GENESIS AND AGE ESTIMATION OF THE THARTHAR DEPRESSION, CENTRAL WEST IRAQ

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ABSTRACT

Tharthar Depression is one of the largest closed depressions in Iraq; it is located in the central western part of Iraq, between the Jazira and Mesopotamia Plains, west of the Tigris River. It covers about 2050 Km^2, oriented almost N – S, then changes to N35° W – S35° E, with a bowl shape, the base being in the south. The exposed rocks in the near surroundings of the depression belong to Fatha and Injana formations, with Al-Fatha Alluvial Fan sediments in its eastern bank. Tectonically, it is located in the Mesopotamia Foredeep of the Unstable Shelf, forming the contact between the Jazira and Mesopotamia Plains. Geomorphologically, it is a large depression with a floor of – 3 m, above the sea level. The maximum length and width of the depression are 120 and 48 Km, respectively. The eastern rim of the depression is higher than the western one; the heights of both rims are 90 and 75 m, respectively.

The Tharthar Depression since 1956 is changed to an artificial reservoir to collect the over flooded water of the Tigris River, during flood seasons, therefore was called Tharthar Lake. The Tigris and Euphrates Rivers, however, link the reservoir, by means of artificial canals. The inlet canal, however, is from the Tigris River, regulated by Samarra Dam, which controls the divergent excess water from the Tigris River, by means of the inlet canal.

The genesis of the Tharthar Depression is a matter of debit, since 1959, many ideas explain the origin of the depression. The aim of this study is to deduce the origin of the depression. This study proves that the depression is of multi genesis, closed depression formed mainly by karstification, due to dissolving of gypsum rocks of the Fatha Formation. The measured parameters, depth/ width ratio, length/ width ratio and width at top/ width at bottom ratio range from 0.017 to 0.125, 27.6 to 300, and 2 to 4.5, respectively. Such ratios assume either collapse or solution doline, of multi origin. The age of the Tharthar Depression is most probably Holocene.

أصـل نشـوء وتقدير عُمر منخفض الثرثـار، وسط غرب العراق

فاروجان خاجيك سيساكيان

المستخلص

إن منخفض الثرثار هو أحد أكبر المنخفضات الطبيعية المغلقة في غرب العراق، ويقع بين منطقة الجزيرة، في الغرب والسهل الرسوبي في الشرق. ويغطي مساحة سطحية تبلغ حوالي 2050 كم^2 على ارتفاع 65 متر فوق سطح البحر، وامتداده باتجاه شمال – جنوب، ومن ثم يتغير باتجاه شمال °35 غرب – جنوب °35 شرق، وله شكل مخروطي وقاعدته نحو الجنوب.

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إن الصخور المتكشفة على أطراف منخفض الثرثار تعود إلى تكويني الفتحة وانجانة. يتكون الأول من ترسبات دورية، وكل دورة تتكون من الطفل وصخور كلسية والجبس، ترسبت جميعها في بيئة بحرية لاغونية مغلقة، والتكوين من عمر المايوسين الأوسط، ويتميز هذا التكوين بظاهرة التخسف نتيجة ذوبان الصخور الكلسية والجبس. أما التكوين الثاني فيتكون من ترسبات دورية أيضاً، وان كل دورة تتكون من صخور رملية وغرينية وطينية، ذات بيئة قارية، والتكوين من عمر المايوسين المتأخر. كما توجد ترسبات مروحة الفتحة من عمر البلايستوسين في الشرق من المنخفض، وتتكون من الحصى والرمال تعلوها طبقة سميكة من الجبكريت.

من الناحية البنيوية، فان منخفض الثرثار يقع في الرصيف غير المستقر، في الحوض العميق للسهل الرسوبي (Mesopotamia Foredeep) وبين منطقة الجزيرة في الغرب والسهل الرسوبي في الشرق. من الناحية الجيومورفولوجية، انه منخفض مغلق كبير يصل ارتفاع قاعدته إلى – 3 متر فوق مستوى سطح البحر. وان أقصى طول وعرض للمنخفض، على ارتفاع 65 متر فوق سطح البحر، هما 120 و 48 كم، تباعاً. إن الحافة الشرقية للمنخفض أعلى من الحافة الغربية، حيث يبلغ ارتفاعهما 90 و 75 متر، تباعاً. تكون الحافة الشرقية أكثر انحداراً من الحافة الغربية، يتراوح انحدار الجرف بين (25 – 55)°، بينما يتراوح انحدار جرف الحافة الغربية بين (4 – 13)°. إن التغذية الرئيسية للمنخفض يكون بواسطة وادي الثرثار الذي يصب في شمال المنخفض ويشكل الرأس الشمالي للمنخفض. ويمثل وادي الثرثار احد اكبر الوديان في المنطقة، إذ يصل امتداده إلى جبل سنجار والذي يبعد عن الرأس الشمالي من المنخفض حوالي 320 كم. وكذلك تصب وديان عديدة في المنخفض من الغرب، وتكون على شكل وديان متوازية تتجه من الغرب إلى الشرق وتجمع حوالي نصف مياه الأمطار الساقطة على منطقة الجزيرة، وتكون هذه المياه الموسمية محملة بملح كبريتات الصوديوم نتيجةً لمرورها على الصخور الجبسية المتكشفة في منطقة الجزيرة.

إن منخفض الثرثار ومنذ عام 1956 تم تحويله إلى خزان لاحتواء مياه الفيضان لنهر دجلة، وعليه سمي ببحيرة الثرثار، وتتصل بحيرة الثرثار بنهر دجلة بواسطة قناة التغذية التي تتفرع من نهر دجلة قرب مدينة سامراء بواسطة سدة سامراء والذي بواسطته يتم التحكم بكمية المياه المحولة إلى البحيرة في مواسم الفيضان. واتجاه القناة هو شمال شرق – جنوب غرب، ثم تتجه في جزئها الأخير إلى اتجاه شرق – غرب تقريباً وتصب في البحيرة في جزئه الجنوبي الشرقي، من خلال احد الوديان الكبيرة (قبل تحويل المنخفض إلى بحيرة). وان مياه البحيرة تفرغ إلى نهري دجلة والفرات بواسطة قناة أروائية، تتجه من الشمال الغربي إلى الجنوب الشرقي ثم تتحول من الشمال إلى الجنوب وتسمى قناة الثرثار وتصب في نهر الفرات، وتتفرع منها قناة أخرى، بعد 28 كم من مخرجها وتسمى ذراع دجلة وتتجه من الغرب إلى الشرق وتصب في نهر دجلة.

