

## **Study of nature, origin, movement and extension of sand dunes by using sedimentological aspects and remote sensing techniques in Baiji area, North Iraq**

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### **Abstract**

The sand dunes in Baiji area causing many problems, such as accumulation of the moved sand on the railway, roads, sand and dust storms which affect and causes pollution for civil constructions and industries in the area, as well as, increasing desertification. This study aims to explain the morphology, origin, grain size and movement of the sand dunes in Baiji area. The study including detail field study of the sand dunes and investigation of the future effect of extension and increasing the desertification in the area within time. Using of remote sensing and geographical information system in the study of desertification by Multitemporal data which including (maps and Landsat Thematic Mapper (TM) images) provided best understanding of the distribution of sand dunes and other aeolian features in the area of study.

### **Introduction**

Baiji city is located south of Makhul mountain and west of Tigris River and bordered by wadi Tharthar on the west (Fig.1). The sand dunes in Baiji area covered about (220) Km<sup>2</sup> to the north and west, and extended to the south of the city.

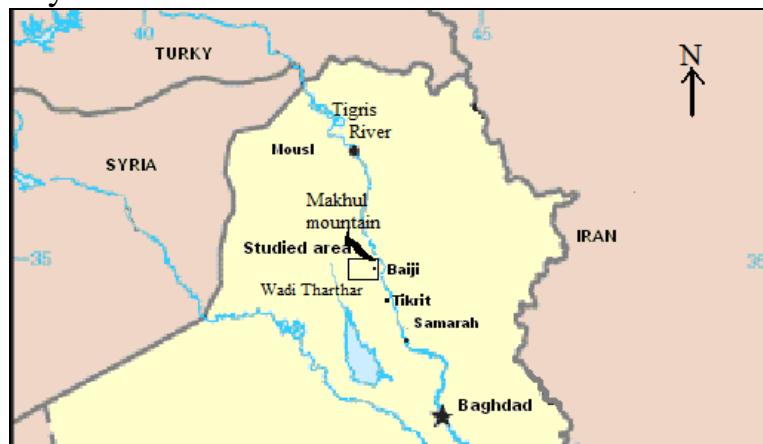


Fig.1: Location map of the studied area.

Most of the sand derived from the older formations such as Injana Formation (mainly contained from Sandstone) and Quaternary fans and terraces (mainly composed from fluvial, alluvial, sandy gravel deposits) Desertification considered on main factors in destruction of agriculture area and desertification was defined by (U.N.of Environment,1992) as a soil degradation in continuous processes caused by climatologically and human being activities(Walker,2007) .Sand movement by wind is a complex process involving several styles of grain movement that occur more or less simultaneously (Bagnold,1941 in Walker,2007).The process of movement of sand is saltation, (Fig.2), surface creep is the jerky forward movement of larger grains that are too heavy to be lifted by the wind, but are jolted forward when struck by smaller flying grains and then the third manner in which smaller sizes of sand moves is by suspension.Suspended grains are so smaller that they are carried for which are thrown in to the air for long distance.One of the reasons dune sand is so well sorted is the narrow size range(2-3Φ)of sand that wind can move under most conditions. (Bill&Phillips,2007).

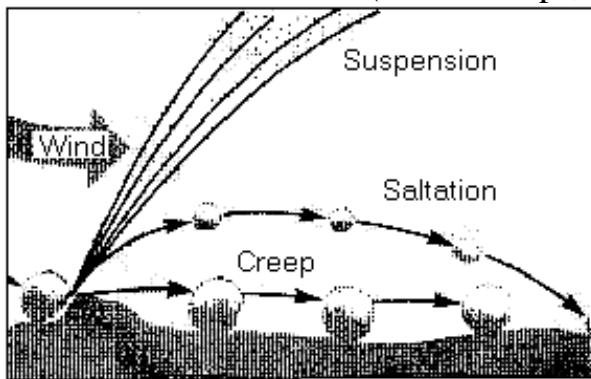


Fig.2: Types of sand movements.

crumble Previous studies threw lights on general aspect of the nature, origin and morphology of some of the sand dune areas.Parsons Company (1955) studied ground water condition of the sand dunes area and gave investigation and general ideas about the sand dunes in the area with limited geological information on Baiji sand dunes. (Al-Saadi, 1972) studied the morphology of Baiji sand dunes including their distribution and orientation. (Aqrabi, et. al., 2006) mentioned the presence of sand dunes as sheet of sand of Pleistocene and recent ages in the area of Baiji as a part of Mesopotamian plain.The study aims to: Field study of the sand dunes in the area including determination of the sand dunes type and sampling from the wind side, lee side and sand sheets which where identified and study of grain size, mineralogy and origin of sand dunes. By using multitemporal

data (Landsat TM images and topographic maps) sand dunes extension and distribution were indicated.

