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STRATIGRAPHY

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ABSTRACT

The stratigraphy of the Iraqi Western Desert is reviewed. The oldest exposed rocks are Permian in age, belong to the Ga`ara Formation, whereas the youngest are Pliocene – Pleistocene, belong to the Zahra Formation. The exposed stratigraphical column is represented by 32 formations. Morover, eight main types of Quaternary deposits, which have wide geographic extent are reviewed too.

For each exposed formation, the exposure areas, subsurface extension, main lithology as described inform of members and/ or informal units, thickness, fossils, age, depositional environment and the lower contact is described. Because, almost all formations are described by different authors from different localities, therefore all descriptions of different authors are reviewed, with occasional comments.The paleogeography is reviewed briefly.

Each formation is discussed, for majority of them the present author`s opinion are given, with many recommendations for future studies. Some new ideas dealing with many aspects for many formations including proposals for establishing new formations are given, too.

الطباقيـــــــــــة

فاروجان خاجيك سيساكيان* و بثينة سلمان محمد**

المستخلص

تمت مراجعة طباقية الصحراء الغربية العراقية من اقدم الصخور المتكشفة والتي تعود الى عصرالبيرمي المتمثلة بتكوين الكعرة والى عصر البلايوسين – البلايستوسين المتمثلة بتكوين الزهرة. ان العمود الطباقي في الصحراء الغربية العراقية يتمثل باثنين وثلاثين تكوين متكشف، اضافة الى ثمانية انواع رئيسية من ترسبات العصر الرباعي ذات الإمتداد الجغرافي الواسع والسمك الكبير.

لكل تكوين متكشف، تم وصف التوزيع الجغرافي السطحي وتحت السطحي، الصخارية وكما جاء في وصف كل عضو او وحدة في التكوين، السمك، المتحجرات، العمر، البيئة الترسيبية والحد الاسفل. نظرا لكون غالبية التكوينات تتكشف في مناطق مختلفة جغرافيا، فقد تم دراسة هذه التكوينات من قبل العديد من المؤلفين، لذا تم وصف المكونات المذكورة في اعلاه لكل تكوين وكما جاء في وصف المؤلفين في المناطق المختلفة. وذكرت الجغرافية القديمة باختصار.

كما تمت مناقشة كل التكوينات مع إبداء الرأي لغالبيتها وإعطاء المقترحات للدراسات المستقبلية وكذلك اضيفت افكار جديدة لبعض التكوينات ومقترحات لتسمية تكوينات جديدة في عدة مناطق.

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INTRODUCTION

During the last three decades of the last century, huge amount of data were acquired concerning the stratigraphy of the Iraqi Western Desert. These were mainly achieved through the regional geological survey, which started in 1970 and was terminated in 1982. The second stage, of data collection, achieved through detailed geological survey, which was mainly forwarded for mineral investigation in selected areas. During this stage, which started in 1984, detailed stratigraphical studies were conducted, too.

Through both aforementioned stages, many new formations were established, others were amended and their new statuses were elucidated more clearly than before. Based on the regional geological survey data, GEOSURV compiled the Geological Map of Iraq, scale 1: 1 000 000, in 1986 (Jassim *et al.,* 1986). The second edition was issued in 1990 (Jassim *et al.,* 1990), based on some additional detailed geological data. The third (last) edition was issued in 2000 (Sissakian, 2000), based on all executed regional and detailed geological surveys, utilizing the compiled series of geological maps scale 1: 250 000 (39 sheets). Within the three editions of the Geological Map of Iraq, scale 1: 1 000 000, main differences could be recognized when concerning the stratigraphy of the Iraqi Western Desert.

This paper is an attempt to review and explain the stratigraphy of the Iraqi Western Desert, aiming to elucidate the geology of the Western Desert.The best available data is used to acquire this paper, which represents GEOSURV`s opinion.

LOCATION

The Iraqi Western Desert covers considerable part of the whole Iraqi territory. Its areal coverage is about 104 000 Km². It extends from the Euphrates River, in the north and northeast to the Iraqi – Jordanian and Iraqi – Saudi Arabian borders, in the west and south, respectively; and to wadi Al-Khir in the east (Fig.1). This wadi divides the desert into two parts, western and southern. Formerly they were called “Al-Badiya Al-Shimaliya and Al-Badiyah Al-Jinoobiyah”, respectively.

GENERAL TOPOGRAPHY

The Iraqi Western Desert is characterized by different topographic natures. The nature of the topography reflects the type of the exposed rocks, their thicknesses and the structural effect. Generally, three main different topographical forms could be recognized, this is mainly due to the presence of Rutbah Uplift, in the middle part. The three parts are:

1– The eastern part, which consists of rocky surface dissected by shallow valleys running northeastwards, with shallow depressions of karst nature. It covers the area extending from wadi Al-Khir to Al-Habbariyah Depression and till the Euphrates River, northwards (Fig.1). The oldest exposed rocks are Paleocene in age and range to Pleistocene.

2– The middle part, in which the Ga`ara Depression is the main upstanding feature. It covers the area between Al-Habbariyah Depression and almost to longitude 40°, northwards to Euphrates River (Fig.1). The area is dissected by dense and deep valleys. The oldest exposed rocks are Permian in age and range to Pleistocene.

3– The western part, which covers the remaining part of the Iraqi Western Desert west of longitude 40° (Fig.1).It consists of flat area usually covered by thin venir of residual soil, dissected by valleys and shallow depressions,which are characterized usually by small and circular shapes, mainly of karst origin. The oldest exposed rocks are Paleocene in age and range up to Oligocene.

