

Juvenile Aeolian Deposits at Badra Area - Eastern Iraq

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Abstract
Badra area represents one of those desertified areas, in which the preliminary stage of aeolian activity is very evident. Nabkha dunes and sand sheets are the major wind formed deposits in the area. Nabkhas or more precisely micronabkhas represent the major dune type which imposes a clear indication of the desertification vitality in the area. Such an area may represent an ideal example of how desertification is acting, whereby a well-vegetated area some three decades ago is turning now to a barren land.These vegetation dunes were studied from the morphological, mineralogical and textural aspects. The special dimensions of these dunes are usually small not exceeding a meter in height and a few meters in length indicating a mild wind action with a predominant NW direction. Ripple marks, and adhesion structures are also noticed.The dune sand samples are mainly formed of silty sand with an average median of 2.56**Ø** (fine sand), average mean 2.55**Ø** (fine sand), average standard deviation or sorting 0.55**Ø** (well to moderately well sorted), and negatively skewed. These parameters reveals a fluvial influence besides the dominant dune action.The light mineral fraction of Badra dune samples composed of quartz, calcite, feldspar, and evaporites as major constituents, while the heavy minerals fraction is dominated by the opaques, chlorites, epidote, garnet, mica, amphiboles, and pyroxenes. Probable sediment sources is greatly controlled by the eastern dune belt that extends from Baiji dunes in the northeast to Chailat dunes in the southeast. The sediments of the nearby alluvial deposits of Tigris river may also have their influence.One of the most effective and sure remedies for the Badra area will be the efficient use of the existing water resources, in which rain water harvesting and ground water resources are maintained and used to develop more effective ways of irrigation so that the area can be rejuvenated.
Keywords: Nabkha Dune, Desertification, Heavy Minerals, Statistical Parameters.

1- Introduction
One of the drastic and serious problems facing the various human activities is the systematic and complex increase in the process of land desertification in arid, semi-arid, and sub-humid areas. One such area represents the topic of this research; it lies within the vicinity of Badra town in Eastern Iraq. The interesting thing about this area is the preliminary stage at which the aeolian activity is acting, as the area was well vegetated some three decades ago, but due to water shortages and negligence, the area is turning to a barren land, causing the remaining scattered bodies of vegetation to trap the wind-blown sand , and to be deposited in the wind-shadow area to form small-scale nabkha dunes. These micro-nabkhas may represent a ringing alarm as being embryos for future buildups of macro-nabkhas and other forms of more developed dune features if the current conditions prevailed and the area is kept unattended. Such harmful environmental consequence not only effects the damaged area, but also the areas near to and even far away from it. The purpose of this paper is to study the morphological, textural, and mineralogical aspects of the aeolian sand that constitutes these features and which is active in this area.

2- Location and Physical Conditions
The area is part of the alluvial fans located on the eastern side of Mesopotamian plane. They extend from Mandali town in the NW to Amara city in the SE. The alluvial fans coalesce to form morphologically impressive bajada up to (15 km) wide and (100 km) thick (Aqrawi, et. al., 2006), along with the alluvial fans there is also alluvial depression filling , marsh sediments, and a thin belt of Pliocene - Miocene sediments (mostly clastics) lies as scattered outcrops along the eastern borders (Fig.1).

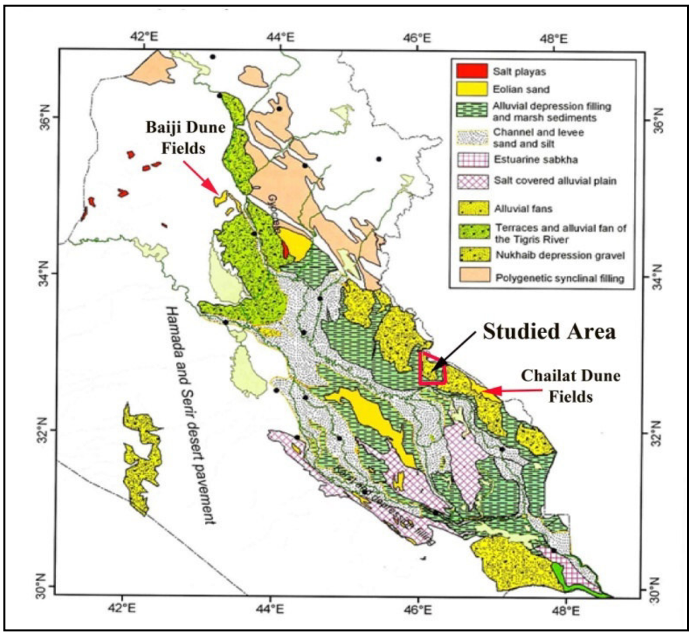

Figure1. Distribution of major Quaternary units and older formations (Aqrawi et. al.; in Jassim and Goff, 2006).

The lithology and geomorphology of the studied area is shown in Table 1. The general topography of the area not exceeding 50 meters ASL. Perhaps, one of the major influences of desertification in this area is the drying up of the marsh bodies (Hor Al -Shuwaicha), besides the diminishing water supply of the ephemeral streams which locally known as "Galal Badra" during the past few years (since 2006) which paved the way for the present aeolian action, as a result the area will most likely be included within one of the three major active dune belts in Iraq. Geographically the studied area lies within the lower half of the eastern dune belt which extends from Baiji dune fields (Fig. 2) in the northwest to Chailat dune fields (Fig. 2) in the southeast along the Iranian borders.

