Journal of the Earth and Space Physics, Vol. 45, No. 4, Winter 2020, P. 203-217

DOI: 10.22059/jesphys.2019.266504.1007044

Reconstructing the Environmental Changes in the Western Border of Lut Plain Based on the Study of Nebkhas

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(Received: 2 Oct 2018, Accepted: 1 Jan 2019)

Abstract

In the old Lut playa underneath the hills of nebkhas, the deepening of the waterways and the extent of the expansion of the cones and the nebkha morphometry are evidences of environmental changes. To study the above-mentioned factors, it is necessary to rebuild the morphodynamic conditions of the region. In this research, the changes in environmental conditions of the area are investigated and rebuilt using the phytogenic hills of nebkha. Sampling was done by carving a surface on the sediments of nebkhas and specifying their layers. The sampled sediments were then studied in a geochemical lab and their age was estimated in a lab in Poznan in Poland, where they were sent. The results show that the region in a period of 735 years of the life of the Nebkhas has gone through several levels of environmental changes. The most intense processes and the wettest period among the studied periods belong to the third period about 735 years ago. These results were gathered by geochemical experiments such as the amount of organic matter, salt and lime on the layers of the sediments. The driest period among the periods studied is the 11th period, which took place around 114 years ago. The least intense processes with the lowest amount of humidity (according to the results related to the amount of organic matter in the sediments) were in this period.

Keywords: Morphodynamic, Environmental changes, Plain of Lut, Nebkhas.

1. Introduction

Vegetation plays an important role in determination of the dynamic and morphology of sand hills in desert areas. It affects the movement and trapping of the sand that is carried by the wind. Wind erosion is dependent on many factors such as the kind of wind, topography, the length of fetch, the texture of the surface sediments, and the dryness of the region (Deotare et al., 2004; Barzani and Khairulmaini, 2013). The interaction between the wind, the movement of wind sediments, the morphology of the sediment location and the formation of sand hills makes wind landforms, which clarify the environmental conditions of that area and the processes that affect it on spatial and temporal scales. For example, the form and size of sand hills in an area defines the climatic and topographic conditions of that area in different periods with different amounts (from some decimeter to some kilometer.) At the moment, 36 percent of the land of the earth is covered by dry and semi-dry areas, of which 19 percent is completely dry and lacks any vegetal life. It is estimated that each year 500 tons of dust is produced and scattered in the air due to soil erosion (Motamed, 1990). It must be added that 17 percent of the world population live in these areas (Marwati Sharif Abad, 2001); therefore, the wind erosion is a serious issue in all continents. Iran is not an exception as two third of the country is in dry regions (Maghsoudi, 2006). The dryness of a great part of Iran along with precipitation less than 150 mm in a year, has transformed about 80 million acres of the country to desert areas, sand hills and areas with little vegetation (Rafahi, 2004). Different forms of sand hills, which are formed when sand is collected somewhere in specific conditions, are found in desert systems. Nebkha hills are the most common and the most prominent type of sand hills (Sauermann et al, 2003, 2001; Tsoar, 2005). They are common in areas where there is wind erosion and some vegetation. Nebkhas formation is dependent on the wind in the region, the amount of

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sediment available, vegetation habitat and vegetation species (Tsoar and Moller, 1986; Wiggs et al., 1995; Wolfe and Nikelson, 1993). Sand is trapped at the bottom of the tree and after some time, with all the sand collected there, a nebkha is formed. Nebkhas are normally formed on flat surfaces where the amount of the sand is moderate and the level of underground water is high or there is enough humidity for the vegetal life (Musick and Gillette, 1996; Bourke et al., 2009). The components of nebkhas are sand, clay and silt. The vegetation species, its height and surface affect the shape of the nebkha. The height of a nebkha can be from some decimeter to some meters and its length can be from one meter to a few meters. A sole tree or bush must be at least ten to fifteen centimeter to trap the sand. If the sand grains lack clay and silt, they are not sticky enough and the size and the volume of the hills change with the wind. With the increase of sediment around nebkhas, the plant continues to grow to resist being buried. This growth is until the plant roots reach the underground water. If the level of underground water decreases, this connection is disturbed and the destruction of the nebkha, which leads to the beginning of its death.

This problem concerns the two sciences of ecology and geomorphology (vegetation + sand hills) and it always occupies the efforts of scientists of these two fields. Nebkhas stabilize moving dunes in desert and semi desert regions and protect human settlements and installations such as roads, rails, power lines, etc. from sand storms. In addition, nebkhas are among beautiful scenes in the desert that attract a lot of scientists and tourists. The region chosen for this study is Takab plain located 18 kilometers east of Shahdad in Kerman province and is in the west of Lut desert. Since the region studied in this paper is located in the west of one of the driest and hottest deserts in the world, it has some natural features discussed first generally, and then in detail according to these factors, the problem of the research will be addressed. Although the study area has dry climatic conditions, the density and diversity of its vegetation is significant. Diversity in vegetation density and variety has caused the region nebkhas to vary greatly in terms of hill height, skirt length, slope, nebkha width, nebkha area, and the species of the vegetation on top of the nebkhas (Fig. 1).

Figure 1. A typical nebkha in the case study area (Takab Lut Desert).

