Kuwait J. Sci. **Vol. 40 (1) June 2013** pp. 165-178, 2013

Geomorphological characteristics of the Um-Rimam depression in northern Kuwait

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ABSTRACT

Um-Rimam depression is one of the largest depressions in Kuwait. It is about 16.5 km^2 and located in northern Kuwait. It consists of a northern and southern playa whose floors cover 0.39 and 0.72 km^2 at 50 m and 60 m above sea level, respectively. The two playas are separated by a narrow zone (250 m in width) called the neck area. The depression is developed on alluvial sediments classified under Kuwait Group (Oligo-Pleistocene). The main geomorphological features of the study area are wadis, playas and yardangs. 73 wadis (11 major and 62 minor wadis) were observed in the field with variable orientations. The depression is a mere erosional feature, because no indications of a tectonic origin have been found in the study area. The depression has a variety of surface sediments such as pebbly sheets, active sand sheets, wadi fill deposits, alluvial fans, falling dunes, and nabkha deposits around shrub (*Haloxylon salicornicum* and *Lycium shawii*). The surface sediments in the Um-Rimam depression are sandy, poorly sorted, positively skewed and very platykurtic. The amount of aeolian deposits (sand and dust) is low in the study area compared to the average deposited aeolian particles in surrounding areas within Kuwait, but the annual amount of sand trapped in the northern playa (31 $kg.yr^{-1}$) is higher than the southern playa. The proposed artificial lakes in the depression might be good for improving the vegetation cover and wildlife, but an environmental impact assessment study should be prepared.

Keywords: Artificial Lake; Um-Rimam depression; playa; geomorphological

INTRODUCTION

The northeastern Arabian Peninsula, including Kuwait, is an arid region where wind is very active, erosional and depositional agent. The terrestrial environment of Kuwait is dominated by a great variety of aeolian landforms, the most common types being sand dunes, nabkhas, sand sheets, ventifacts, granule ripples, grooves, flutes and polished surfaces, yardangs and deflation hollows. The Um-Rimam depression is one of the distinctive geomorphological features in northern Kuwait. The area of the depression is 16.5 km^2 and it is

located between latitude 29° 30' and 29° 35' N and longitude 47° 42' and 47° 46' E (Fig. 1.). Currently the study area constitutes part of a national park in Kuwait (Subah Ahmed National Reserve) which covers about 333 km^2. The first study of Um-Rimam was done by Kellio (1990) who produced a geomorphological map of the depression. Al-Dousari *et al.* (2009) made the first geological map and a more detailed geomorphological map of the study area (Fig. 2). Omar *et al.* (2008) identified all drainage system in the national park, including a few major wadis within Um-Rimam. The latter two studies were done to establish a database before initiating artificial lakes in the depression. The Government of Kuwait is currently constructing these artificial lakes in collaboration with United Nations Environment Programme (UNEP) and the National Commission for Subah Ahmed National Reserve through the supply of surplus, redundant treated water from farms and military camps to the depression. The mean air temperature in summer (May-August) is 37° C with large diurnal temperature ranges (8°-23° C) in winter (October-April) but averaging 17° C. Precipitation (1957-2010) is limited and erratic, ranging between 31 mm in 1964 and 242 mm in 1976 (annual mean of 112 mm). The most active prevailing winds are from the northwest but sometimes blow from the southeast. Mean wind speeds are 4.4, 5.5 and 6 $m.s^{-1}$ at 10, 30, 50 m height respectively. This study aims to investigate the geological, geomorphological, hydrological and aeolian characteristics of the Um-Rimam depression which could provide important data base for future studies.

METHODS

Field Survey and Mapping

To study the geological and geomorphological characteristics of Um-Rimam depression, a preliminary contour map was produced through combining a digital elevation model and interpretation of aerial photos from 1972 (1:29,000 scale) and 1992 (1:33,000 scale) (Fig. 1). Subsequently, field survey of the area was carried out for ground-truthing and field measurements. The drainage systems (wadis and playas) for the study area were delineated on a 1:25,000 scale topographic map with contour intervals of 5 m and superimposed onto Fig. 2.