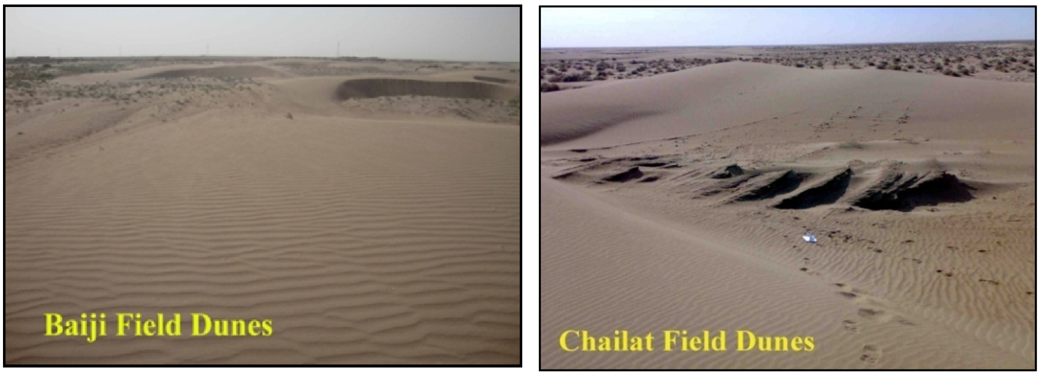

Figure 2. Barchan-brachanoid dune field in Chailat SE Iraq and Baiji NE of Iraq.

Table1. A generalized lithological, and geomorphological section of the studied area.

Age	Lithostratigraphy	Geomorphology
Holocene	Channel Alluvium	Active Channel
	Aeolian Deposits	Fixed Dunes
	Marsh sediments	Dried Depression Active
Pleistocene	River	Active Channel
	Terraces	
	Alluvial Fan	
	Mahmudeya Formation.	
Pliocene	Muqdadiya Formation.	Questa, Hogback, Strike and Hill Valley
Miocene	Injana Formation.	Mesa, Questa, Strike Valley
	Fatha Formation.	

Climate of the area is semi-arid characterized by a very hot, dry, long summer , with an average maximum temperatures of 36.5 C and a short, dry, cool winter with an average minimum temperatures of 10.5"C, and an average annual temperature of 24.5 C. The annual precipitation is 150 mm/yr, mostly occurring from November to March. The prevailing wind is generally dry in a northwesterly direction known as the "shamal" winds, these winds last for about (300 days) of the year then turning to southwesterly and humid for about 60 days. The relative humidity is 24%-29% in summer and 57%-74% in winter. The plant cover is scarce with the prevalence of *Tamarix Mannifera*, and *Alhagi Marurum* with *Aeluropus littorolis* and *Schanginia Aegyptiaca* are less distributed.

3-Methods of Study

15 samples from four sites are collected during two field surveys, (November. 2010 and March, 2011). This study is to cover the following aspects:

A- Morphometric parameters in which the visual size and shape of the sand bodies are investigated, along with the prevailing sedimentary structures. This was done solely in the field.

B- Textural characteristics of the 15 samples is performed by determining the grain size distribution using standard sieving and sedimentation techniques. A sieve interval of 1 phi was used. Statistical size parameters: Medium size; Mean size; Sorting; Skewness; and Kurtosis were calculated according to (Folk, 1974), using Sigma Plot (2011) software.

C-Mineralogical composition of all samples was determined. The whole mineralogy of the samples is determined by XRD using Bruker D2 Phaser instrument in the Iraqi-German Lab in the Geology Department/University of Baghdad while the fine size fractions which include fine sand, very fine sand, and coarse silt were separated into light and heavy mineral fractions using the standard bromoform method. The mineral composition of both light and heavy fractions was determined using the standard counting technique by using Leitz research polarizing microscope.

4-Result and Analysis

4-1 Occurrence and Morphometric Parameters

This study covers an area of about 120 square kilometer and including four stations,Al-Khalid, Al-Faris, Qutaiba, and Jasan (Fig.3).