### **Materials and Methods:**

The field work included measurement of the height, orientation, the wind side, leeside slopes and sand sheets of the dunes to indicate their type and extension. Samples from(15)sites represent wind side lee side and sand sheets were collected for grain size analyses and mineralogical studies. Topographical maps dated(1985)and Landsat satellite images of 2005 and 2007 were used to draw the new sand dune area with different terrain types which used for indicating the sand dune extension and recent covered area.

### **Geology of the area:**

The exposed rocks in the area ranging in age from Miocene to Pleistocene. These rocks are overlain unconformably by Quaternary deposits. The exposed sedimentary sequence (from older to younger) is :

- 1- Fatha Formation: it is composed of cyclic alternation of calcareous claystone (marl), limestone and gypsum and exposed at Makhul anticline north Baiji.
- 2- Injana Formation: it is overlying Fatha Formation by a conformable contact. This formation is composed of alternation of reddish brown, calcarea, claystones, siltstones and sandstones and exposed around Makhul anticline.
- 3- Mukdadiyah Formation: (Pliocene) The formation consists of silty and sandy claystones alternating with sandstones.
- 4- Quaternary deposits: Pleistocene-Recent it is composed of intermixed sand, clay, gravel and silt. Quaternary deposits usually form discontinuous cover of variable kinds and thicknesses unconformable over lain the pre-quaternary sediments. River terraces, flood plain deposits, slope sediments, valley fillings, gypseous soil and gypseous are the main types of Quaternary deposits in the area.

### **Climatology of the studied area:**

Meigs,(1952,1953 in Walker, 2007) remapped areas based on better climatic data and Iraq is located within arid to semiarid region located Iraq as arid to semi-arid regions by using an aridity index was used in combination with information from soils and vegetation for the classification. (Walker,2007).Climatic elements are, rainfall, temperature ,

relative humidity which mentioned in this study. wind is an effective geomorphic agent. The mean annual wind direction at Baiji from the available records for the period (1938-2000) indicate that the mean annual wind direction at Baiji is north westerly and wind velocity is greater during the day than at night and greater in the summer than in winter with the velocity of (2.5-4.5) m/sec which is suitable to form sand dunes from climatic element. Baiji recognized as rainless, hot to very hot in summer and rainy winter, with annual rainfall between (190-200)mm and the minimum temperature in January (8-9) C°. with maximum temperature reaches in July (more than 44C°).According to the application of Thorenthwait and Penman traditional methods by (Al-kaisy, 1992), the climatic of the Baiji area was identified as a semi –arid region (Fig.3).

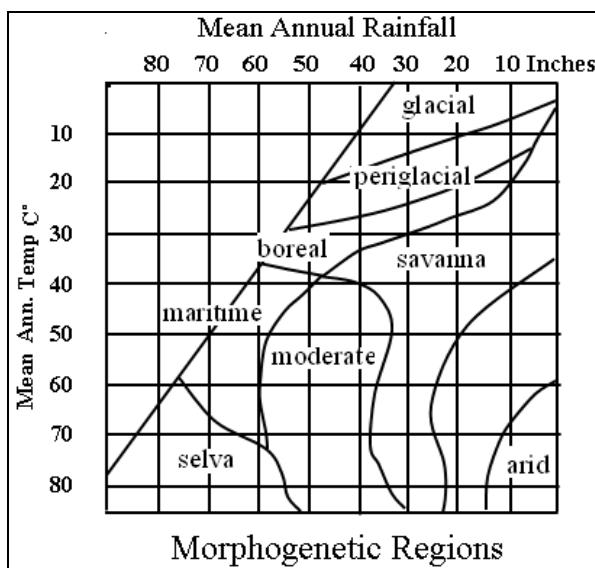


Fig.3:Diagram showing Peltier's attempt relate dominant processed to mean annual rain and temperature and define morphogenetic regions (modified after Peltier,1950).

The lowest value of relative humidity in Baiji area reaches in July a bout 24% while the highest value is a bout 75% in December (AL-Kaisy, 1992).

