Iraqi Bulletin of Geology and Mining *Vol.11, No.1, 2015* *p 79 – 93*
Papers of the Scientific Geological Conference *Part 2*

ALLUVIAL FANS OF THE SLABIAT DEPRESSION, IRAQI SOUTHERN DESERT

Maher T. Zaini[1] and Mawahib F. Abdul Jab'bar[2]

Received: 22/ 08/ 2013, Accepted: 13/ 03/ 2014
Key words: Alluvial fans, Slabiat Depression, Neotectonic, Iraq

ABSTRACT

The Slabiat Depression is one of the largest depressions in the Iraqi Southern Desert; its length in the study area is 65 Km, whereas its width ranges (30 – 32.5) Km. Its depth on the surface ranges (0 – 10) m. The depression is filled with Quaternary sediments. All the main valleys drain in the depression, some of them drain farther the south in Saudi Arabia.

The Quaternary sediments that fill the Slabiat Depression include Sabkha sediments (Pleistocene), alluvial fan sediments (Pleistocene – Holocene), and depression fill sediments (Holocene), in addition to sediments of aeolian origin.

There are eight alluvial fans in the study area, with two stages and clear differences between the fans; in the northwestern and southeastern parts of the depression, they differ in their mode of formation, orientation, size and shape. This is attributed to the different sources of the sediments, supplying the fans. Moreover, the valleys in the northwestern pass through karst terrain.

The development of the alluvial fans requires a drop in gradient, in appition many other factors. However, the drop in the gradient of the valleys and the present gradient of the depression is not sufficient to develop the alluvial fans. Therefore, the development of the alluvial fans had occurred under different conditions than those of the present.

However, neotectonic activity also has contributed to the development of the depression, consequently contributed to the development of the alluvial fans, in the depression.

المراوح الفيضية في منخفض الصليبيات، الصحراء الجنوبية العراقية

ماهر تحسين زيني و مواهب فاضل عبد الجبار

المستخلص

يعتبر منخفض صليبيات احد اكبر المنخفضات في الصحراء الجنوبية العراقية حيث يبلغ طوله في منطقة الدراسة 65 كم ويمتد جنوبا الى جنوب غرب مدينة الناصرية، بينما يتراوح عرضه بين (30 – 32.5) كم. أما عمقه فيتراوح بين(0 – 10) متر. إن المنخفض مملوء بترسبات العصر الرباعي التي تنقل بواسطة العديد من الوديان التي تنحدر من الصحراء الجنوبية العراقية. إن الترسبات الموجودة في منخفض الصليبيات تتكون من ترسبات الصبخه (البلايستوسين)، ترسبات المراوح الفيضيه (البلايستوسين – الهولوسين) وترسبات المالئة للمنخفضات (الهولوسين) بالاضافة الى ترسبات ذات الاصل الريحي.

هنالك ثمانية مراوح فيضية ومرحلتين ضمن منخفض صليبيات. ولوحظ وجود اختلاف في الترسبات في المراوح الموجودة بين الجزء الشمالي الغربي والجزء الجنوبي الشرقي من منطقة الدراسة، وهذا يعود الى مصدر هذه الرواسب واختلاف في شكل المراوح والاتجاه، وسبب هذه الفروقات هو في الغالب يعود الى مصدر الرواسب

[1] Assistant Chief Geologist, Iraq Geological Survey
[2] Assistant Chief Geologist, Iraq Geological Survey

ومرورها بمنخفضات بالاضافة الى وجود صدع ابو جير – الفرات. ان تكون المراوح الفيضية تحتاج الى حدل في الانحدار، إضافة الى عوامل أخرى، إلا أن الانخفاض الموجود في الانحدار الحالي للوديان لا يكفي لتكون المراوح. وعليه فأن المراوح الفيضية الحاليه كانت قد تكونت في ظروف تختلف عن الموجودة حاليا. إن منخفض صليبيات قد تكون بسبب بنيوي، إضافة الى عملية التخسف. إلا أن النشاط البنيوي الحديث قد ساهم أيضا في تكون المنخفض، وهذا بدوره ساهم في تكون المراوح الفيضية في المنخفض.

INTRODUCTION

The eastern part of the Iraqi Southern Desert is characterized by a huge structural feature, represented by the Slabiat Depression, which is in tern represented by Abu Jir Fault Zone. The Dibdibba Formation is exposed in the northeastern edge of the depression, while Nfayil, Ghar and Dammam formations are exposed in its southeast and southwestern edges. The depression drains very large parts of the Southern Desert by numerous (dendritic and sub-parallel) valleys that extend SW – NE direction, where almost all valleys drain in the depression. The depression, which trends almost NW – SE, covers an area of about 2000 Km^2. The length of the depression, is about 65 Km its width is irregular, it ranges (30 – 32.5) Km, the maximum width being in its central part. The depth of the depression ranges (0 – 10) m.

The depression is located in the eastern part of the Iraqi Southern Desert, southwest of Sooq Al-Shiukh town (Fig.1). The study area is approximately limited by 45° 25' 00'' – 46° 15' 00'' E and 30° 25' 00'' – 31° 00' 00'' N.