Examining the various characteristics of the layers can provide very useful information about the changes in the climate and environmental conditions of the region. Determining the age of the nebkha, along with the study of layering, helps determine when these changes of the environmental characteristics have taken place and also the use of the tree ring method to determine age that can help reconstruct a part of the past climatic characteristics of the region. Various researches have been conducted in different countries regarding the use of nebkhas to study environmental changes. Among them, Christopher et al. (2009), in a research studied the nebkhas of four regions, including desert and coastal regions. They used optical luminescence stimulation of organic matter in their sediments, and determined that the hills are 700 to 2400 years old and acknowledged that the nebkhas evidence Holocene recent droughts in the former southern and central forest areas of the United States. Wang et al. (2010) determined three environmental changes in the last 500 years using sedimentary changes by studying Tamarisk nebkhas and sampling the sediments and determining their age. They introduced nebkha formation as an important indicator of environmental changes since a few hundred years ago. Tengberg (1998) in a study compared the morphology and age of the nebkhas in Tunisia and Burkina Faso. After examining the morphology of the nebkhas, and determining the age of the nebkhas using carbon-14, obtained the results that indicate that the higher and the older the nebkhas, the more stable they are in the region. Lang et al. (2013) examined the changes in environmental conditions using the nebkha layers in China, and they looked at the environmental conditions of the past 500 years and identified the fluctuations and changes that occurred in the environmental conditions of the area according to their time of occurrence. In Iran, not many studies have been carried out on nebkhas, and a few researches done are simply related to their description and, in some cases, to their morphology. Mahmoudi (1977) was the premier in nebkha studies in Iran. In this work he describes the formation and evolution of nebkhas and their destruction. He also classified nebkhas according to their morphological characteristics. Although this article was descriptive, it was very important because it was the first systematic study in Iran on nebkhas. Pourkhosravani et al. (2010) have investigated and compared grouping of Sydlitziya Florida, Reaumuria Turkestanica and Alhagi Mannifera based on the vegetative forms of plants in the region of Kheirabad, Sirjan, and concluded that nebkha volume is influenced by the vegetative form and the volume of its constituent species. Vali and Pourkhosravani (2009) in a comparative analytic research studied the relationships between nebkha morphometric components and herb morphology of several plant species in Kheirabad, Sirjan and concluded that for the formation and evolution of nebkha, vegetative forms of plants are effective. In addition, Pourkhosrowani et al. (2009) in another study investigated the relationship between plant morphology and morphometric characteristics of nebkha species of Reaumuria Turkestanica. It was concluded that there was a significant correlation between nebkha height and diameter at the probability level less than 1% with a 49% explanation for the linear relationship and grade 2 and 50% for grade 3 relationship. Maghsoudi et al. (2013) investigated the morphology of nebkhas in a part of Takab plain and identified the most important factor in the development and evolution of the region's nebkhas was vegetation. He then compared the effects of the different types of vegetation on the morphology of the nebkhas. In this study, the changes in environmental conditions of this area were investigated and rebuilt using the phytogenic hills of nebkha. Sampling was done by making a surface on the sediments of nebkhas and specifying their layers.

The study area is located in the eastern part of Kerman province and in the west of the Lut plain, with an area of 180 square kilometers (18,000 acres). This area is located in Takab district of Kerman, 15 km east of Shahdad and adjacent to the villages of Hojjat Abad and Islamabad. The northern boundary of the study area is limited by the river Dahneh Ghar and Hajard which is located on its southern border. Shahdad is located on its western border and its eastern border is limited by the Kalutah (Fig. 2). The studied area is naturally diverse with unique characteristics as hot and cold climates, very rich geomorphology (so that at a distance of less than 40 km, areas such as mountains (Sirch mountains), conifers, alluvial plains, sand dunes, and finally the Kalut can be seen) and sparse but diverse vegetation (due to the fact that the area has a dry climate, but its vegetation is unique in its kind) that can be very much taken into consideration. These natural features have caused enormous variation in the regions in terms of various physical and biological processes. Nebkha layering is a reflection of the past conditions of the environment in the region.