### **Geology of the area:**

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### **Sand dunes**

From the field studies the effect sand dune belt extend NE-SW and covered large area extend for more than 30 km in length with different morphologies and types:

- 1- The Barchan belt lies to north-west and south-west of Baiji city and around Halwatti village with height (1.5–2)m and mostly of different size between (300-450) m of each.
- 2- Transverse belt of dunes to the north west of Baiji. it is believed that they were deposited during the change of wind direction of Sief type with elevation about 2m.
- 3- Sand sheet between the above type with different wide and elevation less than 1m.

### **Grain size analysis**

Fifteen samples have been collected from the sand dunes, wind side, lee side and the sand sediment sheets between the dunes in the area of study. Cumulative percentages were drawn versus phi diameters on a logarithmic-probability papers. Most of the samples were loose and dry and about 100 gm. were sieved with mesh 1000, 500, 250,125 and 63 micron. Each fraction was weight and the weights percentages were calculated (Lindholm,1987) .Inman parameters including Median (Md  $\Phi$ ) mean size

(Mz  $\Phi$ ), sorting ( $\sigma \Phi$ ) and skewness (Sk) were calculated and listed below (Folk, 1980)(Table -1-), according to the following formula:

$$\begin{aligned}
 M_d\Phi &= 50\Phi, MZ\Phi = \frac{\Phi 16 + \Phi 50 + \Phi 84}{3} \\
 \sigma\Phi &= \frac{\Phi 84 - \Phi 16}{4} + \frac{\Phi 95 - \Phi 5}{6.6} \\
 Sk &= \frac{\Phi 16 + \Phi 84 - 2\Phi 50}{2(\Phi 95 - \Phi 5)} + \frac{\Phi 5 + \Phi 95 - 2\Phi 50}{2(\Phi 84 - \Phi 16)}
 \end{aligned}$$

The cumulative curves for the wind side and sand sheets shows similarity in the shape of curves which reflect similarity in the source and mechanism of sand transportation (Fig.4 a, b, c). Most of the curves are comparatively steep as a result of selective sorting of wind. About 95% of the sand dunes are of fine sand size (Table.1) (Lindholm, 1987). The sorting( $\Phi$ ) of the studied samples range from (0.37 to 0.95) and mostly of well sorted to moderately sorted in wind side and in sheet sand samples which moderately sorted in lee side of the dunes. The Skewness of the Baiji sand dunes are mostly positive (85%) and near symmetrical (15%) and that may due to the unimodality of the sand dune nature.

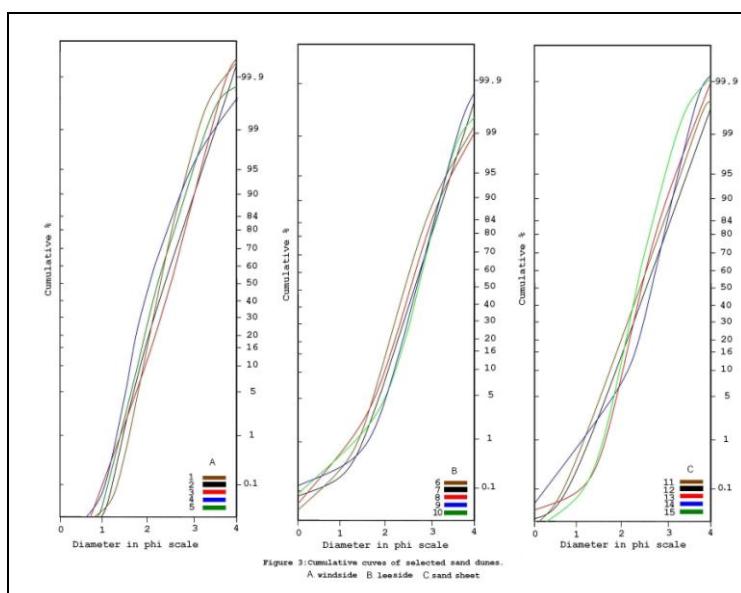


Fig.4: Cumulative curves of the grain size analyzed samples,  
A wind side dune, B Lee side dune and C Sheet sand.

Table 1: Statistical grain size parameters of the studied samples.

