International Journal of Geography and Geology
2016 Vol. 5, No. 1, pp. 1-9
ISSN(e): 2305-7041
ISSN(p): 2306-9872
DOI: 10.18488/journal.10/2016.5.1/10.1.1.9

CHARACTERIZATION OF SAND DUNES TO DETECT THE SAND SOURCE AND THEIR STABILIZATION, ABARDEJ, IRAN

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ABSTRACT

A dune field was investigated to detect dunes morphology, physiochemical and mineralogical specifications in Abardej region in the southeast of Tehran, Iran. The border of dunes was determined using aerial photographs and field observations, and then the various shapes of dunes were found. The results have shown that dune shape is mostly transverse, indicating the existence of a dominant wind in one direction. Also, there are some Nebka dunes infrequently. Based on the chemical analysis of dunes, there isn't any limitation for cultivation of desert plants, and the biologic stabilization of dunes is possible and suitable. The morphoscopic study has shown that the sand grains almost have steep angles; therefore, the dunes may have local sources. The sand grains were almost shiny and semi-shiny in microscope's light, indicating that the source of dunes is generally the river-beds. Quartz, Feldspar and Calcite were the main minerals of sand grains. The mean of sampled sand grains diameter was about 200 microns and 27 percent of them had a diameter of 250 microns or more; these reveal the existence of a local source for the dunes. Based on the obtained results, it would be concluded that the source of sand dunes is floodplains in east and south- east of the dunes.

Keywords: Dune, Characterization, Morphology, Sand source, Abardej, Iran.

Received: 29 May 2015/ **Revised:** 12 October 2015/ **Accepted:** 16 October 2015/ **Published:** 21 October 2015

Contribution/ Originality

This study is one of very few studies which have investigated the physiochemical specifications of sand dunes. The movement of dunes and producing dust in air are as environmental problems that the results of study help to solve these.

1. INTRODUCTION

More than 2/3 of Iran's area has arid and semi-arid climates in reason of geographical and physiographical conditions, and distance from seas. The area of Iran ergs and dune fields (without Nebkas and beach sands) was determined about 35000 Km^2 by interpretation of aerial photos

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(1:55000) which is equal to 2.1% of Iran's area (Mahmoudi, 2001). Identification of morphology, physiochemical and mineralogical specifications of sand dunes have been performed to determine the sand source of dunes, description of their properties, stabilizing the dunes, study of sand dunes activity and so on (Abu-Zeid *et al*., 2001; Al-Enezi *et al*., 2008; Del Valle *et al*., 2008). Aeolian sands are, primarily, unconsolidated sediments formed by the erosion, transportation and deposition of the materials of weathering from the sandy parent material by the wind in the arid environment (Zhu, 1985; Padmakumar *et al*., 2012). Refaat and Hamdan (2015) investigated the mineralogical properties and the morphology of aeolian quartz sand in the Toshka dune area, southeastern Western Desert of Egypt. They have presented that the dunes are composed mostly of sub-angular to sub-rounded fine to medium quartz sands together with minor proportions of feldspars and lithic fragments. The quartz grains demonstrate a variety of surface textures indicating mechanical and chemical processes developed during transportation of these grains in subaqueous and aeolian environments. Hermas *et al.* (2012) were determined movement of sand dunes by multi-temporal remote sensed images (SPOT 4 panchromatic images) in the Sinai desert, Egypt. El Gammal and El Gammal (2010) were determined source of a southeast mobile sand dune field extends west of the Nile Valley (Egypt) and encroaches on the cultivated land. They used morphoscopic and granulometric studies, geological surveys and geomorphological mapping to determine the dunes source. Howari *et al.* (2007) used Landsat 7 ETM+ data sets to study the geomorphology and mineralogy of different dune types in the eastern part of Abu Dhabi in United Arab Emirates. Band ratios 6/4 and 5/7 were very useful for mineralogical distinction. The results of the present study show that these dunes are classified into several main classes based on composition. The first class is low dunes composed of a mixture of quartz and carbonate, the second class is carbonate-rich, the third quartz-rich and the fourth mafic mineral-rich. Dong *et al.* (2000) calculated the mean advance rate of the dunes respectively 7.29 and 5.56 m year^{-1} in 1992 and 1993 in the Taklimakan Desert. This article presents a research study results about identification of Abardej dunes physio-chemical, morphological and mineralogical specifications in Iran. The dunes has important role in producing dust and losing seeing in local area. The morphological study could present the proper methods for sand dune stabilization. For the biological stabilization of sand dunes, the cultivation capability of dunes needs to be determined by identification of their physiochemical properties. Mineralogical specifications are important to determine the sand source of dunes.