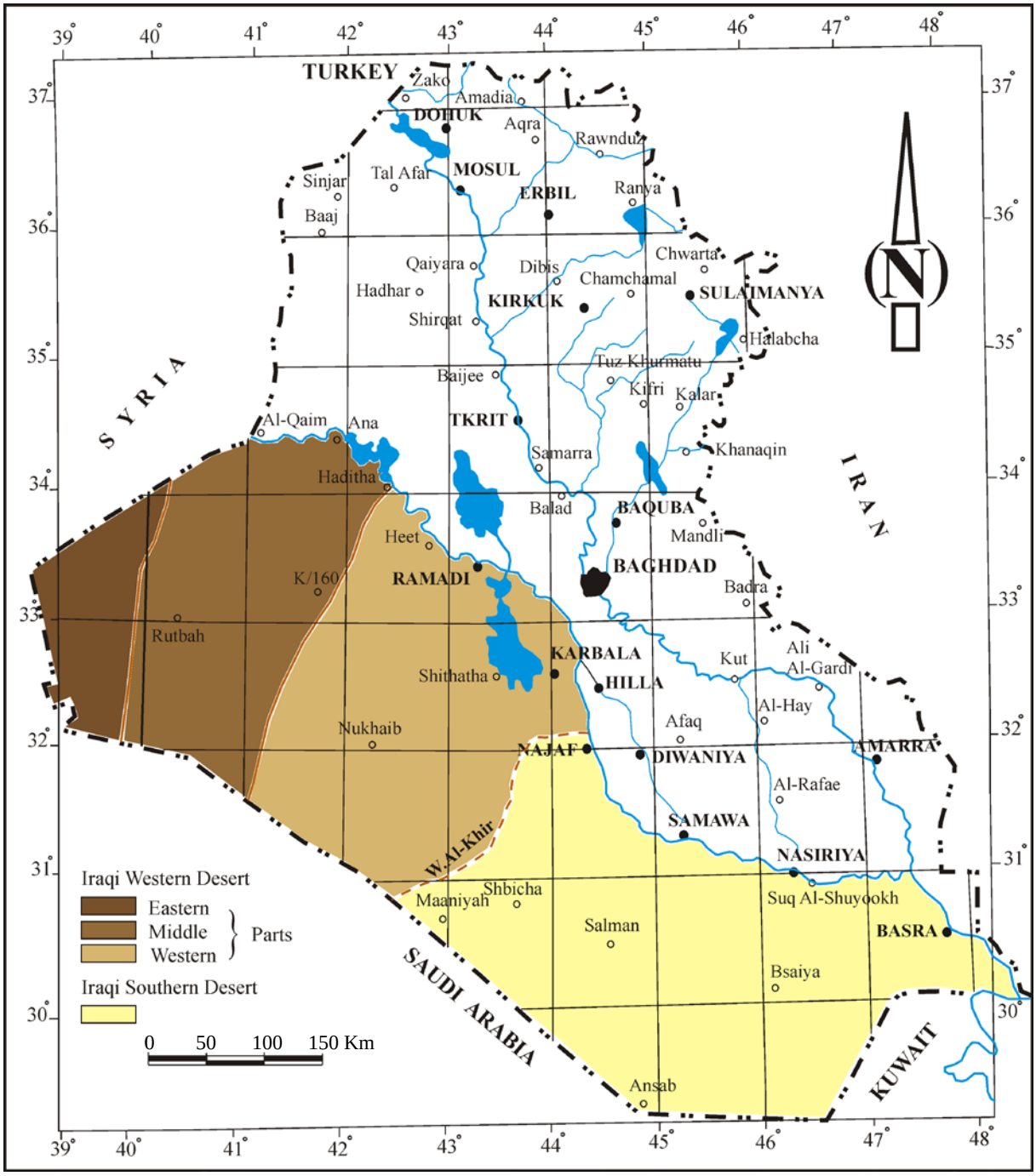

Fig. 1: Location map of the Iraqi Western Desert, with three tentative parts, which are introduced in this study

STRATIGRAPHY OF THE EXPOSED ROCKS

Although the Iraqi Western Desert belongs, tectonically to the Stable Shelf, but the tectonic and structural effects have controlled the type of the exposed rocks, thickness and the extension of the formations. The Rutbah Uplift and Ga`ara Depression have exposed Permian rocks followed by Triassic and Jurassic rocks, which are absent in other parts of the Iraqi Western Desert and the surrounding areas, even in the nearby areas of the neighboring countries. The Rutbah Uplift also has affected the type of the exposed rocks, causing lateral facial changes, due to change in the depositional basin. On the other hand, Nukhaib Graben has caused the deposition of huge amounts of gravel deposits and Pliocene – Pleistocene rocks of Zahra Formation and dividing some depositional basins.

In order to facilitate the description of the exposed geological formations in the Iraqi Western Desert, they are divided, age wise into Paleozoic, Mesozoic and Cenozoic Eras, the eras are divided into epoches. Moreover, each formation is described in a systematic style, starting with the type locality, exposure areas, subsurface extensions, lithology as divided into members and/ or informal units, fossils, age, depositional environment and the lower contact. The whole involved area is divided into the aforementioned three parts, which are used as reference for the geographical locations (Fig.1).

Each formation, generally, is divided by different authors into many members and/ or units. Usually, the same formation is divided into different members and/ or units, by different authors in different localities. Consequently, different names are given to them, within the same formation. The name of the members and units are mentioned in bold letters, as it is proposed by different authors, from different geographic locations, even if they contradict the rules of the International Code of Startigraphic Nomenclature. The name of some formations, however are ammended, from the original name to be in accordance with the rules of the International Code of Stratigraphic Nomencalture. For example the Ga`ara Sandstone Formation is mentioned, hereinafter as Ga`ara Formation. The adopted age by GEOSURV is mentioned between parentheses, beside the name of each formation.

The adopted descriptions of formations with their geographical distribution and other mentioned data is based on the regional and detailed geological survey reports, which attain 21 reports. These are utilized in compilation of geological maps of sacle 1: 100 000, based on the original geological base maps (scale 1: 25 000), which were used in compilation of the published geological maps of scale 1: 250 000.

Within each epoch and/ or period, the paleogeography is reviewed briefly, including the shape of the depositional basin and the effect of the tectonics. This is mainly adopted from Jassim and Buday in Jassim and Goff (2006) and Al-Bassam *et al*. (1990)

The exposed geological formations, from the oldest to the youngest are described hereinafter. Their geographical distribution is elucidated by a geological map, scale 1: 2 000 000 (Figs.2, 3 and 4). The location of the type localities and / or sections is presented in Fig. (5), their reference numbers are mentioned in Table (1).

Wherever the authors were found it is necessary to give explanations, hints, comments concerning the descriptions and/or ideas of previous authors, or when contradictions were met, for any reason or type, then these are entiteled as **"Remark".** The **Remarks** indicate, usually the opinion of GEOSURV that are presented in published geological maps and published or unpublished data.