Sample No.	Location	Mz( $\Phi$ )	Md( $\Phi$ )	$\delta$ ( $\Phi$ )	Sk
1	Wind side	2.40	2.35	0.75	0.09
2	=	2.38	2.48	0.44	0.02
3	=	1.98	2.65	0.42	0.08
4	=	2.24	2.80	0.37	0.12
5	=	2.30	2.60	0.87	0.02
6	Lee side	2.95	3.00	0.90	0.32
7	=	3.05	2.95	0.73	0.15
8	=	2.85	2.75	0.47	0.04
9	=	3.10	2.97	0.55	0.08
10	=	2.96	3.05	0.40	0.10
11	Sand sheet	2.55	2.75	0.37	0.18
12	=	2.40	3.05	0.44	0.15
13	=	2.65	2.55	0.95	0.02
14	=	2.35	2.80	0.50	0.03
15	=	2.70	2.95	0.52	0.11

### **Roundness and Mineralogy of sand**

According to Krumbien's chart (1941) in Lindholm,(1987) each grain is given a roundness number calculated by Wadell's method. The different grades of the examined samples shows that the average roundness of Baiji dune sand is moderate with increase in roundness in the fine grades. Mineralogically, three samples have been examined and it is found that quartz form average of 65% of the light minerals, carbonates and gypsum particles 18%, feldspar and rock fragments 12% with other particles about 3%. Heavy mineral fraction from five samples of fine to very fine sand have been separated by using bromoform liquid (Lindholm,1987) and examined under microscope and it was found that opaque minerals form 85%. The non-opaque minerals includes; epidotes, zircon, tourmaline, garnet are identified.

### **Remote Sensing Study**

Modern technology by remote sensing systems is proving to be helpful in the effort to understand landforms especially arid lands. Landsat satellites provide excellent data with which to monitor temporal variations in a given area. This study carried out by using Landsat Thematic Mapper (TM) true colour image dated 2005 and 2007 and compare it with topographic maps of scale (1/100000) and (1/25000) dated (1985) as well

as geological maps. The study included field work to identify the kind and source of the sand dunes and sand movement as well as collect samples for grain size. The studied area is south the Mukhul mountain which is within the unfolded zone. The area is semi-desert plain. Its elevation range between (150-450m). and classified as a foothill unit (Hussain , 2007) covered with sand sheets and sand dunes. Sandy storms are very common in the area. During the last years many problems were developed by increasing creep of sand dunes to the industrial and establishments, roads and railway as well as decreasing in the size of agricultural area. The moved sand dune field in the area is located western and southern of Makhul mountain within the NW-SE belt of sand dune area in Iraq. Being one of the inhabitants in the study area and observing the sand storms almost most of the each year( even in winter) and initial observation of topographic map of Baiji area in 1985, showed significant active dune field. The dune field is determined at(1985) as Fig.5 which shows the effect of the moved dunes on the main roads, oil-gas pipe lines and railways. By using ArcView GIS 3.3 for computing the area of sand dunes and its effect it is found that the area of moved sand dunes is about 129 Km<sup>2</sup> , the length of the roads affected by sand movement is 23.419 Km , the length of the railways affected is about 16.380 Km , the length of the oil-gas pipes affected is a bout 24.177 Km and the length of indirect effect of sand dunes on roads is about 23.335 Km. In addition to the above the sand storms affect the civil constructions and industries in Baiji area and around areas . Baiji sand field has a similarity in process and producing a dune. Number of dune types which is common to Aeolian areas around the world. The Landsat (TM) images used in this study were geometrical corrected as well as corrected from atmospheric scattering. Images of (6) bands were used and visually analyzed, images of band 1, band 4 and band 7 were chosen as the optimum bands for (R G B) presentation in addition to color composite images were formed to gain maximum information for landform discrimination. A false color composite of (7 4 1) of (R G B) Landsat TM images was chosen for discrimination of study area.

Visual analysis depending on the main elements of interpretation (Tone, colur, size, texture...) (Zuidam & zuidam, 1979 and Sabins, 1989) and low pass filters were applied to the TM images the following terrain types were recognized:

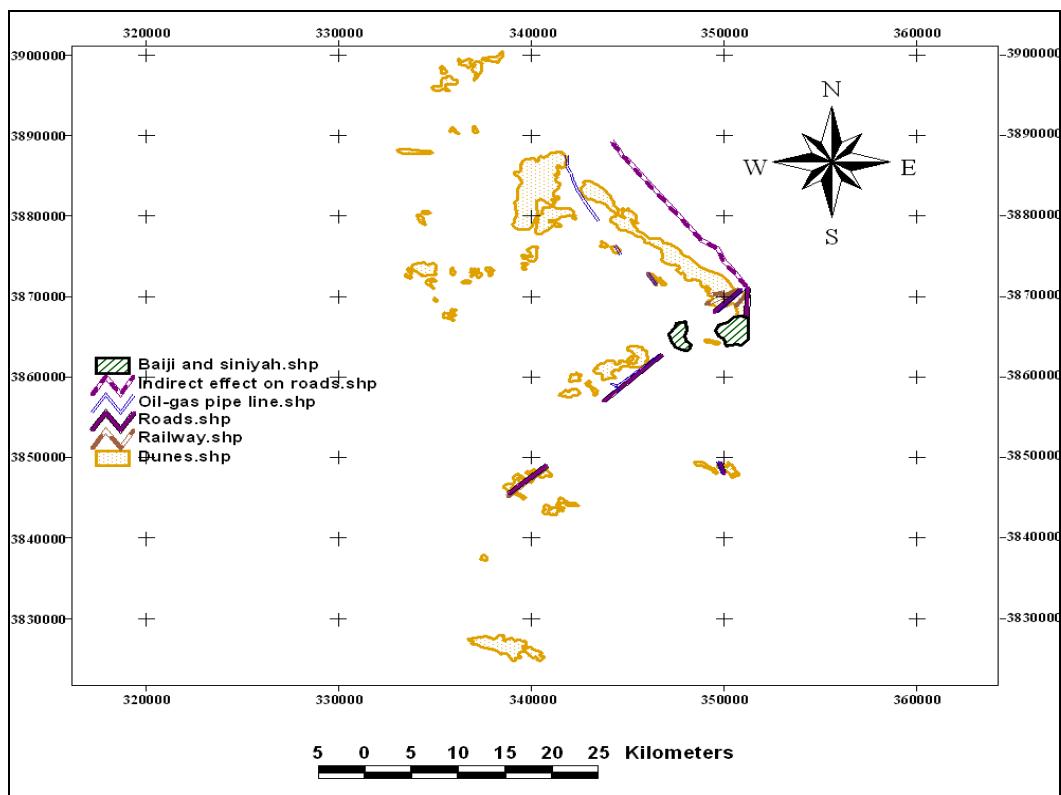


Fig.5: showing the sand dune fields distribution from the special use airspace the topographic map (1985), the thickness of dunes ranged between 2-4m.

1. The sand dune field which includes Barchan and Transverse dune.
2. Sand sheets which are wide spread horizontally deposits found at the margins of sand dune fields. Sand sheets commonly have much more coarse grained material than dunes or even interdunes , also ripple marks identified which indicates the main wind direction as shown in Fig.6.
3. Sabkha deposits are common in very low relief topography area within eolian regions containing gypsous soil and eolian sabkha deposits form when dry sand is blown across damp surfaces near water table (S.G. Fryberger, 2007). Eolian sabkhas consist of flat-lying sediments, commonly very influenced by evaporative processes that have been brought to the site of deposition by wind. Eolian sabkhas are common within the basins and some open flat areas on(the middle) of the study area as shown in Fig.7.

By using true colour Landsat ( TM ) image of 2005 and 2007 a new sand dune field is drawn with indication of different terrain types mentioned above as shown in (Fig.8 map drawn from image) and Fig.9 shows typical relationships of four types of Aeolian terrain modified after (Fryberger, 2007) .



Fig.6: Shows Recent ripple marks sedimentary structure in sand dunes which cover the paved roads.