2. MATERIAL AND METHODS

Abardej dunes is located in geographical latitude from 35° 8' to 35° 10' and geographical longitude from 51° 56' to 51° 59' in southeast of Tehran province, Iran. The area of dunes was determined by interpreting aerial photos and field works.

Primary data for analysis of climatic condition was collected from Abardej climatology site and Garmsar synoptic site, the nearest climatic sites to the dunes. In the dunes area, the warmest months are August and July, and the coldest months are January and February. Annual

precipitation based on ten years statistics (2003- 2012) is 44.5 -136 mm. In this decade, 8-28 days were rainy annually. Climatic class of the area is cold arid desert, and the number of storm days is 6.2 days in average based on ten years statistic of Garmsar site. Directions of main winds are 90 degree (east) and 270 degree (west). For study of topographic condition of the dunes, topographic maps with 1:25000 scales have been used. Boundary and geographical position map of the dunes were prepared by interpreting aerial images with 1:40000 scale (2000) and field works. Also the dunes form (morphology) was determined by the aerial photos and field survey. Also, in the dune field, altitude of the position, vegetation cover, wind directions and stabilization type of the dunes were determined. For identification of the form and morphologic classification of dunes, Lancaster classification approach (Lancaster, 1995) was used. In this approach, sand dunes occur in four main morphologic types: Crescent (transverse), linear, star, and parabolic. Also, the topographic specifications' maps of the dune field were prepared as hypsometric, slope, and geographical directions maps.

2.1. Determination of Chemical and Physical Specifications

In different positions of the dune field, some samples (sand grains) were taken from the sand dunes. In three parts of every dune, two sides and middle, the sand samples equal to 5 kilograms were prepared after mixing sands of the three positions. The samples were prepared from 6 dunes in different points of the dune field. The depth of sampling was 0-30 cm. The granulometric specifications of sands by standard meshes (ASTEM method), pH, Ec, SAR, percent of clay, silt and sand, active limestone and gyps of the sand samples were identified. For granulation of the sand samples, standard meshes with sizes 63, 125, 250, 500, 1000, 2000 and 4000 micron were used. By results of the sand granulometry, median, mean, sorting index and skewness index of sand grains were determined. These indexes are important in determination of the dunes source (Ahmadi, 2008). The median and mean of sand grains diameters present size of the dune grains. The grains median is that which separate 50% of the sample from the other, that is, the median is the 50th percentile (Selley, 2000). The sorting index presents uniformity of the sand grains. The skewness index presents symmetry state of normal distribution curves of sizes of the sand grains. Toward the fine grains the index is negative, toward the coarse grains the index is positive and the index is 0 in symmetry state. GRADISTAT software package (Blott and Pye, 2001) the grain size distribution and statistics package, was used for calculating the indexes.

Table 1 presents the used formulas for granulometry by GRADISTAT. Table 2 presents the classification of sand grains based on their skewness and sorting.