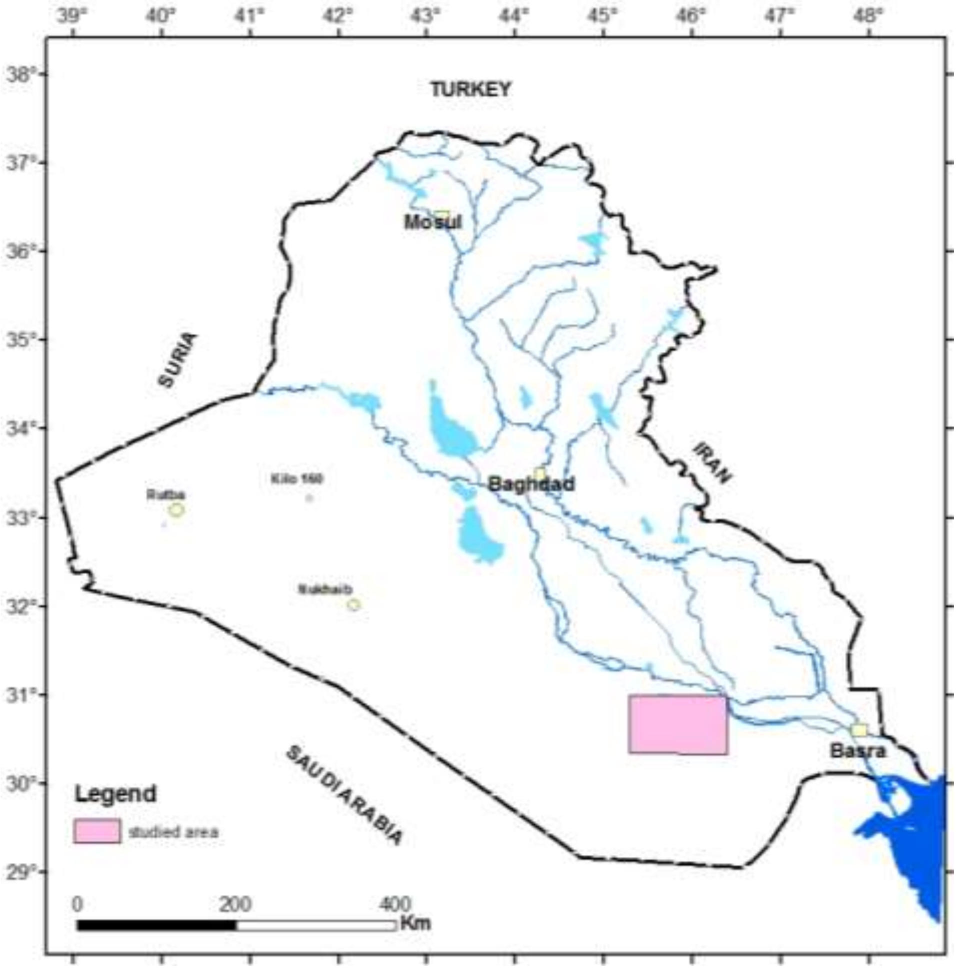

Fig.1: Location map of the study area

The aim of this study is to discuss the origin and geometry of the alluvial fan systems, which is developed in and around the Slabiat Depression. The aim is achieved using different geological data, such as geological field work, geological and topographic maps of different scales, satellite images and GIS applications.

GEOLOGICAL SETTING

The geology of the study area is briefly mentioned hereinafter, depending on the available data.

▪ Geomorphology

The study area is located in two physiographic provinces, which are the Desert Plain and Mesopotamian Plain (Sissakian *et al*., 2008). Each of them has its own geomorphological characteristics. The latter is characterized by flat nature with elevation of (7 – 19) m (a.s.l.), whereas, the former shows a gradual increase in height towards the west and south. The highest and lowest points are 200 m and 7 m (a.s.l.), respectively. The former is located in the southwestern corner, whereas the latter is in the northeastern part of the study area (Fig.2).

Geomorphology of the Slabiat Depression is controlled by three major aspects: climate, lithology and drainage pattern; by means of the last; numerous valleys drop their sediments in the depression. The complex drainage pattern developed the alluvial fans system, which trends SW – NE, is similar to the trend of the main valleys. The developed drainage pattern has a different density, in areas where the Dammam formation is exposed; the density is low, because of the karst features, and the development of immature valleys. In areas where the Ghar and Nfayil formations are exposed; on the other hand the drainage pattern is well developed, being of parallel and/ or dendritic type (Deikran, 1995).

The alluvial fans have almost typical fan shape, with concave to flattened surfaces, two shapes were recognized: the first group has delta shape, whereas the second group has Finger bird shape as displayed in the satellite images. The depression is locally filled by depression fill sediments and has valley fill sediments too; both are typical for desert areas. The geomorphological units in the depression are of alluvial, denudational and aeolian origin.

▪ Stratigraphy

The geological map of the studied area (Fig.3) shows the following succession:

– **Dammam Formation (Eocene):** is described by Al-Mubarak and Amin (1983) as nummulitic, chalky and dolomitic limestone (Early Miocene) 5 – 18 m thick overlain unconformably by the Ghar Formation, which is a certified and sandy limestone (Zaini *et al*., 2013), Al-Ani and Ma'ala (1983). It is overlain by the Middle Miocene Nfayil Formation followed by the Dibdibba Formation which consists of 4 – 23 m of clastic rocks.

– **Quaternary Sediments:** consists of the following constituents:

Valley Fill Sediments (Holocene): The main valleys are filled by different clastic sediments. The main composition is carbonates with silicates; the pebbles are rounded to subrounded, with average size of (1 – 10) cm, but may reach to 25 cm. The thickness ranges (0.5 – 2.5) m, but locally may exceed 5 m.

Depression Fill Sediments (Holocene): The sediments are mainly of clay and silt, locally, within the main Slabiat Depression. The thickness ranges (0.5 – 1.5) m.

Aeolian Sediments (Holocene): The sediments are mainly sand. There are several types of these sediments such as sand dunes which are considered the boundary of all alluvial fans in the study area, Nabkha and sand sheets are developed above the alluvial fan top surfaces.

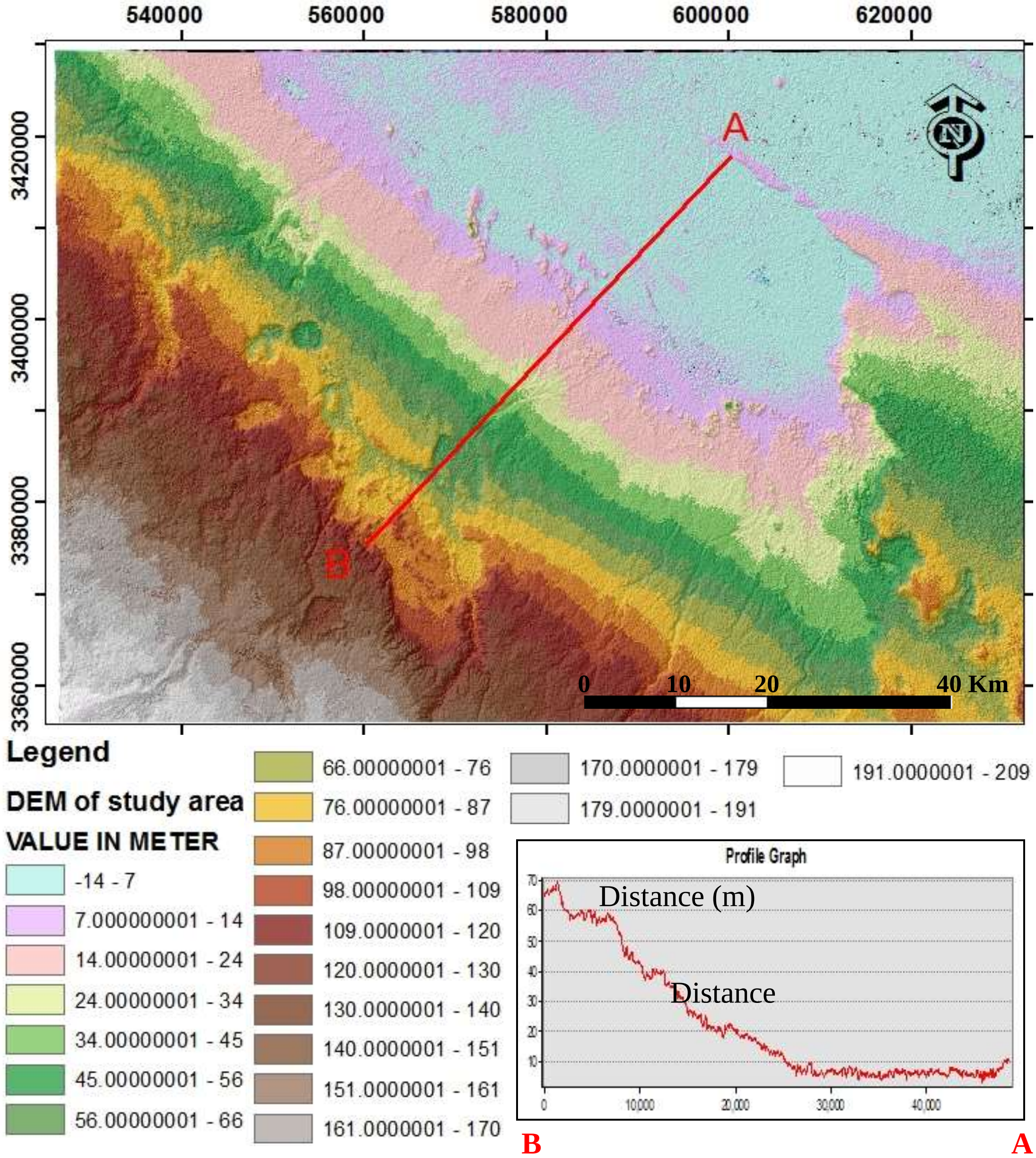

Fig.2: 3D Topographic map of the studied area showing Slabiat Depression and topographic profile

