

## USING REMOTE SENSING AND GIS TECHNIQUES IN DETECTING THE ORIGIN OF UMM CHAIMIN DEPRESSION, WEST IRAQ

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### ABSTRACT

The Umm Chaimin Depression is the most outstanding and conspicuous geomorphic feature in the southwestern part of the Iraqi Western Desert. It is an almost circular depression with 2.9 Km diameter and 28 m depth. The exposed carbonate rocks on the surface and in depth belong to Ratga Formation (Eocene) that forms flat area and the beds dip off the depression. Therefore, the depression is invisible unless from a distance of few tens of meters, although a lot of rock fragments of different sizes occur near the rims.

Previously, different concepts are recorded about the origin of the depression. These are meteoritic impact, volcanic origin, gas explosion and karst origin. In this study, different geological, geophysical and remote sensing data with GIS techniques are used to indicate the origin of the depression. Eighteen different parameters are studied and used for comparing the present characteristics of the Umm Chaimin Depression with those of aforementioned four different origins. Majority of the parameters fit with those of karst origin.

### استخدام تقنيات التحسس النائي ونظم المعلومات الجغرافية لمعرفة أصل منخفض أم جيمين، غرب العراق

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### المستخلص

يعتبر منخفض أم جيمين من أهم الظواهر الجيومورفولوجية الموجودة في جنوب غرب الصحراء الغربية العراقية. وللمنخفض شكل شبه دائري وقطره حوالي 2.9 كم وعمقه 28 متر. إن الصخور المتكشفة على السطح وبالعمق هي صخور كاربوناتية تعود لتكوين الرطكة (الإيوسين) والتي تشكل أرض منبسطة وتميل الطبقات خارج المنخفض. وعليه لا يمكن رؤية المنخفض إلا من مسافة قريبة وبحدود عشرات الأمتار، بالرغم من وجود قطع صخرية وبأحجام مختلفة متناثرة حوله.

توجد عدة أفكار حول أصل نشوء المنخفض، منها سقوط نيزك أو بسبب انفجار غازي أو من أصل بركاني، أو من أصل الإذابة (الكارست). في هذه الدراسة استخدمت معطيات جيولوجية وجيوفيزيائية والتحسس النائي إضافة إلى معطيات الـ GIS للتوصل إلى أصل نشوء المنخفض. استخدم 18 متغيراً مختلفاً لمقارنة الموصفات الحالية الموجودة في منخفض أم جيمين مع موصفات الأنواع الأربعة المذكورة. ولقد وجد أن غالبية المتغيرات تتشابه مع موصفات المنخفضات ذات أصل الإذابة.

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## INTRODUCTION

The Iraqi Western Desert is characterized by different circular features, among them are depressions. Majority of them are very shallow and circular in shape, very few of them are deep, up to few tens of meters, like the sinkhole of Salman Rosa, near Haditha (Fig.1) (Sissakian *et al.*, 1986). Among the deep depressions, is the well known Umm Chaimain Depression that is located in the southwestern part of the Iraqi Western Desert, 95 Km southwest of Rutbah town (Fig.1). It is almost circular in shape, with longest diameter of 2.9 Km (along N – S) and shortest one of 2.5 Km (along E – W), with depth of (28 – 38) m. The surrounding area is quite flat with elevation of (850 – 860) m (a.s.l.), therefore it is almost invisible, unless from very close distance, about few tens of meters from the depression. It could be reached from Rutbah town via H<sub>3</sub> Oil pumping station along a paved road that passes few tens of meters westwards.

The term "**Umm Chaimin**", according to the local "Bedwin" slang language, means an ambush area. Another explanation, however is given too, that means a reservoir.

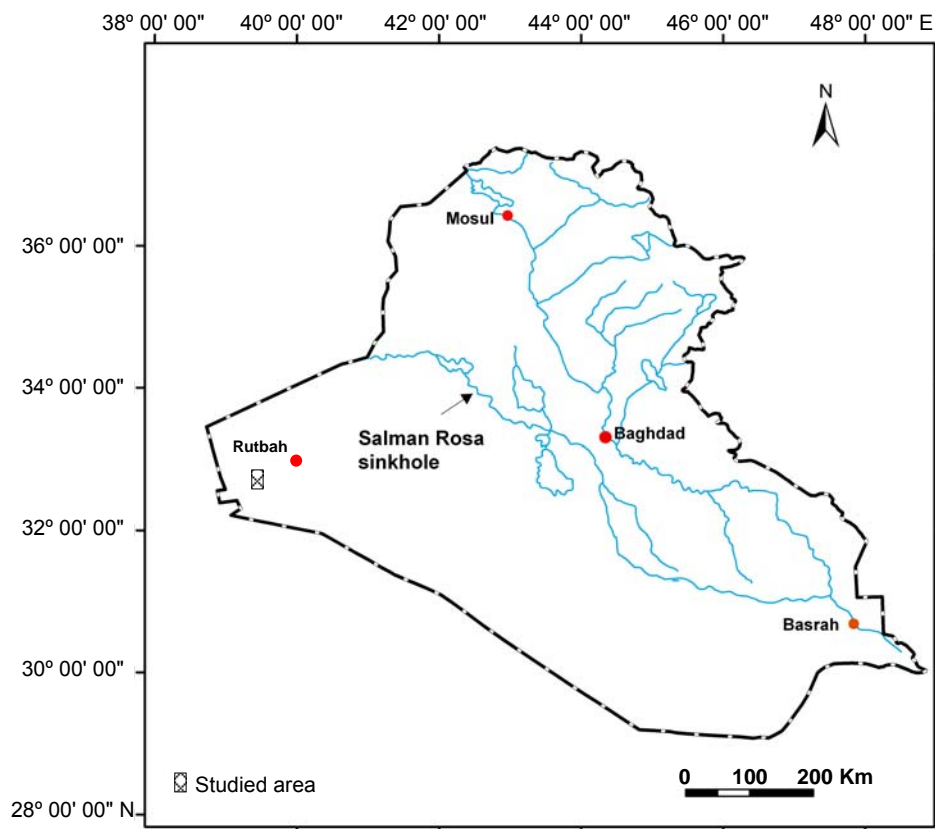


Fig.1: Location of the studied area

## MATERIALS USED

To achieve this study, the existing geological and geophysical reports, scientific papers, drilling data, topographical, geological and geophysical maps, Landsat image, aerial photographs (1954 – 1956) and Google Earth image (2008) are reviewed. Moreover, remote sensing and GIS data and programs are used for interpretation purposes. Computer software is used in calculating the volume of the depression.

## GEOLOGICAL SETTING

### ■ Stratigraphy and Structural Geology

The exposed rocks around the Umm Chaimin Depression belong to Ratga Formation (Eocene), which is the equivalent of Dammam Formation. It consists of well bedded limestones, dolomitic limestone and occasional marls and cherts, the thickness of the Ratga Formation in the involved area is about 40 m (Hagopian, 1979). From structural point of view, it is located within the Stable Shelf of the Arabian Platform (Al-Kadhimi *et al.*, 1996); therefore, the strata are almost horizontal, with regional westerly dip of less than (2 – 4) degrees. Two normal faults with E – W direction dissect the area, 5 and 12 Km north of the Umm Chaimin Depression, respectively. The farthest being the longest that is about 27 Km, whereas the shortest is 13 Km both have northern down-thrown blocks. Moreover, the depression lies within a very shallow graben of bounding faults trending NE – SW (Fig.2) and are 8 Km apart, with down thrown of about (5 – 15) m (Hagopian, 1979). Such main faults create the setting in which karst development can take place (White and White, 2006). From Neotectonic point of view, the area is uplifted more than 400 m, with uplifting rate of more than 0.2 cm/ 100 years (Sissakian and Deikran, 1998). According to the seismological data, no seismic activity is recorded in the area. The nearest earthquake epicenter is located 120 Km east of the depression, with magnitude of (4 – 5) degrees (Richter scale) and focal depth of less than 33 Km (Scientific Research Council, 1985).