Table 1: Reference number of the the type locality and/ or type section of each exposed formation, as indicated in Fig. (5)

Serial No.	Formation	Serial No.	Formation	Serial No.	Formation
1	Ga`ara	13	Hartha	25	Baba
2	Mulussa	14	Tayarat	26	Anah
3	Zor Hauran	15	Marbat Beds	27	Ghar
4	Ubaid	16	Digma	28	Euphrates
5	Hussainiyat	17	Um Er Radhuma	29	Jeribe
6	Amij	18	Akashat	30	Fat`ha
7	Muhaiwir	19	Dammam	31	Nfayil
8	Najmah	20	Ratga	32	Injanah
9	Nahr Umar	21	Jil	33	Dibdibba
10	Mauddud	22	Jaddala	34	Zahra
11	Rutbah	23	Shurau		
12	Ms`ad	24	Sheihk Alas		

1. PALEOZOIC

The Paleozoic rocks are exposed only in the middle part of the Iraqi Western Desert. They are characterized by continental nature of deltaic environment. Only one formation belongs to this era:

1.1. Ga`ara Formation (Early – Late Permian)

Type Locality: The type locality is in Ga`ara Depression, Tal Al-Afaif, it is defined by the following coordinates (Fig.5) (Bellen *et al*., 1959):

Longitude 42° 28′ E
Latitude 33° 31′ N

Exposure area: The Ga`ara Formation is exposed only in the Ga`ara Depression, the middle part of the Iraqi Western Desert (Fig.2). The subsurface extension is obscure, because few deep wells exist in the Iraqi Western Desert. Althouhg Anah 2 and Akazz 1 oil wells have penetrated the Permian rocks, but instead of the Ga`ara Formation Red Beds of Early Carboniferous age are described (Al-Jubori *et al.,* 1997) However, Risha 3, in Jordan (7 Km west of the Iraqi – Jordanian borders) struck the Ga`ara Formation. It is also penetrated by Akashat water wells and borerholes KH 3/5, KH 7/5 and KH 9/7 (Fig.5).

Lithology: The Ga`ara Formation, in the type locality consists mainly of red and varicolored sandstones, shales and claystones, with plant remains. The three main rock types interfinger with each other, vertically and laterally. The included conglomerates was found by Al-Bassam *et al.* (1990) to be of Cretaceous age and called them as Marbat Beds. Originally Nijili Formation was introduced by Boesch (1938) in Bellen *et al.* (1959) within the Ga`ara Formation. This was abandoned by Antonents *et al.* (1963) and was accepted by all other authors. The Sufi Formation was introduced by Sarnavka (1964) in deep water KH 5/1 (Fig.5) to be the underlying formation of the Ga`ara Formation. This formation is not announced officially, therefore the authors cannot ascertain the presence or otherwise. However, Jassim and Buday in Jassim and Goff (2006) renamed the formation as Bir Al-Rah Formation.

Thickness: The thickness of the Ga`ara Formation is obscure. The exposed thickness is 140 m (Buday and Hak, 1980). The subsurface sections showed different thicknesses like 770 m in KH 7/5, 655 m in KH 5/6, 565 m in KH 5/1 (Tamar-Agha, 1986), 780 m in KH 5/1 (Sarnavka, 1984).

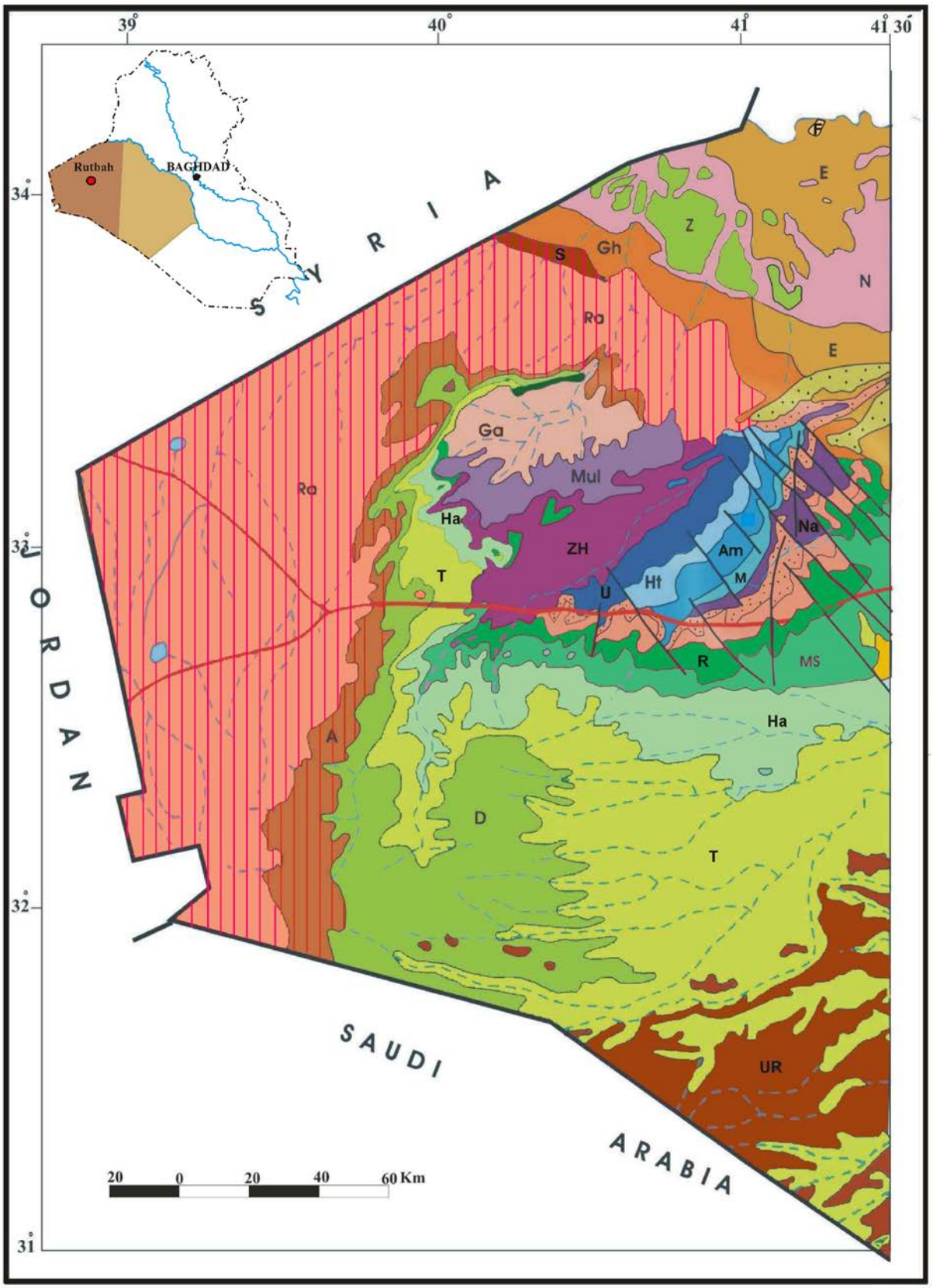

Fig. 2: Geological map of the Iraqi Western Desert (Part I) scale 1: 2 000 000 (modified from Sissakian, 2000). For legend refer to Fig. 4