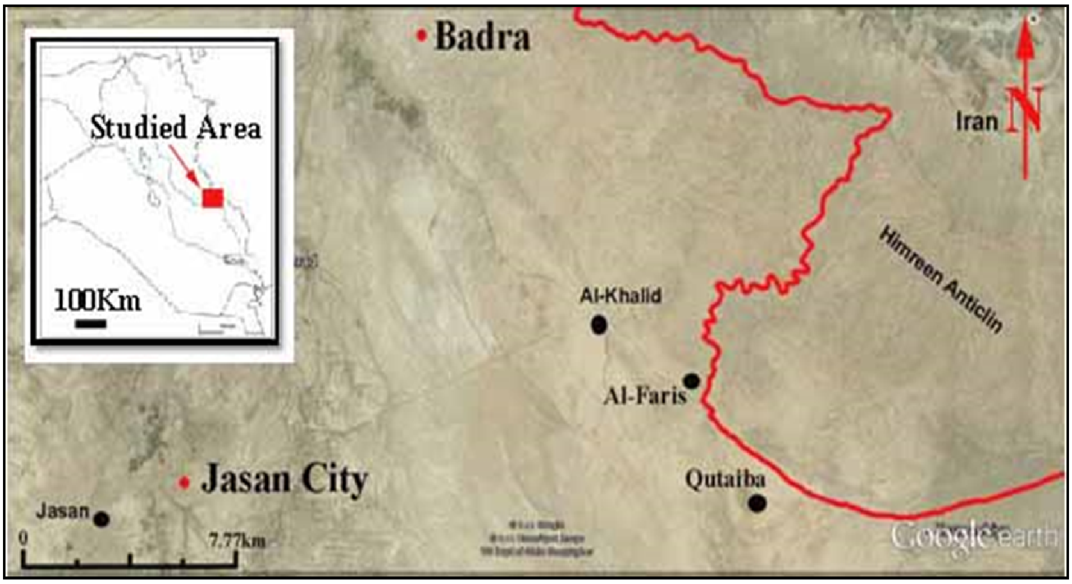

Figure 3. Location of the studied sites.

The vitality of the aeolian sand as evident from the clustering and nature of nabkha dunes is most pronounced in the Al-Khalid area while it is progressively decreasing at Al-Faris, Qutaiba, and Jasan respectively. The presence of the ephemeral stream channel (Galal) in Al-Khalid location may be the main reason for wind activity, as this channel acts as a wind corridor, in addition to the fact that it is now receiving far lesser amount of water than before (Fig. 4).

Figure 4. The ephemeral stream channel with apparent wind activity in Al-Khalid area.

Few varieties of aeolian landforms and structures exist in the studied area. However, those most pronounced include nabkha dunes, and sand sheets.

4-2 Nabkha Dunes

Nabkha dune is an Arabic word denoting a small sandy hillock (Khalaf et al,1995), it is a mound-like accumulation of wind-driven sediments around vegetation. Other common names include tarfa, coppice dune, sand shadows, sand tails, wind drift, and tailing dunes. Le Houeren (1986) used the term "rehboub" to describe small asymmetric mounds of loose, coarse windblown sand which accumulate in the lee of shrubs in arid and semi-arid regions. Such miniature dunes (maximum height of about 1 meter) are a characteristic feature of plains in regions with a mean annual precipitation of between 50 and 200mm. Some authors have considered nabkhas as a type of dune (Nickling & Wolf, 1994; Lancaster, 1995).

Only certain kinds of plants are associated with nabkhas, because only those "edifying" species that can form new roots and shoots from buried branches can continue to grow as the sand accumulates around them. If the sand accumulates faster than the plant can grow, the plant will die, and the dune will usually be deflated by wind. The nebkha morphology is mainly controlled by *Tamarix* mannifera shrubs, and is characterized by convex sand piles (Fig.5). The top of the mound is smooth and the slope is gentle. The vertical (height) and horizontal (length and width) of nabkhas change a lot, ranging from several meters to several tenth centimeters. The upwind sides commonly exhibit a litter of broken branches that suggests upwind erosion and downwind growth of the plant and migration of the nabkha.

Figure 5. One of the common nabkhas found in the studied area.

Cycles of nebkha deposition and erosion, functions controlling their size and density, and growth habit of its parent plant, which enforce nabkhas to pass through phases of growth, stabilization, and decay that are further controlled by fluctuations in the water table. In other words, nabkhas have a poor preservation potential (Gunatilaka and Mwango, 1987). Based on such phenomena several stages of nabkha development were noticed:

A- Early stages where nabkhas are small and have heights of less than meter, the vegetation had a fresh green color (Fig. 6).

Figure 6. An early stage nabkha as evidenced from the fresh green mound.

B- An intermediate stage in which mature well-developed nabkhas of more than one meter in height, the vegetation have a faint green to yellowish color (Fig. 7).

C- A late stage in which the nabkhas are partially or completely eroded, and where the shrub crowns are partially or completely dried up (Fig. 8).

Figure 7. A mid stage of nabkha formation.

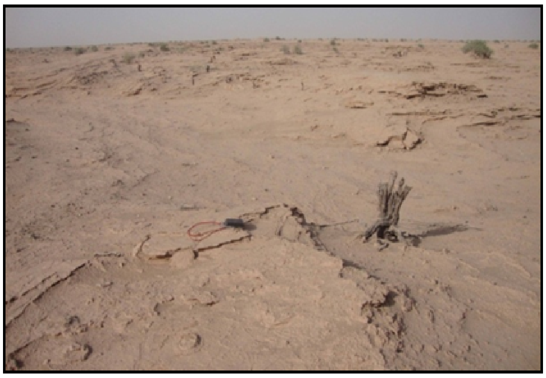

Figure 8. A late stage in which nabkha erosion is evident with the dried vegetation (right).

2- A multistage in which more than one generation of vegetation exist on the same nabkha where the new green shrubs growth is controlled by the nabkha crests (Fig.9).

Figure 9. Recently grown shrubs on former nabkhas (centre). Coalesced nabkhas (top).