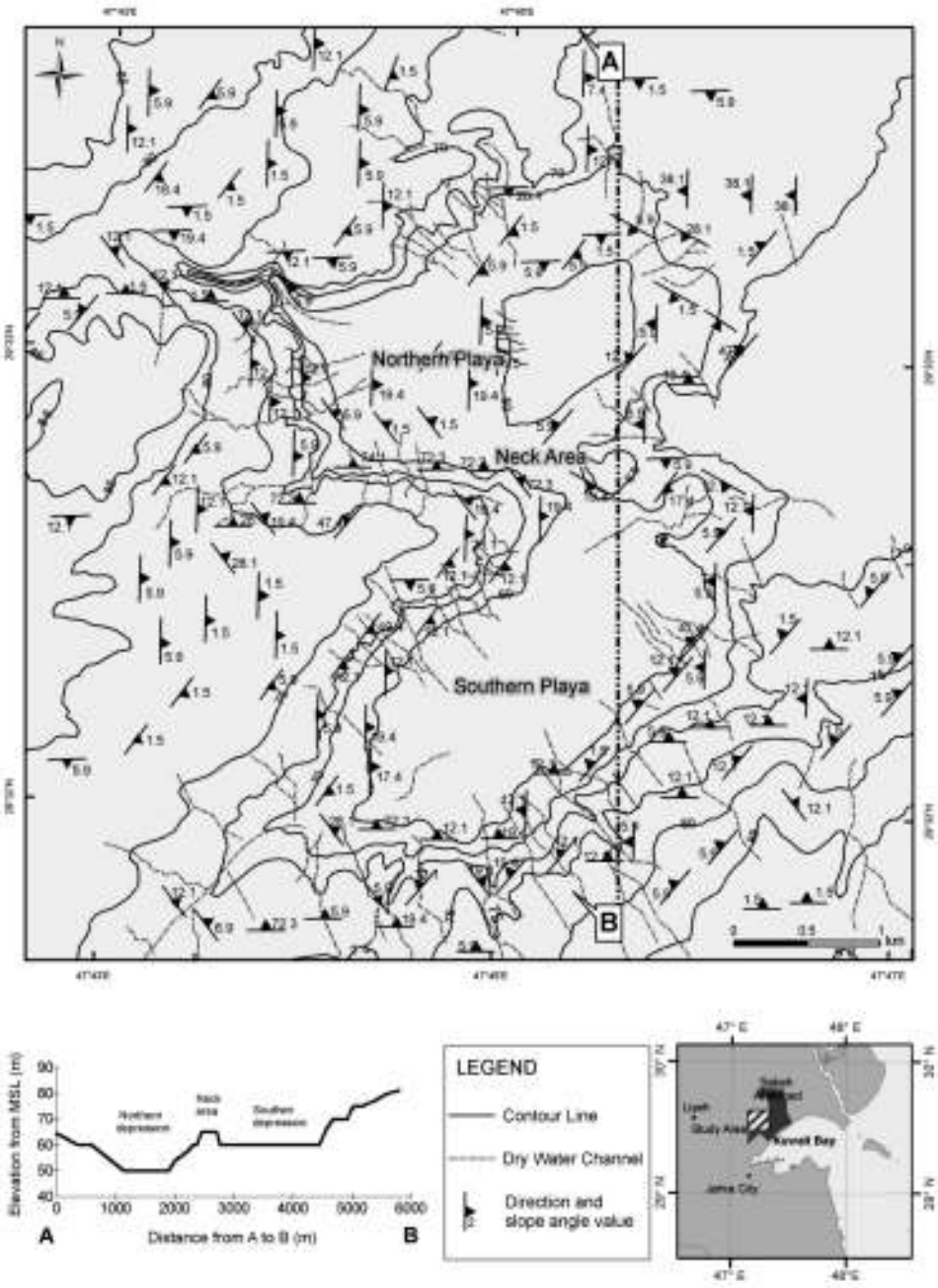

Fig. 1. Contour map with slope angles and directions for the catchment area within Um-Rimam depression.