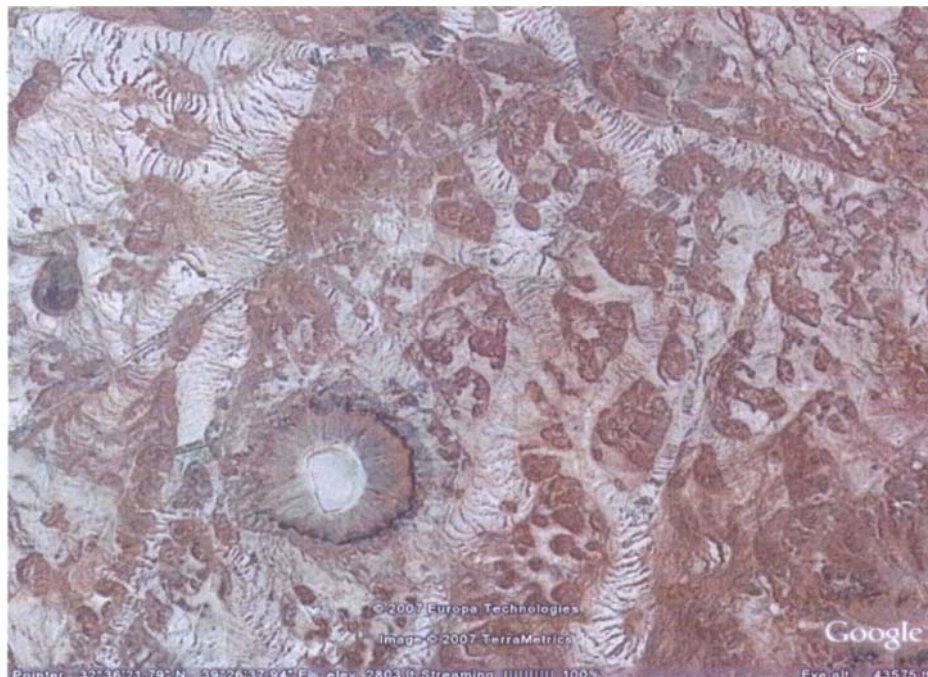


Fig.2: Umm Chaimin Depression, note the circular form, flat floor, bowl shape, E – W and NE – SW trending faults, the density of lineaments, circular features and dens deranged drainage pattern

A borehole was drilled in the floor of the depression, with depth of 106 m (Hagopian, 1979), the borehole penetrated Quaternary sediments to depth of 72 m, followed by limestones and claystones of Paleocene or Late Cretaceous (Jassim, 1980). Al-Hashimi (1982) described 72 m of soil and clay and then the remaining 34 m consists of marls, chalks and limestones. Jassim (1981), however, described the penetrated Quaternary sediments as 76 m of compact fine illite clay underlain by 30 m of breccia.

The exposed rocks on the rims are (from top to bottom) (Jassim, 1980):

- 10 m of silicified limestones interbedded with dolomitic limestone
- 20 m of very coarse crystalline limestone, the last meter contains Nummulites (Early Eocene).

Along the surface and the uppermost part (2 m) of the rim that includes crushed rock fragments (mixed with soil) of different sizes, some of them are up to one meter and more, different rock types were found and studied (Jassim, 1980), among them are:

- Silicified limestone and Nummulitic limestone, as those which are exposed in the bottom of the depression.
- White sandstone, that belongs either to Umm Radhuma Formation (Paleocene), recently announced as Akashat Formation (Al-Bassam and Karim 1997), or to Rutbah Formation (Late Cretaceous). Such sandstones are encountered in the base of Akashat Formation in wadi Hauran vicinity. The present authors would like to deduce that no such sandstones are encountered in Akashat Formation. Therefore, they belong most probably to Rutbah Formation.
- Yellow, soft claystone that occurs usually in the Umm Radhuma Formation (Paleocene) or the base of Dammam Formation (Eocene), recently announced as Ratga Formation (Karim and Al-Bassam, 1997), or belongs to Zor Hauran Formation (Triassic). The present authors would like to deduce that the yellow claystone belongs, most probably, to Digma Formation (Late Cretaceous) which underlies directly the Akashat Formation (Paleocene) that is cropping out 23 Km east of the depression.

It is worth mentioning that Al-Hashimi (1982) carried out paleontological study for the rock boulders that exist in the 2 m deep artificial channel (aforementioned by Jassim (1980) as different rock types of different ages), he found in 3 samples (among 12) fossils indicating most probably Middle Paleocene age. Moreover, Al-Hashimi studied 14 core samples from the drilled borehole (the lower 34 m) and found them to be of Middle Paleocene too, as those found in the blocks of the artificial channel.

Geochemical sampling of soil in the surrounding mantle did not reveal anomalies of base metal, thus a volcanic origin may be eliminated (Jassim and Buday in Jassim and Goff, 2006). The present authors will consider this factor as a negative one for the possibility of gas explosion. Because during a gas explosion, certainly some strange materials, with geochemical anomalies, must be thrown from the depth, over the near surroundings.

The drainage pattern is centripetal, although the strata are dipping ( $4 - 6^\circ$ ) off the depression. About 30 small valleys drain inside from the near surroundings, although Al-Walaj valley, which is 175 Km long and 1 Km wide, runs in N – S direction, just 200 m west of the depression, it has no effect on the centripetal drainage (Fig.3). It is also bounded with dens net of Al-Walaj branches, which also drain northwards with tens of circular features (Fig. 2).

Along the slopes of the depression, coalescent alluvial fans are formed in the form of Bajada; they are still active, as indicated from Landsat and Google Earth images and aerial photographs. They terminate in the flat dry lake that forms the floor of the depression, which is covered by silty clayey soil of fluvial origin.

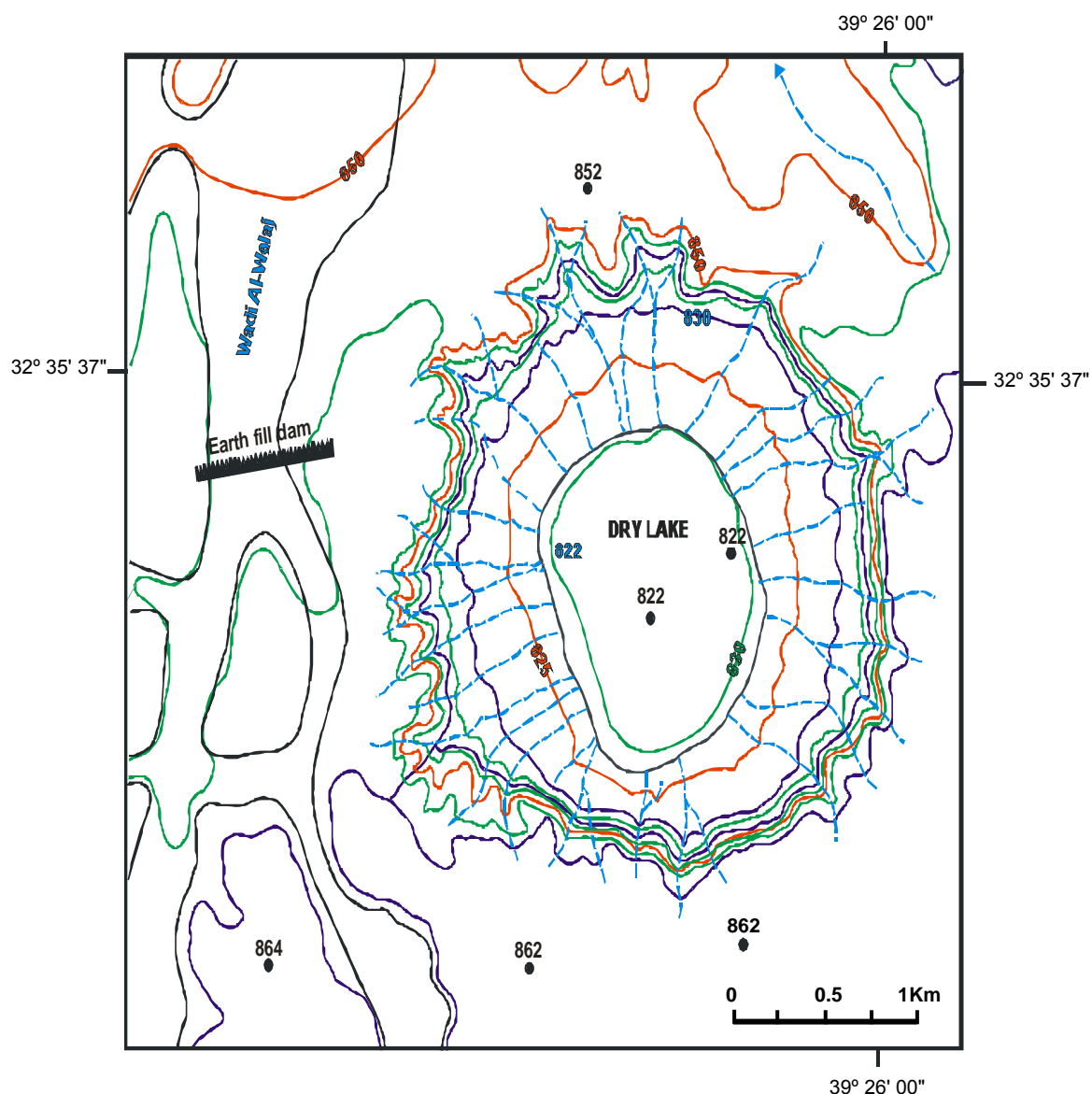


Fig.3: Topographic map of Umm Chaimin Depression, note the circular form, steepness of the southern rim, the dry lake in the floor, Al-Walaj valley and the centripetal drainage pattern

#### ■ Morphology and Geometry

The Umm Chaimin Depression has almost circular rim and bowl-shaped. The longest diameter is 2.9 Km, in N – S direction, whereas the shortest one is 2.5 Km, in E – W direction. The depth is between 28 m to 38 m, as measured from the northern and southern rims, respectively (Fig.3). It is worth mentioning that the original depth of the depression was about 130 m, as indicated from the thickness of the penetrated alluvial sediments and breccia by the drilled borehole (Jassim, 1980). The steepest rim is in the south, with slope of 1: 10, whereas in other directions the slopes range from 1: 30 to 1: 40, the beds along the rims show clear radial inclination off the center. The elevation of the surface is 852 m, along the northern rim and 862 m, along the southern rim. This difference in the heights of the northern and southern rims is equal to the general gradient of Al-Walaj valley (Fig.3). The floor that forms



a dry lake is of oval shape, almost parallel to Al-Walaj valley, with longest N – S diameter of 1.8 Km and shortest E – W diameter of 1 Km. The floor is flat with elevation of 822 m (Fig.3).