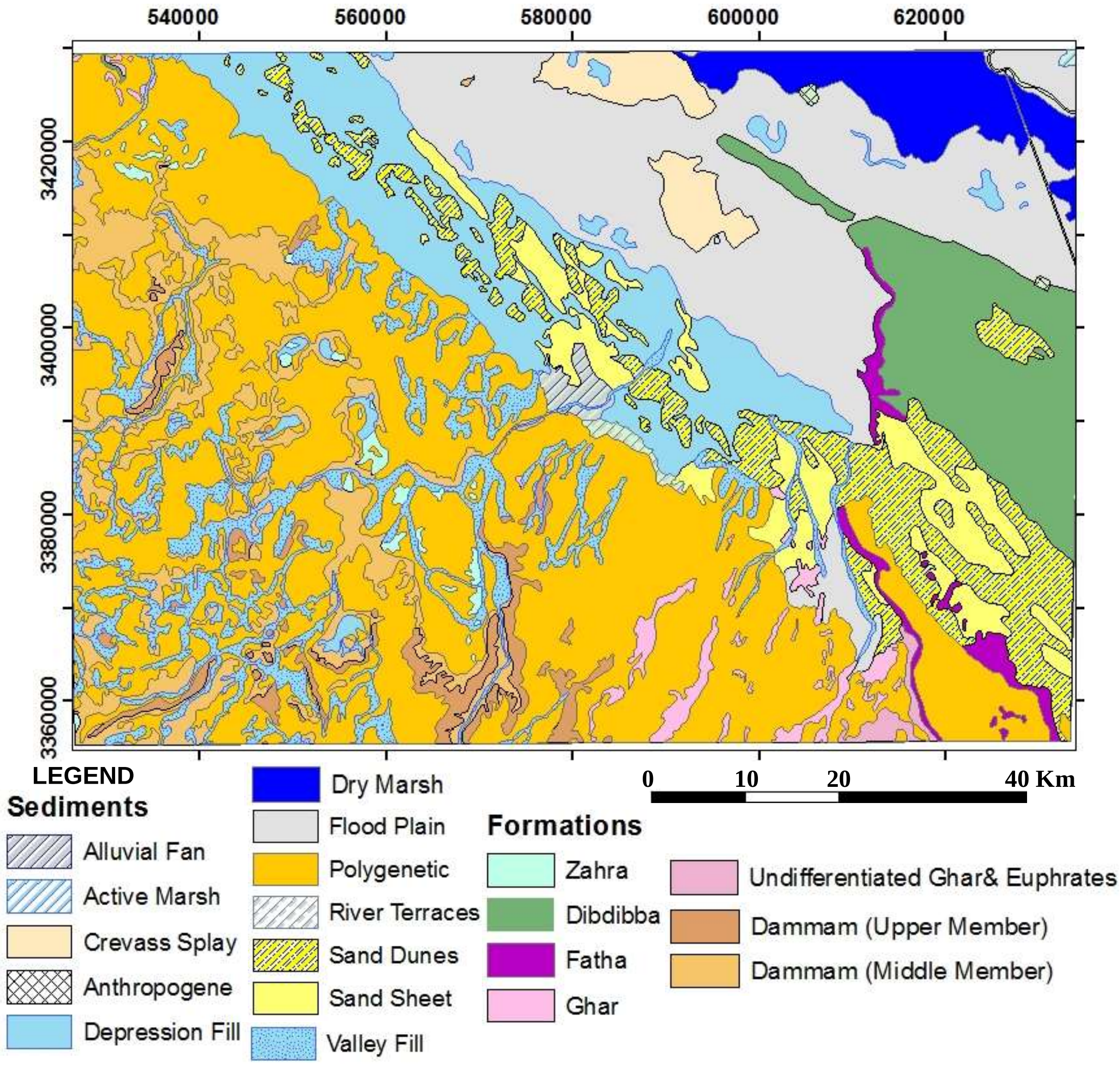

Fig.3: Geological map of the study area (after Deikran, 1995)

- **Structural Geology**

The study area is located within the Stable Shelf of the Arabian Plate (Buday and Jassim, 1984; Al-Kadhimi *et al*., 1996; and Jassim and Goff, 2006). However, according to Fouad (2012), it is located within the Inner Platform of the Arabian Plate. From the Neotectonic point of view, the study area is uplifted. The amount of the uplift ranges (325 – 400) m, whereas the estimated rate of the uplift is about 0.2 cm/100 year (Sissakian and Deikran, 1998).

The tectonic effect is often interrelated with the development of the alluvial fans. Alluvial fans are usually developed at the margins of sedimentary basins, which can be sites for tectonic activity, with fault movements along the basin margins; creating uplift of the catchment area and subsidence in the basin (Fig.4). It is, therefore, possible to see evidence of neotectonic activity within the alluvial fan succession (Bull and McFadden, 1977; and Bull, 2009).

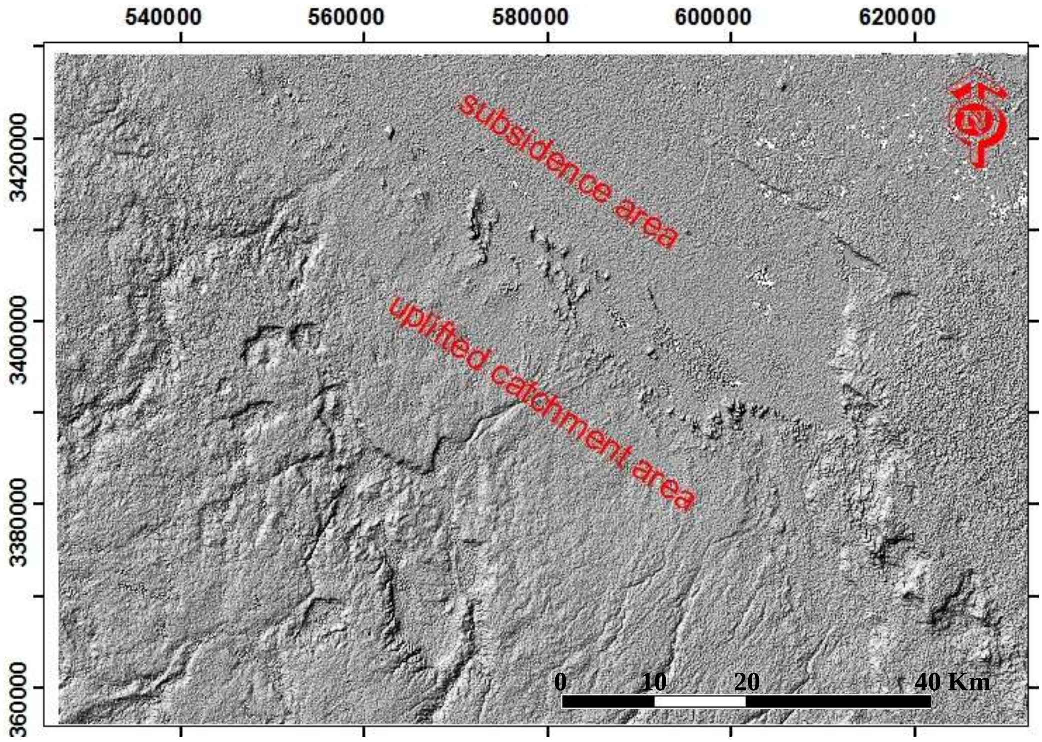

Fig.4: 3D image of the study area shows the uplifted catchment area and subsidence area