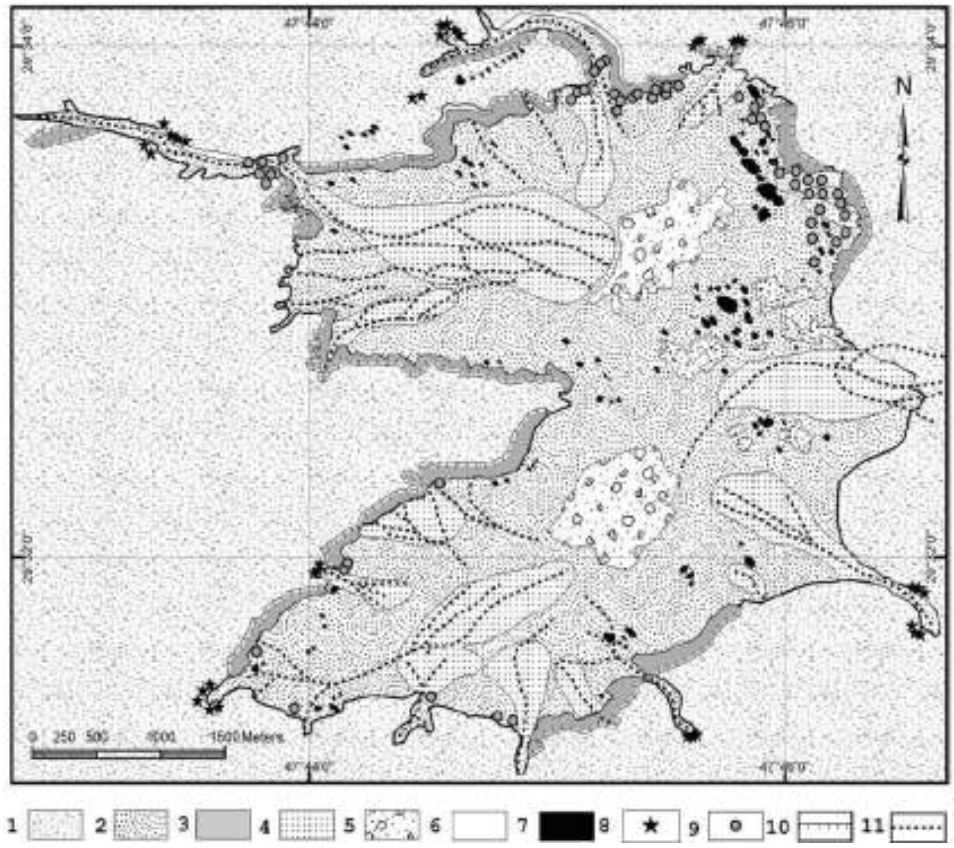

Fig. 2. Geomorphological map of the Um-Rimam depression: (1) erosional platform; (2) floor of the depression; (3) piedmont slopes; (4) alluvial fans; (5) playa floor; (6) falling dunes; (7) single yardangs; (8) *Lycium shawii* nabkhas; (9) *Haloxylon salicornicum* nabkhas; (10) cliff; (11) main water channels and gullies (after modification from Al-Dousari *et al*., 2009).

Field Sampling and Analysis

About 40 locations in the depression were selected for sampling of surface sediments. In addition, the movement of aeolian particles was monitored on a monthly basis by installing four sand traps (R01, R02, R03 and R04) and two dust fallout traps (R03 and R04) in the study area for one year (Fig. 3). The dust fallout traps were fixed at 240 cm above the surface with a 20 cm diameter, while the sand traps were one meter in height and had a 1 cm aperture facing the dominant wind direction ($N45^0W$) (Fig 4). Several other dust collectors were fixed in Sabah Alahmed National Park (9 traps), Liyah (10 traps) and Jahra City (11 traps) for comparison (Fig. 1). All aeolian and surface sediment samples were weighed and analyzed for grain size

distribution using standard sieving techniques for sand size fractions (2 mm-0.063 mm) and a Centrifugal Particle Analyzer (Shumadzu, SA-CP3) for mud size fractions (less than 0.063 mm).

The hydrological characteristics of the catchment area were obtained from a number of groundwater wells in addition to infiltration tests. The infiltration test measures the rate at which water penetrates into the soil by using a double-ring infiltration (30 cm in diameter) and was conducted at all sampling sites.

In order to assess the structural stability of the area, the seismic activities in and around Um-Rimam depression were monitored using the Kuwait National Seismic Network (KNSN) stations. There are eight permanent stations (Table 1) and three portable stations. The permanent stations started to operate on the 1st of March 1997 and the portable stations were installed on 12 June 2006, and ran until 15 February 2007. Attempts were made to identify potential subsurface faults, orientation and depth.