إن أصل نشوء منخفض الثرثار كان موضوع نقاش علمي وطويل ومنذ عام 1959، وهناك العديد من الأفكار التي تناولت أصل النشوء. إن الهدف من هذه الدراسة هو بحث أصل نشوء المنخفض وإثباته. وللوصول إلى إثبات علمي ورصين، فقد استخدمت معلومات جيولوجية وجيومورفولوجية وبنيوية وبنيوية حديثة، بالإضافة إلى معلومات تاريخية استنبطت من كتب التأريخ وكما دونه المؤرخون. كما تمت مراجعة الخرائط الطوبوغرافية من مقياس 1:100000 و1:125000 للمنخفض قبل أن يملأ بالماء ويتحول إلى بحيرة، لمعرفة شكل المنخفض. وكذلك تمت الاستعانة بالبيانات الفضائية والصور الجوية وصور الگوگل (Google). وقد أثبتت الدراسة بان المنخفض هو من النوع المغلق، متعدد النشأة، تكون نتيجةً للتخسف واندماج أكثر من خسفة واحدة مع بعضها، بسبب ذوبان صخور تكوين الفتحة، إضافةً إلى الهبوط المستمر بسبب وجود منخسف تحت سطحي. وان المنخفض هو من نوع "الدولاين" التخسفي أو الإذابي. وان القياسات المختلفة التي أجريت على أبعاد المنخفض، مثل نسبة كل من العمق/ العرض، العرض/ الطول والعرض في السطح/ العرض في القاع تراوحت من 0.017 – 0.125 و 27.6 – 300 و 2 – 4.5 على التوالي، تؤيد بان المنخفض هو متعدد النشأة من أصل إذابي.

INTRODUCTION

The Tharthar Lake is a natural closed depression, before being filled by flooded access water from the Tigris River, since 1956, and hence was called Tharthar Lake (Soosa, 1966). It is located within Salah Al-Deen Governorate, in the central western part of Iraq (Fig.1). It is a natural depression, with almost N – S trend, in its upper (northern) third, then changes to N35° W – S35° E trend, in its remaining part; having a bowl shape, the base of which is in the south (Fig.1). Naturally, it is drained by Tharthar valley, which flows from the central and eastern parts of Sinjar Mountain and adjacent hills, in the north, before it merges to the depression, it has almost straight form towards N – S, for about 90 Km, beside many valleys, which drain the Jazira Plain with W – E trend, and few others from the eastern side (Fig.1).

Fig.1: Google Earth image showing the location of the Tharthar Depression

Artificially, the Tharthar Lake receives water from the Tigris River by means of an artificial inlet canal (Fig.1); named Tharthar Canal. The canal diverts the access water, by means of a regulator dam; near Samarra, it is called Samarra Dam. The inlet canal is almost in NE – SW direction, but changes to E – W direction, before it merges with the lake in its southeastern bank, through one of the main valleys that previously was draining into the depression (before being changed to reservoir). However, the lake has an artificial outlet, which is towards NW – SE; it is called Tharthar Canal, which drains to the Euphrates River, directly. The canal, after 28 Km from its outlet; bifurcates to another canal, which is towards W – E and is called "Dhira'a Dijla", it returns the water back to the Tigris River.

The main aim of the Tharthar Lake is to collect the access water in the Tigris River during flood seasons and to recharge water to the Tigris and Euphrates Rivers during dry seasons, when there is deficiency in water in both rivers. Moreover, it aims in washing out the salts from the stored water, in the lake by means of natural continuous draining of the stored water. It is worth mentioning that one of the largest collected amounts of water in the depression was in the flood of 1963, where 14 x 10^9 m of water was diverted to the depression (Soosa, 1966).

▪ **Aim**

This study aims to find the genesis of development of the Tharthar Depression, and to discuss the present ideas about the genesis. Moreover, to confirm the achieved idea by using different aspects, which have direct and indirect contribution in the development of the depression. Besides, age estimation of the development of the depression.

MATERIALS USED AND METHODOLOGY

In order to achieve the aim of this study, the following materials were used:

- Topographical maps at scale of 1: 100000, of the depression, before and after filling by water.
- Geological maps at different scales.
- Landsat images, Google Earth images, and aerial photographs.
- Geological, hydrogeological, hydrological, geomorphological, geophysical, and geological hazards maps and reports.
- Historical books and other relevant articles.

The aforementioned data were used as an integrated study to achieve the indications about the genesis of the Tharthar Depression. Topographical maps were used to indicate the height of the floor, and the slope of the banks; before being filled by water, in addition, to deduce the shape of the bottom and circumference of the depression. Geological maps and reports were used to indicate the type of the exposed rocks and Quaternary sediments around the depression, and their relation with the depression, age wise. Tectonic, structural, and geophysical maps were used to indicate the presence or otherwise of structural features, such as faults, folds, and subsurface grabens, which might have contributed in the development of the depression. Geomorphological maps, aerial photographs, Landsat images, and Google Earth images were interpreted to indicate any geomorphological phenomenon, which have contributed in the development of the depression. Finally, historical books were reviewed to indicate weather the depression was present or otherwise in near history. All these data, together have given sound indications for the genesis of the development of the Tharthar Depression.

PREVIOUS WORK

The following work was carried out concerning different aspects of the Tharthar Depression.