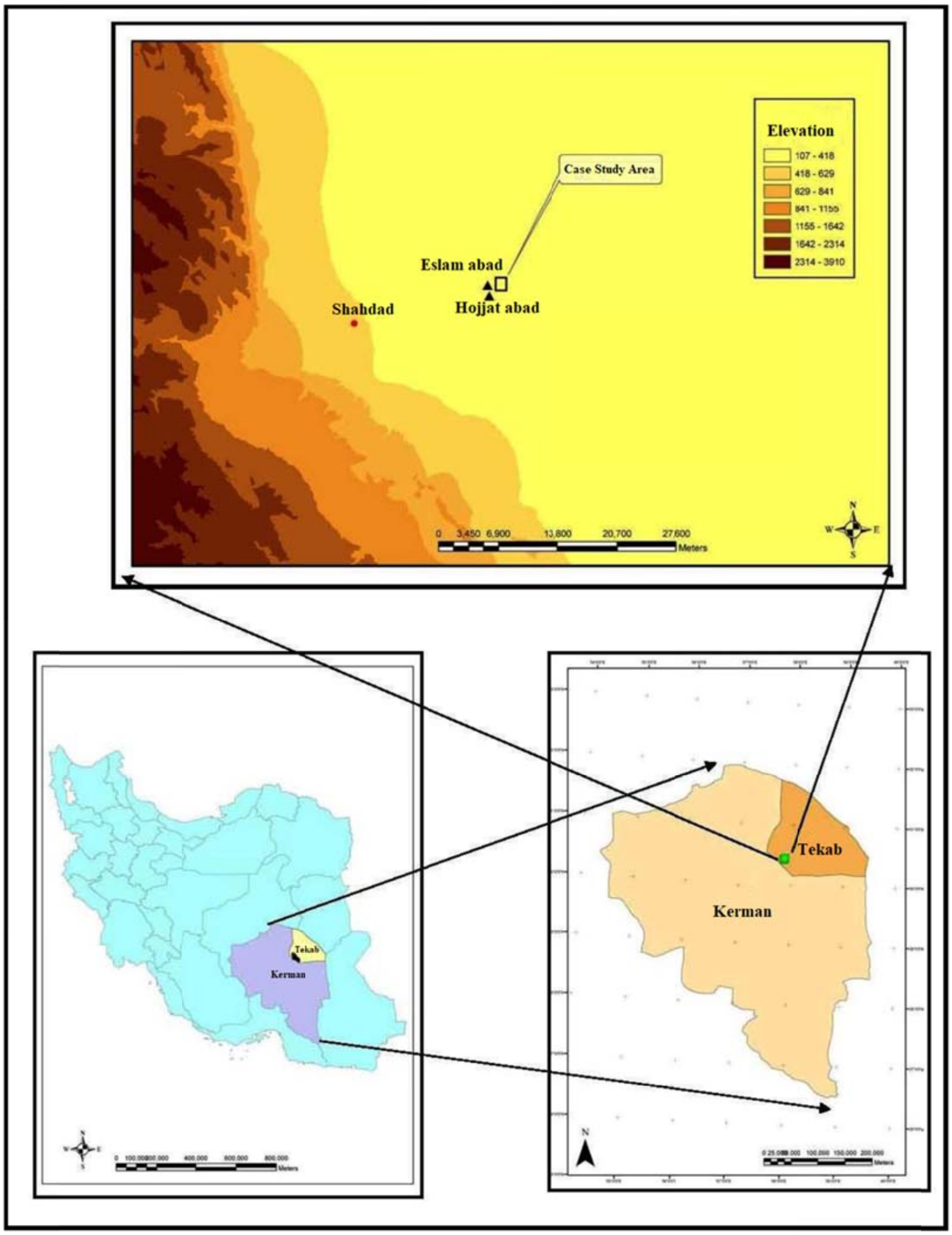

Figure 2. Satellite image and map of the location of the studied area.

2. Materials and methods

In order to investigate the changes in these environmental conditions, the evidences present in the region are used. One of the methods for assessing the environmental conditions is to use the evidences in the layers of the sediments of the nebkhas. In order to do this, first, several profile cuts were created and sediments were removed from different layers regularly. The deposits of sediments should be done so carefully that the layers are not mixed together. Therefore, the deposits of each layer were taken and coded (to determine the order of the layers) on every spot. After removing the sediment, the samples were transferred to the lab, and the evidence in the layers was examined with great accuracy and they were compared with each other. Given the work done, including work of Wang et al. (2010), evidence may include the presence of more organic material (tree leaves) in one layer than other layers, or the presence of coarse-grained sediments in a layer or thicker sediment etc. According to these evidences, changes in the environmental and climatic conditions in the region were identified. In order to investigate the changes in climatic characteristics and the age of the nebkhas of the region, the carbon-years 14 method has been used in recent years. In this method, the materials taken from the nebkha layering were used to determine the age. In general, the stages of the sampling work and choosing nebkhas is as follows:

a. The studied nebkhas belong to Imperial Tamarisk group. In general, the selection of the nebkhas under study was based on a variety of parameters that are referred to below. In the study area, nebkhas had certain stability, so that in a wide range, similar nebkhas were numerous, all of them had the typical and special form of nebkhas, among which the nebkha of the study was chosen.

b. Selected nebkhas had a more specific layer layout than others. This facilitated the work to a great extent. The studied nebkha is located in the longitude of 56 degrees and 53 minutes and 17 seconds east and the latitude of 30 degrees and 26 minutes and 51 seconds north and it is 293 meter above the sea level. This nebkha is located three kilometers east of Hojatabad village. Considering that the direction of most winds are northerly and northwesterly, for the sake of more precision, sampling was done from the eastern side of nebkha.

2-1. Stages of the study

- Choosing a nebkha with appropriate layers and height (not all nebkhas are layered; among nebkhas, normally those with the height of more than 3 meters have appropriate layers (Fig. 2)
- Creating a profile cut on the nebkha and specifying the boundaries of their layers (Fig. 2)
- Taking the sediment sample from each layer in a way that the sediments do not mix with each other (Fig. 2).
- Placing sediments in special bags and transferring them to the laboratory.
- Preparation of sediment for grading (here the sediments are pounded so that the pieces that are stuck together separate.).
- Putting the sediments in the shaker and measuring the grains.
- Entering the grain size results in special forms and preparing them for analysis.
- In the next step, the layers of sediment are transferred to another laboratory to determine the amount of organic matter, lime, salt (EC) and PH (it should be noted that among the layers taken, seven layers were taken for the above-mentioned tests).
- To determine the age, a part of the sediments of the two layers of 4 and 11 were sent to the Radiocarbon Laboratory in Poznan, Poland.

3. Results and Discussion

As indicated in the material and method section, to study the layers of the nebkhas, a cut was made on their sediments and the related layers that were identified with great precision, and the boundary of each layer was determined.

The corresponding results showed that the nebkhas of the region have 16 layers, each of which represents the environmental characteristics of its time. After sampling and performing some experiments that were mentioned, their results were obtained, among which the results of gravimetric and geochemical experiments on the sediments of each layer will be represented; and then the results and the final analysis of each, depending on their age will be presented. The results are presented in Figures 4, 5 and 6.

Figure 3. Stages of making surface cuts on the nebkhas of this study.