The area of the depression as measured from the highest closed contour (850 m) (White and White, 2006) is about 5.73 Km<sup>2</sup>. The ratio of the diameter at the top of the depression to the diameter at the bottom of the depression (White and White, 2006) is

$$W_t / W_b = 2.9 / 1.8 = 1.6$$

whereas, the depth / width ratio (White and White, 2006) is

$$d / W_t = 33 / 2900 = 0.001 \text{ and if the true depth is considered, then}$$

$$d / W_t = 130 / 2900 = 0.045$$

where,

$W_t$  is the width in the top

$W_b$  is the width in the bottom

$d$  is the depth

From reviewing the indicated values, it can be concluded that the depression has collapse doline shape, which resembles the "tiankengs" (White and White, 2006).

The volume of the Umm Chaimin Depression is about 109530000 m<sup>3</sup>, as measured by means of ARC GIS, depending on the average height of the bottom and average height of the top (Figs.3 and 4).

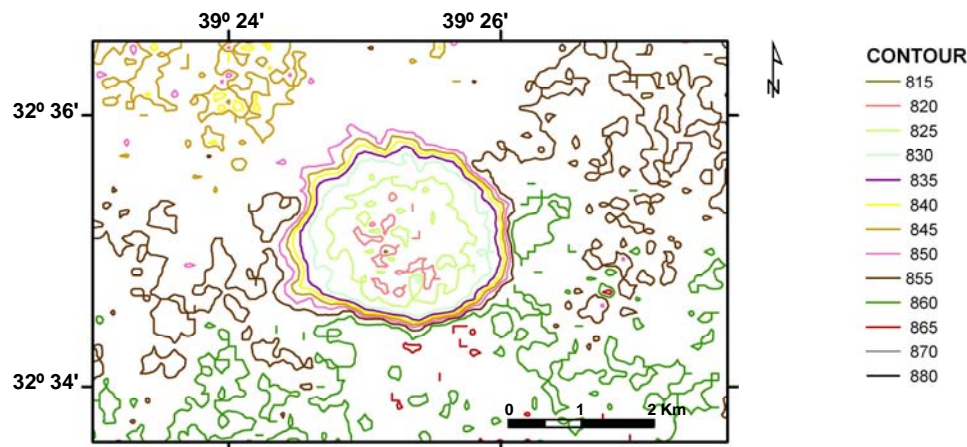


Fig.4: Topographic contour map of the studied area, constructed by Spatial Analysis of DEM using ARC GIS

#### ■ Activity

Along the periphery of the flat floor, clear indications can be observed for recent subsidence within the recent sediments, forming a dry lake. They are in form of crescentic cracks and cliffs of (1 – 2) m height (Fig.5), indicating recent activity for subsidence. The northern part, however, subsided twice; this might indicate that, originally, the northern part was deeper. The authors believe that this activity is attributed to the weight of the water that flows to the depression through the artificial channel from Al-Walaj valley, after construction of the earth fill dam (Fig.3), beside rain water.

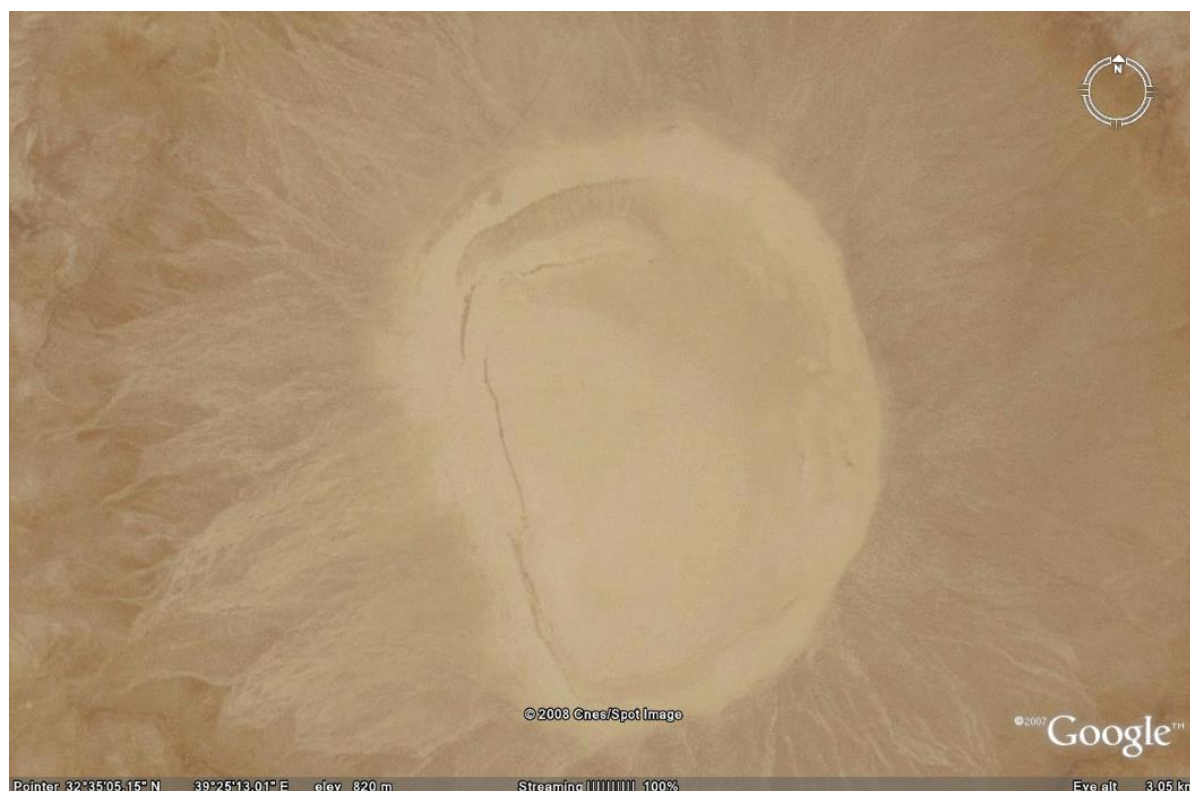


Fig.5: The coalescent alluvial fans, note the dry lake in the floor, recent cracks (two stages) and cliffs in recent sediments of the floor of Umm Chaimin Depression (Google Earth image, 2008)

### ■ Dating

Jassim (1980) estimated the age of the depression to be (50000 – 100000) years. This was based on a rate of deposition of 2 mm/ year, but he mentioned not to take this assumption as strict dating. Al-Hashimi (1982) assumed post Eocene age.

In this study, the climatic changes during Pleistocene and Holocene (Jado and Zofl, 1978), besides average rate of sedimentation in fluvial sediments are considered in estimating the age of the depression. Accordingly, a sedimentation rate of 1.5 cm/ 10 years is assumed, depending on the assumed rate of 3.2 cm/ 10 years for fluvial sediments in littoral margins (Bookstrom *et al.*, 2004), this assumption is based on the fact that the Umm Chaimin Depression is a closed basin with very limited catchment's area. In calculating the humid and arid phases during Holocene and Pleistocene with the supposed time span for each (Gradstein *et al.*, 2004) the following intervals can be fixed:

<b>Holocene</b>	10000 – 12000 years	dry climate
<b>Late Pleistocene</b>	20000 years	humid climate
	20000 years	arid climate
	100000 years	humid climate

The thickness of the penetrated fluvial sediments in the drilled borehole is about 75 m, by dividing the thickness over the assumed depositional rate, a time interval of about 50000 years is indicated. In reviewing the humid and dry phases, mentioned above, then the age of the depression can be assumed as early Late Pleistocene, within the first humid phase of Late Pleistocene. But, this dating can not be considered as accurate dating.