- NEDECO (1959), conducted irrigation project in the Tharthar Depression and gave an idea about the origin of the depression, it is summarized as: **1)** The contact between Lower Fars and Upper Fars (Fatha and Injana) formations. **2)** The occurrence of Bakhtiari Formation (Mukdadiya and Bai Hassan formations) and gravel plateau to the east and south, and thinning towards the depression. **3)** The eastwards dipping of the Lower Fars (Fatha) Formation. **4)** The SSE wards pitching of the axis of the Samarra syncline, which caused the resistant eastern and western sides of the depression to converge to the north. **5)** The step-like profile of the bottom of the depression suggests a genesis in two successive phases of development: **a)** Process of wind deflation and the erosion of the sides by running water, which began in Pliocene – Pleistocene and lasted into the Holocene Period. **b)** A graben like subsidence of the bottom of the depression, during the Late Pleistocene or early Holocene, resulted in the step-like profile of the eastern side. Rejuvenated erosion through the uplift of the plateau anticline in the south caused the step in the southern side to be removed. **6)** Climatic variations, during the Pleistocene, the climate was characterized by the periodic alternation of pluvial and interpluvial periods. During the first pluvial period, at the beginning of the Pleistocene, erosion of the exposed folded Upper Miocene rocks went out. Selective wind erosion set in during the following interpluvial period, and further during the next pluvial and interpluvial periods, already existing depression became deepened and widened.

- Soosa (1966) mentioned the Tharthar Depression was formed due to karstification. However, he mentioned that it might be formed due to an earthquake in the year 1423.
- John (1899) in Soosa (1966) mentioned that the Tharthar Depression has formed due to successive earthquakes.
- Ibrahim and Sissakian (1975) carried out regional geological mapping for the western and northern banks of the Tharthar Depression, but they did not mention any thing about its origin.
- Hamza (1975) carried out regional geological mapping for the southern bank of the Tharthar Depression, and adopted the idea of NEDECO (1959).
- ATOMOENERGOEXPORT (1985) contributed in a feasibility study, which aimed in selection of a nuclear power plant site, in Baiji – Samarra area. They mentioned that there is an active fault, running parallel to the Tharthar valley, and had contributed in the development of the Tharthar Depression.
- Sissakian *et al*. (1991) considered a Tharthar – Razzaza Fault Zone to coincide with geophysically evidenced Tharthar – Razzaza Active Deep Fault Zone, which has no surface expression, except the direction of valleys, especially between Al-Qanater and Hadhar area, northwest of the depression. Moreover, it is characterized by N – S trending deep seated faults, which are traced along the northern part of Tharthar valley, south of Hader area. They are believed to be caused by Hejaz Orogeny.
- Sissakian *et al.* (1991) considered the development of the Tharthar Depression due to karst origin, although tectonic origin could not be ignored.
- Yacoub *et al*. (1991a and b) claimed Pleistocene – Holocene age for the Tharthar Depression.
- C. E. S. A. (1992) considered the Tharthar Depression is located within two Neotectonic zones, named as Tharthar and Samarra – Tikrit Zones.
- Al-Sakini (1993) in Ma'ala (2009) attributed the development of the Tharthar Depression due to Neotectonic activity in Falluja anticline, which converted the direction of Tharthar valley towards the north and modifying it to influent river through sinkholes, consequently the depression was developed due to karstification.
- Ma'ala (2009) considered the origin of the Tharthar Depression as a collapse doline.

THARTHAR DEPRESSION

The following data are available about the Tharthar Depression.

▪ Characteristics

The Tharthar Depression is characterized by the following data (Fig.2), some of the data are from Soosa (1966), and others are measured from topographic maps.

- It is a natural closed depression, in between two almost flat plains, Al-Jazira and Mesopotamia.
- It has N – S trend, in the upper third (northern) part, with longitudinal shape, then changes its shape and trend to N35° W – S35° E, having almost a bowl shape, the base being towards the southeast.
- Its length is 120 Km, the width in the upper third part ranges between (0.4 – 18) Km, whereas in the remaining part ranges between (24 – 48) Km, as being measured on top elevation of 65 m, a.s.l.
- The slope of the cliffs of the eastern bank ranges between (25 – 55)°, whereas the western bank ranges between (4 – 13)°.
- The elevation of the floor ranges between (– 3 to 42) m, the deepest one being towards the north of the depression. However, unfortunately the existing topographic maps did not show the details of the floor, due to scale limitation.
- The depth/ width ratio ranges from 0.017 to 0.125. According to White and White (2006) such ratio considers collapse doline origin for the depression.
- The length/ width ratio ranges from 27.6 to 300. According to White and White (2006) such ration considers "solutionally widened fractures of various sources" as the genesis of the depression is concerned.
- The width at top/ width at bottom ratio range from 2 to 4.5. According to White and White (2006) such ratio considers a collapse doline origin for the depression.
- The storage capacity of the depression is 73×10^9 m^3 and 78×10^9 m^3, in surface elevation of 60 m and 65 m, a.s.l., respectively. The depression was changed to a reservoir in 1956, to collect the access-flooded water in the Tigris River. It was commissioned successfully to protect Baghdad from dangerous floods during the last century. The construction of the dam near Samarra and the whole project was the idea of Sir William Wilcox in 1910, the estimated cost of the project was 12 000000 Iraqi Dinars (Soosa, 1966).

▪ Historic Review

According to Soosa (1966), the Tharthar Depression consists, originally of two depressions: A southeastern one, it is called Al-Rafa'i, with floor elevation of 42 m (a.s.l.) and a northwestern one, it is called Umm Al-Rahal with floor elevation of – 3 m (a.s.l.). Moreover, wadi Tharthar was draining from Khabour River, near present location of Zakho, in northwest of Iraq, passing from Hatra, and had changed its course, which was joining Tigris River south of Tikrit, by 2 Km. Moreover, there was a branch of wadi Tharthar, which was joining the Euphrates River near Umm Al-Roos castle, 35 Km northwest of Falluja. These data was mentioned by many historians, among them are Abu Al-Fida'a (732 Hijriya, 150 A.C). However, Tharthar Depression was not existing during the historians Yaqoot Al-Hamawi (1226), Abin Al-Haq (1338) and in the map of Al-Idrisi (1664) (Soosa, 1966). He also mentioned that the map of the Al-Idrisi (1664) shows many small depressions, which confirm that the Tharthar Depression was not present; otherwise it should appear in the map. Soosa (1966) mentioned detailed data concerning the geographical locations of many streams and rivers that have close relation to Tharthar valley, without mentioning the presence of the depression until 17th Century.