Table-1. Statistical formulae used in the calculation of grain size indexes

Mean	Standard Error(Sorting)	Skewness
$_g = \exp \frac{\Sigma f \ln m_m}{100}$	$_g = \exp \sqrt{\frac{\Sigma f (\ln m_m - \ln \bar{x}_g)^2}{100}}$	$k_g = \frac{\Sigma f (\ln m_m - \ln \bar{x}_g)^3}{100 \ln \sigma_g{}^3}$

f is the frequency in percent; *m* is the mid-point of each class interval in metric (*m*ϕ).

Table-2. Classification of sorting and skewness of sand grain sizes (Micron)

Class number	Sorting (σ_g)		Skewness (Sk_g)	
1	Very well sorted	< 1.27	Very fine skewed	<-1.30
2	Well sorted	1.27 – 1.41	Fine skewed	-1.30 – -0.43
3	Moderately well sorted	1.41 – 1.62	Symmetrical	-0.43 – + 0.43
4	Moderately sorted	1.62 – 2.00	Coarse skewed	+ 0.43 –+ 1.30
5	Poorly sorted	2.00 – 4.00	Very coarse skewed	>+1.30
6	Very poorly sorted	4.00 – 16.00		
7	Extremely poorly sorted	> 16.00		

2.2. The Morphoscopy of Sand Grains

The morphoscopy of sand grains was studied as the shape and surface features of sand grains. These characters were used to determine the destructive and erosion factors, and they could be alluvial or aeolian factors or both. Various destructive factors on sand grains deform the shape of them. Sand grain is created from alluvial and aeolian erosions, which appears "shiny or semi shiny" and "opaque" in microscope light, respectively (Ahmadi, 2008). The surface feature has been studied based on 3 groups according to process of damage included Polish, Impression mark grains and Frosting grains. Water erosion causes Polish and Impression mark grains (shiny grains); wind erosion causes frosting grains (opaque grains). Also, a classification based on the rate of abrasion and roundness of the sand grains was performed. This index could show the distance of grains source that the round grains come from more distance until the angular grains usually. In the used classification, the grains are classified in four categories as angular (unabrasion), sub-angular, sub-rounded and rounded. Therefore, after washing the sand grains, appropriate numbers of them (quartz grains generally) were observed for determination of the morphoscopy of sand grains by Binocular Microscope.

2.3. Mineralogy

The determination of sand grains minerals is important in identifying the source of sand dunes. In this study, XRD (X-ray diffraction) and ocular methods were used to identify the sand dunes minerals. The 5 samples of sands were obtained from 4 corners and center of the dune field, and then they were mixed in one sample for XRD. In ocular method, a thin layer of the sand grains was prepared, and the minerals were observed by a microscope with polarized light.

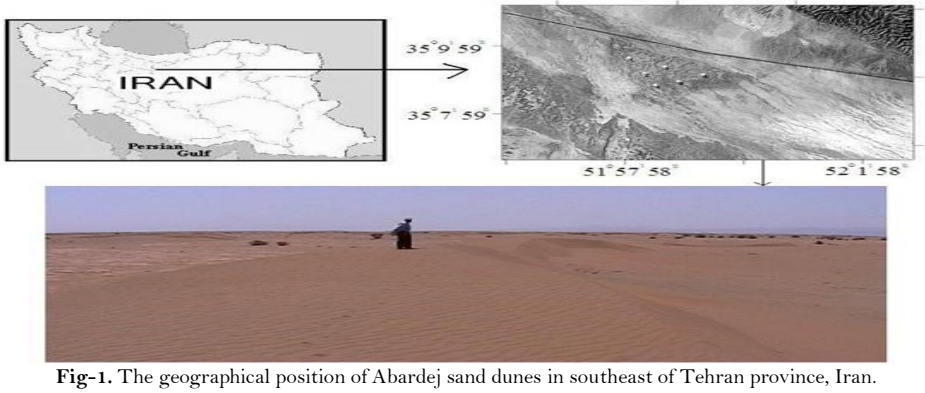

Fig-1. The geographical position of Abardej sand dunes in southeast of Tehran province, Iran.