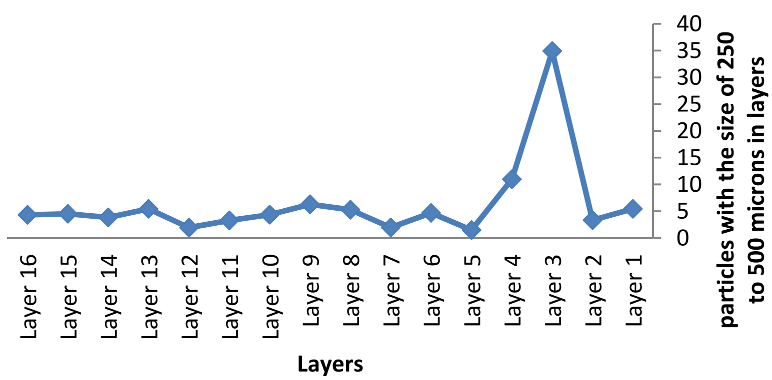

Figure 4. The percentages of particles with the size of 250 to 500 microns in layers.

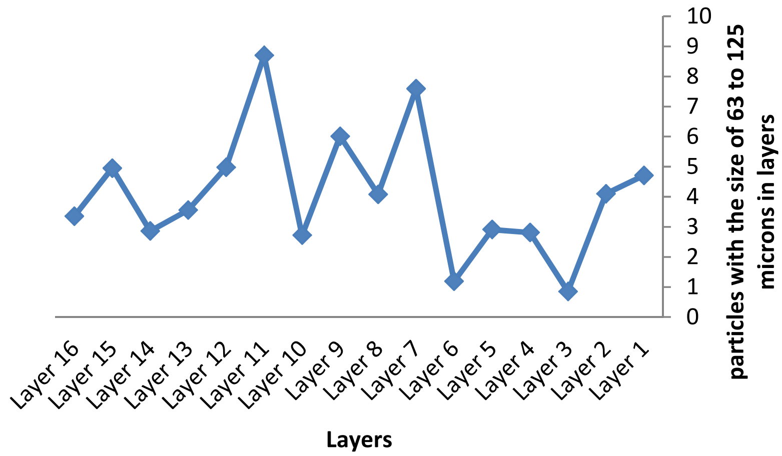

Figure 5. The percentages of particles with the size of 63 to 125 microns in layers.

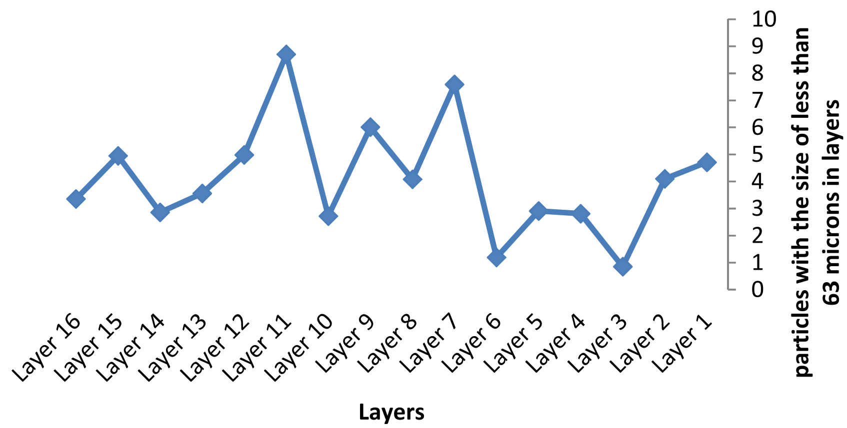

Figure 6. The percentages of particles with the size of less than 63 microns in layers.

The first experiments were carried out on sediment grains, which were done on all specimens. According to the results of the analyses on the grains, among the studied layers, about seven layers were selected as more characteristic layers. The geochemical analysis (including organic matter (OM), salt (EC), limestone and PH) were done for these layers. Only organic and salt tests had quite good results, the results of which are presented in Figures 7, 8 and 9.

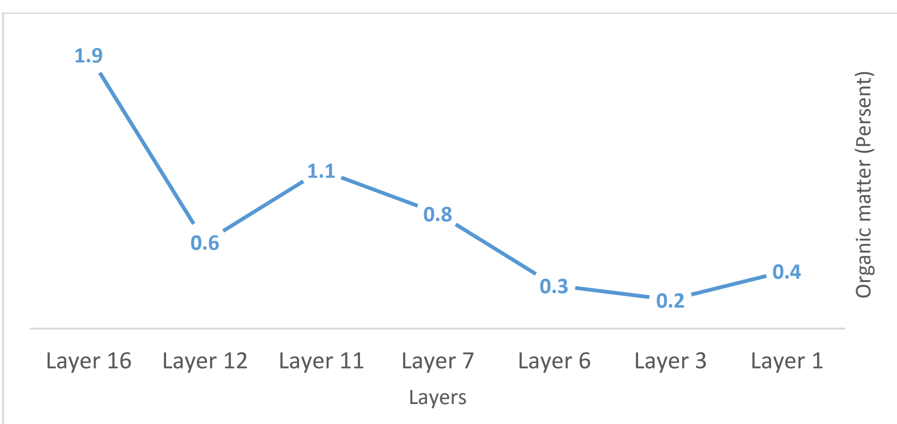

Figure 7. Changes in the amount of organic matter in different layers.