According to John (1899) in Soosa (1966), successive earthquakes during 1680, 1769, 1864, 1866 and 1867 have occurred. Other mentioned earthquakes were felt south of Mosul, in 1641 and 1666, which caused the vanishing of 5 towns and 45 villages, which might have contributed in development of the depression. He also mentioned that the depression first appeared in 1429 due to an earthquake.

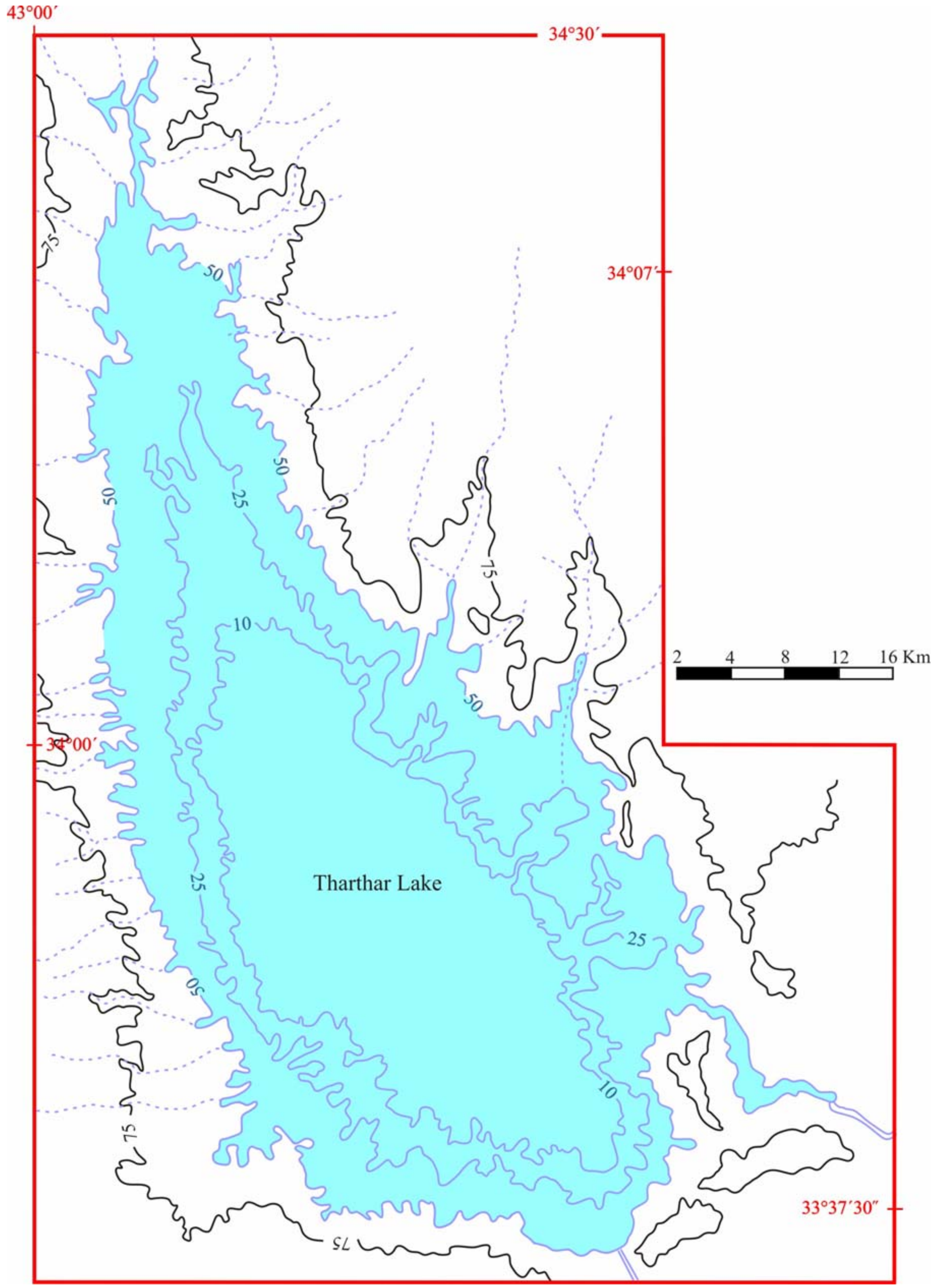

Fig.2: Topographic map of the Tharthar Depression, showing the floor morphology, Note that the details are not clear, due to scale limitations. Moreover, the two mentioned depressions by Soosa (1966) with their depths are not expressed by the contour lines

GEOLOGICAL SETTING

The Tharthar Depression is located within the Outer Platform (Unstable Shelf), in the Mesopotamia Foredeep, between the Jazira and Mesopotamia Plains (Fig.3). The former represents the northwestern sector of the Mesopotamia Foredeep, whereas the latter represents the southeastern sector (Fouad, 2010a). According to Fouad (2010a and b), many subsurface grabens are located north, northwest and west of the Tharthar Depression, all of them have the same trend, which is almost NW – SE (Fig.3). No surface structural features occur around the depression. The regional dip is eastwards, being (1 – 3)°. However, an E – W trending surface anticline runs northwest of the depression, with length of 12 Km, and recorded dip of 13°, it is called Al-Qanater anticline (Ibrahim and Sissakian, 1975).