## **PREVIOUS WORKS**

Due to the conspicuous shape of the Umm Chaimin Depression, many studies were carried out to indicate its origin, among them are:

- Marriam and Holwerda (1957) described it as a meteorite impact.
- Mitchell (1958) described it as a volcanic origin.
- Al-Naqib (1967) described it as a volcanic origin.
- Matveev and Podgornov (1962) carried out Car-borne Radiometric Survey, in the involved area, for the purpose of locating promising phosphate bearing layers; therefore their measurements didn't refer directly to the origin of the crater and mentioned nothing about the origin.
- Al-Din *et al.* (1970) carried out magnetic and gravity measurements to indicate the origin of the crater. They didn't find any geophysical anomaly that may indicate the impact of a meteorite. Therefore, they suggested that ground-water action on limestone rocks is responsible for the present depression. They, however, didn't ignore the possibility of a crypto volcanic origin.
- Blizkovsky (1971) carried out with a geophysical group from NIMCO, currently GEOSURV, magnetic and gravity measurements and some electrical measurements. The work was especially forwarded to indicate the origin of the depression. They concluded that the concentric anomalies and central positive gravity residual anomalies could indicate one or more elevations of rocks, regardless if they are originated from bottom of the depression or from some collapsed beds. They also added that it is possible that the elevated bedrock consists of heavier material, when compared with existing limestone beds, such as anhydrite lenses. Finally, they excluded the meteorite impact origin and the volcanic or crypto volcanic origin, because no significant magnetic anomaly was recorded. Therefore, they concluded, "an erosional process probably by ground-water action should be considered as possibly responsible for the depression".
- Hagopian (1979) carried out regional geological mapping for the involved area and drilled a borehole in the floor of the depression with a depth of about 106 m. He concluded that the depression was most probably related to gas explosion that took place during Quaternary. A volcanic vent, however, was not excluded.
- Jassim (1980) studied the depression and evaluated the previous studies; he concluded that the origin is related to gas explosion.
- Al-Hashimi (1982) carried out paleontological study for the rocks within the rims and those present as pieces and blocks, in near surroundings and concluded that the origin is related to gas explosion, due to the presence of Middle Paleocene rocks within blocks encountered in an artificial channel near the western rim. Moreover, he found Middle Paleocene rocks at depth interval of (73 – 106) m within the drilled borehole. He did not recognize any of the rock types mentioned by Jassim (1980).
- Jassim and Buday in Jassim and Goff (2006) mentioned that the depression is originated from gas explosion, which could be seeped from Paleozoic sandstones through fractures and accumulated in reservoirs below Late Cretaceous shales. An explosion followed when gas pressure exceeded hydrostatic pressure.



## **APPLICATION OF GIS AND REMOTE SENSING TECHNIQUES**

Three types of Landsat images were used in this study (Fig.6), these are: Landsat MSS, 1975; Landsat TM, 1990 and Landsat ETM +, 2002, in order to recognize any topographic or geomorphic changes that have occurred in the depression, but no changes were detected. Moreover, the thermal band for the sensor TM of Landsat, 1990 (Fig.7) was used, because the thermal curve of the rocks and metals is related to their mineral composition, hence they could be detected. Through the thermal curve, the silicate rocks can be differentiated from non-silicate rocks, depending on the absorption ratio that is indicated from the shape of the thermal curve (Joseph, 2004). The indicated silica rich sediments in the northwestern slopes of the depression (Fig.7) are attributed to the silica rich sediments of Al-Walaj valley that infill to the depression with the flood water through the artificially dug channel.

Panah (2003) proved that the thermal band received by means of the sensor TM of Landsat is better in determining organic content in soils and rocks than the thermal band received by means of the sensor ETM + of Landsat. Therefore, for determining the presence of organic content in the rocks of Umm Chaimin Depression (Parameter No.10), the thermal band of the sensor TM of Landsat is divided on the spectral Band 4 for the same sensor, because it gives the best results (Panah, 2003), the result is shown in Fig. (8).

For determining the presence of iron oxides in Umm Chaimin Depression (Parameter No.9), the spectral signature of the ferrous minerals is used, besides the Band Ratio Technique, which is the most common used technique for indicating iron oxides. The highest reflection is divided on the lowest one that is measured in two spectral bands; the result is the reflection ratio between the two bands of iron oxides. Then the spectral signature of ferrous minerals (USGS Library of Minerals) is used from ERDAS IMAGIN (Fig.9). Consequently, the highest reflection is indicated that is in Band 5, received by means of the sensor TM of Landsat, this was divided on the lowest reflection, which is in Band 4 for the same sensor, (5/4) and this is the best ratio for differentiating ferrous minerals (John, 1999) (Fig.10).

Digital Elevation Model (DEM) is used through GIS techniques in preparation of topographic contour map (Fig.4); this was used for matching the occurrence of organic materials and ferrous minerals (Fig.11) along the eastern rim of the Umm Chaimin Depression, to indicate their accurate position. This matching showed that both organic materials and ferrous minerals are concentrated only at elevation of 834 m, along the eastern rim. This means that this abnormal concentration has syn-sedimentary origin within the carbonates of Ratga Formation. Otherwise, their occurrences must be along the whole slopes of the depression. Moreover, this map is also used in calculation of the volume of the depression.

Hydrological extension of ARC GIS is used in preparation of drainage distribution map (Fig.12). This was compared with the topographic map to indicate the direction of the fine tributaries that are not presented on the topographic map, scale 1: 25000 (Fig.3). From this map it was found that the direction of the fine valleys is towards the center of the depression. Whereas, in the surrounding area, deranged drainage pattern prevails.

Digital image for the terrain (Fig.13) and 3D Images of Landsat ETM +, 2002 (Fig.14) are used to indicate the morphology of the rim and near surroundings (Parameter No.1). It was found that there is no elevated rim and the inclination of the ground surface is towards the center of the depression. The absence of the elevated rim is also indicated from the topographic map (Fig.3), which originally has contour interval of 2.5 m, not 5 m as shown in Fig. (5).