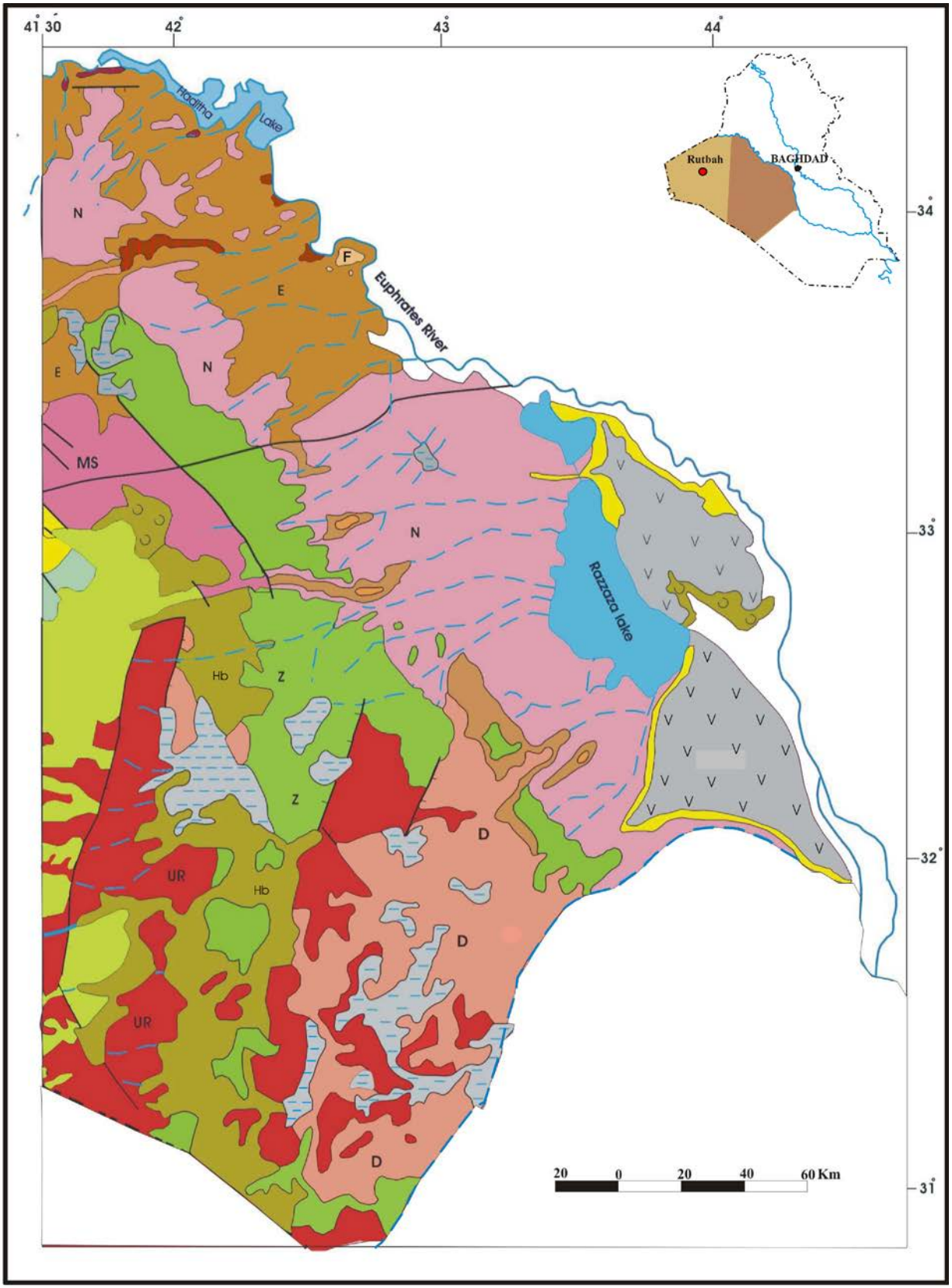

Fig. 3: Geological map of the Iraqi Western Desert (Part II) scale 1: 2 000 000 (modified from Sissakian, 2000). For legend refer toig. 4