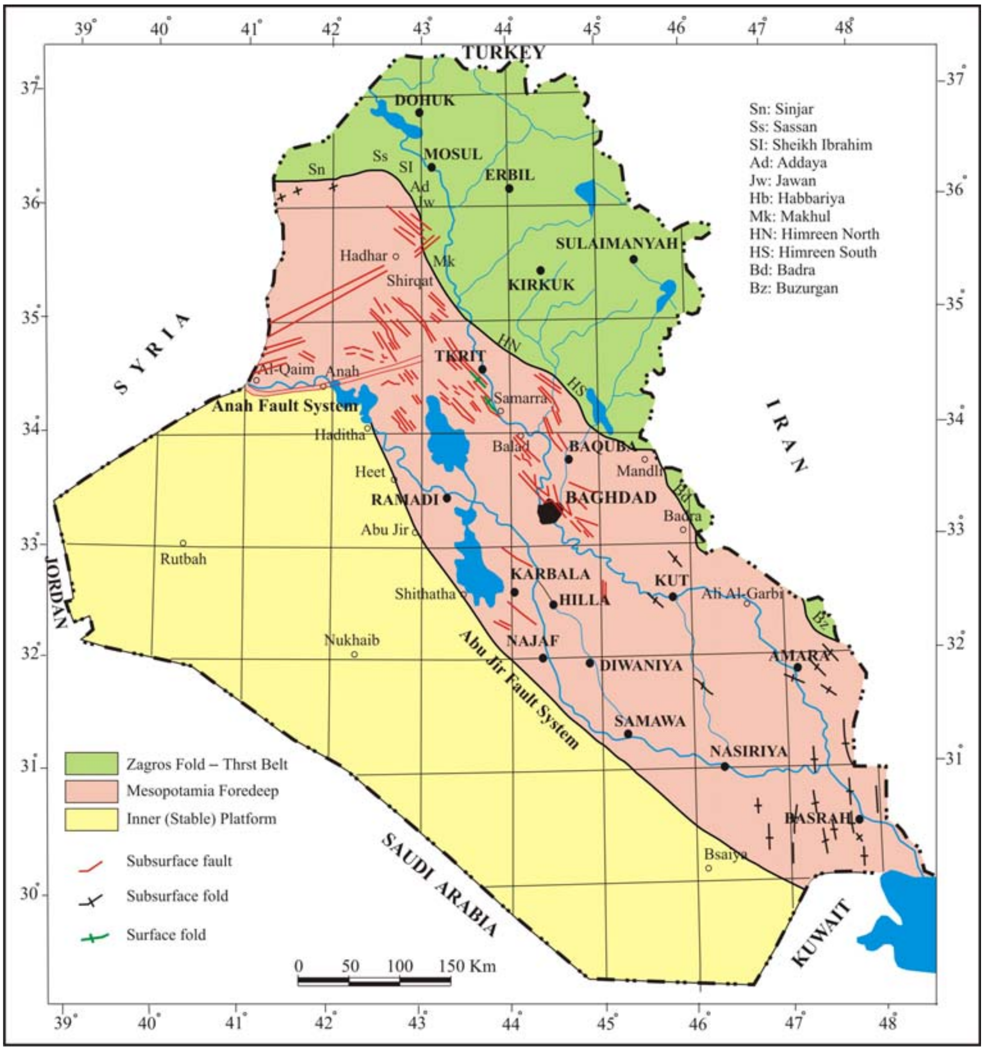

Fig.3: Structural map showing the details of the Mesopotamia Foredeep (after Fouad, 2010a)

Buday and Jassim (1987) and Jassim and Buday (2006) in Jassim and Goff (2006), considered the boundary between the Mesopotamian and Salman Zones to run just along the western bank of the Tharthar Depression. They also supposed a deep seated fault to run in NE – SW trend just in the middle part of the depression. They called it Amij – Samarra Fault, depending on gravity interpretation, with overall down throw towards the south.

From physiographic point of view, the Tharthar Depression is located between two provinces, Al-Jazira Plain, in the west and Mesopotamia Plain, in the east (Fig.4). The filling of the depression by water, hindered the geological, geomorphological and structural details of both eastern and western banks. Therefore, almost no previous workers have mentioned where the boundary runs between different physiographic provinces and/ or tectonic and geomorphological units (Al-Kadimi *et al*., 1996; Hamza, 1997; Fouad, 2010a; Sissakian *et al*., 2011, among others).

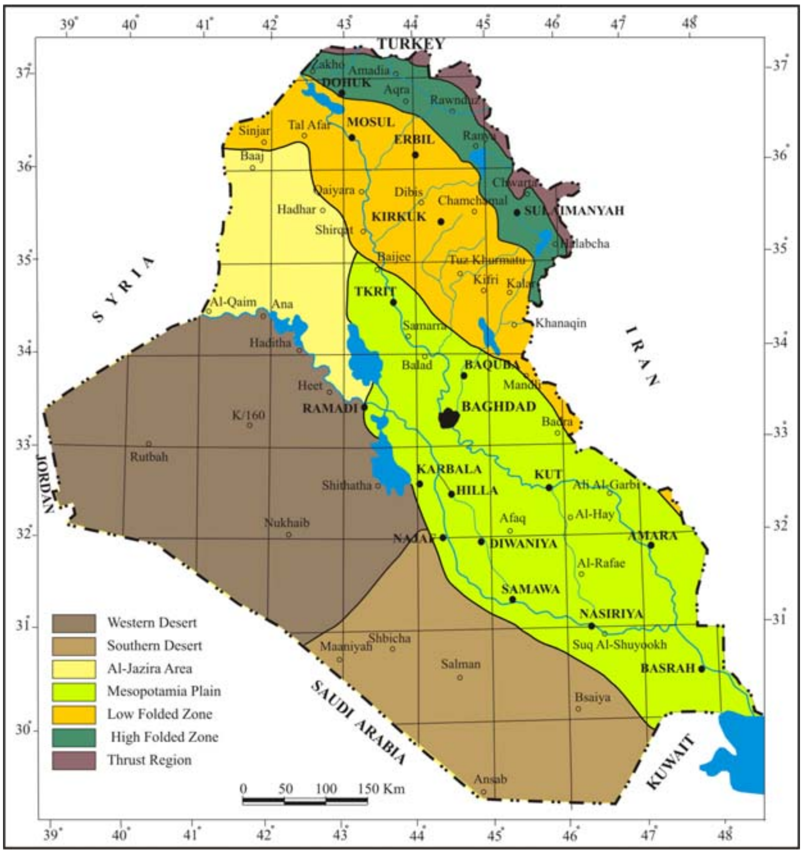

Fig.4: Physiographic Map of Iraq (after Sissakian *et al*., 2011)

Stratigraphically, Fatha Formation (Middle Miocene), which consists of cyclic sediments of marl, limestone, and gypsum, covers the western part of the Tharthar Depression (Sissakian, 2000). The formation is characterized by dens karstification, due to the presence of limestone and gypsum rocks. The developed sinkholes in the former are almost circular in shape, with diameter and depth ratio that range between (1 – 20) and (3 – 35), respectively (Ibrahim and Sissakian, 1975; Hamza, 1975, and Sissakian and Al-Musawi, 2007).