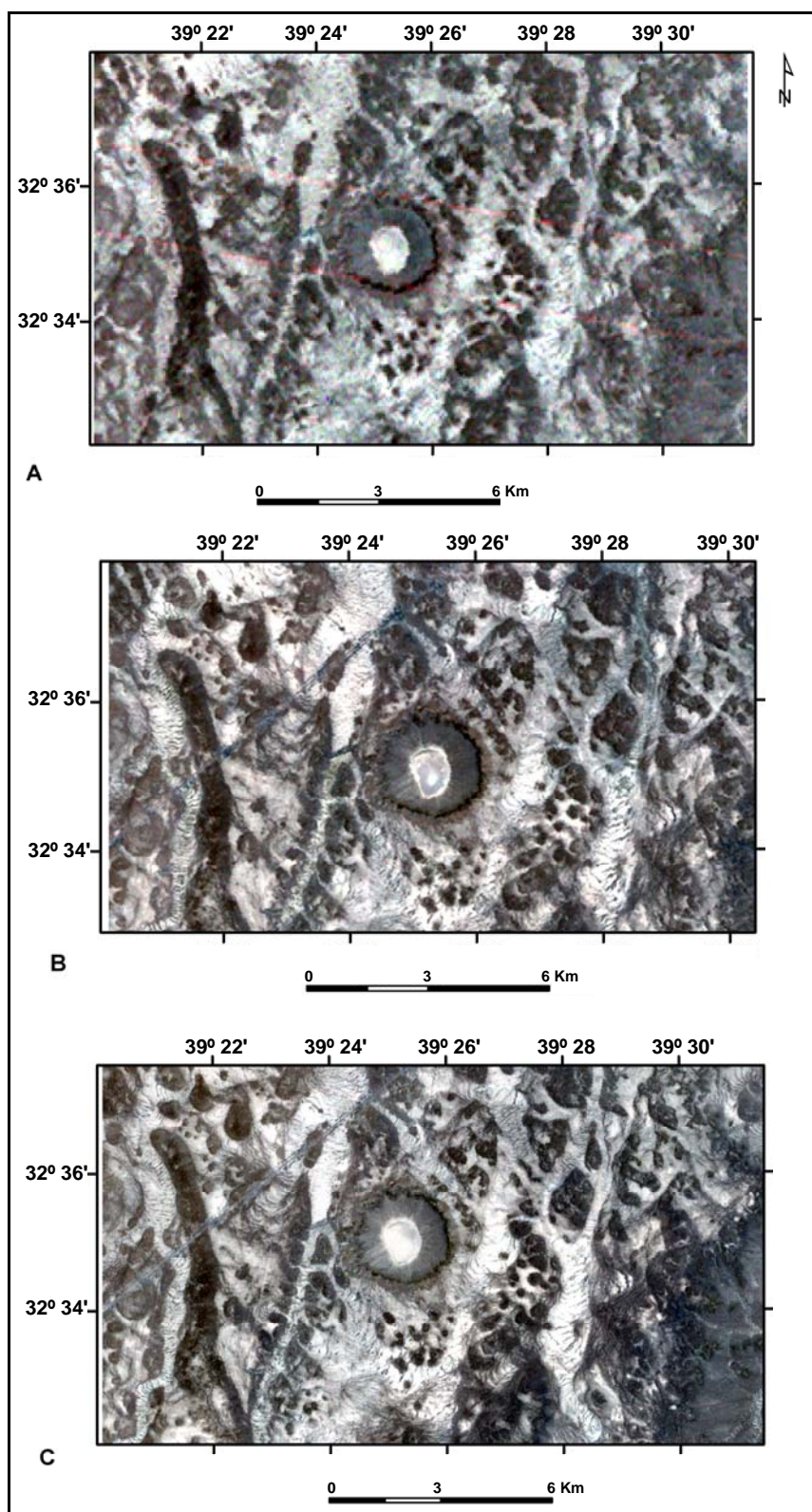


Fig.6: A) Landsat MSS, 1973, B) Landsat TM, 1990 and C) Landsat ETM+, 2002

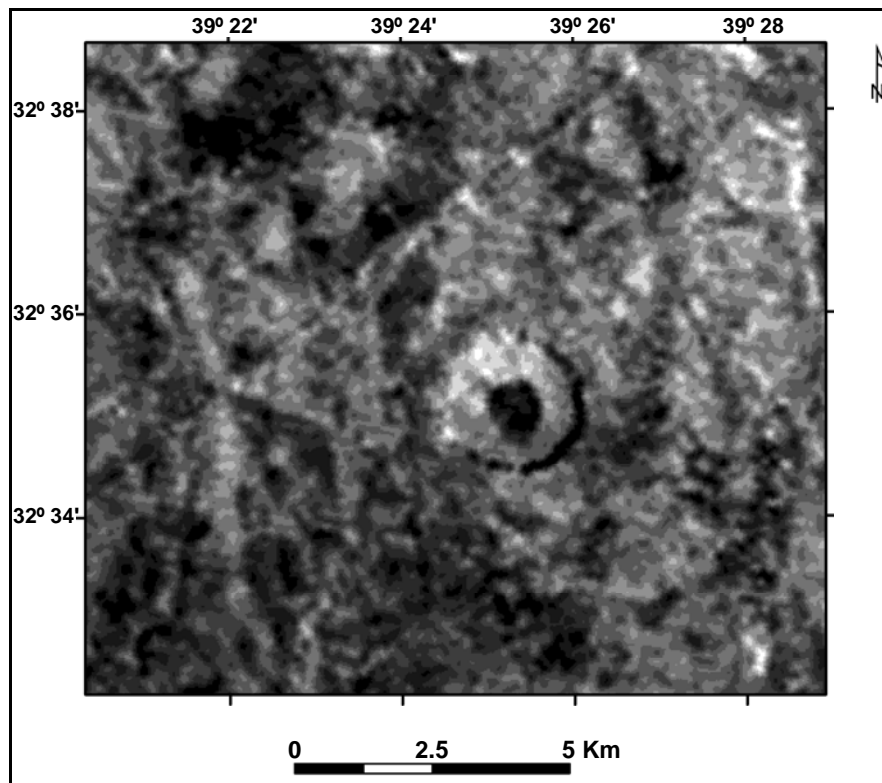


Fig.7: Thermal Band of Landsat TM, 1990

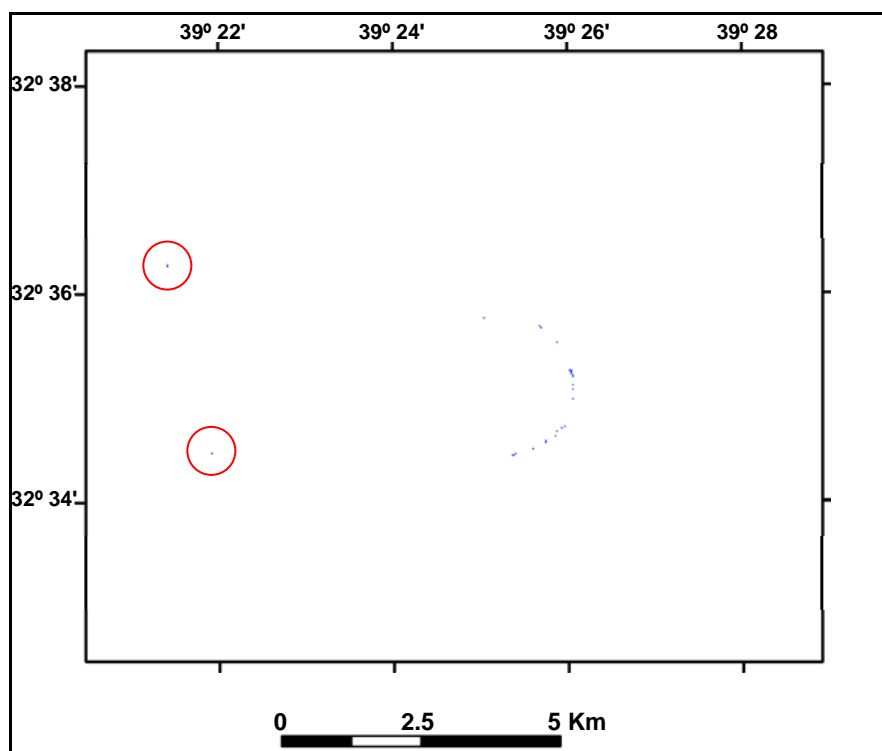


Fig.8: Result of application of the Band Ratio Technique, for indicting organic materials, 6/ 4.

Note: the distribution of the blue dots that indicate the location of the organic materials along the eastern rim and scattered two points (encircled by red color), along Al-Walaj valley

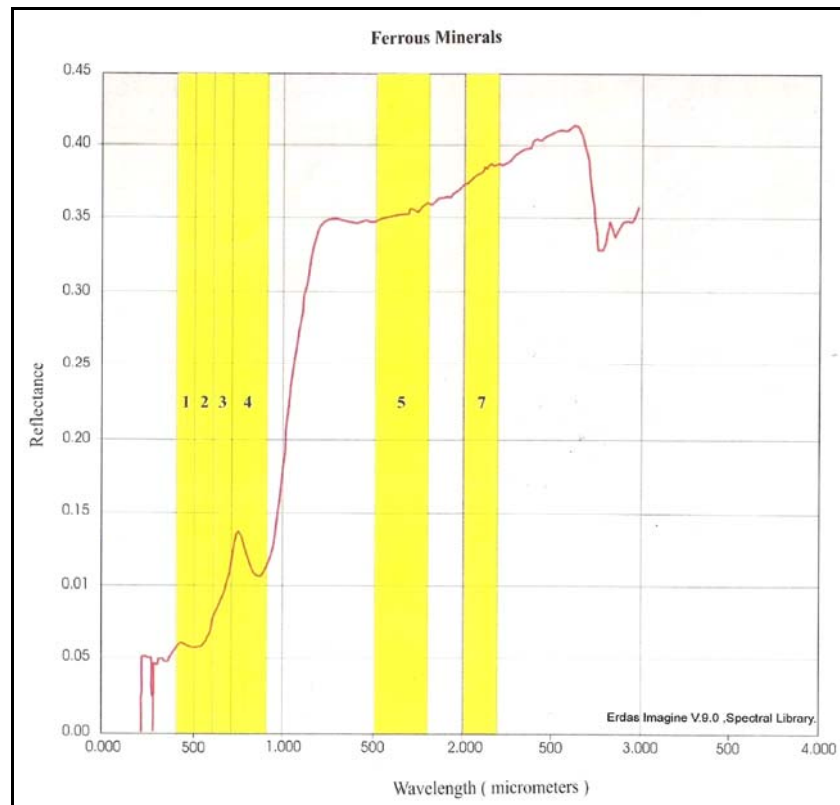


Fig.9: Spectral signature of the ferrous minerals

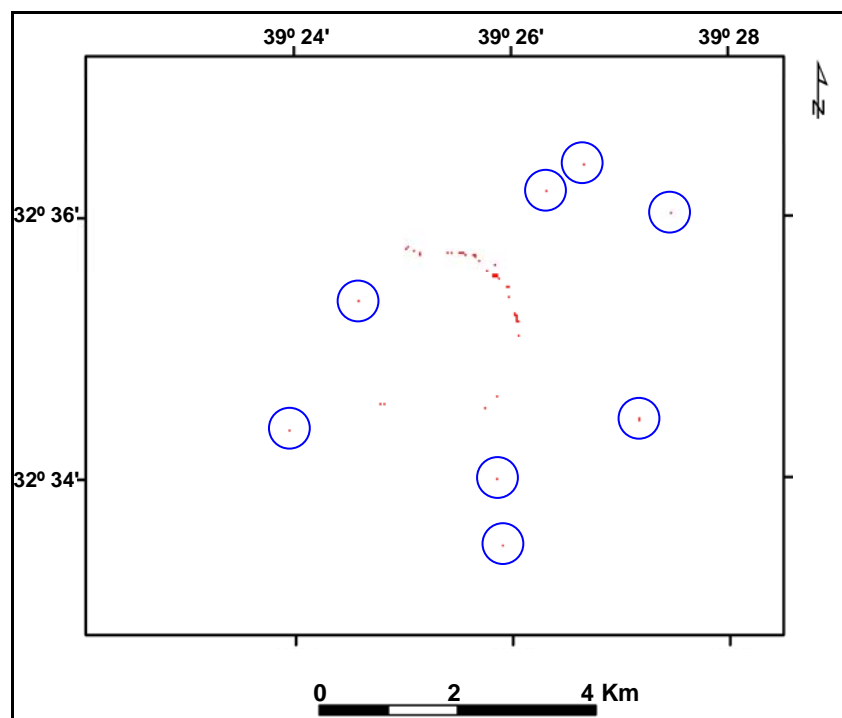


Fig.10: Result of application of the Band Ratio Technique, for indicating ferrous minerals, 5/ 4.  
 Note: the distribution of the red dots that indicate the location of ferrous minerals  
 The scattered locations are encircled by blue color