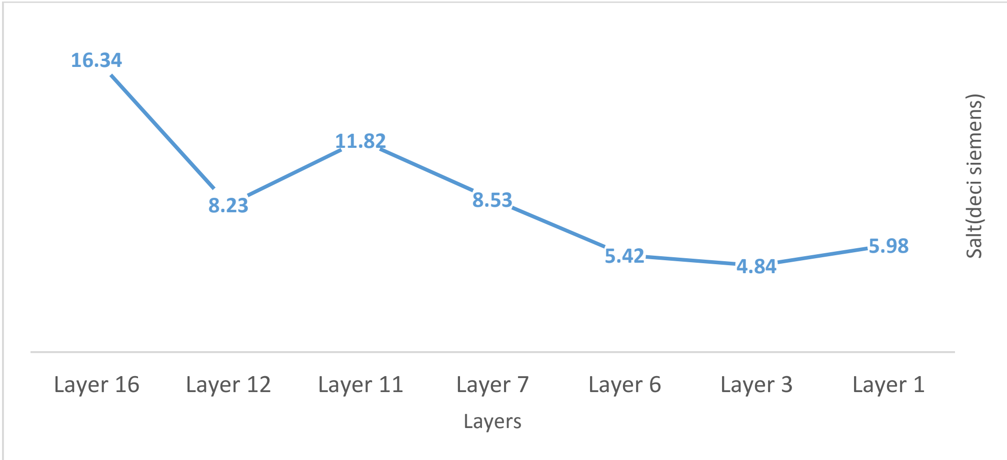

Figure 8. Changes in the amount of salt in different layers.

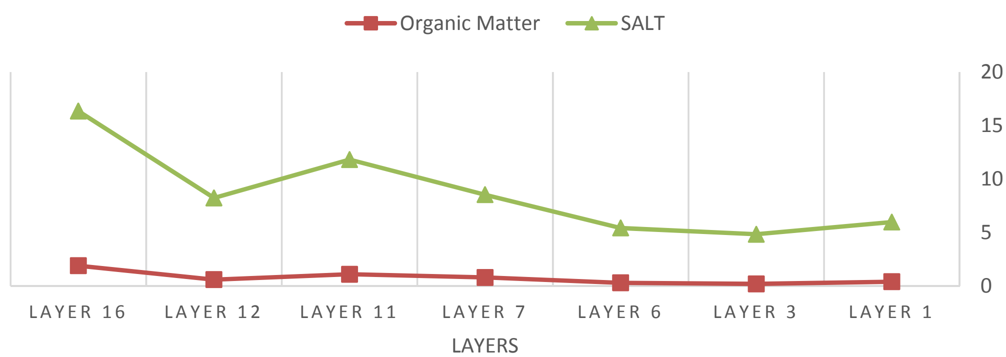

Figure 9. Comparison of salt and organic matter in different layers.

In the following, the results of laboratory analysis of the sediment of each layer will be discussed. It should be noted that according to the laws on geological LOG and the investigation of sediments in geology, sediment layering and numbering are carried out from the lowest layer; therefore, in the figure, the numbering of layers has been made from the bottom to the top.

3-1. The results of gauging and geochemical studies of the sediments layers

The First Layer: The first layer is the lowest layer, located over the ground level. There was no layer below this layer. Its thickness is 38 cm and it contains gypsum particles with darkish brown color. The size of the sediments in this layer is medium to small and its organic matter is very small. The sediments of this layer are horizontal. Granulometric analysis of sediments shows that the most abundant sediments in this layer are particles between 125 and 250 microns, with a frequency of 53.5%, while particles between 63 and 125 microns are the second in frequency. There are few particles with the size of 1000 micron. Besides, particles of less than 63 microns are 7.7 percent that is almost noteworthy (Figures 4, 5 and 6). The data of the first layer sediment analysis in the laboratory show that the amount of salt and EC in this layer is about 5.98 decimeter, and the amount of lime in it is 20.3 percent. The organic matter in this layer is 0.4% and the pH is 8.9 (Figures 6, 7 and 8).

The information presented above shows that the region has had a calm environment, so that the most abundant sediment particles in this period are sediments of less than 250 microns. Moreover, the amount of sodium in this period is almost high, which is indicative of the dryness of the region and the presence of a lot of salt in wind sediments.

The Second Layer: The thickness of this layer is 22 cm. Gypsum traces appear as continuous lines throughout the layer. Its color is lighter than the first layer and there is some organic matter in it. Dried, powdered leaves of tamarisk are also seen in this layer. The sediments are horizontal and their texture is very fine.

Screening of the sediments of this layer shows that the characteristics of this layer are almost different from the first one. The most abundant size of sediment particles is between 125 to 250 microns and its frequency is about 47%, 6% less than the first layer. In addition, particles between 63 and 125 microns are about 43 percent, about 8 percent more than the first layer, and particles less than 63 microns are almost equal to the first layer (Figures 4, 5 and 6). These show that the processes were weaker in this period than the first period.

The Third Layer: This layer has a dark color and its thickness is 19 cm. This layer is horizontal and the grains of its sediments are coarse. The sands resemble those of the river basins. The analysis of the grains of this layer shows a great difference between the sediments of this layer and other layers. The particles between 250 and 500 microns in this layer are quite abundant. Its frequency is twice as much as other layers and it also includes particles smaller than 63 microns. The particles from 63 to 125 microns have the lowest abundance of all periods. These cases indicate the more energetic power of the processes in this period, compared to other periods (Figures 4, 5 and 6).

The results of sediment geochemical experiments show that the amount of organic matter in this period is about 0.2 percent that is less than other periods. The amount of salt in the sediments of this period is 4.84 decimeter, which is the lowest among all the studied periods. Calcareous materials in the sediments of this period have the highest frequency, which is 21.7%. The PH content of the sediments in this period is 8 (Figures 6, 7 and 8).