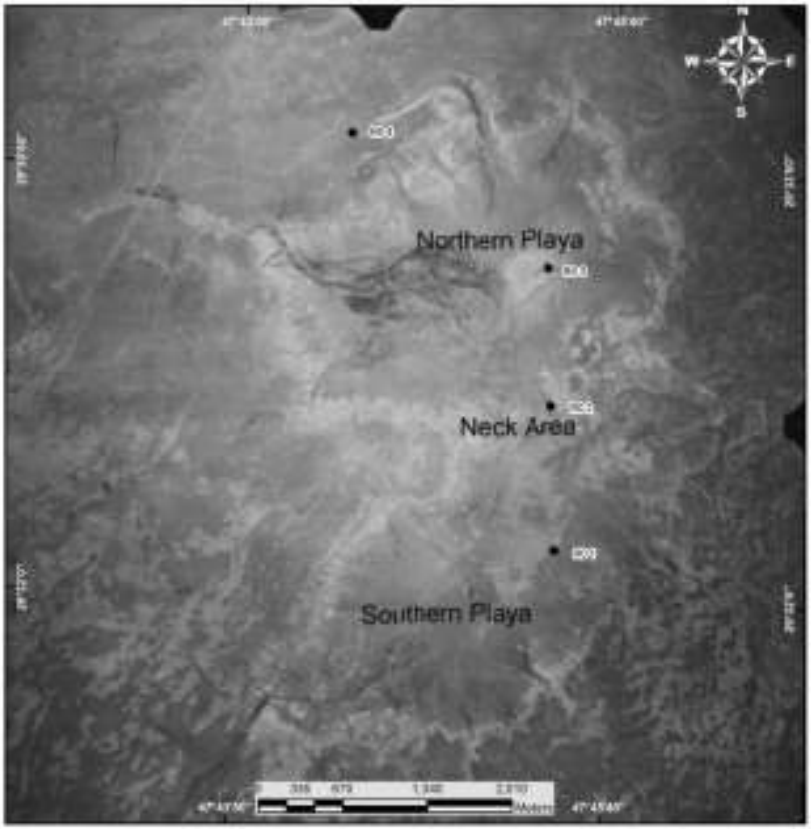

Fig. 3. Location sites for aeolian traps (R01-R04) in the Um-Rimam depression.

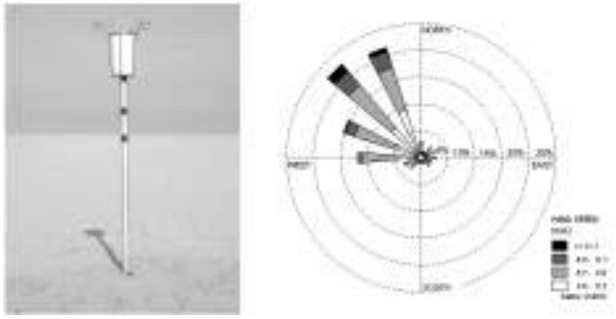

Fig. 4. Aeolian monitoring by sand trap (left) and dust trap (middle), with average wind rose during 2010 (right) in the Um-Rimam depression.

Table 1: Locations of Kuwait National Seismic Network (KNSN) stations.

Location	Latitude	Longitude
Khabid	29 10.533	47 41.600
Qurain	28 44.665	47 55.063
Ridyfa	28 55.553	47 32.983
Failaka	29 44.056	48 33.472
Nayam	29 14.935	47 14.527
Um-Rriwisat	29 30.017	46 59.833
Mutrabah	29 48.191	47 20.326
Um-Rimam	29 33.115	47 42.950

RESULTS AND DISCUSSION

Geological and Geomorphological Characteristics

A contour map with slope angles for the catchment area around Um-Rimam depression containing all major and minor wadis was prepared (Fig. 1). This map shows that the depression is approximately 8 km across from east to west and about 9 km evens from north to south. The surrounding terrain is 80 m above sea level (a.s.l), while the southern and northern playas are at about 60 and 50 m a.s.l, respectively. The Um-Rimam, depression is formed within Kuwait Group which is composed of Oligo-Pleistocene continental sediments. This group is divided into three formations, namely Ghar, lower Fars, and Dibdibba formations. The northern and northwestern parts of the depression are composed of sand and gravels from the Dibdibba Formation (Miocene to Pleistocene); while the southeast parts are composed of sand, clay and limestone

from lower Fars and Ghar formations. These formations are horizontally layered and show no structural deformation.