The Injana Formation (Late Miocene) is exposed in the northern, eastern and southern parts of the depression (Sissakian, 2000). The formation consists of cyclic sediments of sandstone, siltstone and claystone. Moreover, the exposed rocks of the Injana Formation in the eastern bank are covered by the sediments of Al-Fatha Alluvial Fan (Sissakian, 2000), which consists of conglomerate (0 – 20 m thick) overlain by gypcrete (1.3 – 7.4 m thick) (Yacoub *et al*., 1991a). The former is exposed in a narrow strip above the rocks of the Injana Formation, whereas the gypcrete of the Fatha Alluvial Fan covers the whole plain towards east and south, until the Tigris River.

From Neotectonic point of view, the Zero line of Middle Miocene Sea passes almost in the middle part of the Tharthar Depression, and almost parallel to the depression and Tharthar valley. The eastern side of the depression is down warped by amount of – 250 m, whereas the western side is up-lifted by 100 m, as being measured in the first recorded amounts of down warping and up-lifting, on both sides of the depression, respectively (Sissakian and Deikran, 1998). The constructed contour lines, on the Neotectonic Map of Iraq (Sissakian and Deikran, 1998), which represent the amount of down warping and/ or uplifting, have the same trend of the depression, on both sides and especially northwards. They run parallel to the Tharthar valley, for about 50 Km, and then diverge on both sides of the valley, towards east and west, respectively. It is worth mentioning that ATOMOENERGOEXPORT (1985) had supposed the presence of an active fault, which runs parallel to the Tharthar valley and considered it as a Neotectonic feature. They called it "Tharthar Active Fault".

From geomorphological point of view, the eastern side of the Tharthar Depression represents the top part of the Fatha Alluvial Fan, which consists of gypcrete (1.3 – 7.4 m thick) underlain by conglomerate. The surface is almost flat with small circular depressions, not exceeding (1 – 3) m, formed due to dissolving of the gypcrete (Yacoub *et al*., 1991a). The western side forms the Jazira Plain, which is built up by the rocks of the Fatha Formation. The plain is characterized by the presence of sinkholes, due to karstification, the depth and diameter of the sinkholes ranges between (3 – 35) m and (1 – 25) m, respectively (Ibrahim and Sissakian, 1975). The southern part of the depression is characterized by dense presence of gypsum blisters, which are elevated and circular forms, developed due to the expansion of the gypsum. The diameter and height of the blisters range between (1 – 15) m and (0.5 – 3) m, respectively (Hamza, 1975). Ma'ala (2009) considered the western side of the depression to be located within the Hader Plain, which is characterized by karstification.

According to Al-Sanawi (2006) in Jassim and Goff (2006), the Tharthar Depression is located in Zone VIII, within the Historical Isointensity Map of Iraq. Moreover, he considered the depression to be located in Zone (0.2 – 0.3) within the Seismic Acceleration Map of Iraq, with design of 100 years, and within Zero Zone, within both Seismic Hazards Map and Seismic Index Map of Iraq. No seismic epicenters were observed nearby the depression.

According to the available geophysical magnetic and gravity data (CGG, 1974 and Al-Kadhimi *et al*., 1984), the Tharthar Depression is dissected by N – S trending fault that almost has bifurcated the depression into two longitudinal parts. The fault is believed to be a deep seated, within the basement, and is responsible for termination of the existing structures on the eastern and western sides of the depression, along the fault. The structures in the east have NW – SE trend, whereas those in the west have NNE – SSW trend. Moreover, the fault is responsible for the development of other depressions, which are located south of Tharthar Depression. The other three depressions are: Habbaniyah, Razzazah and the last one, "which is located between Karbala and Najaf, it is bounded between two vertical cliffs, called Tar Al-Najf and Tar Al-Sayed, it is the only one which is filled by Pliocene – Pleistocene sediments, represented by Dibdibba Formation, which is underlain by Nfayil Formation (Sissakian, 2000). The age of the sediments could be used for estimation of the age of the depressions" (Mr. Jassim Al-Bdaiwi, personal communication).

AGE DETERMINATION

The age of the Tharthar Depression, if the historical data is considered, should be during the 17^{th} Century, which means late Holocene, because the Tharthar Depression was not existing during the historians Yaqoot Al-Hamawi (1226), Abin Al-Haq (1338) and in the map of Al-Idrisi (1664) (Soosa, 1966). When the conventional geological factors are assumed, then the author claims Holocene age. This is attributed to the presence of gypcrete layer covering the plateau in the eastern side of the depression and along the eastern cliffs of the depression. The age of the gypcrete is Pleistocene – Holocene (Yacoub *et al*., 1991a and b), therefore the depression must be developed after the formation of the gypcrete, otherwise the gypcrete would not be present only along the cliffs, but also in the floor of the depression, and because it would be eroded by active erosional processes, as it is continuously eroding nowadays. It is worth mentioning that Yacoub *et al*. (1991b) claimed Pleistocene – Holocene age for the development of the depression. However, the claimed age by Al-Bdaiwi (personal communication) is beyond the estimated age in this study.

RESULTS

The Tharthar Depression is a natural closed depression; it was changed since 1956 to a lake to collect the flooded water in the Tigris River. It has longitudinal shape in its northern part, with N – S trend, which is the extension of the Tharthar valley. Then changes to a bowl shape with almost N 35° W – S 35° E trend. The depth/ width ration ranges from 0.125 to 0.017 and length/ width ratio ranges from 27.6 to 300. Whereas, the width at top/ width at bottom ratio ranges from 2 to 4.5. According to White and White (2006) such ratios give the depression a term of doline and "solutionally widened fractures of various sources". The exposed rocks in the eastern side are clastics of the Injana Formation (Late Miocene), overlain by conglomerate and gypcrete of Al-Fatha Alluvial Fan sediments (Pleistocene – Holocene). In the western side, the Fatha Formation is exposed (Middle Miocene), with cyclic sediments of marl, limestone, and gypsum, the formation is characterized by dens karstification. The depression is located between Al-Jazira Plain, in the west and Mesopotamia Plain, in the east. Both plains belong to the Mesopotamia Foredeep, which is a part of the Outer Platform of the Arabian Plate (Fouad, 2010a). Many subsurface grabens are located towards west, northwest and north of the depression (Fouad and Nasir, 2009). The Tharthar Depression was formed due to karstification and continuous sinking of a subsurface graben. At least two main karst forms were conjugated together to form the bowl shape of the present form of the depression, the southern one being the larger one. Whereas the longitudinal shape of the northern part is attributed to the merging of the Tharthar valley in the depression, and due to its continuous extensive erosion of the exposed rocks in the extreme northern part, which are soft clastics of the Injana Formation. The estimated age of the depression is Holocene.