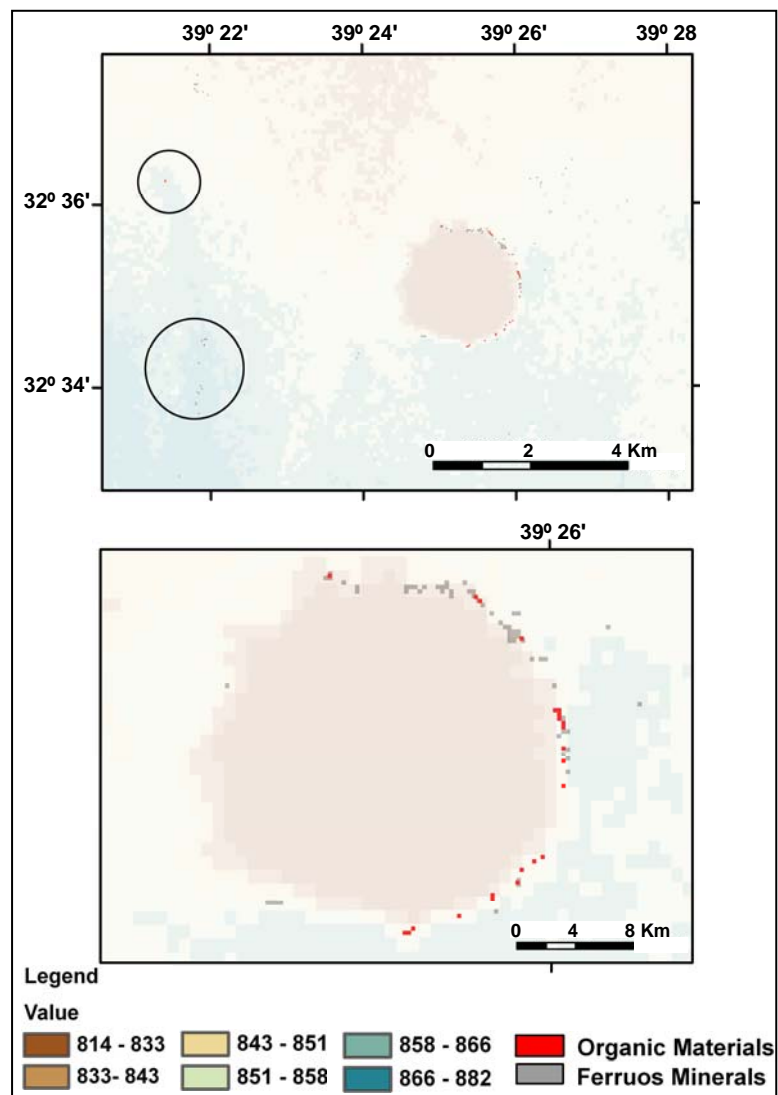


Fig.11: A) Location of the ferrous minerals and organic materials, indicated in the studied area, note the concentration of the red and blue dots. B) Close-up view

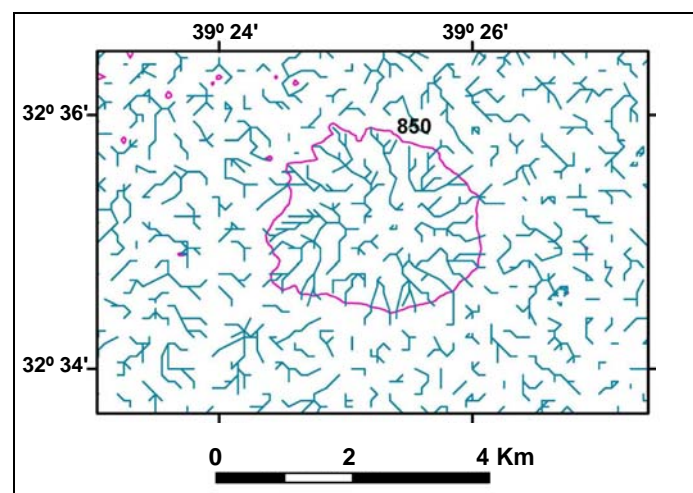


Fig.12: Drainage map of the studied area, constructed by hydrologic extension using ARC GIS technique



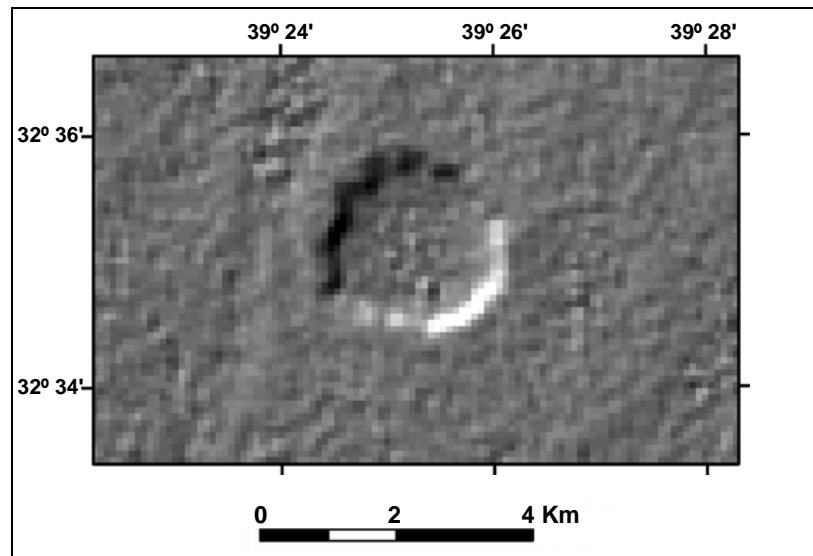


Fig.13: Digital image represents the relief of the studied area

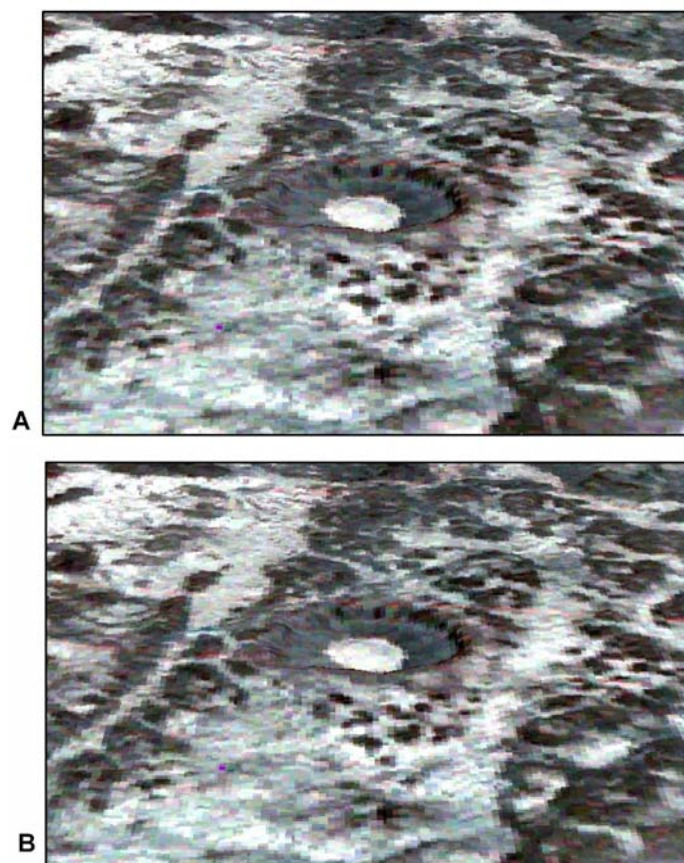


Fig.14: 3D image of Landsat  
A) MSS, 1973  
B) ETM +, 2002

## DISCUSSION

A depression like Umm Chaimin, with estimated volume of 109530000 m<sup>3</sup>, a diameter of 2.9 Km and depth of 28 m, can only be developed due to:

- Gas explosion
- Volcanic eruption
- Meteoritic impact
- Karst origin

The aforementioned four possibilities are discussed in detail, hereinafter, to indicate the most probable origin that fits with the present characteristics of Umm Chaimin Depression. To indicate the origin, eighteen parameters are defined (Table 1). They deal with the common characteristics of depressions formed by the aforementioned four origins (Bucher, 1920; Shoemaker, 1960; Beals and Engelhardt, 1970 in Wikimedia, 2008; Sissakian *et al.*, 1986; Koeberl and Vergil, 1992; Pilkington and Grieve, 1992; Hamelton, 2001; Florida Geological Survey, 2003; White and White, 2006 and Herak, 1972 and Roglic, 1972 in Blair, 2007).