Accordingly, several types of nabkhas have been identified in the studied area depending on size, shape, and state of preservation. In some areas, several nabkhas have coalescenced together to form amalgamated dunes (Fig. 9). These amalgamated dunes often form arcuate forms grading into downward elongate chains. At a larger scale, a nabkha-covered landscape can be considered a nabkha field or a sand sheet with nabkhas

4-3 Sand Sheets

While Badra nabkhas are relatively uniform in appearance, and develop rough topography, the smooth, flat, and locally undulatory surfaces of Qutaiba and Jasan areas (Fig.10) along with the intervening nabkha areas in Al-Khalid and Al-Faris localities constitute sand sheets which are devoid of slip faces. In the rainy season these sheets show both adhesive and slump structures.

Figure 10. A sand sheet in Qutaiba area showing the adhesive and slump structure.

The temporal and spatial variability of the sand sheets is represented by their rippled surface few centimeters thick, and by the presence of horizontal lamination and sometimes truncated by low angle cross-lamination . Glennie (1987) pointed out that such change in lamination patterns is caused when the mode of transport changes from traction to grain fall (Fig. 11).

Figure 11. A part of a sand sheet showing the horizontal and cross-lamination**.**

5-Textural Characteristics

5-1 Grain Size

Grain size distribution is determined on undispersed samples which were taken from nabkhas crests and sand sheet surfaces, and then sieved at one-phi intervals in the range -1.0 to +4.0 phi (2.0 – 0.063 mm) to represent the effective grain-size distribution under field conditions. Folk and Ward (1957) parameters were calculated, In addition the graphic standard deviation (σG) of Inman (1952) was calculated for their necessaries in Stewart's diagram (1958), although these parameters are criticized because they necessitate the log-normal transformation of grain-size data (Bagnold1, 973), they remain a powerful tool in analysis of aeolian sedimen (Lancaster,1986). Bagnold (1941) defined dune sands as any particle with a grain size between (0.02 mm) and (1.0mm). Ahlbrandt (1979) used the range (0.1 mm) and (1.6 mm).

The cumulative probability grain size curves of most samples show various degrees of departure from a log normal distribution, in which several truncation points are observed. Most samples show a major saltation population at (3 phi), however there are other curves that either lack such a point, or have an additional truncation point at (2 phi). This can be directly related to the various types of nabkhas and the presence of sheet sands (Fig.12).

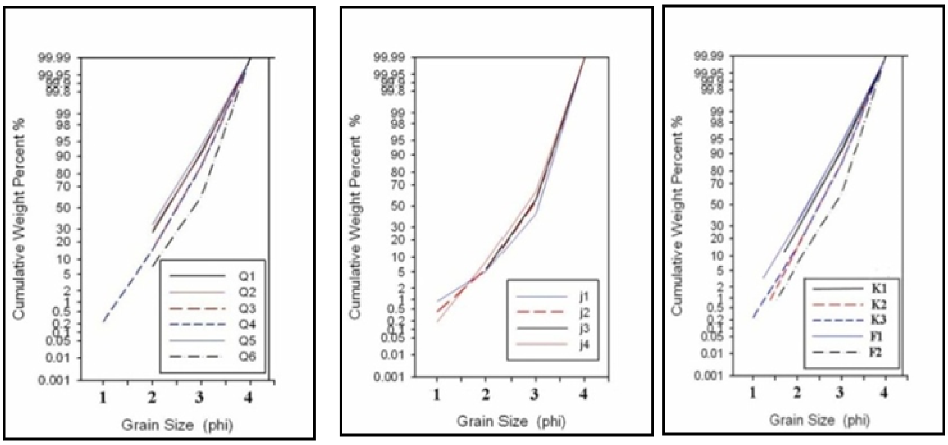

Figure 12. The cumulative curves of Qutaiba samples (left) and Jasan samples (middle), Al-Faris and Al-Khalid (right).

Relative frequency percentages of the various size classes and the values of size parameters of the studied dune deposits are given in (Tables 3, 4).

Table 3.The statistical parameters of the studied samples.

Statistical Parameters	Range Ø	Average Ø	Folk's Classification (1974)
Median (MDZ)	3.5 - 2.1	2.56	Fine Sand
Mean Size (MZ)	2.97 - 2.13	2.55	Fine Sand
Standard Deviation (σI)	0.95 - 0.44	0.55	Well to Moderately Well Sorted
Skewness (SKI)	0.81 - 0.01	0.23	Positively Skewed
Kurtosis (KG)	1.23 - 0.98	1.06	Mesokurtic
Graphic Standard Deviation (σG)	0.32 – 1.02	0.66	Well to Moderately Well Sorted

Table 4. The range and the average of the statistical parameters of the studied samples.