THE SLABIAT ALLUVIAL FANS

Alluvial fans are common features in many arid and semi-arid regions and provide an important record of Quaternary tectonics and climate change (Bull, 1991). The sediments of the fans are often expressed as multiple surfaces that can be distinguished from one another by their relief and height above the active channel (Crouvi *et al*., 2006). Three conditions are necessary for optimal alluvial fan development, these are: **a)** a topographic setting where a channel becomes unconfined by emerging from an upland drainage basin on to a relatively flat lowland, **b)** sufficient sediments production in the drainage basin for fan construction, and **c)** infrequent intense precipitation to create high water discharge basin to the fan site. The most typical topographic setting for alluvial fan is marginal to uplifted structural blocks boundary by faults with significant dip-slip. Fans in desert traditionally have been studied due to their excellent exposure and ease of access (Blair and McPherson, 1994).

There are eight alluvial fans, which can be recognized by satellite images and field works; in the study area. They are divided into two groups (Fig.5). Hereinafter, the fans are described in details as they are present; from the northwest to the southeast.

- **First Group**

This group includes three alluvial fans.

– **Ain Hinood Alluvial Fan (No.1):** It is composed of soil (silt and clay). It's 3 Km long, 2 Km wide, and (1.0 – 1.5) m thick, with a total area of about 5 Km^2.

– **Al-Dheeb Alluvial Fan (No.2): It is composed of soil (silt and clay). Its length and** width are 1.7 and 2 Km, respectively, with a thickness range of 1.0 – 2 m, and total area of about 2.8 Km^2.

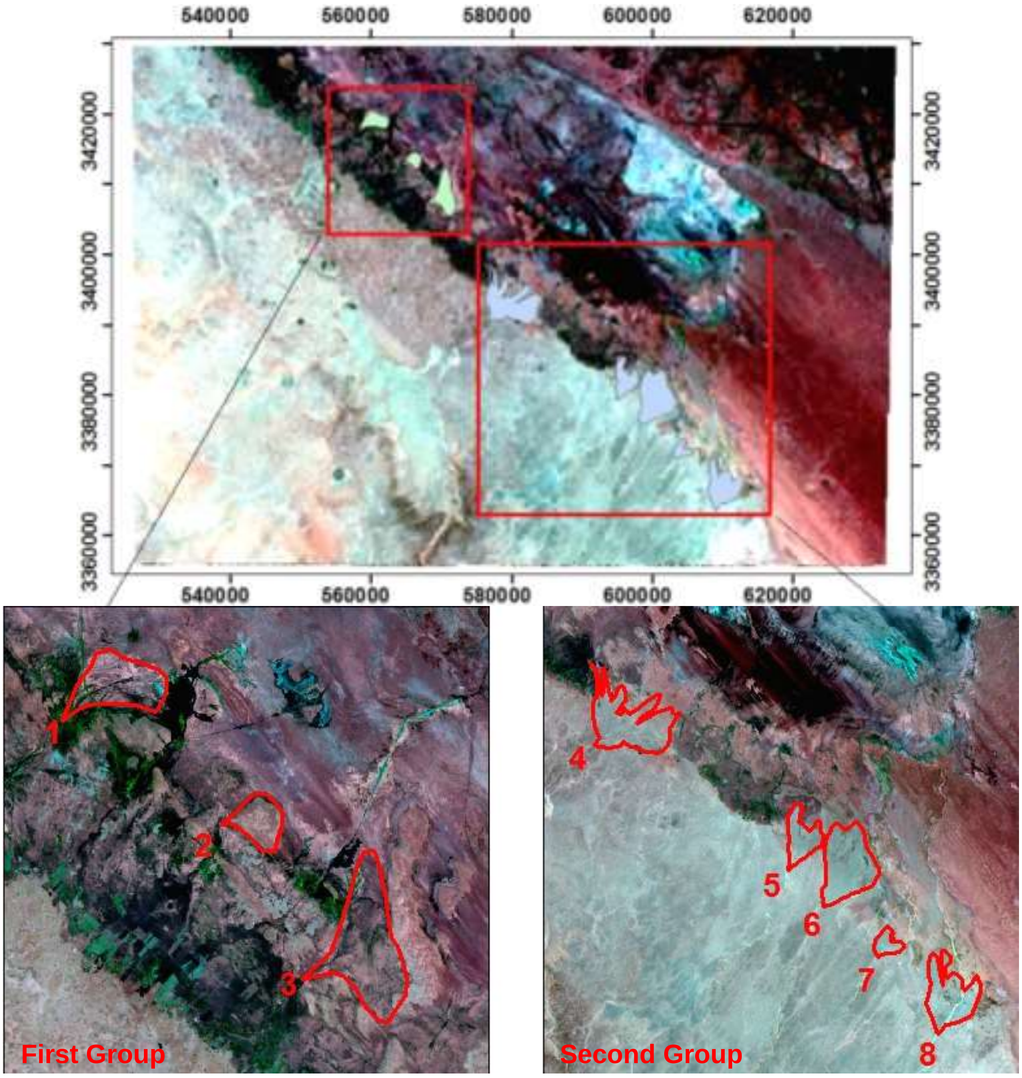

Fig.5: First and Second Groups of alluvial fans in study area

— **Shali Alluvial Fan (No.3):** It is composed of soil (silt and clay). Its length and width are 4 and 3.5 Km, respectively, with a thickness range of 1.0 – 2 m, and total area of about 9.7 Km^2.

The alluvial fans of the First Group are composed of soil because their source is from Dammam Formation (Middle and Upper Members), which are composed of hard carbonate rocks, with several karst features along the valleys, where most of the sediments are dropped in the karst forms.

- **Second Group**

This group includes five alluvial fans:

— **Qusair Alluvial Fan (No.4):** It is a mixture of soil and carbonate rock fragments with a cover of gypcrete, its length and width are 5.5 Km and 7.5 Km, respectively, and a thickness range of 3.0 – 7.0 m, with total area of about 34.5 Km^2.

– **Ghwair Alluvial Fan (No.5):** It is a mixture of soil and carbonate rock fragments. it is 6.5 Km length, 4.25 Km width, and has thickness range of 1.5 – 3.50 m with total area about 10.7 Km^2.

– **Sdair Alluvial Fan (No.6):** It is a mixture of soil and carbonate rock fragments, 6.7 Km length, 4 Km width, and has thickness ranges of 2.0 – 4.5 m with total area about 23 Km^2.