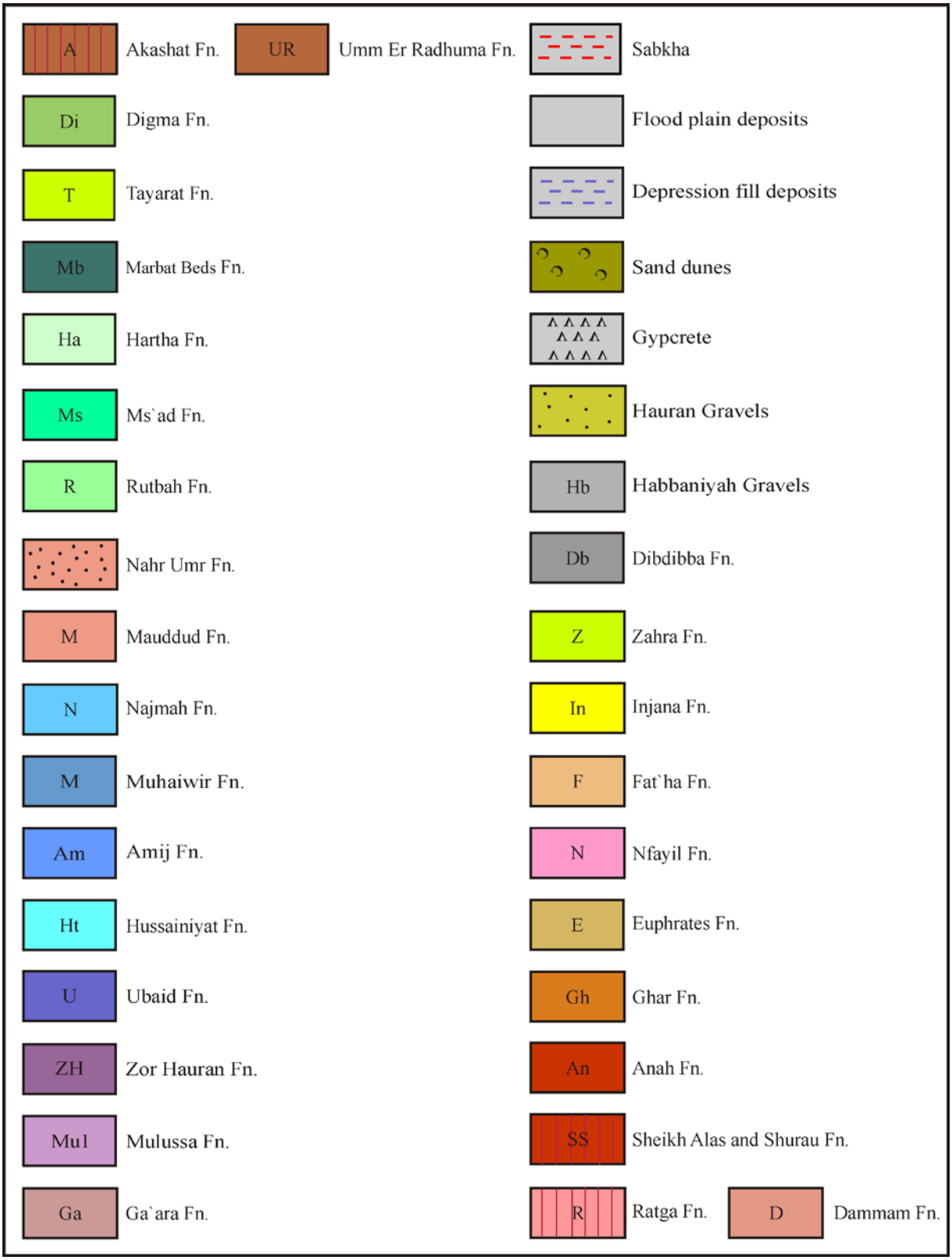

Fig. 4: Legend for figs. 2 and 3

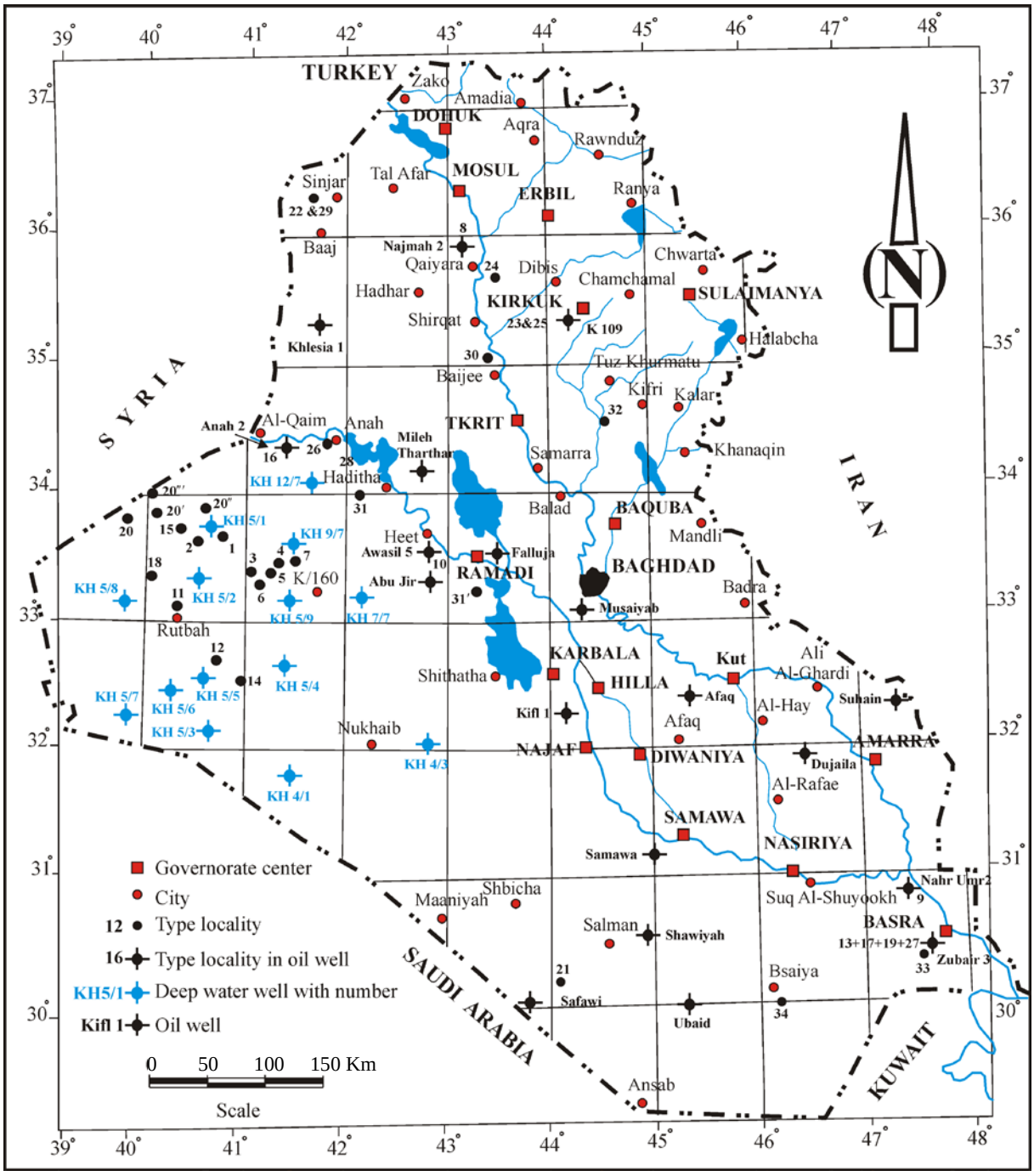

Fig. 5: Location of the type locality or type section of the exposed geological formations

Fossils: The following fossils were recognized by different authors:
Annularia sphenophylloides (ZENK), *Lobatannularia beianesis* (KODAIRA), *Pecopteris sp., Pecopteris units* BRONG, *Odontopteris sp., Taeniopteris sp., Fructification, Plagiozarnites oblongifolius* HALLE, *Protoblechaum sp.* and the following flora in section of KH 5/2 *Punctatosporites sp., Leiolriletes sp., Cyclogranisporites cf. torispora, Granulatisporites sp., Apiculisporites sp., Lopholriletes sp., Convolulispora sp., Cirratrovadites sp., converrucosisporites sp., Laevigatiosporites* florinites, *Vesicaspora vesicaspora* (SCHEMETLII), (Buday and Hak, 1980).
Trisporia, Thymospora, Bunctatosporites, Cadiosporia, Schopfites, Hamiapollenites, Vittatina, Striatopodocarpites, Vesicaspora wilsoni, Platyscaaus Popilionis and *Potonieisporites* (Isho, 1989 and Nadir *et al.,* 1989).
Age: According to Buday and Hak (1980), the age is Early – Late Permian, the surface section being Late Permian only.
Depositional Environment: Buday and Hak (1980) reconstructed the depositional environment as fluviatile and lacustrine. Petranick (1981) indicated liminic character of sedimentation for the lower part of the surface sequence and possibly, of marine sedimentation, deltaic environment of coastal marine is suggested for the lower part too. Tamar-Agha (1986) reconstructed the depositional environment of the surface section as fluviatile with large meandering rivers. Some fluvio – lucstrine (deltaic) sequence are also found in the southeastern exposures in the Ga`ara Depression.
Lower Contact: Because the base of the formation is not exposed anywhere, therefore nothing could be mentioned about the nature of the lower contact. Although Sufi and Bir Al-Rah formations are proposed, but because they are not announced officially, therefore they are not considered here for the lower contact.