Location	Sample No.	Median MDZ	Mean Size MZ	Standard Deviation σI	Skewness SKI	Kurtosis KG	Graphic Standard Deviation σG
Qutaiba	Q1	1.4	1.1	0.8	-0.38	1.5	0.95
	Q2	1.4	1.1	0.77	-0.38	1.2	0.95
	Q3	1.8	1.67	0.66	-0.04	1.19	0.59
	Q4	1.98	1.76	0.67	-0.58	1.06	0.5
	Q5	2.05	1.93	0.74	-0.4	1.81	0.67
	Q6	1.99	1.94	0.55	-0.37	1.32	0.32
Al-Faris	F1	2.02	1.89	0.72	-0.38	1.47	0.65
	F2	2	1.86	0.72	-0.39	1.52	0.6
Al-Khalid	K1	2.05	1.96	0.89	-0.24	0.86	0.87
	K2	1.4	1.72	0.9	-0.22	1.18	1.02
	K3	2	1.9	0.71	-0.55	1.31	0.8
Jasan	J1	2.1	1.96	0.48	-0.46	1.36	0.49
	J2	2	1.89	0.52	-0.32	1.04	0.54
	J3	1.95	1.85	0.48	-0.28	0.88	0.5
	J4	1.8	1.7	0.42	-0.31	0.76	0.5

The most sensitive parameters that are useful for environmental distinctions include mean, standard deviation (sorting), and skewness (Martin, 2003). Following Folk's textural classification (Folk, 1974), the majority of Badra samples are of fine sand mean size, well to moderately well sorted, and positively skewed. The mean grain diameter (Mz) indicates the strength of the transporting environment i.e. the greater the strength, the larger grains could be transported (decreasing Mz). The standard deviation measuring sediment sorting describes the changeability and dynamics of transport, the smaller the value, the better the sorting. Positive skewness (SK1), according to Martin (2003) is due to the competence of the transporting unidirectional flow agent which indicates depositional influences, and that about 90% of dune sand show positive skewness. Hails and Hoyt (1969) pointed out that the sign of skewness is related to energy variations and indicated that (70%) of dune sands are positively skewed. There seems to be no significant differences of grain size among the different samples of both nabkhas and sand sheet indicating that the area had sustained similar wind energy.

The grain size parameters carefully obtain a potentially useful tool for recognizing sedimentary environments. Scatter plots with mean, standard deviation and skewness can be used successfully for distinction between dune, beach and river environments (Martin, 2003). Although the studied sands are surely dune, there is an evident influence of river activity (Figs. 13, 14), such a case may be explained in terms of provenance as these sediments are brought forth by the wind from the nearby alluvial deposits.

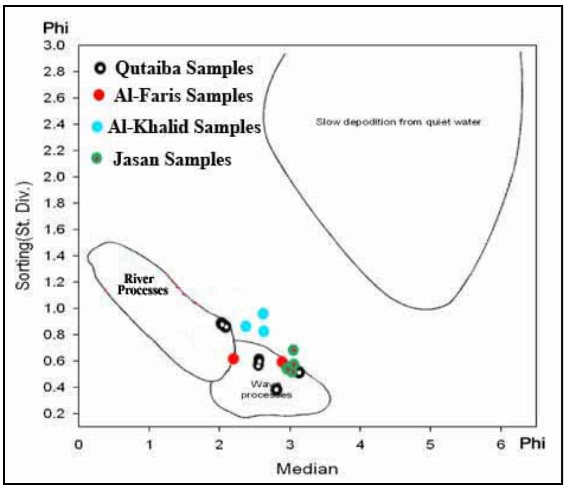

Figure 13. Bivariate Discrimenates Diagram of Badra Dune Sand according to Stewart, 1958.

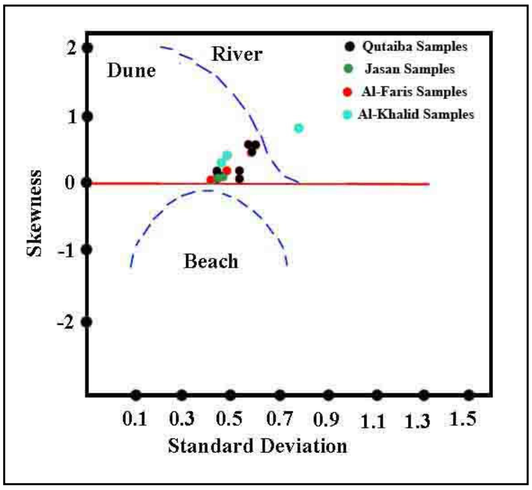

Figure 14. Bivariate Discrimenates Diagram of Badra Dune Sand according to Martin, 2003

6-Mineralogical Composition

Mineralogy of the sediments offers reliable inputs on the provenance and subsequent history. Heavy Minerals though present in small quantity are resistant to weathering and abrasion and therefore represent the parent lithology even after many cycles of erosion and deposition. Lighter minerals have this potential to a limited extent. Quartz being the most important (Saini, 2003).

The 2-4 phi fraction of the 15 samples are treated with 10% HCL, washed and dried, then 5 grams of each sample was gravity settled in bromoform. Light and heavy fractions were separated. The heavy minerals were weighed to obtain the weight percent. Both fractions were mounted on petrographic slides and were examined and counted using the petrographic microscope.

6-1 Light Minerals

The light mineral fraction of Badra dunes samples comprise more than (98%) of the total mineralogy, with an average of 60.25 % quartz (including chert fragments), 6.77% feldspar, 16.69% carbonates, 5.54% sedimentary, igneous, and metamorphic rock fragments, 7.6% evaporites, and 4.7% clay coated grains (Table. 5).

Table 5. Modal percentages of the light fraction in the studied samples.