Each parameter is studied and checked with the present nature of the Umm Chaimin Depression and compared with the common characters of depressions formed by the four mentioned origins, the results are tabulated in Table (1). In applying each parameter and checking its presence in the characters of one of the four origins and those of Umm Chaimin Depression, four cases are supposed, these are:

- Yes, when the parameter is present in the compared origin
- No, when the parameter is not present in the compared origin
- More common, when the presence of the parameter in the compared origin is more likely
- Less common, when the presence of the parameter in the compared origin is less likely

To achieve the mentioned results different data are used, like topographical, geological and geophysical maps, Landsat and Google Earth images, GIS techniques and remote sensing data. The details of the used data, for indicating the coincidence of each parameter with the characteristics of Umm Chaimin Depression are described hereinafter:

- **Topographic map**, scale 1: 25000 (Fig.3) is used to indicate the parameter nos. 1, 3, 4, 5, 6 and 15.
- **Geological map**, scale 1: 25000 (Hagopian, 1979); Al-Hashimi (1982); Jassim and Buday in Jassim and Goff (2006) and Figs. (2 and 5) are used to indicate the parameter nos. 2, 7, 8, 11, 14, 15 and 16.
- **Geophysical map and geophysical measurements** (Blizkovisky, 1971 and Al-Din *et al.*, 1970) are used to indicate the parameter nos. 12 and 13.
- **GIS and remote sensing data** (Figs. 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14) are used to indicate the parameter nos. 9, 10, 14, 15, 16, 17 and 18.

### ■ Statistical Data

In gathering the data of the eighteen parameters (Table 1) and coincide them with the characteristics of Umm Chaimin Depression, it could be seen that the characteristics of Umm Chaimin Depression have best fit with depressions of karst origin (Table 2). The parameters may coincide with the present characters of Umm Chaimin Depression positively or negatively. When a parameter is present in Umm Chaimin Depression and any type of the four origins, then there is a positive coincidences and when the parameter is not present in Umm Chaimin Depression and any type of the four origins, then there is a negative coincidence (Table 1).

Table 1: Characteristics of depressions formed by four different origins

Umm Chaimin Depression	Karst	Meteoritic impact	Volcanic eruption	Gas explosion	ORIGIN		Character No	COMMON CHARACTERISTICS
					Topographic inclination towards center		1	
					Dipping of the beds towards center		2	
					Circular form		3	
					Elevated from flat surroundings		4	
					Symmetry		5	
					Centripetal drainage towards the center		6	
					Presence of foreign materials on surrounding		7	
					Presence of older rocks on surrounding		8	
					Concentration of iron oxides and silicates		9	
					Presence of organic materials within rims		10	
					Presence of fused rocks		11	
					Presence of foreign bodies, inside		12	
					Presence of magnetic anomaly, inside		13	
					Related to nearby faults		14	
					Associated circular forms, nearby		15	
					Infilling by recent sediments		16	
					Subsidence in recent infilled sediments		17	
					Activity		18	

	Yes		No		More common		Less common
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Table 2: Statistical data for the coincidence of the 18 parameters with the Characteristics of Umm Chaimin Depression and other depressions of 4 origins

ORIGIN	Number of parameters			
	Coincide		More Common	Less Common
	Yes	No		
Gas Explosion	5	6	2	5
Volcanic	6	9	1	2
Meteoritic Impact	3	8	4	3
Karst	8	4	4	2

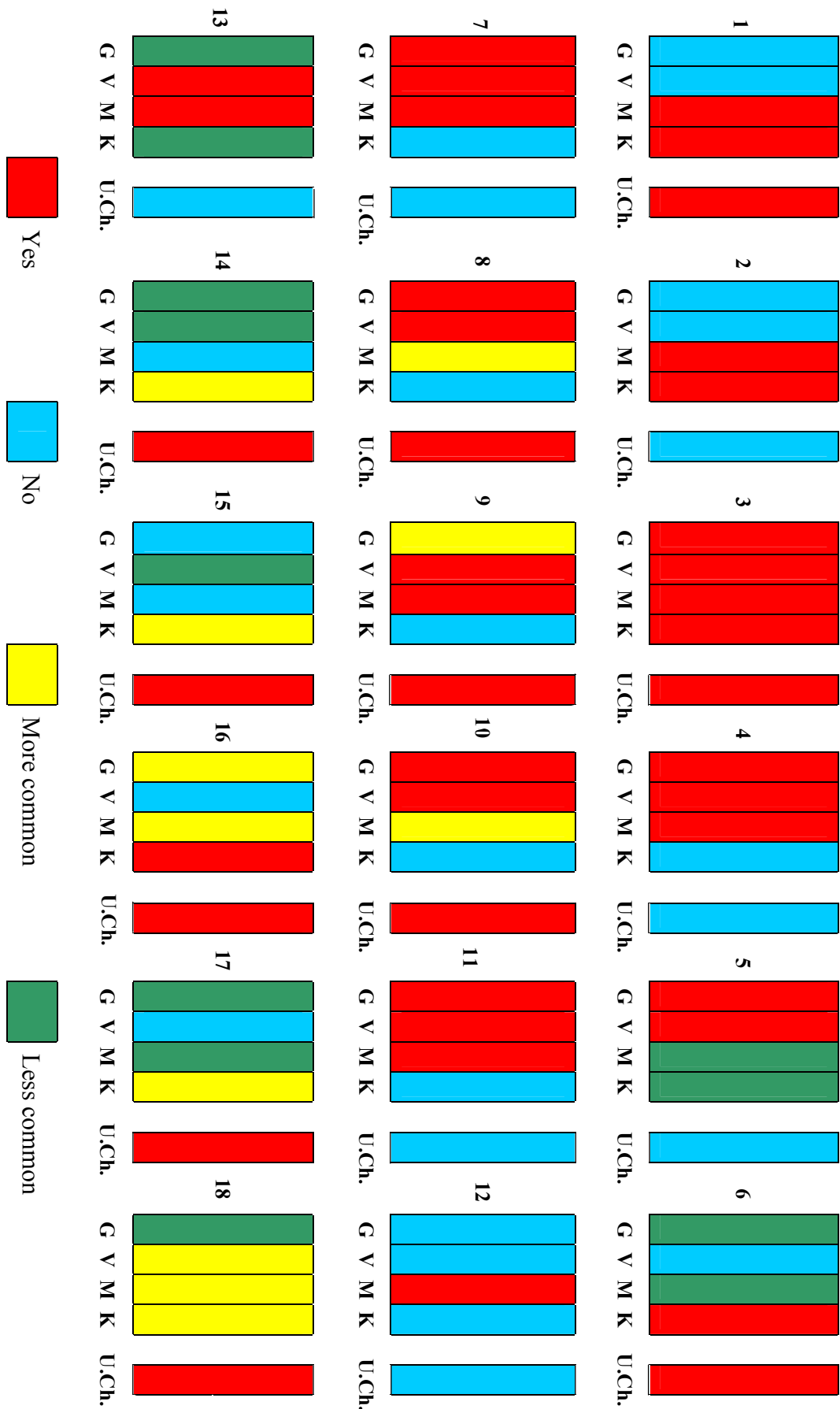
In reviewing the tabulated data in Table (2) and the statistical distribution of the 18 parameters (Fig.15), it can be seen that:

- 8 parameters of **karst origin** coincide with the characteristics of the Umm Chaimin Depression (either positively or negatively)
- 4 do not coincide
- 4 are more common and
- 2 are less common

Therefore, the characteristics of **karst origin** fits more with the characters of Umm Chaimin Depression, when considering the number of the coincided parameters and as compared with other three mentioned origins (Gas explosion, Volcanic eruption and Meteoritic impact).

The four parameters, which do not coincide with the present characteristics of Umm Chaimin Depression, are dipping of the beds towards the center, presence of older rocks on the surroundings, concentration of iron oxides and presence of organic materials (Parameter nos. 2, 8, 9 and 10, respectively). These can be attributed to:

- Concerning the **dip of the beds out of the center** (Parameter No.2), as it is the case in Umm Chaimin Depression (Hagopian, 1979 and Jassim, 1981) and that is not a normal case in karst forms, this could be attributed to either drag of the beds due to the presence of faults around the depression (Fig.2) and as in many karst cases that are associated with faults (Roglic, 1972 in Blair, 2007), or due to upwards movement. The latter assumption can be explained by the change of the anhydrite to gypsum and accompanied volume change. Anhydrite and gypsum are present in the Rus Formation that underlies the Dammam Formation in the Iraqi Southern Desert. The presence of anhydrite below the floor of Umm Chaimin Depression is probable, as indicated by the positive geophysical anomaly (Blizkovisky, 1971), because it has higher density than the exposed limestones of the Ratga Formation. The presence of the Rus Formation in the Iraqi Southern Desert had caused enormous karst features (Sissakian and Al-Mousawi, 2007 and Ma'ala, 2008).
- Concerning the second parameter that does not coincide with the characteristics of Umm Chaimin Depression is the **presence of older rocks on surroundings** (Parameter No.8). Al-Hashimi (1982) studied some of the limestone blocks that are present in the eastern rim and in the artificial channel in the western rim of the Umm Chaimin Depression and found them of Early and Middle Eocene, for the first locality and Middle Paleocene age for the second locality; he assigned them to the Umm Er Radhuma Formation, the equivalent of Akashat Formation that underlies the Ratga Formation. The only possible explanation for the presence of Middle Paleocene rocks is that they are moved upwards due to forces exerted during volume change, from anhydrite to gypsum. Because the blocks are found in the uppermost part of the rim, not scattered on the surface. If the Middle Paleocene rocks are moved upwards due to a gas explosion, as mentioned by Jassim (1980), Al-Hashimi (1982) and Jassim and Goff (2006), then they must be scattered over the surface in near surroundings. Because, an explosion that develops a depression like that of Umm Chaimin must have a great kinetic energy, then the blocks will be thrown up as projectiles and not placed in the uppermost part of the rim. Moreover, Al-Hashimi (1982) found Middle Paleocene rocks directly below the recent sediments that form the floor of the depression. This also contradicts with the assumption of gas explosion, because Middle Paleocene rocks shouldn't be there if a gas explosion had took place.