3. RESULTS

Area of the dunes was determined about 700 ha, and they are located in lands with less than 1 percent slope. The dunes are located in land elevation classes of 750-800 m and 800- 850 m from free sea surface.

3.1. Morphology of the Dunes

The eastern wind (90 degree wind) has main role in formation of the dunes because of existence of a sand grains source. The western wind (270 degree wind) has important role in shaping the dunes. The eastern wind comes from a flood plain in east of the dunes. Based on the study results, the dunes are in the inverse dunes group in shape of Barchan and Helali and nebkas, also sand plains was observed. Embowed shape is obvious in the dunes. The length of inverse dunes crosses the vector of eastern wind. Color of sand gravels is Orange Dull yellow based on Munsoll color notebook.

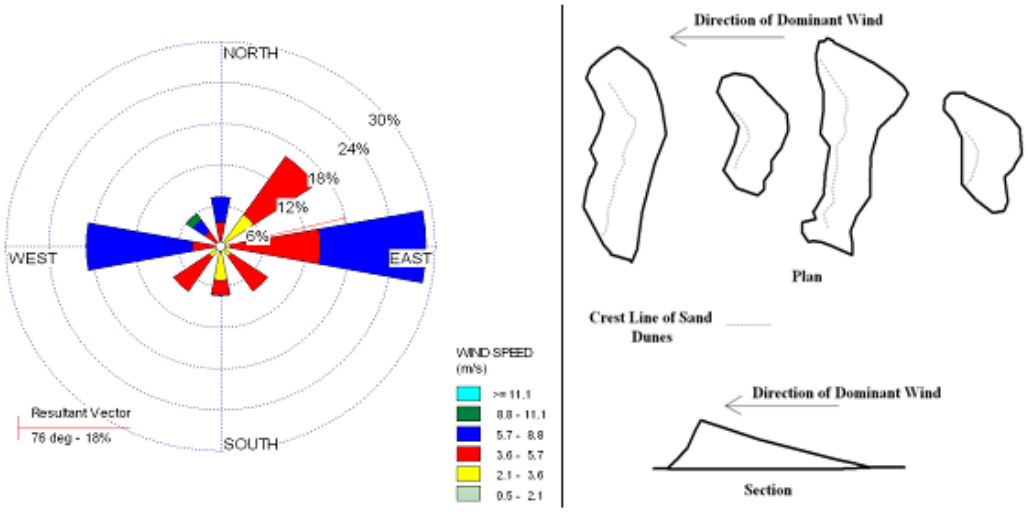

Fig-2. The plans of some of Abardej dunes (right) and the wind rose of Garmsar station innear of the dunes

3.2. The Chemical Specifications of Sand Dunes

The chemical specifications of the sand dunes are presented in table 3 based on 4 obtained samples. PH of the sand samples is very low alkaline. This condition in general is suitable for cultivation of plants. Also, there isn't any limitation of salinity for cultivation of plants. The SAR measure is made no limitation.

Table-3. The chemical specifications of sand dunes

Number of sample	SAR	Gypsum Meq/lit	Ca Co3 (%)	Sum Cat. Meq/L	Ca+ Mg Meq/L	Na Meq/L	pH	Ec ds.m^{-1}
1	2.32	0.2	16.6	16.7	11.2	5.5	7.98	1.83
2	2.35	0.5	16.2	17.75	12	5.75	8.1	1.88
3	2.18	0.3	16.2	16.85	11.6	5.25	8.2	1.79
4	2.58	0.4	15.6	16.8	10.8	6	7.98	1.72

Based on this reality that the desert plants are resistant species, the chemical results show the sand dunes are suitable sites for forestry cultivation and carbon sedimentation.

3.3. The Granulometric Specifications of Sand Dunes

Granulometry was done by standard sieves with 63, 125, 250, 500, 1000, 2000 and 4000 micron meshes. The result of granulation is presented in table 4.The sand dunes didn't have the grains more than 2000 micron. The numbers in the table's cells present the percent of sand grains that reminded on every sieve.