The depression constitutes two playas (northern and southern) separated by a narrow zone called the neck area. The edges of the depression are surrounded by many small valleys with steep slopes. The low-relief floors (lowest parts) of the northern and southern playas cover 0.39 km^2 and 0.72 km^2, respectively. The two playas contain Quaternary alluvial and aeolian sediments. There are two kinds of morphological features in the area: depositional and erosional features. The depositional features are mainly found within the low-relief floors in the northern depression and include sand sheets, granule ripples, pebbly sheets, falling dunes and nabkhas. The erosional landforms in the study area are ventifacts, grooves, flutes and polished surfaces, yardangs and deflation hollows. The latter two features are the most dominant in the study area. Vegetation cover in the depression varies from none to dense. The mobile sand is bare of vegetation, especially in the northern part of the depression. Field observation recorded perennial shrubs such as *Stipagrostis plumose, Citrulus colocynthis, Haloxylon salicornicum* and *Lycium shawii*. The former two plant species commonly grow on alluvial fans, in the main wadis and in water channels draining into the depression, while the later two species commonly cover the upstream and cliff areas. *Haloxylon salicornicum* and *Lycium shawii* form nabkhas up to 2 m in height. The distributions of nabkhas are closely associated with yardangs, with both forming at the sides of the depression and in the neck area.

Hydrological characteristics

The main hydrological characteristics of the Um-Rimam depression are as follows:

- The depression has numerous drainage networks, 73 wadis were observed in the field; 11 of them are major wadis (longer than 500 m) and 62 are minor wadis within the depression
- The surface sediments of the depression are sandy with high porosity and permeability (average percentage of sand size particles ($>$ 0.063 mm) is 97.5%). Samples are poorly sorted, positively skewed and very platykurtic, with mean grain size ranging from 2.06 (fine sand) to 0.68 (coarse sand) in phi scale. The average percentage of the mud size fractions is 2.5%. Surface sediments coarsen towards the sides of the depression and fine towards the playas and the neck area (Fig. 5).
- Groundwater occurs at depth of 50 m from the ground surface of the northern playa.
- Average infiltration rate in both playa floors is about 5 $cm.^3min^{-1}$.

- The salinity of ground water is 1000-2000 $mg.l^{-1}$.

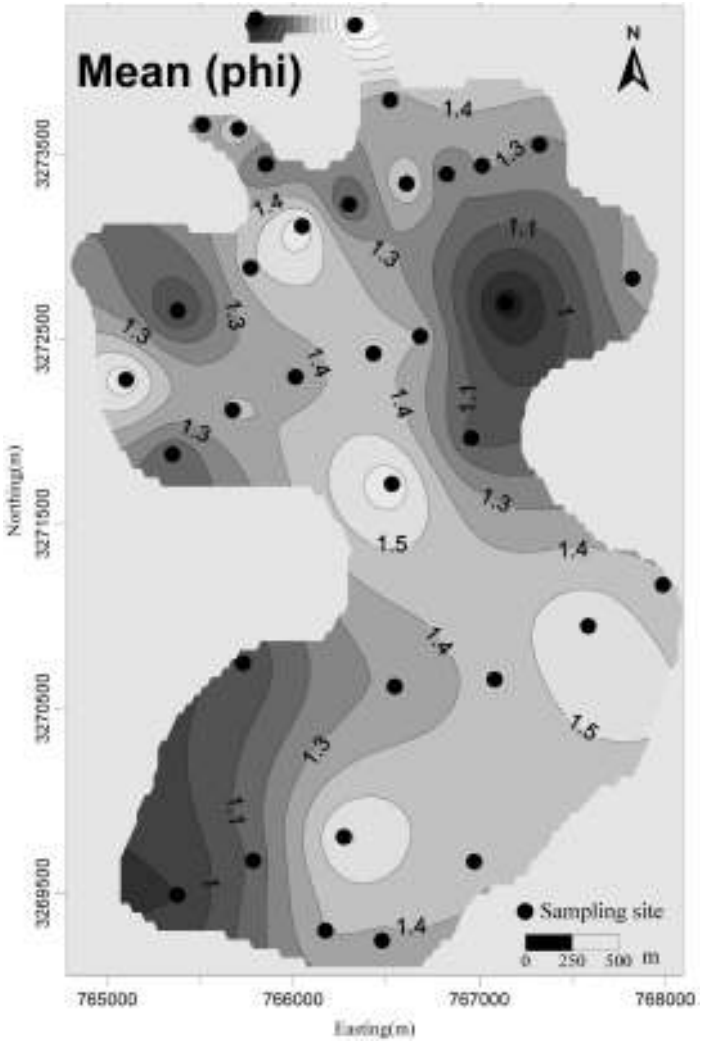

Fig. 5. Mean size particles in phi scale and sampling sites for surface sediments of Um-Rimam depression.