– **Khanga Alluvial Fan (No.7):** It is a mixture of soil and carbonate rock fragments. it is 2.5 Km lenth, 1.7 Km width, and has thickness range of 2.0 – 5.0 m with total area about 3.4 Km^2.

– **Abu Ghar Alluvial Fan (No.8):** It is a mixture of soil and carbonate rock fragments, 6 Km long, 4.5 Km wide, and has thickness range of 2.0 – 4.0 m, with a total area of about 21 Km^2.

Alluvial fans of the Second Group are composed of rock fragments because their source is from Ghar and Euphrates formation, which are composed of carbonate and clastic rocks.

The distribution, composition and geometry of the studied alluvial fans in the Slabiat Depression reflect a characteristic depression asymmetry that consists of small and asymmetrical fans located along southwestern margin. The difference in the alluvial fans geometry and composition implies that the margin of Abu Jir fault zone exhibits some control on the sediments, therefore these alluvial fans indicate neotectonic activity.

- **Climatic Effects**

Alluvial fans are a prominent land form type commonly related to climatic regimes. The role of the climate in the formation of alluvial fans is discussed by different authors, among whome are Tuan (1962); Lusting (1965); Melton (1965); Wells *et al*. (1990); Bull (1990), and Dorn (1994). They all believe that the climatic changes influence the weathering, stream flow, mass movements and sediment supply in the drainage basin above the fans; as well as the wadies, and soil development of fan deposits. Therefore, the role of the climate in the formation of alluvial fans is essential. In the study area, although the present dry climate prevails, but during Pleistocene and Holocene, successive wet and dry stages were commen as indicated by the present two stages of fans, and the gypcrete cover indicating the dry climate of the present day, especially in the Second Group of fans.

- **Formation of the Fans**

Alluvial fans are formed due to decrease of gradient of a stream; due to drop in local base level, hence the coarse grained solid materials carried by the water are dropped (Sissakian and Abdul Jabbar, 2013). As this reduces the capacity of the channel, the channel will change direction over time; gradually building up a slightly mounded or shallow fan shape (Sissakian, 2011).

A change in climate can also result in changes in the processes of deposition on a fan. For example, with an increase in rainfall more water is available and this may result in a predominance of sheet flood and stream-channel processes, with less debris-flow events occurring (Harvey, 2002; and Harvey *et al*., 2005). The more resistant rocks will break down to pebble and gravel size, which is transported and deposited by sheet flood and stream-channel processes (Ryder, 1971 and Blair, 2003) such sediments is found in Khanga fan, which is developed in the southeast part of the study area. Therefore, the sediments are usually coarse grained, poorly sorted and heterogeneous. "The fan shape can also be explained with a thermodynamic justification: the system of the sediment introduced at the apex of the fan will trend to a state, which minimizes the sum of the transport energy involved in moving the sediment and the gravitational potential of material in the cone" (American Geological Institute, 1962). Therefore, there will be iso-transport energy lines forming concentric arcs about the discharge point at the apex of the fan. Thus, the materials will tend to be deposited equally about these lines, forming the characteristic cone shape (National Aeronautics and Space Administration, 2009). In the study area, valleys flow from the plateau of the Southern Desert that is highly dissected by dense valleys, the gradient drops gently along the southwestern margin of the Slabiat Depression, consequently the energy decreases leading to deposition of the coarse sized materials and the formation of the first stage of alluvial fans. After this break in the slope, the transportation and deposition of the materials continue depending on the particle size, either to form the second stage fans or to be deposited as depression and/ or valley fill sediments.

- **Mode of Deposition**

Alluvial fans are sediments with a form that resembles the segments of a cone radiating down-slope from a point where a channel emerges from an upland (Bull, 1991). Fans commonly have a semi-circular or pie-piece plan view shape whereas cross-profile displays a Plano-convex shape. In the study area, alluvial fans are Delta-like (First Group) and Finger bird-like (Second Group) deposits of granular debris that extend from a high front to a low land below. Each fan radiates from a single source channel, and has fan-like shape in plane view, slopes are usually less than (3 – 4)°. The fans are best developed in semiarid deserts, where elongate mountain ranges that are tectonically active (basin-and-range topography) and lack protective vegetation cover are subjected to erosion by episodic heavy rain precipitation (Bull, 1991 and Veronica, 2010). In the studied area, the Southern Desert is the source area for formation of the alluvial fans; it forms a wide plateau covered by Cenozoic rocks, with maximum height of 200 m, almost with poor vegetation cover, forming the range topography. In front of it, the Slabiat Depression is the depositional basin, where the alluvial fans are formed. Therefore, the "basin-and-range topography" is not typically formed in the studied area. The range area is in form of plateau, not a mountainous area, consequently the gradient of the valleys, which dissect the range, is not high.

- **Shape**

The detail descriptions for the constituents of the alluvial fans; of the study area are acquired from field work. The shape of the fans is related to grain size. Fans built of gypsious soil, small rock fragments and pebbles have a high pronounced arch, whereas, those built of silt, sand and fine gravels have broad, flattened profiles (Bull, 1991). In the study area, the average size of the pebbles ranges of 1 – 10 cm, for the Second Group. The pebbles are composed mainly of limestone, dolostone and chert. The exposed thickness of the alluvial fans of the Second Group ranges of 1.0 – 2.0 m for first stage, and may reach (2.0 – 4.0) m for the second stage, whereas the exposed thickness of the First Group ranges 1.0 – 2.0 m. The large pebbles were carried in a matrix of semi-fluid mud; therefore, they have typical fan shape, whereas the finer sizes were carried to farther distances, to form the Second stage. Part of the sediments was also carried and transported by valleys (streams) and deposited either as valley fill sediments or to form the depression fill sediments of the Slabiat Depression.

"The First Group fans have ideal fan shape, because the shape is a function of the size, as coarse the materials are, as typical concave shape is formed" (USGS, 2004). The typical concave shape also indicates the activity and transportation ability of the stream, because there will be iso-transport energy lines forming concentric arcs about the discharge point at the apex of the fan (Sissakian and Abdul Jabbar 2013). However, the Second Group fans have less concave shape with broad flattened top (Fig.6). Because the sediments are finer as compared to the constituents of the First Group, the insufficient renewal of the supplied materials that decrease as the climate changes to more dry with less rain fall, consequently less sediments supply, and also the karsts present along wadies.