2. MESOZOIC

The formations of this era are exposed only in the middle part (Fig.1) of the Iraqi Western Desert. Their presence in the middle part and their absence in other parts is attributed to the Rutbah Uplift and Ga`ara Depression. The exposed formations belong to three periods and are described hereinafter, from the oldest to the youngest:

2.1. TRIASSIC

During Late Triassic, the Stable Shelf was submerged due to the opening of the Tethys Sea and drifting of the Gondwana, comprising innershelf carbonates and clastics. The formations of this period are exposed only in the middle part of the Western Desert, maily due to Rutbah Uplift. Within this period two formations are exposed, these are:

2.1.1. Mulussa Formation (Late Triassic)

Type Locality: It is in the southern rim of Ga`ara Depression, defined by the following coordinates (Fig.5):

Longitude 40° 18' E
Latitude 33° 30' N

The type locality was not designated by the author and many subsidiary type sections are suggested in wadi Hauran and wadi Aujrumiyat (Bellen *et al.,* 1959)
Exposure Area: The Mulussa Formation is exposed only along the southern rim of Ga`ara Depression and part of its eastern rim, also few kilometers along wadi Mulussa (Fig.2). The subsurface extension is obscure; it is not struck in oil wells Akazz 1 and Anah 2, although Triassic rocks are penetrated in the latter (Sissakian, 2000). However, it is struck in oil well Risha 3, this may indicate that the formation has subsurface extension only

westwards. However, some water wells indicate the presence of the Mulussa Formation, like KH 5/5, KH 5/6, KH 5/2, KH 5/4, KH 5/3 and KH 5/7 (Fig.5).

Lithology: The Mulussa Formation in the type locality consists mainly of limestone, in the lower part with subordinate yellow marls (Bellen *et al.,* 1959). Buday and Hak (1980) described the main lithology as silty and marly sandstone and sandy siltstone, at the lower part, dolomites and dolomitic limestones, at the upper part. Antonents *et al.* (1963) and Tamar-Agha (1986) described the main lithology as carbonates, at the lower part and dolomites at the upper part. Qaser *et al*. (1992) described the main lithology as dolomitic marl, at the middle part and interbedding of marls and dolostones, at the upper part.

Thickness: In the type locality is 160 m (Bellen *et al*., 1959), in Ga`ra Depression is 140 m (Buday and Hak, 1980), (145 – 155) m (Antonents *et al*., 1963), 160 m (Tamar-Agha, 1986); 20 m in Al-Hussainiyat vicinity (Qaser *et al.,* 1992); 100 m in Ajroomiyat; 6 m in wadi Mulussa and 3 m in wadi Samhat (Jassim *et al.,* 1984).

Fossils: The following fossils were recorded by different authors, in different localities:
Myophoria c.f. *postern* MOORE, *M.* c.f. *kefersten* (MUNSTER), *Mytilus minutus* (GOLDFUSS*), Trocholina* sp., *Problematica* sp., *Archaediscus* sp. and *Textularia* sp. (Bellen *et al.,* 1959). *Septihorersia joanisaustriae* KLIPSTEIN, *Filopecton filosus* HAVER, *Entolium c.f. hallense* WOHRMAN, *Entoloides c.f. subdemissum* MUNSTRE, *Homomya bittneri* FORMASI, *Rhizocorallium* ZENCER and MASSALONGO, *Zoophycas, Isopodichnus* BORNEMANN, *Imbrichnus* HALLAN, *Thahalassionides* EHRENBERG and *Planolites* NICHOLSON, *Trocholina biconvex* OBERHAUSER, *T. procers* LIEBUS, *Involutina pragsoides* OBERHAUSER, *I. sonousa* WEYNSCHERNK, *Glomospirella* sp., *Glomospirella friedi* KRISTAN and TOLIMAN, *Agathamina* sp. and *Endothyra* sp. (Buday abd Hak, 1980).*Earlanindia tintiniformis* MISIK, *Trocholina multispira* OBERHAUSER, *T. bicovexa* OBERHAUSER, *Cerebrosparites mezozoicus* and *Podocarpidites decriodites* (Yougoslavian Team, 1981, in KH 5/2, near Rutbah).

Age: Carnian – Nornian age (Late Triassic) is accepted for the formation by the following authors, Bellen *et al.* (1959), Buday and Hak (1980), Tamar-Agha (1986) and Qaser *et al*. (1992).

Depositional Environment: The following depositional environments are suggested by different authors: Supratidal to intertidal with lagoon influence (Buday and Hak, 1980). Sabkha environment for the upper part of the formation (Skocek and Hussain, 1980). Marine, lagoon, tidal flats and shallow shelf environment, in arid to semi arid climate (Tamar-Agha, 1986 and Qaser *et al.,* 1992).

Lower Contact: The Mulussa Formation is always underlain unconformably by the Ga`ara Formation, the contact is very sharp, based on the first carbonate bed after the clastics.

2.1.2. Zor Hauran Formation (Late Triassic, Rhaetic)

Type Locality: The lower part of the type section is 1 Km southwest of base of west limb of large meander, northeast of Zor Hauran, approximate coordinates are:

Longitude 40° 55' 25" E
Latitude 33° 26' 25" N

and the upper part of the type section is in eastern limb of wadi Hauran meander, 32 Km northeast of H_2 water wells and 20 Km west of Muhaiwir (Fig.5) (Bellen *et al*.,1959) , approximate coordinates are:

Longitude 40° 56' E
Latitude 33° 28' 40" N

Exposure Area: It is exposed south of the Ga`ara Depression, extending for about 55 Km, covering Al-Rutbah town (Fig.2). The subsurface extension is obscure. It is not struck in Akazz 1 and Anah 2, although Triassic rocks were penetrated in the latter (Sissakian, 2000). However, it is struck in Risha 3; this may indicate that the formation has subsurface extension only westwards, most probably due to tectonic effects.