The information and experiments carried out on sediments related to this period show the more power of processes in this period in comparison to other studied periods. The prevalence of coarse grains in this period is significant and the amount of organic matter and salts in the sediments of this period is less. There is a rule that says the less salt content, the less dry the land will be, so the wind carried less salty particles. More organic matters of vegetation show that the region was more humid, so the plants have shown less sensitivity to dryness.

According to the presented data, until now, it has become clear that the first period was almost calm and its processes were weak in the second period. However, in the third period, there was a sudden change in the environmental conditions of the area. As a result, the processes became stronger and the climate has become wetter (Figure 9).

The Forth Layer: The thickness of this layer is 21 cm. There are abundant gypsy deposits in this layer, which can be seen in the form of pellets and veins. The layer is horizontal and there are plenty of fine-grained sediments in this layer.

The results of the sediment analysis of this layer indicate that the processes of the third period have been completed and, except in some, there are no traces of them. For example, the sediments with the size of 250 to 500 microns are still abundant and are the second in abundance among all periods. However in general, the climate during this period had been a very calm environment compared to the third period (Figures 4, 5 and 6).

The Fifth Layer: The thickness of this layer is 27 cm. There are very fine deposits and little gypsum pellets are seen. It has a bright color and organic matter powder is visible in this layer. The sedimentary characteristics of this period are very similar to the fourth period, although in some cases, such as the abundance of sediments over 250 microns, changes have taken place and their percentage has decreased. The results of the sediment analysis of this period indicate the continuation of the conditions of the fourth period, although the processes of this period are weaker than the fourth period (Figures 6, 7 and 8).

The Sixth Layer: The thickness of this layer is 42 cm. It has coarse dark brown sediments. The layers are from northeast to southwest. Gypsum particles are scattered in this layer. The analysis of the sediments of this period shows that its processes are more powerful than the previous two periods, with more than 71 percent particles between 125 and 250 microns and particles less than 125 microns are less frequent than other particles, as compared to other layers (Figures 4, 5 and 6).

The results of geochemistry of sediments of this period show that sediments of this period, after the third period with about 42.5 cm, have the lowest salinity (EC) and also with 0.3%, the lowest amount of organic matter. The amount of lime is about 1/20, which is a significant amount (see Figures 6, 7 and 8). The above-mentioned evidences show that the processes of the sixth period have been more energetic than that of the previous period, and the environmental conditions had been less dry.

The Seventh Layer: The thickness of this layer is 24 cm. Inside it, there are holes in the gypsum material. Its sediments are very fine. The layer is horizontal. It has a bright color. The results of the sediment analysis of this layer indicate that sediments of this period are very fine grained so that sediments of 63 to 125 microns are the most frequent not only on this layer, but also among all studied layers. Clay sediments (sediments less than 63 microns) are very abundant in this layer and they are in fact the second in abundance among all the studied layers (Figures 4, 5 and 6). Laboratory study of geochemical properties of the seventh layer sediments showed that the salinity of sediments was 8.53 dSi, much more than other previous periods, and the amount of organic matter in the layer is about 0.8% which is higher than other periods and with 19.4 percent, it has the lowest amount of lime compared to other previous periods (Figures 6, 7 and 8).

The results of study of the seventh period show that after the sixth period, when the processes were very energetic, the seventh period was very calm and that during this period the processes were very weak. The existence of some organic matters, compared to other periods, show the drought in this period. In general, among the seven primary periods studied, the seventh course has the calmest environmental conditions, and the third period has the strongest environmental conditions (Figure 9).

The Eighth Layer: The thickness of this layer is 51 cm, the layer is completely disintegrated and it is a nest to reptiles. It has a bright color. The sediments are coarse and fine particles. The sediment of this layer is completely clear. There are holes in it due to the gypsum material. The most frequent particles in this layer are particles between 125 and 250 microns and clay materials less than 63 microns are less frequent than the seventh period (Figures 4, 5 and 6). In general, the characteristics of the eighth period show that the calm conditions of the seventh period is finished and the process during this period has become more energetic.

The Ninth Layer: Its thickness is 25 cm. It has a bright brownish color. Inside the layer, there are sandy veins. Its sediments are medium sized. The results of the measurements of the grains show that the characteristics of this layer are almost similar to the eighth period, with the difference that the amount of clay material is slightly higher, and in some sizes, it is slightly different from the eighth period (Figures 4, 5 and 6). In general, the environmental conditions in the area have not changed a lot, and this layer seems to be a continuation from the eighth period.

The Tenth Layer: This layer has a thickness of 35 cm. It has a dark color and its building is loose. It also has a lot of holes. The results of the measurements of this layer indicate that its processes are somewhat more energetic than that of the ninth period, but this amount is not significantly larger, so that the abundance of sediments has changed in some sizes to a small extent, for example, the clay particles of this layer compared with the eighth and the ninth period is less, and the particles between 125 and 250 microns are somewhat larger than those for the two previous ones, but as noted, these changes are minor (Figures 4, 5 and 6).

The Eleventh Layer: Its thickness is 32 cm and it has a bright brown color. This layer is full of organic matter and tamarisk foliage leaves. Its structure has holes in it with very tiny deposits and this layer is horizontal. The results of the measurements of this layer show that its sediments are very fine grains, so that the highest amount of sediments is

less than 63 microns, among all studied layers, in this layer, which is 8.7%, also the amount of particles with the size of larger than 250 microns in this layer is less than 5% (Figures 4, 5 and 6).
The results of the geochemical experiments on the sediments of this layer indicate that the amount of salts in the sediments of this layer is 11.22 dS, which is very high compared to the other previous periods, also the organic matter content of this layer is 1.1%, which is more than those of all other studied layers (except for the first layer). In addition, about 19.6% of lime was observed among sediments, which is the lowest after the seventh period (Figures 6, 7 and 8). Considering the sediments of the eleventh layer, the highest amount of organic matter and salts were observed in this one. Besides, in terms of grain size, the highest amount of fine-grained clay sediments was found in this period. All of these cases indicate that there were very calm conditions in this period, so that the processes were much weaker than those of other periods studied and more drought conditions were observed in the area (Fig. 9).