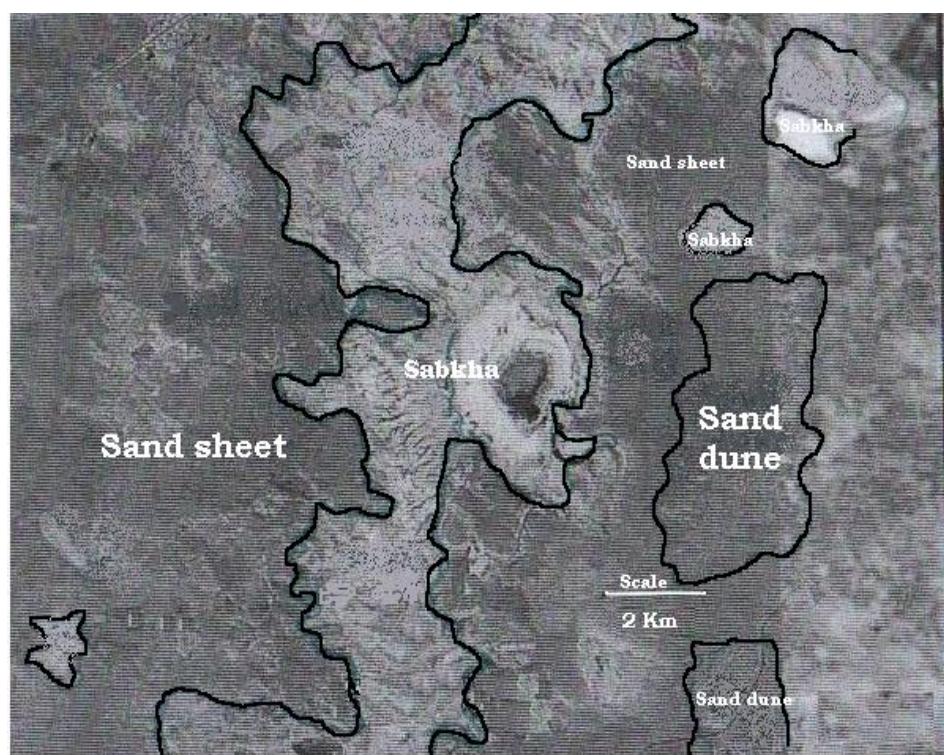


Fig.7: Shows a Landsat TM true color image dated (2005) of Sabkhas which seen in the light areas.

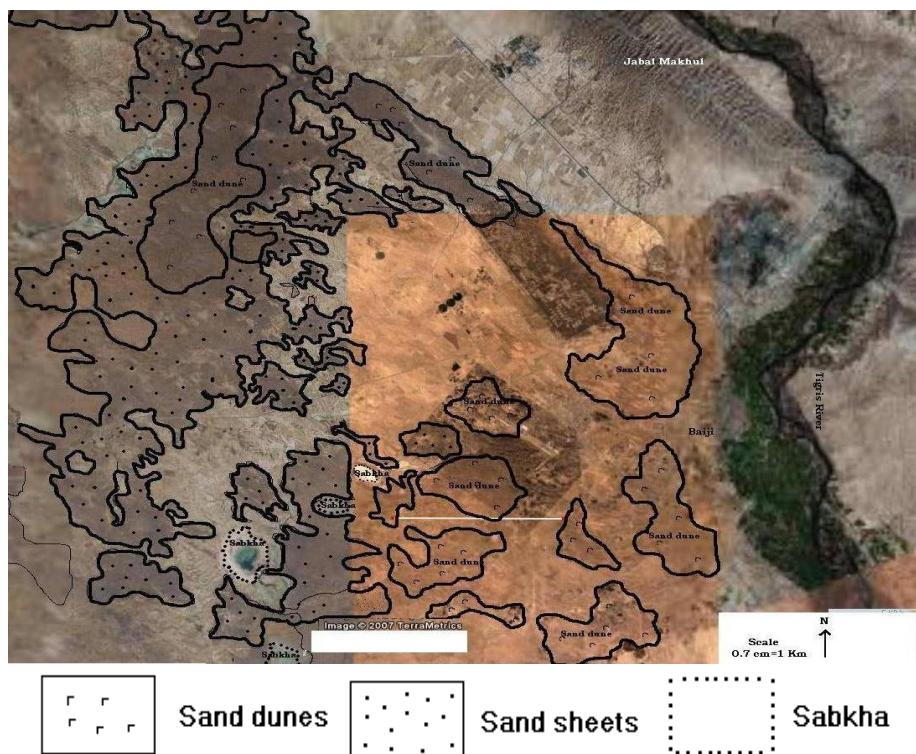


Fig.8: Map showing the distribution of the fixed and moved sand dune fields with sand sheets around Baiji city from interpretation of the Landsat TM true colour image 2007.