Structural Stability

Drainage into enclosed basins most commonly results from tectonic movements, but might also result from alluvial or aeolian deposition, erosion or volcanic activities (Cooke *et al.*, 1993; Shaw & Bryant, 2011). Milton (1965) considered the Um-Rimam depression to be an erosional feature, because no indications of a tectonic origin have been found in the study area. According to observations

from the KNSN stations, only six seismic events have been detected around the Um-Rimam depression (Table 2). The local magnitudes of these microearthquake events range from 0.8 to 2.3. Al-Asfour (1982) related the origin of the Um-Rimam to fluvial action. It is believed that terraces in Um-Rimam depression were resulted from the sea level drop and not related to any tectonic uplifting as there was no post-Eocene tectonic history in Kuwait including the study area in reference to the morphostructural interpretation and analysis done by Al-Sulaimi & El-Rabaa (1994).

There is very little information regarding the age and rate of formation of the Um-Rimam depression. The important morphological features of the depression are the presence of three main terraces. The age of the terraces at 3 km south of the Um-Rimam depression was estimated by Al-Asfour (1982) using radiocarbon dating. With reference to this radiocarbon dating, the ages of the three main terraces in the depression are 23300 +/-600, 28350 +/-1150 and 31900 +/- 1300 radiocarbon yrs BP (Fig. 6). Also, according to Chapman (1974) and El-Sayed (1994) the calcrete crust within Tertiary sandstone outcrop must have developed during the early Holocene in northeastern Arabia including the study area, when wide climatic variations and gradual increase in aridity occurred. Such solid calcrete crusts play an important role in yardang development within the depression. 52% of the yardangs in the area are capped with calcretc crusts, which prevent underlying sediments from wind erosion (Al-Dousari *et al.*, 2009). Mid Holocene (roughly 6000 to 7000 years ago) archaelogical sites suggest that the climate at that time was considerably wetter than at present in Arabia (Cole *et al., 2001*). Cole *et* al. (2001) used plant macrofossils and pollen contained within middens and also found an interval of extreme aridity between 4600 and 2500 yrs B.P. No systematic climatic change seems to have occurred over the past 2500 years (Le Houérou, 1998). The approximate estimation of the depressions age is these around 35,000 years, in conformity with local and regional studies (Chapman, 1974; Al-Asfour, 1982; El-Sayed 1994; Cole *et al.*, 2001).

Table 2. Recorded Seismic Events in the Um-Rimam depression over the period between 1999 to 2005.

Date			Time			Location		Magnitude		
Year	Month	Day	Hour	Minute	Seconds	Latitude	Longitude	Depth (km)	Coda	Local
1999	5	28	14	53	51.6	47 53.040	29 36.060	5.2	2.6	2.3
1999	5	29	18	54	8.2	47 52.380	29 37.020	3	2.3	1.6
1999	6	5	2	5	23.1	47 51.960	29 35.340	4.5	1.9	1.3
2001	7	5	22	11	50.3	47 47.880	29 36.660	0.2	0.8	0.8
2005	12	1	17	17	11.3	47 52.440	29 32.520	4.1	2.2	1.9
2005	12	18	14	39	51.3	47 49.500	29 31.980	5	1.7	1.7