DISCUSSION

The Tharthar Depression is the largest closed depression in the Jazira Area (Plain), beside many other small depressions, though not with the same depth. It is one of the deepest closed depressions in Iraq, with the deepest part in the floor being – 3 m (a.s.l.). Because the depression is used as a natural reservoir to collect the flooded water in the Tigris River since 1956 (it is called Tharthar Lake, since 1956) therefore, the topographic details of the floor and the morphology of the banks are hindered. The details of the floor and the banks, if were available, then better idea could be achieved about the origin of the depression. Because the details of the floor are hindered, therefore, it is not possible to decide whether it is solution or collapse doline. Soosa (1966) mentioned detailed information about the origin of the development of the Tharthar Depression, especially about the floor. He mentioned that the depression consists of two depressions; the elevation of the shallower one is 42 m (a.s.l.). But, in reviewing the topographic map (Fig.2), it is clear that the whole depression shows elevation of 10 m (a.s.l.), as the deepest part, although the deepest part is not shown on the map, due to the accuracy of the scale (1: 100000). However, in reviewing Fig. (5), though the depression is filled by water, but still it could be seen two separate depressions, within the main depression, which confirms what was mentioned by Sossa (1966).

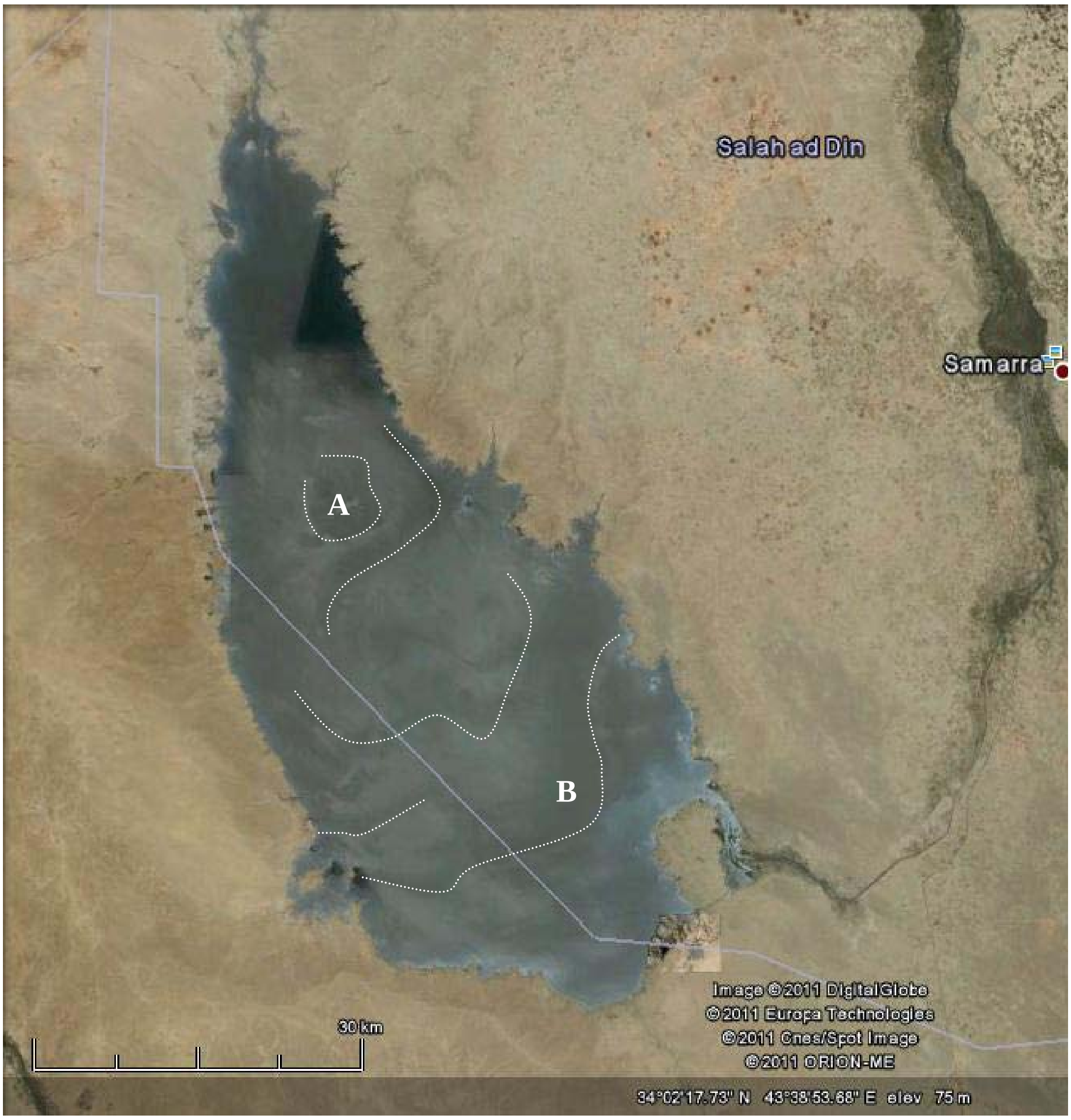

Fig.5: Google Earth image of the Tharthar Lake,
note the presence of two separated depressions (**A** and **B**),
which can be distinguished from the difference in the tone of the water,
due to depth differences.
Also, note the parallel and step-like cliffs(represented by doted lines),
which may indicate step like subsidence

The author is not in accordance with the assumption of NEDECO (1959) and Soosa (1966) about the development of the Tharthar Depression due to karstification and earthquakes, especially the earthquakes. Because, all the present data did not show any earthquake epicenters, neither in the depression, nor in near surroundings, beside the recorded seismicity concerned zones, which show that there is no any seismic hazard in the involved area (Al-Sanawi, 2006 in Jassim and Goff, 2006).