The Twelfth Layer: Its thickness is 53 cm. It has a bright color with fine grained sediments. There are gypsum holes inside this layer. The layer is again horizontal. The results of the sediment measurement of this period show that its particles have become coarser than the 11th period, so that particles of more than 125 microns were found to be more frequent during this period, also clay materials had decreased during this period to about half of the 11th period (about 4.97%) (Figures 4, 5 and 6).
The results of the geochemical experiments show that the amount of salts in this layer is about 8.34, which is almost high but less than that of the 11th layer, and the amount of organic matter in this layer is about 0.6% that is less than that of the 11th layer period.
The results of the study of the characteristics of this layer indicate that after the conditions of the eleventh period are almost complete, the processes during the formation of this layer were more powerful, also the reduction of organic matter among the sediments of this period indicates a decrease in the dry environmental characteristics of this period.

The Thirteenth Layer: The thickness of this layer is 42 cm and its sediment has a small amount of litter. The granulometric study of sediments of this layer shows that the particles sizes have the highest frequency between 250 and 125 microns, and the particles between 63 and 125 are the second in frequency, the clay particles of this layer have decreased compared to that of the other two previous periods (Figures 4, 5 and 6).
The features of this layer indicate that the dry conditions of the 11th and the 12th period are not seen anymore and their severity has decreased, so that the conditions returned to normal.

The Fourteenth and Fifteenth Layers: The thickness of the 14th layer is 55 cm and the fifteenth layer is 48 cm. The granularity characteristics of these layers are very similar to the thirteenth layer. The particles between 250 and 125 microns are the most frequent, and the particles between 63 and 125 microns are in the second place (Figures 4, 5 and 6).
The investigation of these layers indicates the continuation of the thirteenth period processes in these periods and the environmental conditions in these three periods have a certain stability and similarity to each other.

The Sixteenth Layer: This layer is the newest layer of nebkhas, in which organic matter and foliage are abundant. The thickness of this layer is 58 cm in the peak of the nebkha, but the layer thickens to the sides so that in some parts it is about 50 cm thick. The color of this layer is brown that is very different from the other layers. This color's difference seems to be due to the high impact of the climate on this layer (especially precipitation and temperature).
The most frequent sediments of this layer are particles with the size of between 125-63 microns and the least frequent particles are those of more than 2000 microns. This layer expresses the environmental characteristics of the present age and granulometric analysis showed that very small particles with a size of less than 125 microns have the highest frequency among sediments and sediments with a size of less than 63 microns are in the second place. This case is indicative that there were calm conditions in the region (Figures 4, 5 and 6).

In this layer, due to the fact that it is still affected by many processes, the parameters are much higher than those of the other layers. The results of laboratory analysis of sediment geochemical parameters indicate that the amount of salts in this layer is about 25%, and the organic matter is about 4% (Figures 6, 7 and 8). The presence of large leaves in this layer indicates the dryness of the climate in this period, because leaf loss in dry conditions is a plant adaptation method, and the leaf fall strongly affects the ratio of root to leaf and the carbon balance of the plant, as a result, the abundant leaves in the first sedimentary layer indicate the domination of dry climatic conditions in the region in the current period, and also the prevalence of sediments of less than 125 microns, indicates poor natural transportation processes in the region.

3-2. Determination of the Age of Nebkhas in the Study Area

In this part, the age of the nebkhas in the region was studied. To do this, after making a profile cut in the nebkha sediments and taking samples of the sediments, some containing organic matter were taken to determine the ages. Then the sediment was sent to the Poznan laboratory in Poland to determine its age with carbon 14 (C14) method. After calibration, the results of age determination were used to study environmental changes.

Sampling for determination of age was performed on several layers of the nebkha, of which two were effective but age determination was difficult in several layers due to the lack of organic matter within them. The ages of the fourth layer and the eleventh layer were determined; the fourth layer was at a height of 1 meter from the ground and the eleventh layer at 36.3 meters. The results of the dating of the mentioned layers showed that the eleventh layer, which was younger and located in the upper parts of nebkha, is about 114 years old, and the fourth layer, which is older, is about 735 years old (Fig. 10).

3-3. The Environmental Conditions of the Area over Time

Investigation of the different layers of the studied nebkha has shown different fluctuations, as it was mentioned in the introduction and review of each of the layers. These fluctuations have occurred over the lifetime of nebkha. In this study, it was found that there were two severe dry periods in the region as well as a period of wet conditions with strong processes. Other periods, according to their adjacency to these three periods and under their conditions, have seen fewer fluctuations.