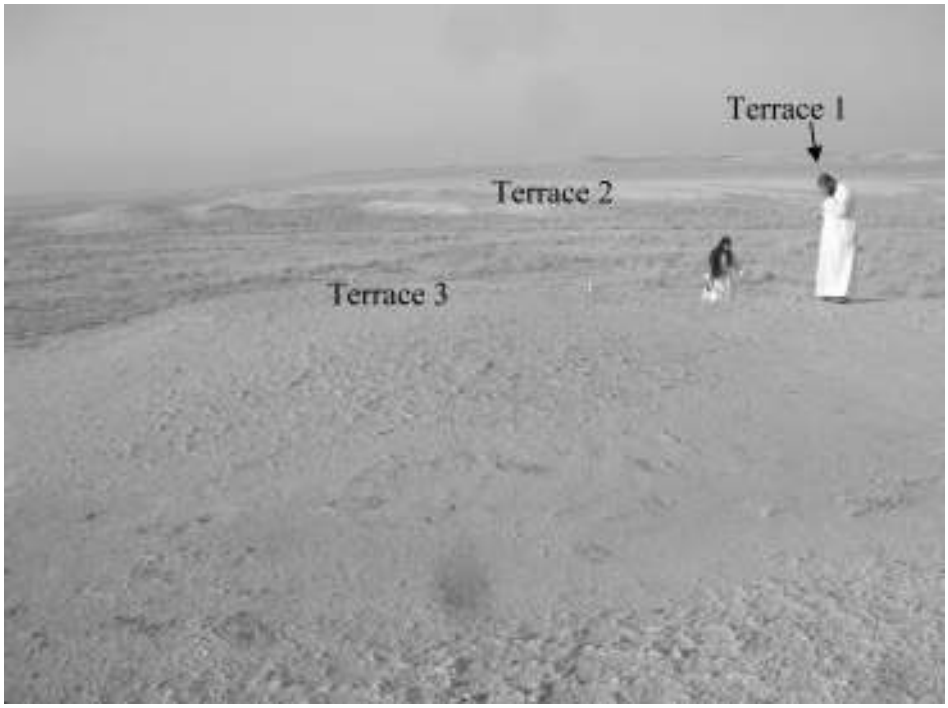

Fig. 6. The three terraces in the Um-Rimam depression

Aeolian Activities

Results from aeolian traps show that the concentration of dust is very high near wadis and open areas (i.e. away from the cliffs of the depression), but the quantities of deposited dust in Um-Rimam are much lower than Jahra and Liyah areas (Fig. 7). The average monthly dust fallout for Jahra City and Liyah area can reach above 3 $t.km^{-2}$ while at Um-Rimam is only 0.21 $t.km^{-2}$. The largest annual quantities of trapped sand were in the northern part of Um-Rimam (about 31 kg) (Fig.8). The average annual amount of trapped sand in Kuwait is 203 kg (Al-Nassar *et al.*, 2005). Mobile sand is very active represented by presence of variety of aeolian land features such as nabkha.

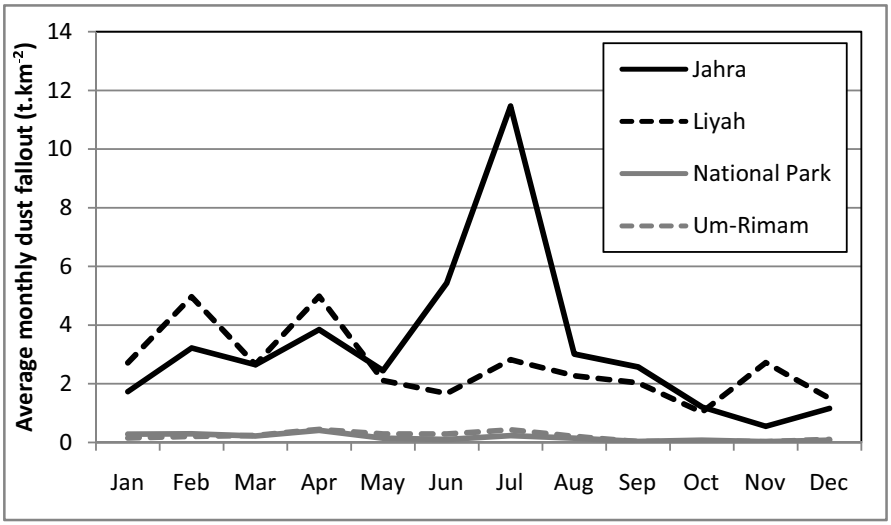

Fig. 7. The average monthly dust fallout (t.km^{-2}) in Um-Rimam depression in comparison to surrounding areas.