NEDECO (1959) mentioned that the Tharthar Depression is developed due to step-like subsidence of a graben associated with karstification. Moreover, they attributed the genesis to many other factors, such as wind deflation, dipping of the beds eastwards, and the presence of Bakhtiari Formation in the eastern side of the depression. The author is not in accordance with the last three mentioned factors, because the role of the wind and the dip direction cannot contribute in development of such a huge depression. Otherwise, why no other depressions have developed in nearby areas, which are under the effect of the same two factors. Concerning the role of Bakhtiari conglomerate, though the conglomerate belongs to the sediments of the Fatha Alluvial Fan, the presence or otherwise of conglomerates can not contribute in development of such a huge depression. The comparatively alternated light and dark tones may indicate a step-like subsidence in the depression. Such forms are clearly visual in Fig. (5), which may indicate the subsidence due to the presence of a subsurface graben.

ATOMOENERGOEXPORT (1985) attributed the development of Tharthar Depression to an active fault, which they assumed to run N – S along Tharthar valley and extends southwards, they called it "Tharthar Active Fault". The author is not in accordance with their assumption. Careful inspection and interpretation of aerial photographs, Landsat and Google Earth images, did not show any indication for the presence of a fault. The absence of the fault was confirmed also by Yacoub *et al*. (1991a and b), C.E.S.A. (1992) and Fouad and Nasir (2009). Even though, the presence of a fault hardly can develop such a huge depression, with a maximum width of 48 Km and surface coverage area of 2050 Km^2.

The Tectonic Map of Iraq (Fig.3, Fouad, 2010a) shows that many subsurface grabens occur west, northwest, and north of the Tharthar Depression. They have almost the same trend of the depression, when observed in part, not as the whole depression. Their widths are almost the same as that of the northern and central parts of the depression (not the whole size of the depression, which is widened by collapsing and erosional factors). This may indicate that the depression may include many subsurface grabens, although not indicated by Fouad and Nasir (2009), due to absence of seismic data in the area. However, according to OEC (1989) three subsurface grabens, with NW – SE trend exist in the depression, as deduced from seismic data. Moreover, two drilled oil wells near the depression, named Milih Tharthar and Falluja show thickening of Shiranish and/ or Pilsner Formation, 445 m and 501 m, respectively. Whereas, in Musayib oil well, which is about 150 Km southeast of the depression, the thickness of the Shiranish Formation is only 186 m (I.P.C., 1963). These abnormal thicknesses may indicate the presence of subsurface grabens, in which the Late Cretaceous sediments show abnormal thickening, representing syn-rift sediments, as it is the case in the majority of subsurface grabens in the Jazira Area, like Anah, Khlessia, and Tayarat (Fouad and Nasir, 2009). Moreover, Fig. (5) clearly shows the presence of parallel lines, especially along the eastern bank, beside the step-like lines inside the depression, although it is filled by water. Those parallel lines may indicate the graben cliffs, whereas the step-like lines may indicate step-like subsidence. The grabens, west of the depression were inverted to anticlines, during Late Cretaceous – Paleocene, and show extensive fault dragging and development of anticlinal fold on the footwall (Fouad and Nasir, 2009 and Fouad, 2010b). Therefore, the crestal parts were highly deformed, thus, contributed and accelerated in the cracking of the surface. Consequently, the surface was eroded more quickly than other areas and the depression was developed, besides the role of the karstification. Large scale structures, mainly folds and faults, create the setting in which karst development can take place (White and White, 2006); the author believes that this assumption is almost the same as that of the Tharthar Depression.

Continuous sinking of depressions, due to the presence of subsurface grabens and karstification, and conjunction of more than one circular karst form together is a common phenomenon in the Jazira Area, west and northwest of the Tharthar Depression. Good examples are Snaisla and Ashqar Salt Marshes, which are located about 150 Km and 120 Km northwest of the depression, respectively. Ashqar Salt Marsh has almost the same scenario in its development (Sissakian and Abdul Jabbar, 2009), although it is not matured yet as Tharthar Depression is. Moreover, such huge depression developed due to karstification (only) is well known phenomenon in Iraq, especially in the Southern Desert (Sissakian and Al-Musawi, 2007). Good example is Salman Depression, which is well known as "Nuqrat Al-Salman", its length and width are 20 and 10 Km, respectively, with depth of 25 m. Many other karst depressions exist near Salman Depression, like Al-Sa'ah and Al-Haddaniyah. The length and width of both depressions are (8.5 x 3) Km and (11.5 x 7) Km, respectively. The three depressions, with many other smaller depressions are located within an area of 21 x 30 Km. The distance between them, in some places is less than 1 Km, this means they will merge together after continuous collapsing of their rims. Their shapes, however, indicate clearly that each one of the three main depressions was originally consisting of more than one depression. The Tharthar Depression could have very similar development origin, as it is the case in Salman vicinity, but with excluding the effect of the subsurface graben in the genesis of the Tharthar Depression.

It is often difficult to distinguish a real collapse doline from other types of karst depressions. It is even more difficult in the case of the older features, which have been modified by erosion processes, and where the primary origin is no longer clear (Kranjc, 2006). Moreover, the filling of the depression by water had hindered the details of the floor and the surrounding cliffs, which would help in concluding the origin of the depression more precisely, if were not inundated by water.

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CONCLUSIONS

The following could be concluded about the Tharthar Depression from this study.

- The Tharthar Depression is a natural closed depression; its floor being the deepest point in Iraq, bellow surface, the floor height is – 3 m (a.s.l.).
- The Tharthar Depression was formed due to karstification and continuous sinking of a subsurface graben. At least two main karst forms were conjugated together to form the bowl shape of the present depression.
- Polygenetic genesis is assumed for the development of the depression, due to large length/ depth ratio, which ranges from 27.6 to 300, it is in part a collapse doline, due to its depth/ width ratio, which ranges from 0.125 to 0.017, and it is of collapse doline origin, due to its width at top/ width at bottom ratio, which ranges from 2 to 4.5. However, solution doline origin should not be ignored
- The age of the development of the Tharthar Depression is most probably Holocene, and might be during the 17th Century.

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