Light Components	Samples Number					Average %
	Q3	Q6	J2	K1	F2	
Monocrystalline Quartz	43.61	45.29	39.80	44.40	41.10	42.85
Polycrystalline Quartz	4.82	6.14	8.36	3.01	3.70	5.22
Alkali Feldspar	5.70	4.82	3.68	4.74	2.35	4.27
Plagioclase Feldspar	1.75	2.19	1.67	5.59	1.35	1.92
Carbonate Rock Fragments	19.35	13.11	16.05	15.09	19.86	16.71
Chert Rock Fragments	6.14	9.21	11.04	11.19	13.8	10.29
Igneous Rock Fragments	1.31	1.75	2.34	3.45	3.03	2.39
Metamorphic Rock Fragments	1.75	3.07	2.67	1.3	2.69	2.17
Mudstone Rock Fragments	2.63	0.88	2.34	1.3	2.02	1.84
Evaporites	9.65	8.77	5.70	8.19	5.72	7.62
Clay coated grains	3.29	4.77	6.35	4.74	4.38	4.72

These mineral types and their relative abundances agree well with data gathered from the XRD analysis of the total samples (Fig.15).

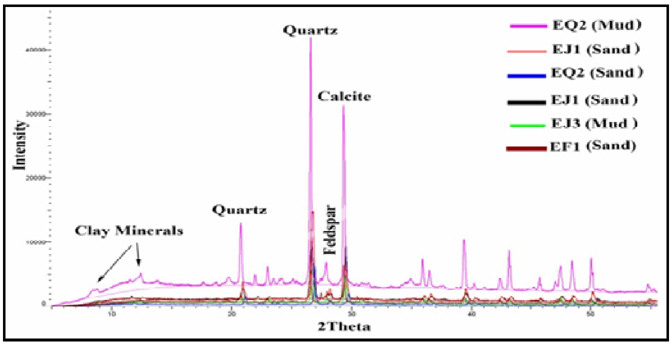

Figure 15 - X-Ray Diffractograms of six representative samples.

The majority of the quartz grains are monocrystalline , with dominant straight extinction and no inclusions. Subordinate amounts of polycrystalline and chert fragments making the silica content more than 60% of the light fraction. Feldspars range between 11-6% of the light fraction and includes sodic-plagioclase, microcline and orthoclase, many of these grains show different degrees of alteration. Carbonates make up between 13-20% , and constitute mainly of calcite occurring as rock fragments of the older formations that show their distinct micritic and recrystallized components , and to a lesser extent as clear crystals or biogenic shell fragments. Evaporates range in abundance between 3-10% of the light fraction, they mainly composed of gypsum. The clay coated grains could be either intensely altered feldspar grains or clay mineral coatings that are very fragile and are easily abraded away during eolian transport which will result in decreasing the mean particle size of the sand grains. These minerals are shown in (Fig. 16).

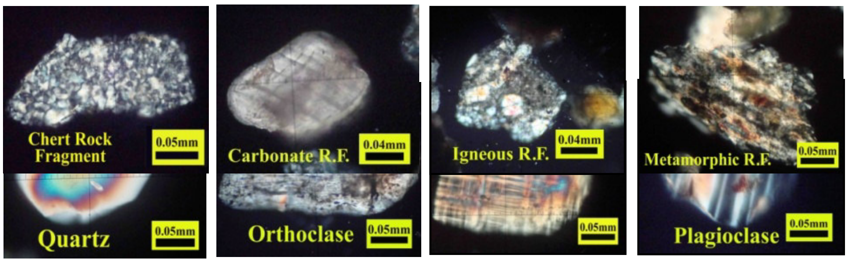

Figure 16. Images of the light minerals the in studied samples.

6-2 Heavy Minerals

The heavy mineral residue of the studied samples is composed of opaque minerals as a main component 46.17% and non-opaque minerals.The non-opaque mineral assemblage is mainly composed of chlorite 15.48%, mica (muscovite and biotite) 9.88%, epidote 8.42 %, garnet 6.76%, pyroxenes 4.79%, amphiboles 4.28%, zircon 2.73%, tourmaline 1.05%, and rutile 0.45% arranged in a decreasing order of their average content (Table-6). The minerals grains vary in shape from prismatic to spherical and are mainly subrounded to rounded (Fig. 17).

Table 6- Percentages and average content of the heavy minerals in the studied samples.

Heavy Minerals	Samples Number					Average %
	Q6	Q3	J2	K1	F2	
Opaques	48.02	45.61	42.17	47.29	47.74	46.17
Chlorite	15.13	15.80	15.38	14.88	16.21	15.48
Zircon	3.29	0.88	3.42	2.48	3.60	2.73
Garnet	7.90	7.02	5.98	6.61	6.31	6.76
Pyroxene	5.92	2.63	9.40	3.30	2.72	4.79
Amphibole	3.95	5.26	4.29	2.48	5.40	4.28
Tourmaline	-	0.88	2.56	-	1.80	1.05
Epidote	5.92	11.40	7.69	10.74	6.30	8.42
Rutile	1.32	-	-	-	0.91	0.45
Biotite	3,95	2.63	3.42	3.30	2.70	3.20
Muscovite	4.60	7.89	5.69	8.92	6.31	6.68