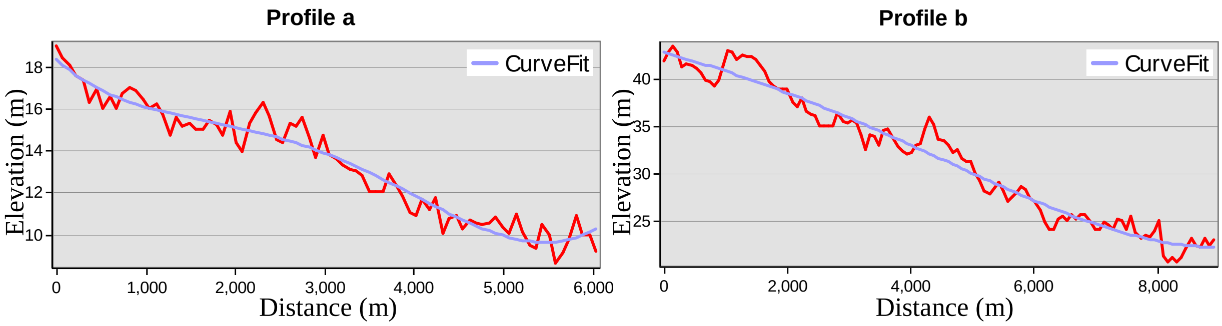

Fig.6: **a)** Profile section along alluvial fans of the First Group,
b) Profile section along alluvial fans of the Second Group
(Taken from DEM)

Alluvial fans are composite structures whose units differ in surface shape and structure. "Components of the fans include: Active stream channels that originate in the high lands and which transport detritus to areas of deposition as well as cut into, erode, or override previous deposits. Abandoned and locally elevated older areas of deposition lie between channels. Internally formed dendritic channels within older deposits erode the developed surfaces and redistribute the debris to depositional areas down slope" (Bull, 1991 in Sissakian and Abdul Jabbar 2013). In the studied area, the "active stream channels" are very rare, nowadays, due to the semi arid climatic conditions, as compared to prevalent wet climate during formation of the alluvial fans (during Pleistocene and early Holocene), they could be seen on the satellite images, as light tone valleys or streams, whereas the older ones are more darker. The "abandoned elevated areas" could be seen very clearly, especially in the first stage of the Second Group alluvial fans, where the Qusair Alluvial Fan in the typical fan shape (No.4) (Fig.7). The "internally formed dendritic channels" also could be seen everywhere in the fans of the studied area. The light tone parts of alluvial fans are the younger and active parts of the fans (USGS, 2004). This criterion was used in this study to indicate the active parts of the alluvial fans, as well as the active streams and/ or valleys, along the fans.

- **Gradient**

The low gradient also causes drop in transporting energy, consequently the iso-transport energy lines will lose their concentric shapes (American Geological Institute, 1962 and National Aeronautics and Space Administration, 2009). In the study area, transporting energy drops down continuously in the two stages (Fig.8). This is another reason that explains the deposition of the sediments, between the fans as normal valley and/ or depression fill sediments. The first break in the gradient is along the southwestern rim of the Slabiat Depression. The second break in the gradient is within the depression, indicating neotectonic activity in the area (Sissakian and Deikran, 2009).

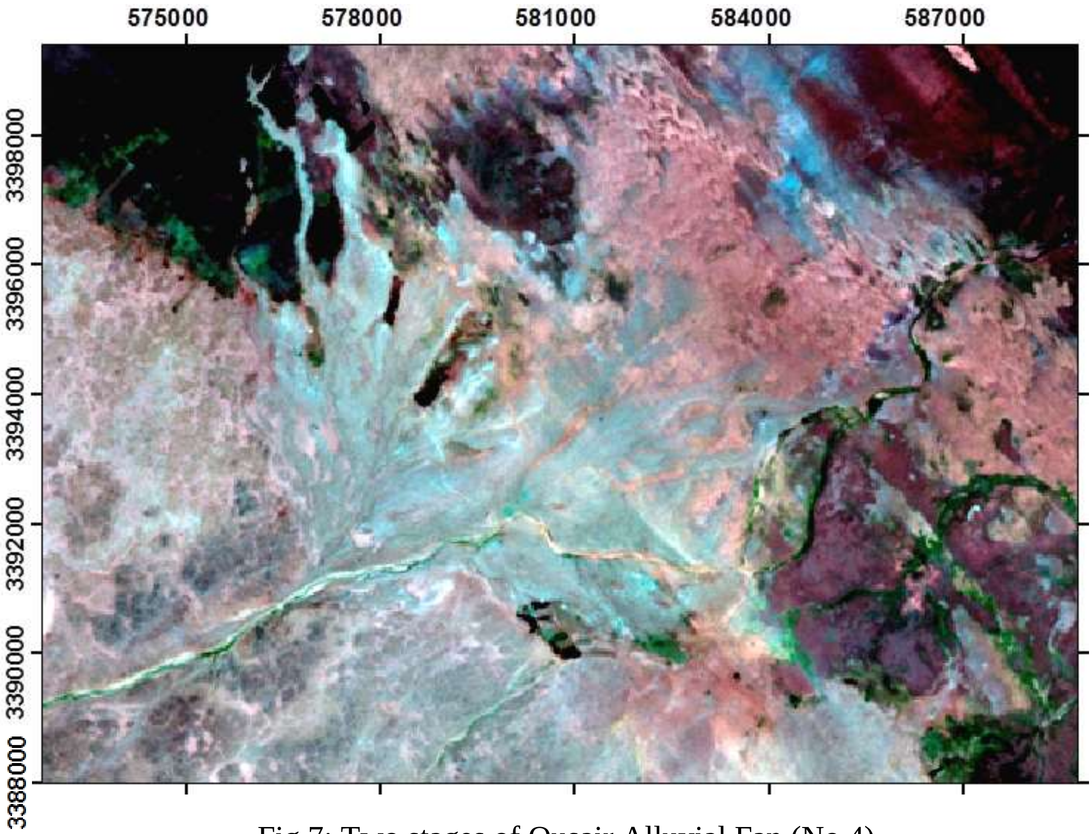

Fig.7: Two stages of Qusair Alluvial Fan (No.4)

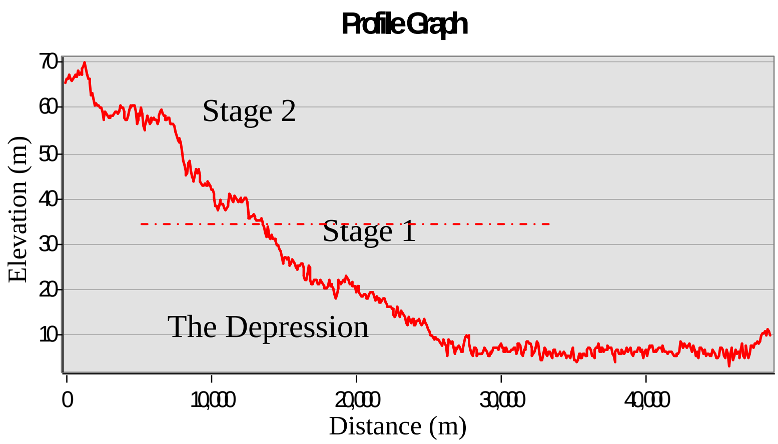

Fig.8: Two breaks in the gradient along Qusair Alluvial Fan

▪ **Streams and Channels**

Within the alluvial fans of the study area, the flowing active stream channels could be clearly seen in Satellite images (Fig.9).

The active stream transport the sediments to areas of deposition as well as cut into, erode, or override previous deposits, abandoned and locally elevated older areas of deposition that lie between channels. Also well developed dendritic channels could be seen, although partly inactive, as indicated from their dark color, as compared to those, which are active and appear in lighter tones.