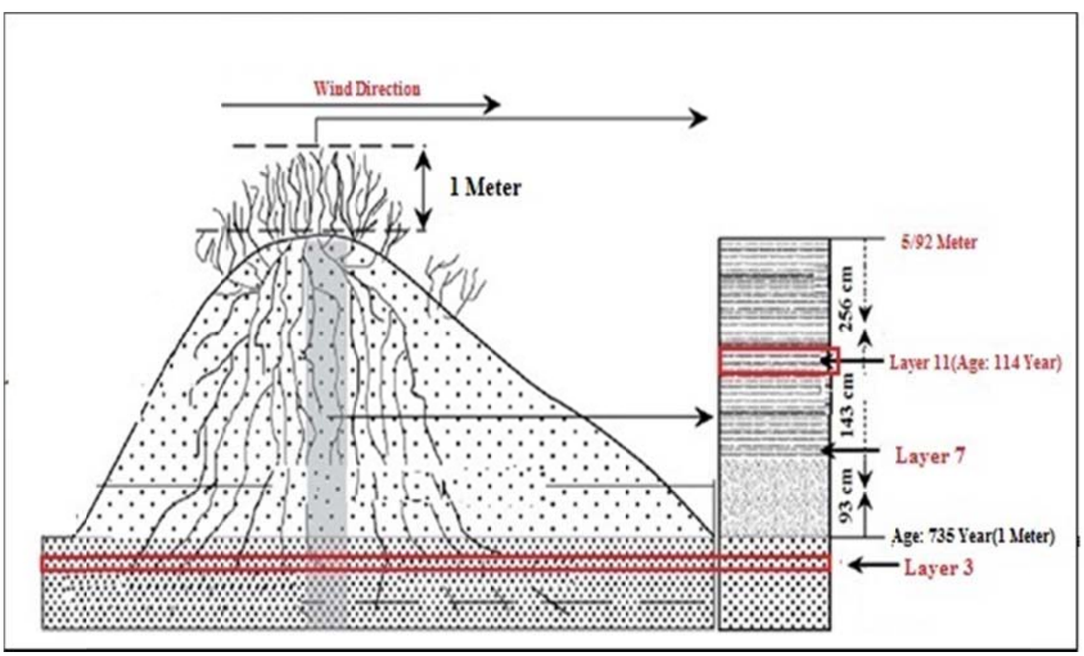

Figure 10. A vertical profile of nebkha layering, with ages of some layers.

According to the studies carried out on the sediments of each of the layers, it was found that in the first period the environmental conditions of the area were calm and as a result, Necka began to calmly form under such conditions. The second period also followed this trend and its conditions are very similar to the first period, although in some cases the conditions of the region were calmer than the first period. These two periods are the first 60 cm of nebkha.

The study showed that the third period, which is 60-80 cm above the base and is considered as one of the earliest periods (the early stages of formation of Nebkha), has very coarse grained sediments and contains little organic matter, salt and clay materials, so that it has the first place in all the studied periods in the above mentioned matters. For example, the lowest amount of salt, organic matters and clay is measured in this period and its deposits are similar to river sediments as they were almost rinsed. These showed that this period was recognized as the wettest period among all periods whose processes were very strong, and given that the age of the fourth layer, which is above this layer, is estimated 735 years. Hence, it is concluded that more than 735 years ago, the area has undergone a period of intensive and much wetter processes than today's period.

As shown in Fig. 8, the fourth period has been accompanied by a mitigation of the environmental conditions, so that the power of processes of the third period is no longer seen, and processes have become weaker, this period which was 735 years ago, was a period of tranquility after the storm. In addition, these conditions continued in the fifth period. In the sixth period, the processes became a little more intense and the calmness of the fifth period was disturbed.

With the advent of the seventh period, the conditions have been very calm in the region, so that among the seven periods before this period, the seventh had the calmest conditions. This period after the eleventh has the highest amount of clay materials as well as organic materials and salt in its sediments, and formed between 114 and 735 years ago. The calmest studied period is the seventh period. The height of the layer related to this period is about two meters from the ground.

The features of the eighth period show that the calm conditions of the seventh layer are over and processes have gained more power, and these conditions continued in the ninth and tenths periods. With the advent of the eleventh period, the environmental conditions of the region change completely; this period, with the highest amount of organic matter, salt and clay, as well as very poor processes, is known as the driest period. The age of this period is about 114 years. In this period, the processes of transportation were very weak and the height of the layers related to this period was about 3.5 meters from the ground.

By the end of this period, the environmental conditions change slowly, and in the twelfth period, the conditions of the eleventh period are not so severe. This situation has dominated the area from about 114 years ago to the present. Accordingly, there has been very little fluctuation in the environment, and in general it has remained almost constant.

4. Conclusion

In this study, the morphodynamic changes in the western margin of Lut plain were studied based on the nebkhas hills. In this regard, and according to the main purpose of the work, profile cuts were created in Nebkhas and their layering was determined, and then the sampling from each layer was done separately and carefully. The sample was examined in the laboratory. Investigating the changes in the environmental conditions of the area using nebkha layering showed that during the age of 735 years, the nebkhas have undergone several stages of changes in the environmental conditions. The most intense processes, as well as the wettest period among the studied periods belong to the third period. In this period, the sediments were coarse-grained and there were the lowest amounts of salt and organic matter, which determined stronger processes and a wetter region than other studied periods. It should be noted that such situation was dominant in the region since about 735 years ago. These conclusions are drawn using the results of geochemical experiments (amount of organic matter, salt and lime) in the sediments of the layers. The driest period among the studied periods of the region occurred in the eleventh period, which was about 114 years ago. In this period, the weakest processes and the least amount of moisture (according to the results of organic matter in sediments) existed in the region. In addition to these two periods, the seventh period also had a dry climate and poor processes. In general, the results show that several changes have occurred in the environmental conditions of the region, which have led to changes in the main Lut platform, where the nebkhas are located and its surface is affected by erosion. These changes are clearly visible using the location of the nebkhas hills. In general, the results of this part of the study showed that nebkhas can show environmental changes of the region.

Acknowledgements
The authors would like to thank Shiraz University for their support in the project and Iran Meteorological Organization for providing some meteorological data.

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