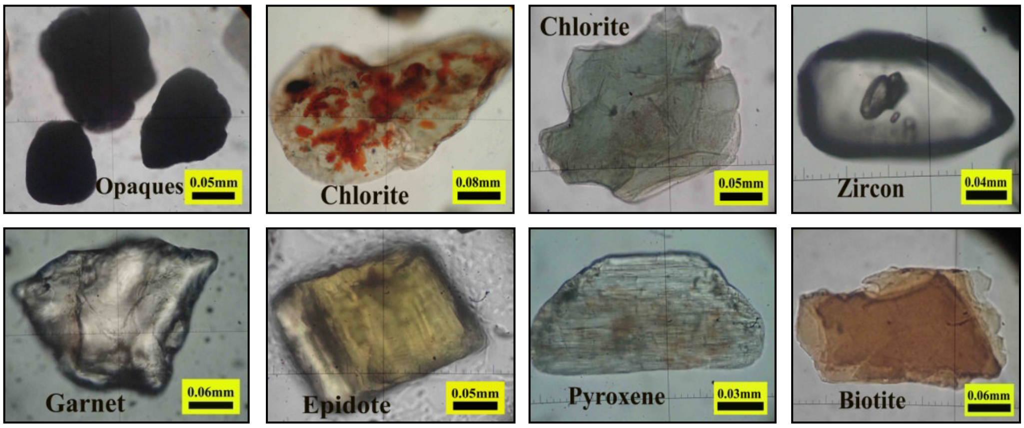

Figure 17. Images of the major heavy minerals in the sediments of Badra dunes.

7- Source of Sediments

Badra dune sands represent residues produced by the destruction of pre-existing rocks in which they are dispersed by both air and water until they came to rest as sediment. In such case, both direction and distance of transportation must be ascertained. The wind direction which is mostly northwesterly is highly acknowledged, as along this direction one of the major Iraqi dune belts lies (Fig.18), while the distance can be predicted from the percentages of both light and heavy mineral assemblages.

The light mineral assemblage of Badra area when compared with similar mineral assemblages of known active dune areas conforms greatly with assemblages of Baiji dunes (Al-Saddi, 1972) in the northwest, and East Maysan dunes (Al-Saddi, 1972) to the southeast (Table.7). The increase in quartz and feldspar percentages and decrease of rock fragments percentages of Badra and East Maysan areas with respect to those of Baiji is a direct evidence of the common source as the higher percentages of rock fragments which are mainly of igneous and metamorphic affinity reworked from Miocene – Pliocene sedimentary strata had been dispersed into quartz and feldspar.

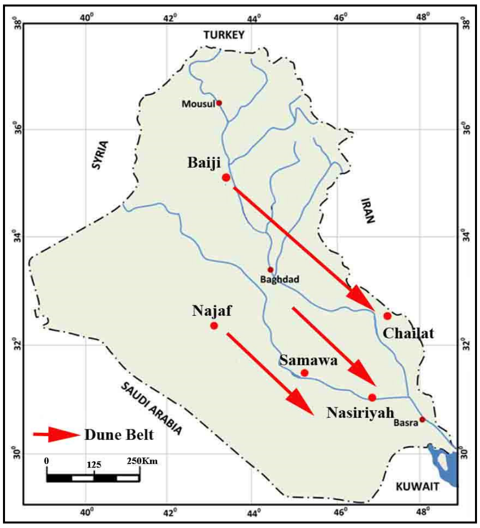

Figure 18. The three main sand dune belts in Iraq. The position of the studied area lies within the eastern belt.

Table 7- Comparison between the light mineral components within the active major dune belt.

Dunes Field	Quartz %	Feldspar %	Rock Fragments %	Carbonates %
Baiji	58.00	5.70	14.20	22.10
Badra	61.11	8.03	9.63	21.23
Chailat	62.80	12.50	5.10	19.50

Similarly, more direct evidence from the heavy mineral suit is apparent regarding the common source of Baiji, Badra and East Maysan dunes (Table.8). The heavy minerals of these areas are characterized by the predominance of the metastable minerals (epidotes, garnets, amphiboles, and pyroxenes), and their association within the active continental margin of the MF-MT-GM suits (Fig.19) of Nechoev and Isophording (1993). As a result, the common source can be predicted as being the eroded products of both the Zagros and Taurus highs in Northern Iraq.

Table 8 - Heavy mineral assemblages of Baiji, Badra and Chailat.

Dune Field	MF	GM	MT
Baiji	36.20	28.75	35.0
Badra	31.89	13.29	54.82
Chailat	35.10	19.95	44.95

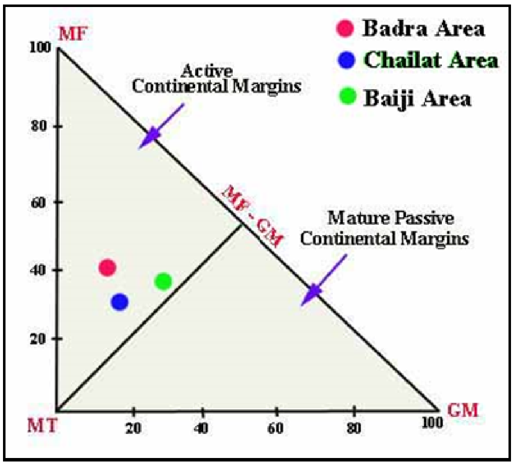

Figure 19 - Interrelationship of the MF-MT-GM suits of Badra sands Nechoev and Isophording (1993). Where by MF: Pyroxene, Amphibole, Olivine. GM: Zircon, Tourmaline, Staurolite, Kyanite, Andalusite, Monazite, Silimanite. MT: Epidote, Garnet.