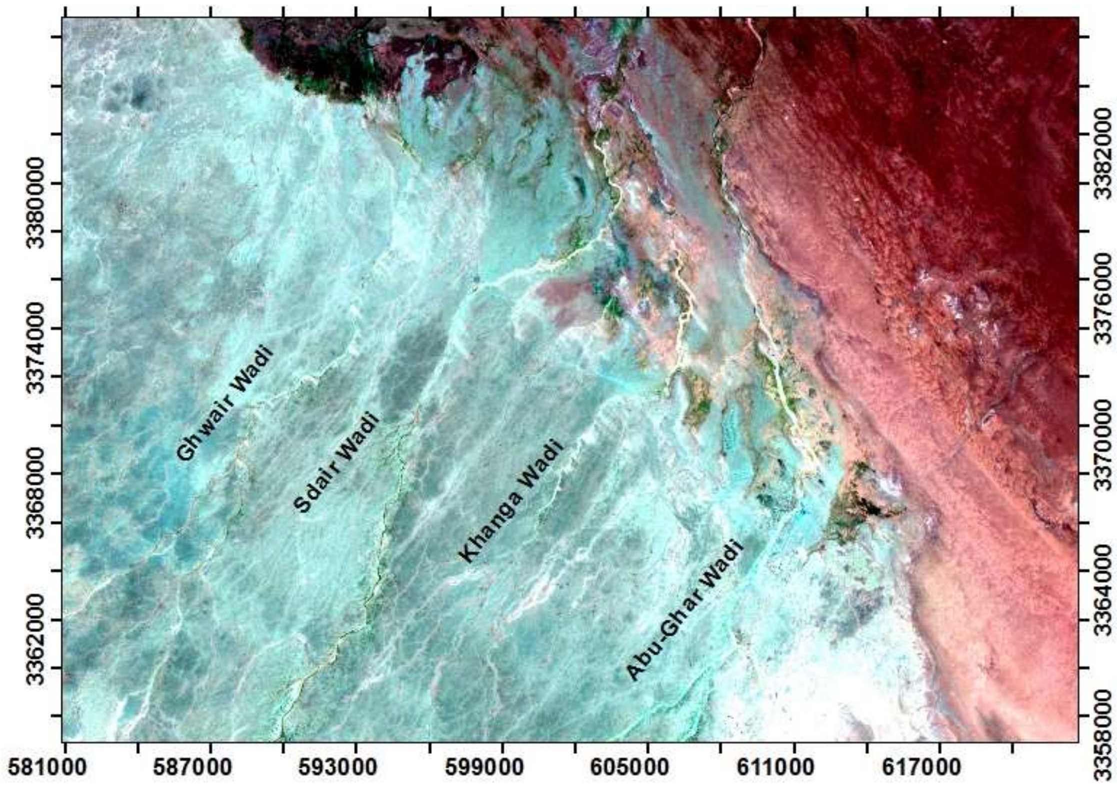

Fig.9: The flowing active stream channels appear in lighter tones

DISCUSSION

The main source of the alluvial fans is the Cenozoic formations that are exposed in the eastern and central parts of the Southern Desert. The exposed formations are Dammam, Euphrates, Ghar, Nfayil and Dibdibba. These formations contain considerable amount of soft rocks interbedded with hard rocks. Therefore, they are easily eroded and transported and deposited in the active Slabiat Depression, as alluvial fans.

The age of the alluvial fans of the first stage is most probably of Early Pleistocene, whereas, those of the second stage are of Late Pleistocene – Holocene. This assumption is based mainly on the climatic changes during Pleistocene – Holocene with the related rate of sediments supply, and the shape of the fans, beside the tone differences in the fans' sediments and those of the dissected streams and valleys. It is also believed that the fans of the second stage still receive sediments, but not those of the first stage.

The Slabiat Depression is tectonically an active depression, which receives sediments from numerous valleys that drain the eastern part of the Iraqi Southern Desert. These valleys drop their sediments in the depression forming alluvial fans, due to drop in the stream gradients. Although the drop in the gradient is not large, still two stages of alluvial fans are developed, indicating, most probably neotectonic activity. The fans are composed of medium to fine sized materials, in the southeast (fan numbers from 4 – 8), whereas fans (numbers 1 and 3) are composed of soil only (silt and clay) in the northwest. As this difference between them lie in the source of the sediments, therefore, the developed fans have typical concave profile shape.

Eight alluvial fans are developed in the study area, they are divided into two groups because they are different in shape and composition, and each group consists of two stages.

The first stage is the older with more coarse sediments and more concave shape, as compared to the second (younger) stage. The coarse size of the first stage indicate wet climate, as compared to the second stage, with more transportation ability. The second stage is of Holocene age, and they are still active, especially during heavy floods in the valleys of the Southern Desert. These valleys are also indicated by the light tone surface of the fans, as well the light tone valleys, which are good indication for their activity (USGS, 2004).

The development of the two stages of alluvial fans indicates a break in the gradient of the Slabiat Depression; otherwise only one stage would have been developed. However, the break in the gradient inside the depression should be accompanied by a subsidence in the depression, which means neotectonic activity. Such activity is proved by Sissakian and Deikran (2009).

Although the studied area is located in the Inner Platform of the Arabian Plate, it suffers from tectonic unrest. The active Abu Jir Fault Zone and its extension, the Euphrates Fault Zone are good examples (Fouad, 2007). The continuous changes of valley trends and abnormal terrace accumulation along them especially at wadi khanga, the dislocated valleys and to control of their courses, are good indications for Neotectonic movements.

Such activities are attributed to Neotectonic movements by different researchers (Markovic *et al*., 1996; Kumanan, 2001; Cohen *et al*., 2002; Mello *et al*., 1999; Bhattacharya *et al*., 2005; Jones and Arzani, 2005; Philip and Vidri, 2007; and Woldai and Dorjsuren, 2008) in Sissakian and Abdul Jabbar, (2013)

It is believed that all the valleys were continuously flowing northeastwards and discharging to the Slabiat Depression due to subsidence of the Slabiat Depression where the valleys are terminated. The subsidence of the depression is also indicated by the fact that many of the fans are still active, as indicated by their tones. Such active fans may indicate active subsidence, indicting Neotectonic movements (Mello, 1999; Jones and Arzani, 2005; Philip and Virdi, 2007; and Woldai and Dorjsuren, 2008)

CONCLUSIONS

This study has the following conclusions:

- There are eight alluvial fans within the Slabiat Depression and its surrounding.
- The alluvial fans are divided into two groups according to their lithology, shape, and geometry.
- There are two stages of alluvial fans for two groups which are developed due to break in the gradient within the Slabiat Depression. The break of the gradient is attributed to continuous subsidence of the depression. The subsidence might be due to tectonic effect.
- The age of the alluvial fans is probably Early Pleistocene, for the first stage and Late Pleistocene – Holocene for the second stage, parts of which are still active, although the present day climate witnesses a dry condition.

REFERENCES

Al-Kadhimi, J.A.M., Sissakian, V.K., Fattah, A.S. and Deikran, D.B., 1996. Tectonic Map of Iraq, scale 1: 1000 000, 2nd edit. GEOSURV, Baghdad, Iraq.

Al-Ani, M.Q. and Ma'ala, K.A., 1983. Report on the regional geological mapping of North of Busaiya area. GEOSURV, int. rep. no. 1349.

Al-Mubarak, M. and Amin, R.M., 1983. Report on the regional geological mapping of the eastern part of the Western Desert and western part of the Southern Desert. GEOSURV, int. rep. no. 1380.

American Geological Institute, 1962. Alluvial Fan. Dictionary of Geological Terms. New York, Dolphin Books. Wikipedia, the Free Encyclopedia.

Bellen, R.C. van, Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq.

