --- | 80 | 272 | --- | --- |
| Sample abrasion coefficient | -------- | | | | 352 | | | |

Table 5. Taken abrasion coefficients from studding morphoscopy of samples

| Transect | Samples | Abrasion coefficient |
|---|---|---|
| $T_1$ | 1 | 292 |
| | 2 | 352 |
| | 3 | 364 |
| $T_2$ | 1 | 340 |
| | 2 | 364 |
| | 3 | 362 |
| | 4 | 448 |
| $T_3$ | 1 | 326 |
| | 2 | 344 |
| | 3 | 394 |
| $T_4$ | 1 | 298 |
| | 2 | 362 |
| | 3 | 366 |

## 4. Discussion and Conclusion

Certainly, the wind play mainly role for grain maturity in the desert region .Mainguet (1986)studied this role as the wind action in desertification in Sahro-Sahelian and Bagnold (1941) conducted primary researches exactly and partially in relation to sand movement and its morphological change.

### *4.1. Sediment maturity*

Sediment maturity is a measure of *distance-time* from the source - to - depositional area. Lots of factors such as climate condition, weathering, transport condition, and mineralogy of the source rock affect in the grain maturity. But according to a general rule," more time and far distance, more grain maturity". Maturity can be measured in terms of texture (textural maturity), mineralogy (mineralogical maturity), and composition (compositional maturity).The terminology used to describe above maturities are: immature, sub mature, mature, and super mature. In this study grains maturity studied based on textural maturity.

### *4.2. Textural maturity*

Texture maturity is measured by grain size, grain sorting, and grain roundness. In the origin area the weathering process produce a wide range of grain sizes but generally big chunks. In this condition, grains tend to have a rough or angular exterior. The maturation process fractures big blocks to smaller sizes. Medium sizes of sand grains resist to size reduction. The maturation process also round and smooth the angular and sharp corner of the grains. Table 6 show the relationship between maturation process with sorting, grain size, and roundness (J.Dockal, 2006).In this table we used the abrasion coefficient based on the roundness instead of roundness term (Mashhadi, 2008).

Table 6. grains characteristic in the term of texture maturity

| degree of maturity / grain characteristic | Immature | Sub mature | Mature | Super mature |
|---|---|---|---|---|
| sorting | Extremely poorly sorted to very poorly sorted | poorly sorted to moderately sorted | moderately sorted to well sorted | very well sorted |
| mean size | very coarse or bigger | coarse | medium | fine |
| roundness | very angular, angular | sub- angular, sub-rounded | rounded | well rounded |
| abrasion coefficient | 0-150 | 150-400 | 400-600 | 600-1000 |

### 4.3. Textural maturity of sediment grain

According to presented results from granulometry and morphoscopy of sediment, samples maturity conditions in each transect have been shown in tables 7-10.

Table 7. Texture maturity of samples of transect 1

| degree of maturity / grain characteristic | Immature | Sub mature | Mature | Super mature |
|---|---|---|---|---|
| sorting | | ▲ ○ * | | |
| mean size | | ▲ ○ | * | |
| roundness | | ▲ ○ * | | |
| abrasion coefficient | | 292 352 364 | | |

Table 8. Texture maturity of samples of transect 2

| degree of maturity / grain characteristic | Immature | Sub mature | Mature | Super mature |
|---|---|---|---|---|
| sorting | | ▲ ○ * | □ | |
| mean size | | ▲ * | ○ □ | |
| roundness | | ▲ ○ * | □ | |
| abrasion coefficient | | 340 364 362 | 448 | |

Table 9. Texture maturity of samples of transect 3

| degree of maturity / grain characteristic | Immature | Sub mature | Mature | Super mature |
|---|---|---|---|---|
| sorting | | ▲ ○ * | | |
| mean size | | ○ | * | ▲ |
| roundness | | ▲ ○ * | | |
| abrasion coefficient | | 326 344 396 | | |

Table 10. Texture maturity of samples of transect 4

| degree of maturity / grain characteristic | Immature | Sub mature | Mature | Super mature |
|---|---|---|---|---|
| sorting | | ▲ * | ○ | |
| mean size | | | ▲ | ○ * |
| roundness | | ▲ ○ * | | |
| abrasion coefficient | | 298 362 366 | | |

▲The sample no.1 in each transect O The sample no.2 in each transect
□ The sample no.4 in each transect * The sample no.3 in each transect

The samples evolution analyses (tables7-10) indicate that in all transects, the samples from upper lands (near to sand sources) are more mature than lower lands (in transport area).
Detailed studies of texture maturity indicators show that abrasion coefficient or roundness, sorting and grain's mean size indicators are the most reliable measures for determination of maturity respectively. Williams (1964); Stapor et al. (1963); Willetts et al. (1982) and Willetts (1983) argued that in addition to influencing grain size, it is known that grain shape also affects their mobility.

As the texture maturity tables (7-10) show, all of samples, except of sample 4 from transect2 are in the sub mature range, which present either low transport distance or low power of wind abrasion action. The granulometry and morphoscopy( grains surface features) analyses show that grains are more affected by physical and chemical erosion rather than wind erosion.
Krinsly(1970) , based on field observation and extend of the Khartouran Erg conclude that these process possibility happened in the past with more rainy winter and windy summer than present.. In overall at present, the rate of sand

flux and the balance between erosion and sedimentation are dominant factors in evolution of geomorphology by wind.

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