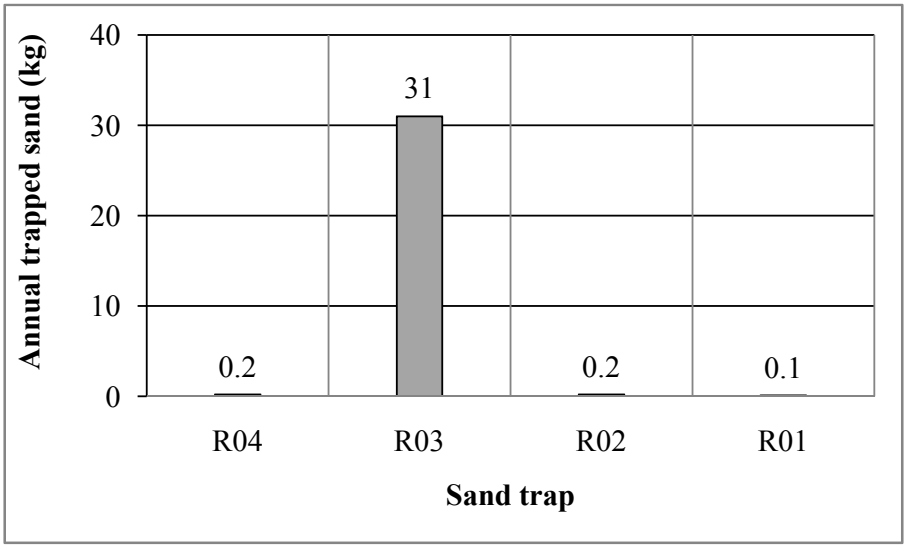

Fig. 8. Annual trapped sand in Um-Rimam depression.

CONCLUSIONS AND RECOMMENDATIONS

Um-Rimam playas are occasionally supplied with treated water in order to form artificial lakes. An environmental impact assessment of these activities should be

prepared. The presence of the artificial lake might have a positive effect on wildlife, vegetation cover, soil quality in the study area, but may have some negative effects such in the groundwater and karst formation. It is strongly recommended to develop more studies to quantify and qualify livestock and rangelands in the study area to build up a reference database as part of environmental impact assessment study.

AKNOWLEDGMENTS

This work was funded by the Kuwait Institute for Scientific Research-KISR (Project EC073K). Thanks are extended to Dr. Redha from Kuwait National Seismic Network (KNSN\KISR) for providing valuable information. Thanks also to Mrs. Tharwat and chemist Mrs. Al-Elaj for help with in analyzing surface sediment samples and images.

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Submitted : *1/5/2011*
Revised : *17/4/2012*
Accepted : *1/5/2012*

الخواص الجيومورفولوجية لمنخفض أم الرمم في شمال الكويت

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خلاصة

يعتبر منخفض أم الرمم أحد أهم أكبر المنخفضات في الكويت فهو يغطي مساحة تقارب 16,5كم2 ويقع في الجزء الشمالي من الكويت ويزمع إقامة بحيرة صناعية فيه من فائض المياه المعالجة. يتكون المنخفض من خبرتين شمالية و جنوبية و التي تعادل مساحتيهما السطحية 0,39 و 0,72 كم2 و على ارتفاع يقدر بـ 48م و 60م فوق مستوى البحر على التوالي. يفصل الخبرتين نطاق ضيق يسمى بمنطقة العنق يبلغ عرضه 250م. تكون المنخفض على رواسب فيضية صنفت رسوبيا ضمن مجموعة الكويت (أوليجوسين-بلستوسين). أهم المظاهر الجيومورفولوجية في المنخفض: الأودية والخباري واليارداتج. يوجد 73 واديا (11 منها رئيسي و 62 أودية صغيرة) تم رصدها في الحقل وبتوزيع عشوائي. إن المنخفض أقرب ما يكون أسباب نشأته نتيجة النحت حيث لم ترصد أي مظاهر تكتونية في منطقة الدراسة. يحوي المنخفض على أنواع عديدة من الرواسب السطحية مثل: الفرشات الحصوية والفرشات الرملية النشطة ورواسب الأودية والمراوح الفيضية والكثبان الرملية الهابطة ورواسب النباك حول نباتي الرمث والعوسج. إن متوسط التصنيف الرسوبي لهذه الرواسب أنها رملية وبعيدة التجانس وموجبة التفرطح وذات معامل إلتواء مسطح. معدل الرواسب الريحية (الغبار والرمال) في المنخفض متدنية بالمقارنة مع المناطق المحيطة في الكويت ولكن معدل الترسيب السنوي للرمال في المنخفض الشمالي (30 كجم/ سنة) وهي أكثر بكثير منه في الجنوبي. إن البحيرة المقترح إقامتها في هذا المنخفض قد يكون لها أثر إيجابي للحياة الفطرية في المنطقة ولكن لا بد من دراسة المردود البيئي لتفادي الآثار السلبية إن وجدت.