Blair, T.C. and Mcpherson, J.G., 1994. Alluvial Fan Processes and Forms. Geomorphology of Desert Enviroments. London, p. 354 – 366, Chapter 14.

Blair, T.C., 2003. Features and origin of the giant Cucomungo Canyon alluvial fan, Eureka Valley, California. Geological Society of America Special Paper 370, p. 105 – 126.

Buday, T. and Jassim, S.Z., 1984. Tectonic Map of Iraq, scale 1: 1000 000, 1st edit. GEOSURV, Baghdad, Iraq.

Bull, W.B., 1991. Geomorphic Responses to Climate Change. Oxford University Press.

Bull, W.B., 2009. Tectonically Active Landscape, 280pp.

Bull, W.B. and McFadden, L.D., 1977. Tectonic geomorphology N. and S. of the Garlock fault, California, In: Doehring, D.O., Geomorphology in arid regions, Binghampton, Suny, p. 115 – 138.

Bramkamp, R.A., 1941. Dammam Formation in the regional Geology of Iraq.

Crouvi O., Ben-Dor E., Beyth M., Avigad D., Amit R., 2006. Quantitative Mapping of arid alluvial fan surface using field spectrometer and hyperspectral remote sensing .Remote Sensing of Environment, p. 103 – 117.

Deikran, D.B., 1995. The geology of Suq Al-Shookh Quadrangle Sheet No. NI-38-07, scale 1: 250 000. GEOSURV. Baghdad, Iraq.

Fouad, S.F., 2007. Tectonic and Structural Evolution. In: Geology of the Iraqi Western Desert. Iraqi Bull. Geol. Min., Special Issue, No.1, p. 29 – 50.

Fouad, S.F., 2012. Tectonic Map of Iraq, scale 1: 1000 000, 3rdedit. GEOSURV, Baghdad, Iraq.

Harvey, A.M., 2002c. The relationships between alluvial fans and fan channels within Mediterranean mountain fluvial system. In: Bull, L.J., and Kirkby, M.J., Dryland rivers: Hydrology and geomorphology of semi-arid channels. Wiley, Chichester, p. 205 – 226.

Harvey A.M., Mather A.E., Stokes M., 2005. Alluvial fans: Geomorphology, Sedimentology, Dynamics. Geological Society Special publication No.251, London, 248pp.

Jones, S.J. and Arzani, A., 2005. Alluvial fan response times to tectonic and climatic driven processes: example from the Khrud mountain belt, Central Iran. Geophysical Research Abstracts, Vol.7, 07380. European Geosciences Union

Jassim, S.Z., and Goff, J.C., 2006. Geology of Iraq. Published by Dolin, Prague and Moravian Museure, Brno, Czech Republic, 341pp.

Kumanan, C.J., 2001. Remote sensing revealed morphotectonic anomalies as a tool to Neotectonic mapping, experience from South India. 22nd Asian Conference on Remote Sensing, 5 – 9 November, 2001, Singapore, National University of Singapore.

Markovic, M., Pavlovic, R., Cupkovic, T. and Zivkovic, P., 1996. Structural pattern and Neotectonic activity in the Wider Majdanpek area, NE Serbia, Yugoslavia. Acta Montanistica Slovaca, Rocnik 1 (1996), 2, p. 151 – 158.

Mello, C.L., Metelo, C.M.S., Suguio, K. and Kohler, C.H., 1999. Quaternary sedimentation, Neotectonic and evolution of the Doceriver middle valley lake system (SE Brazil). Revista do Instituto Geologico, IG Sao Paulo, Vol.20, No.1/2, p. 29 – 36.

National Aeronautics and Space Administration, 2009. Geomorphology from Space; Fluvial Landforms, Chapter 4. Internet data.

Philip, G. and Virdi, N.S., 2007. Active faults and Neotectonic activity in the Pinjaur Dun, NW Frontal Himalaya. Wadia Institute of Himalayan Geology, 33, Gen. Mahadeo Sing Road, Dehra Dun, 248 001, India.

Ritter, D.F., Kochel, R.C. and Miller, J.R., 2002. Process Geomorphology. McGraw Hill, Higher Education, 560pp.

Ryder, J.N., 1971. The stratigraphy and morphology of south central British Columbia, Canadian Journal of Earth Sciences 8, PP:279–298.

Sissakian, V.K., 2011. Alluvial fans of Sinjar Mountain, Northwest Iraq. Iraqi Bull. Geol. Min., Vol.7, No.2, p. 9 – 26.

Sissakian, V.K. Abdul Ahad, Ayda D. and Qanber, Ala'a Sh., 2013. Series og Geological Hazurd maps of Iraq,Sooq Al-Shyookh Quodrangle, scale 1: 250 000. GEOSURV, Baghdad, Iraq.

Sissakian, V.K. and Deikran, D.B., 2009. Neotectonic movements from west of Iraq. Iraqi Bull. Geol. Min., Vol.5, No.2, p. 59 – 73.

Sissakian, V.K. and Abdul Jabbar, M.F., 2013. Alluvial fans of the Habbariyah depression, Iraqi western desert. Iraqi Bull. Geol. Min., Vol.5, No.1, p. 59 – 73.

USGS, 2004. Desert Working Group, Knowledge, Science Incorporation, Alluvial Fans. Internet data.

Veronica, I.S., Mechael, A.M., William, R.O., Lin, D. and Ran, Z., 2010. Structural evolution of the Neogen Gar Basin, Western Tibet. Implications for releasing bend development and drainage patterns. Geological society of America Bulletin, May/June 2010.

White, W.B. and White, E., 2006. Size scales for closed depression landforms: The place of "tiankengs". Speleogenesis and Evolution of Karst Aquifers. The Online Scientific Jour., ISSN 1814-294X.

Woldai, T. and Dorjsuren, J., 2008. Application of remotely sensed data for Neotectonics study in Western Mongolia. Commission VI, Working Group V, Internet data.

Zaini M.T., Al-Shawi, S., Beshir, W.Ph., Al-Kubaisi, K.N., Rheema, R.H., KHadhem, F.Z., Al-Doori, A., Al-Samarrair, B.A., Mousa, H., 2013. Geological Mapping of South Al-Nasiriya, scale 1: 25 000. GEOSURV, Baghdad, Iraq. in press.

About the authors

Mr. Maher. T. Zaini graduated from University of Baghdad in 1994 with B.Sc. degree in Geology, and joined GEOSURV in 1999. He got M.Sc. in Structural Geology from University of Baghdad in 2006. Currently, he is working as Project Manager of a mapping field group. He has 7 documented reports and published articles. His major field of interest is structural geology.

e-mail: mahirzaini@yahoo.com
Mailing address: Iraq Geological Survey, P.O. Box 986, Baghdad, Iraq

Mrs. Mawahib F. Abdul Jab'bar graduated from Baghdad University in 1994 and joined GEOSURV in 1999; she got her M.Sc. Degree in Geomorphology (Morphotectonics) in 2012, from Baghdad University. Currently, she is working as Assistant Chief Geologist in the Geology Department. She has 18 documented reports in GEOSURV's library and 17 published articles in GIS applications and remote sensing interpretations. Her main field of interest is GIS applications and remote sensing interpretations.

e-mail: mawaheb_geosurv@yahoo.com
Mailing address: Iraq Geological Survey, P.O. Box 986, Baghdad, Iraq