Table-4. The granulometry of sand grains based on percent

Size of Sieve meshes(Micron) / Number of Sample	63	125	250	500	1000
1	7.8	66.81	24.05	0.49	0.02
2	7.49	65.33	25.9	0.6	0.02
3	11.83	53.42	29.73	3.5	0.78
4	9.9	69	19.51	0.53	0.02
5	7.6	65.31	25.75	0.48	0.03
6	7.38	66.57	25.34	0.58	0.03

In table 5, the calculated indexes of the dunes granulation are presented (calculated by GRADISTAT software).

Table-5. The calculated indexes for the size of sand grains (micron)

Number of sample	Median	Mean	Sorting	Skewness
1	192.8	199.5	1.472	0.234
2	195.6	202.8	1.482	0.219
3	204.1	213.6	1.667	0.404
4	186	190.6	1.468	0.259
5	195.2	202.2	1.480	0.200
6	194.7	202	1.476	0.251

Based on the presented classification in table 2, the sorting state of the sand samples is in the third class, and this state presents the moderately well sorted grains. Skewness of all samples is symmetric and in third class. These two indexes, in the classes, show the sand grains of Abardej dunes are close together and the same based on their size and sorting, therefore they have one source.

3.4. Morphos Copy of the Sand Grains

Based on survey of the grains by microscope, they are shiny or opaque, but the percent of shiny grains is more than opaque grains. The high percent of the shiny sand grains shows the important role of alluvial factors in the production of sand grains and formation of the dunes.

The grains were angular, but the angles aren't sharp that shows low effects of erosion factors on the sand grains and short distance of the removing area (sand source) and the dunes. The sand grains are classified in semi-angular with minor friction. The morphoscopy state of sand grains is presented in table 6 based on the 4 obtained samples.

Table-6. The result of sand grains morphoscopy

Number of sample	Shape of sand grains	Percent of shiny sand grains	Percent of opaque sand grains
1	semi-angular with minor friction	70	30
2	semi-angular with minor friction	50	50
3	semi-angular with minor friction	40	60
4	semi-angular with minor friction	75	25

3.5. The Mineralogy of Sand Grains

In figure 3, the different identified minerals in the sample of sand dunes by XRD method are presented. The identified minerals based on the XRD method are Quartz, Albite, Calcite, Alkali Feldspar, Analcime, Mica-Illite di-Oct, Gypsum, Chlorite, Dolomite, Hematite and Amphibole. Quartz, Feldspar and Biotite minerals have been observed in the sample by using polarized light microscope (Figure 4).

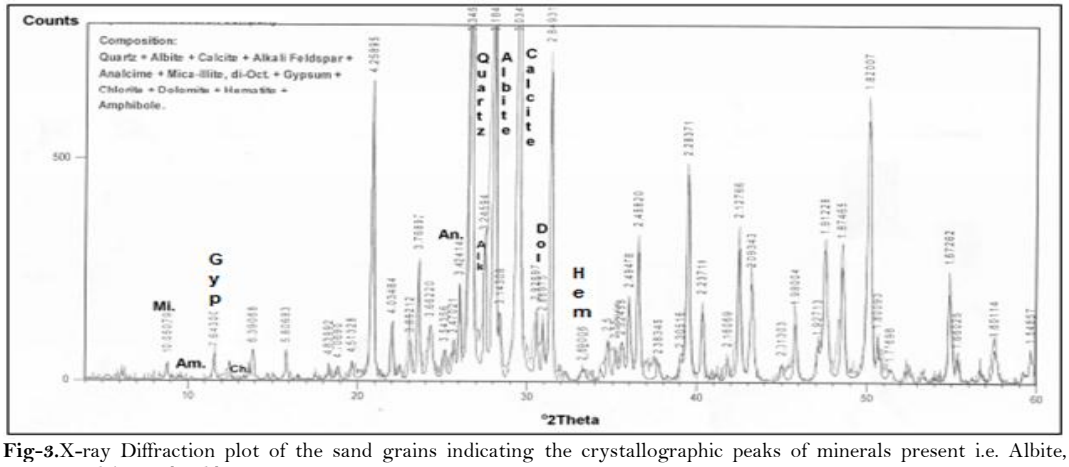

Fig-3.X-ray Diffraction plot of the sand grains indicating the crystallographic peaks of minerals present i.e. Albite, Quartz, Calcite, and Feldspar.