**G** = Gas Explosion, **V** = Volcanic Eruption, **M** = Meteoritic Impact, **K** = Karst, **U.Ch.** = Umm Chaimin Depression

Fig.9: Statistical distribution of the 18 parameters versus the 4 depressions of different origins and their coincidence with the characteristics of Umm Chaimin Depression

(indicated number on the left of each column refers to the parameter number)



- Concerning the third and fourth parameters (Nos. 9 and 10) that does not coincide with the characteristics of Umm Chaimin Depression are the **presence of ferrous minerals concentration** and **organic materials** along the eastern rim (Figs. 8, 9, 10 and 11). But, the concentration is only along a line that has elevation of 836 m (Fig. 11A and B) that means in the lower third part of the eastern rim. If this abnormal concentration is due to a gas explosion, then it shouldn't be concentrated along the eastern rim and along a certain thickness that does not exceed (2 – 4) m. The only possible explanation will be that it is abnormal concentration, not related to a gas explosion, but it is of syn-sedimentary origin, otherwise the whole exposed succession should show such abnormal concentration. This assumption also could be confirmed by the presence of few scattered anomalies in the recent sediments of Al-Walaj valley and other scattered points along the near surroundings (Fig. 11).

Therefore, the aforementioned two parameters (Nos. 9 and 10) will not be considered as negative parameters for indicating the karst origin for Umm Chaimin Depression, but the otherwise; hence the behavior of the 18 parameters will be as follows:

- 10 parameters coincide
- 2 parameters does not coincide
- 4 parameters are more common
- 2 parameters are less common

The other three possible origins are gas explosion, volcanic eruption and meteoritic impact. All of them have common characteristics that do not coincide with those of Umm Chaimin Depression (Tables 1 and 2; Fig. 15).

For **gas explosion** origin, only 5 parameters (Nos. 2, 3, 8, 10 and 12), among 18, coincide with those of Umm Chaimin Depression, 6 parameters do not coincide, 2 parameters are more common and 5 parameters are less common (Tables 1 and 2). The parameter Nos. 4, 7, and 11, which must show positive coincidence, didn't show coincidence with the present characteristics of Umm Chaimin Depression. Moreover, in a gas explosion the older formation (Akashat, Middle Paleocene) that underlies Ratga Formation (Eocene) wouldn't be penetrated in the drilled borehole, as it is found by Al-Hashimi (1982), because the rocks must be disturbed and broken due to the gas explosion. Another very important fact that do not coincide with the gas explosion is the presence of tens of circular features nearby to Umm Chaimin Depression, although much smaller in size (Figs. 2 and 6). The authors believe that they are buried karst features; this assumption is also supposed by Jassim and Goff (2006). The last important parameter which is not present along the rims is the absence of fused and/ or altered rocks, any gas explosion will cause combustion and the rocks should be fused.

For **volcanic eruption** origin, only 6 parameters (Nos. 2, 3, 8, 9, 10 and 12), among 18, coincide with those of Umm Chaimin Depression, 9 parameters do not coincide, 1 parameter is more common and 2 parameters are less common (Tables 1 and 2). But, when eliminating parameter Nos. 9 and 10, because they are proved to be syn-sedimentary in origin, then only 4 parameters will coincide and 11 will not. Moreover, parameter Nos. 4, 7, 11, 13 and 18, which must show positive coincidence, didn't show coincidence with the present characteristics of Umm Chaimin Depression. The most important parameters that do not coincide with the characteristics of Umm Chaimin Depression are the absence of bombs, ejectas, fused rocks (along the rims) and volcanic rocks not only on surface, but also in depth, as proved by geophysical studies (Al-Din, 1970 and Blizkovisky, 1971).

For **meteoritic impact origin**, only 3 parameters (Nos. 1, 3 and 9), among 18, coincide with those of Umm Chaimin Depression, 8 parameters do not coincide, 4 parameters are more common and 3 parameters are less common (Tables 1 and 2). Moreover, parameter Nos. 4, 7, 11, 12 and 13, which must show positive coincidence, didn't show coincidence with the present characteristics of Umm Chaimin Depression. The most important parameters that do not coincide with the characteristics of Umm Chaimin Depression are the absence of strange body inside the depression, absence of ejectas, fused rocks along the rims, magnetic anomaly and presence of tens of circular forms nearby. The authors believe that they are buried karst features; this assumption is also supposed by Jassim and Buday in Jassim and Goff (2006).

### **Confirmation of the Borehole Data for the Karst Origin**

The recorded data of the drilled borehole is not well documented by Hagopian (1979), as it is clear from the mentioned data by Jassim (1980 and 1981) and Al-Hashimi (1982). But, still the mentioned data can be used as good indication for confirming the karst origin.

According to Jassim (1981) the lower 36 m of the borehole is breccia. This can be explained as accumulation of fallen blocks from the roof and rims, such forms are very common in karst features (White and White, 2006). This could be confirmed by observation of recent cracks in the dry lake sediments in the floor (Fig.5). The authors believe that the subsidence is due to piping phenomenon, after converting of the flooded water in Al-Walaj valley towards the depression, by means of a constructed earth fill dam (Figs. 2 and 3) and the accumulated rain water. Such phenomenon is described too by White and White (2006).

The description of Al-Hashimi (1982) for the borehole, however, can also be used as indication for the karst origin. He mentioned that the encountered rocks, in the last 36 m of the drilled borehole belong to Umm Er Radhuma Formation. This will be a normal case for a karst depression, because Akashat Formation underlies Ratga Formation, which is exposed along the rims and on surface area. In case of a gas explosion, the rocks of Akashat Formation wouldn't be encountered in the bottom of the borehole and found to be laid down along the uppermost part of the rims as blocks, because they would be subjected to destruction and thrown out of the depression by the released energy of the explosion. Moreover, the Rus Formation could be present between the Akashat and Ratga formations, although it is not encountered in any drilled well in the vicinity. But, the presence of isolated basin with lagoon conditions may have caused the deposition of anhydrite (Rus Formation). This also could be supported by the presence of rocks with density more than of limestones, as indicated by the geophysical studies (Blizkovisky, 1971).

From the aforementioned presented data, it is more obvious that the **karst origin** is the best one which coincides with the characteristics of Umm Chaimin Depression, when compared with other three supposed origins. Moreover, karst forms are very common in Iraqi Western and Southern Deserts (Sissakian and Al-Mousawi, 2007 and Ma'ala, 2008). In the Southern Desert, depressions larger than that of Umm Chaimin Depression are common, like Al-Sa'a and Al-Salman, although not so deep but depths up to 60 m and diameters up to few kilometers are common. Around and northwards of Umm Chaimin Depression, hundreds of circular features are developed (Figs. 2 and 6) within the same rocks (Ratga Formation), many of them have diameters more than 1 Km, but all of them are buried by recent sediments. In Al-Tinif vicinity, about 170 Km NE of Umm Chaimin Depression, many drilled boreholes, in such a buried circular form, showed depressions of more than 100 m, which are filled by recent sediments (Sissakian, 2007). On contrary, none of the existing depressions in the Iraqi Southern and Western Deserts show any evidence for gas explosion or volcanic eruption or meteoritic impact origin. This fact could also be used as a positive factor for assigning karst origin to the Umm Chaimin Depression.

## CONCLUSIONS

- Umm Chaimin Depression has most probably karst origin, developed within limestones of Ratga Formation (Eocene).
- The depression is formed after solution of the limestones and probably some anhydrite and gypsum beds of Rus Formation, this was followed by the collapse of the roof.
- The depression is bounded by two sets of faults that accelerated the solution of the rocks and possibly have caused drugging of the beds.
- The depression is associated with numerous numbers of circular features that may indicate buried karst features.
- No foreign bodies and magnetic anomalies were found inside the depression, bellow the recent sediments, in the floor.
- The presence of some Middle Paleocene rocks in the uppermost part of the rim may support the assumption of upward movement of older rocks by the exerted forces due to volume change of anhydrite to gypsum and not due to explosion forces.
- The depression has bowl-shape, with flat floor that is infilled by recent alluvial sediments.
- The recent sediments in the floor show clear recent cracks and cliffs, indicating recent subsidence in the infilled sediments, most probably due to piping phenomenon.
- No distinct indications were found to prove other previously supposed origins, like gas explosion, volcanic eruption or meteoritic impact.
- No fused and/ or altered rocks were found along the rims.
- No strange materials, like ejectas, bombs etc. were found in near surroundings.
- The indicated organic materials and iron oxides, by means of remote sensing data, only along the eastern rim are attributed to syn-sedimentary origin.
- The age of the Umm Chaimin Depression is estimated to be early Late Pleistocene.

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