Lithology: The formation, in the type locality consists mainly of yellow and green gypsiferous marls and shales, interbedded with yellow marly limestone, limestone and dolostone (Bellen *et al.*, 1959). It consists of yellow gypsiferous clay, marl and siltstone alternated with limestone, at the upper part (Antonents *et al.,* 1963). It consists of yellow calcareous mudstone, marlstone, siltstone, alternating with limestone (Buday and Hak, 1980). It consists of yellow gypsiferous and fossileferous marl, interbedded with yellowish green dolomitized limestone (Tamar-Agha, 1986). Al-Naqib *et al.* (1986) divided the formation into four lithologic units, these are: **(1) Stromatolitic Unit** consists of marly dolostone and dolostone**. (2) Cross bedded Unit** consists of marl, marly dolostone and limestone. **(3) Crystal Mold Unit** consists of marl, dolostone, arenaceous dolostone, marly dolostone, marly dolosiltite and dolomitic limestone. **(4) Oolitic and Stromatolitic Unit** consists of marls and limestones in cyclic nature, seven cycles were recorded. Qaser *et al.* (1992) divided the formation into three units, these are**: (1) Lower Zor Hauran Unit** consists of marl, dolomitic marl and dolostoe. **(2) Middle Zor Hauran Unit** consists of oolitic dolostone and yellow marls, alternated with limestone and dolomiti**c** limestone**. (3) Upper Zor Hauran Unit** consists of dolomitic marl and dolostone. Al-Azzawi and Dawood (1996) divided the formation into three units, these are: **(1) Lower Zor Hauran Unit** consists of yellow and green marl. **(2) Middle Zor Hauran Unit** consists of yellow dolostone and sandy dolostone. **(3) Upper Zor Hauran Unit** consists of yellow dolostone.

Thickness: The following thicknesses are recorded by different authors: 45 m in the type locality (Bellen *et al.*,1959); 45 m (Antonents *et al.*,1963); 50 m (Buday and Hak,1980); 150 m in wadi Hauran and decreases towards northwest to (20 – 60) m (Qaser *et al*., 1992); (65 – 70) m east of Rutbah town (Al-Naqib *et al*., 1986) and 40 m NW Kilo160 vicinity (Al-Azzawi and Dawood, 1996). The large thickness variations are due to wedging out of the formation westwards.

Fossils: The following fossils are recorded by different authors: *Lingula* sp., *Myphoria, Archaediscus* sp., *Glomospira* sp., *Trocholina* sp. and ostracods, echinoids (Bellen *et al.,* 1959). *Involutina* sp., *Nodosaria* sp., *Gervilla praecurson* QUENSTADT, *Glomospirella cf. freidle* KRISTAN and TOZIMAN (Buday and Hak, 1980). Shell fragments and algal stromatolites, in the lower part, wheras the upper part contain the following fossils: *Trochammina cf. helicta* TAPPAN, *Ammodiscus* sp., echinoids plates and abundant oyster and other shell fragments (Karim in Qaser *et al*., 1992). *Glomospirella* sp., *Ammodiscas* sp., O*pthamidium* sp., *Frondicularia* cf. *wrodwsarda* HOWCH, *Milioporella* sp., *Involutinal* cf. *Communis* KRISTAN and *Involutinal cf impresa* KRISTAN and TOLLMAN (Kaddori, 1984 and 1988).

Age: All concerned authors agree with Rhaetic age (Buday and Hak, 1980; Al-Jumaily, 1984; Tamar-Agha, 1986; Karim in Qaser *et al.,* 1992 and Al-Azzawi and Dawood, 1996).

Depositional Environment: The following depositional environment is suggested by different authors: Euhaline of subtidal up to intertidal zone, the local presence of evaporates indicate hyperhaline environment (Bellen *et al*., 1959). Lagoon regressive period, with evaporate type of sediments (Buday and Hak, 1980), intertidal to subtidal and lagoonal highly influenced by fluctuating sea level (Al-Jumaily, 1984, in KH 5/9). Supratidal sabkha, intertidal to inner shelf, marine (Qaser *et al.,* 1992). Shallow intertidal flat, shelf lagoon, tidal flat and restricted platform (supratidal) (Al-Azzawi and Dawood, 1996).

Lower Contact: The Zor Hauran Formation is always underlain conformably by the Mulussa Formation; the contact is sharp based on the bottom of the first yellow marl.

2.2. JURASSIC

The formations of the Jurassic Period are exposed only in the middle part (Fig.1) of the Western Desert, mainly due to Rutbah Upift. The frequent break in sedimentation and cyclic regression and transgression of the sea caused cyclic deposition of fluvial to fluvio-marine clastics followed by inner shelf to coastal carbonates. This is attributed to differential subsidence during Late Jurassic due to tectonic activity, prior to the opening of the Southern Neo Tethys led to periodic isolation of the intra-shelf basin from the Neo Tethys; consequently calcareous neritic and lagoon facies were depoited. Five sedimentary cycles represent this period; each cycle consists of clastics overlain by carbonates, with some exceptions. Among the five formations only two were recorded previously, the other three formations are recognized during the regional geological surveys and ascertained during the detailed geological surveys. The five exposed formations are described hereinafter:

2.2.1. Ubaid Formation (Early Jurassic, Lias)

Type Locality: It is along wadi Hauran, from a point 2 Km northwest of the junction of wadi Hauran and wadi Husainiya, 5 Km west of Muhaiwir, at approximate coordinates:

Longitude 41° 02' 50" E
Latitude 33° 32' 00" N

to the junction of wadi Hauran and wadi Ubaid (Fig.5) (Bellen *et al.*,1959) at coordinates:

Longitude 40° 58' 40" E
Latitude 33° 30' 20" N

Exposure Area: It is exposed northeast of Al-Rutbah town about 25 Km and extends along wadi Hauran till Qasir Muhawir, forming a narrow strip with width of 10 Km (Fig. 2). The subsurface extension is obscure, because it is not struck in any nearby wells, like Akazz 1, Anah 2, Risha 3 and Awasil 5... etc. (Fig.5).

Lithology: The following descriptions are given by different authors from different localities: In the type locality, it consists of crystalline limestone, dolomitized limestone with marl intercalations, dolomitized limestone with abundant chert nodules, the upper limits are unknown (Bellen *et al.,* 1959). Buday and Hak (1980) divided the formation, south of the Ga`ara Depression into two members. **(1) Hussainiyat Member** (25 – 30) m thick composed of sandstone with interbeds of marl and iron or lenses. **(2)Ubaid Member** (40 – 50) m thick, consists of sandy limestone with abundant chert, at the bottom and the top, occasionally interbeds occur too. Al-Mubarak and Amin (1983) divided the formation NW of Kilo 160 vicinity into two members, these are: **(1) Lower Clastic Member** (exposed thickness is 10 m) it consists of coarse sandstone interbedded with claystone, the dominant color is yellow, brown and red, some quartziitic sandstone lenses and ferruginous materials occur too. **(2) Upper Carbonate Member**, the thickness is (70 – 88) m and consists of three parts. The lower part (28 m) consists of dolomite and dolomitic limestone with common yellow grey color and chert nodules. The middle part (40 m) consists of dolomitic, recrystallized and shelly limestone, with abundant chert nodules. The upper part (20 m) consists of alternation of gypsiferous marl and recrystallized shelly limestone. Buday and Hak (1980) divided it into Lower Uba`id and Upper Uba`id. **(1) Lower Ubaid** (40 – 45 m) consists of dolostone, dolomitic limestone with chert nodules. **(2) Upper Ubaid** (58 m) consists of dolostone with silty or mudy admixture. In between Lower and Upper Ubaid, they considered **Hussainiyat Member** (55 m), which consists of sandstone interbedded with purple mudstone and iron ore

(23 m). Al-Naqib *et al.* (1986) didivded it east of Rutbah into two units: **(1) Lower Clastic Unit** (2 – 5 m) consists mainly of sandstone, occasionally pebbly, with common yellow, brown, pink and red colors. **(2) Upper Carbonate Unit** (42 m) consists mainly of alternation of marl and dolostone, dolomitic limestone, with chert nodules in the uppermost part. Qaser *et al*. (1992) described it in Husainiyat vicinity as carbonates, dolostone with abundant chert nodules and thin layers, followed by marl with geodes, dolostone with common light brown color. Al-Azzawi and Dawood (1996) described it between NW Kilo 160 and Rutbah as yellow, brown, red, grey and pink dolostone, with chert nodules and bands, in the lower and middle parts.