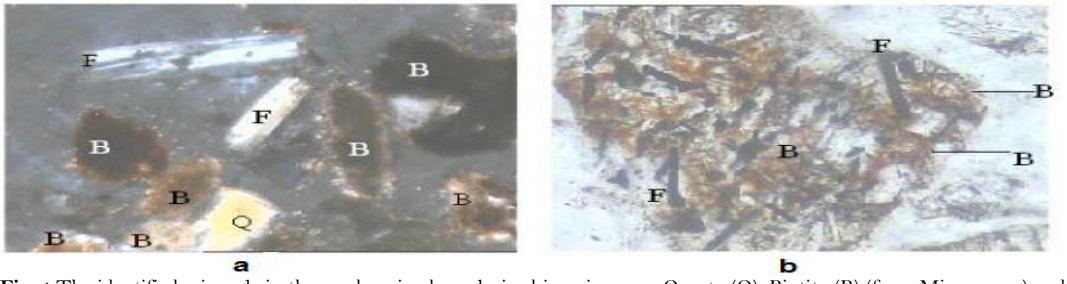

Fig-4. The identified minerals in the sand grains by polarized imaginary. **a**: Quartz (Q), Biotite (B) (from Mica group) and Feldespar (F) - **b**: Feldespar (F) and Biotite (B)

4. DISCUSSION & CONCLUSION

Abardej area is the sedimentation location of sands. One of the topographic specifications of the area is existence of high mountains (Koh-e-Sorkh) in front of the sand dunes, and this condition is very important in formation of the dunes.

Based on the granulometry study of sand grains, the median of sand grains diameter is 186 – 202 microns in the each sample. Medians of the sand grains are near to each other. This point can reveal that the dunes have a single source. The diameter mean of sampled sand grains is about 200 microns, and about 20 – 34% of the sand grains have a diameter more that 250 microns in each sample. Based on these points, the dunes have a local source. The source can be in distance of 5-20 km from the dunes. Existence of sand grains with a diameter more than 250 microns is the reason of being near sand source location to sedimentation location (Ahmadi, 2008). Wang *et al.* (2003) have reported the sand grains diameters of central Taklimakan Sand Sea (china) between 63- 250 microns.

The sand grains are shiny or opaque that implies the role of alluvial or aeolian factors in formation of the dunes. Existence of high percent of the shiny grains shows main role of alluvial factors in the formation of dunes. The shape of the grains is semi-angular that shows low distance of the sand grains' transportation. Existence of transitory minerals such as Feldspar and Gypsum is another reason of nearing the sand source of dunes.

The Abardej dunes are located in an area surrounded by some mountains and hills in north and west sides. The sand grains come from east and south-east sides to the deposition site. The dunes have been formed on a flood plain land type with many low depth channels. The existence of multiple channels in the land type is another reason to tangle of the sand grains and to form the dunes.

Based on the direction of dominant winds, morphoscopy and physical specifications of the sand grains and form of the dunes that shows east to west wind (eastern), it would be concluded that the source of sand dunes is flooded plains in east and south- east of the dunes. These plains are place of seasonal rivers, and these rivers carry out a large quantity of sediments. In these plains, there are the thin vegetation cover and fine textured soil, which are the important sand sources for formation of the dunes.

Funding: This study received no specific financial support.

Competing Interests: The authors declare that they have no competing interests.

Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study. We are grateful to Research Institute of Forests and Rangelands of Iran for their scientific and financial supports.

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