8- Conclusion

From the morphometric parameters of the nabkha dunes, the mineralogical composition and textural characteristic, the dune sands indicate that the aeolian activity in Badra area is in its infantile dune stage (few years) as compared to the more developed Iraqi dune areas.

Badra area seems to represent midway station between the source area in Baiji dune fields and the chailat dune fields. Chailat is one of those areas when six decades ago it was a green zone with a good deal of tourism, however, it is now represent one of the great barchans and barchonoid dune fields. Such a drastic consequence is feared for Badra area as the prevalence of the present conditions within the area, and the continuous supply of sediments from the source area (Baiji) may transfer, on the long run, the nabkah dunes into barchans and barchanoids. Therefore, in order to avoid more worsening, it is vital to impose solutions within Badra area first, and then deal with the more complicated Baiji and Chailat situations.

References

1. Ahlbrandt, T.S. 1979. Textural parameters of eolian deposits. In E. Mckee (Ed.), AStudy of global sandseas (pp. 21-51) : Prof. Pap. US Geol. Surv., No. 1052.
2. Al-Saadi, S.N. 1971. The sedimentology, geomorphology, and origin of the Baiji dunefield. Unpublished M.Sc. thesis, University of Baghdad, Iraq. 110 p.
3. Aqrawi, A. , Domas, J., and Jassim, S.Z., 2006. Quaternary deposits. In S.Z. Jassim and J.C. Goff (Eds.) : Geology of Iraq . Dolin. 341p.
4. Bagnold, R.A, 1941. The physics of blown sand and desert dunes. Methuen, London,pp. 265.
5. Bagnold, R.A., 1973. The nature of saltation and "bed-load" transport in water. Proc. RSoc. London. Ser. A 332, 473-504.
6. Folk, R.L., 1974. Petrology of sedimentary rocks. Hemphill publishing Co., Austin ,TX, 182 pp.
7. Folk, R.L., and Ward, W.C., 1957. Brazos river bar: a study in the significance of grainsize parameters. J. Sediment. Petrol., 27, p. 3-26.
8. Glennie, K.W., 1987. Desert sedimentary environments, present and past- a summary. Sediment. Geol. 50, pp. 135-165.
9. Gunatilaka A., and Mwango S., 1987. Continental sabkha pans and associated nebkhas in southern Kuwait, Arabian Gulf. Geol. Soc. London, Special Pub., v. 35, pp. 187-203

10. Hails, J.R., and Hoyt, J.H. 1969. The significance and limitations of statistical parameters for distinguishing ancient and modern environments of lower Georgia coastal plain. Jour. Sediment. Petrol., vol. 39, no.2, pp. 559-580. Tulsa, USA.
11. Hassan, A.A., 2009. Sedimentology of eolian deposits northeast of Maysan Governorate, Iraq. Unpublished M.Sc. Thesis, University of Baghdad, 151 p.
12. Inman, D. L., 1952, Measures for describing the size distribution of sediments: Jour. Sed Petrol, V. 22, P. 125-145.
13. Khalaf, F.I., Misak, R., and Al- Dousari, A.M., 1995. Sedimentological and mophological characteristics of some nabkha deposits in the northern coastal plain of Kuwait Arabia. Jour. of Arid Environment, vol. 29, pp. 267-292.
14. Lancaster, N., 1986. Grain size characteristics of linear dunes in the southwestern Kalahari. Journ. Sediment. Petrol., vol. 56, pp. 395-499.
15. Lancaster, N., 1995 . The geomorphology of desert dunes. Routledge, London, 290 p.
16. Le Houerou, H.N., 1986. The desert and arid zones of Northern Africa. In : Evernari, M., NoyMeir, I., and Goodall, D.W. (Eds.). Ecosystems of the world 12B. Hot deserts And arid shrublands, B. pp. 101-147. Amsterdam; Elsevier, 451 p.
17. Martin, L.R., 2003. Recent sediments and grain size analysis . Gravel , vol. 1, pp. 90-105. Porto Alegre
18. Nechaev, V.P., and Isphording, W.C. (1993). Heavy mineral assemblages of continental margins as indicators of plate-tectonic environments. Jour. Sed. Petrol. v. 63 (6), pp. 1110-1117.
19. Nickling, W.G., and Wolfe, S.A. (1994). The morphology and origin of nabkhas, Region of Mopti, Mali, West Africa. Jour. Arid Environ. V. 28, pp. 13-30.
20. Saini, H.S., (2003). Sedimentological characters of the late Quaternary aeoliansediments of Haryana. Proc. Indian Nat. Sci. Acad. 69, A, no. 2, pp. 201-215.
21. Stewart, H. H., 1958, Sedimentary reflections of depositional environment in San Miguel Lagoon; Baja California, Mexico: AAPG. Bull. V. 42, P. 2567- 2618.