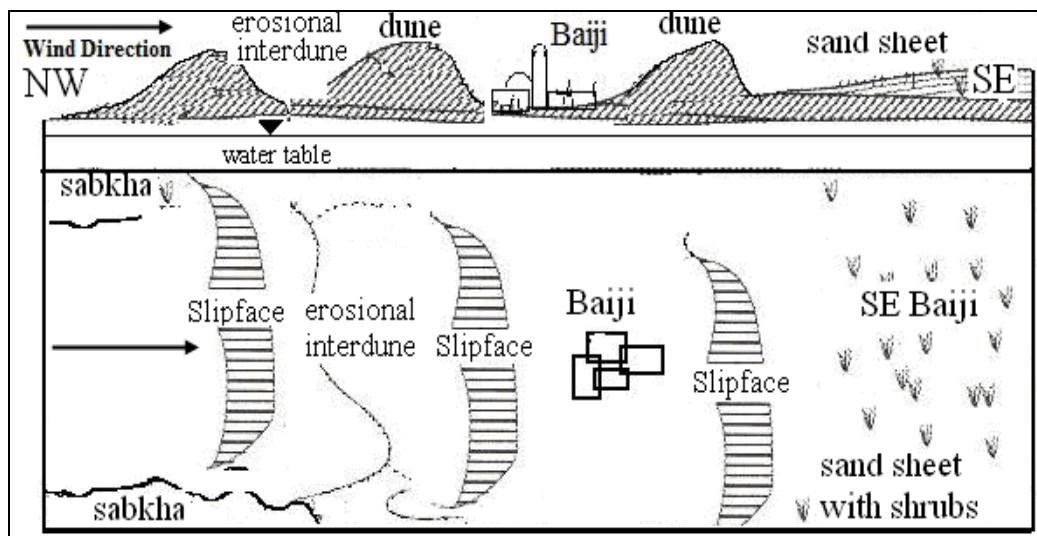


Fig.9: Schematic drawing showing relationships between sabkhas, dunes, and sand sheets with the wind direction from NW to SE of Baiji, (modified after Fryberger, 2007).

## **Dune growth and movement**

Dune growth and movement is a result of sand flow on and around a dune during periods when the wind is strong enough to move sand, for dry sand this threshold is about 15 m/h, (Fryberger, 2007).Dunes are constantly changing shape in response to changes in wind velocity and direction. Dunes grow when more sand drifts on to them from surrounding areas than is removed down-wind as those occurring in Baiji area. During storms sand flows over all parts of the dune. Sand that flows over the center parts of the dune settles on the upper part of the slip surface as grain fall deposits formed by setting in the lee of the dune. When the sand accumulates to certain thickness, it becomes unstable and slides down the slip surface. This process, known as avalanching is the basic mechanism of forward advance of most of the bed forms at the movement. The sand dunes in Baiji area under study are almost formed, growth and have movement under the same condition mentioned above as indicated by morphological, mechanical and mineralogical studies. The movement and growth of the dunes identified by comparison between the two figures(5 and 8) which represent the sand dunes in 1985 and 2007 respectively showing that the sand dunes area extend toward east and south east directions.

## **Conclusions**

From the present study of the sand dunes it is concluded changes in sand dunes areas due to the following reasons:

1. From the comparison between the Landsat image (2007) and the topographic maps ,it found that the sand dunes in Baiji area increased during the last two decades years because of arid condition and heavy uses of earth for agriculture.
2. The active belt of sand dunes located in the North West and west of Baiji with different morphological types such Burchan, Transverse, Sief and isolated dunes.
3. From the grain size analysis and mineralogical study most of the size are of medium to fine grade with different mineralogical composition.
4. From visual analysis and manipulations of various images with different scales concluded that the desertification and the area of sand dunes increased during the last few years.

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## دراسة طبيعة، أصل، حركة وامتدادات الكثبان الرملية باستخدام الدراسات الرسوبية وتطبيقات الاستشعار عن بعد في منطقة بيجي/شمال العراق

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### الخلاصة

الكثبان الرملية في منطقة بيجي تسبب عدد من المشاكل كتجمع الكثبان على مسارات السكك الحديدية والطرق وكذلك تأثير العواصف الرملية على المنشآت المدنية والمجمعات الصناعية إضافة إلى زيادة رقعة التصحر في المنطقة. تضمنت الدراسة الحالية توضيح أشكال وأصل هذه الكثبان إضافة إلى طبيعة وحجم الحبيبات الرملية ومسارات حركتها بواسطة الدراسة الحقلية والمخترية المفصلة. كذلك تم استخدام تقنيات الاستشعار عن بعد في دراسة التأثيرات والامتدادات لهذه الكثبان وتحديد المساحات المتأثرة وكثافات الرمال المتحركة باستخدام الخرائط والمرئيات الفضائية.