Remark: It is worth to mention that the described lithology of the Ubaid Formation, by different authors, is not the same considered rock sequence. It consists of carbonates only; the described clastics (by some authors) are included to the recently announced Hussainiyat Formation.

Thickness: The following thicknesses are given to the Ubaid Formation, by different authors in different localities. In the type locality it is 75 m (Bellen *et al.*, 1959); 80 m (Buday and Hak, 1980); 47 m east of Rutbah town (Al-Naqib *et al.*, 1986); 98 m NW of Kilo 160 vicinity (Al-Mubarak and Amin, 1984); 65 m along southern rim of Ga`ara Depression (Qaser *et al.*, 1992) and 23 m (Al-Azzawi and Dawood, 1996).

Remark: The difference in the mentioned thicknesses is due to different exposure areas and considering the Husainiyat Formation with the Ubaid Formation, by some authors.

Fossils: The following fossils are recorded by different authors from different localities: *Achaediscus* sp., *Prohlematina* sp., ostracods and pelecypods (Bellen *et al*., 1959); *Spiriferina walcitti* (SOWERBY) (Buday and Hak, 1980), *Neomegalodon* sp., *Grammatodon* sp., *Mytilus* sp. and *Cardita* sp. (Karim and Ctyroky, 1981).

Age: The following ages are suggested by different authors: Early Jurassic (Bellen *et al.*, 1959); Liass (Buday and Hak, 1980 AND Al-Azzawi and Dawood, 1996); Late Triassic – Early Jurassic (Karim and Ctyroky, 1981).

Depositional Environment: The following depositional environments are suggested by different authors: Shallow littoral – lagoonal, showing progressive change from the littoral clastic sedimentation to the near evaporatic lagoon (Buday, 1980); Tidal flat (Skocek and Hussain, 1980); Fluvial origin, represented by flood plain facies, followed by shallow lagoon with hypersaline conditions (Al-Jumaily, 1984) and fluviatile, in the lower part, followed by shallow lagoon (Al-Azawi and Dawood, 1996).

Lower Contact: Almost all the aforementioned authors have considered unconformable contact between the Ubaid Formation and the underlying Zor Hauran Formation. Moreover, they considered the first appearance of the clastic rocks above the marls and/ or dolostones (of Zor Hauran Formation) as the base of the Uba`id Formation. However, Qaser *et al*. (1992) and Al-Azzawi and Dawood (1996) considered the contact between the two formations is the first appearance of dolostone horizon, without mentioning the type of the contact.

2.2.2. Hussainiyat Formation (Early Jurassic, Lias)

The Hussainiyat Formation is recently added to the stratigraphic column of Iraq. The formation was recognized and described for the first time by Al-Mubarak and Amin (1983) during the regional geological mapping of Kilo 160 vicinity. However, it was officially announced by Hassan (1997). Previously, the involved sequence was included within the Uba`id Formation. It represents the second Jurassic cycle.

Type Locality: It is in wadi Hussainiyat (Fig.5) and is defined by the following coordinates (Al-Mubarak and Amin, 1983 and Hassan, 1997):

For the Lower Unit Longitude 40° 40' 00" E Latitude 33° 02' 00" N
For the Upper Unit Longitude 41° 10' 00" E Latitude 33° 34' 00" N

Exposure Areas: It is exposed along wadi Hussainiyat, starting from 42 Km east of Rutbah town and extends northeastwards in a narrow belt, with width of (3 – 12) Km and pinches out in wadi Hauran, 6 Km northeast of Qasir Muhawir (Fig.2).

Lithology: The following descriptions are given by different authors from different localities: In the type locality, Al-Mubarak and Amin (1983) divided it into two units, **(1) Lower Clastic Unit** consists of cyclic sequence of sandstone and claystone. **(2)Upper Carbonate Unit** consists of dolostone, dolomitic limestone and fossiliferous limestone, chert nodules and lenses are common, especially in the middle part. Al-Naqib *et al.* (1986) divided it east of Rutbah into two units, **(1) Lower Clastic Unit** consists of quartzitic sandstone, silty clay, clayey siltstone and claystone. Locally ironstone, sandy conglomerate, kaolinitic calystone, all red in color, occurs as cyclic deposits. **(2) Upper Carbonate Unit** consists of cavernous and nodular dolostone, with oolitic limestone. Al-Mubarak and Amin (1983) divided it in wadi Hauran and wadi Hussainiyat into two members. **(1) Lower Clastic Member** which is subdivided into two units, **(a) Lower Hussainiyat Unit** consists of alternation of sandstone and claystone in cyclic nature, in the northeastern part of the exposure areas, kaolin and iron ore occur within the cycles. **(b) Upper Hussainiyat Unit** consists of alternation of reddish brown and grey, stromatolitic, sandy, shelly limestone and grayish brown, reddish brown and greenish grey, cross-bedded, ferruginous, quartziztic sandstone. **(2) Upper Carbonate Member** consists of brownish grey dolostone, dolomitic, fossileferous limestone, locally they are silicified. Black chert nodules and lenses occur in the middle part. Al-Azzawi and Dawood (1996) divided it west of Kilo 160 into two units, **(1) Clastic Unit** consists of sandstone, clayey sandsone, silty claystone and claystone, in cyclic nature. **(2) Carbonate Unit** is subdivided into two subunits, **(a) Clastic – Carbonate Subunit** consists of alternation of dolostone, sandy dolostone and dolomitic limestone. **(b) Carbonate Subunit** consists of crystalline dolostone, dolomitic limestone, with pelecypods at the uppermost part.

Thickness: The following thicknesses are recorded by different authors, from different localities: 120 m in the type locality (Jassim *et al*., 1984); 60 m in the southwestern part and 97 m in the northeastern part of Kilo 160 vicinities, respectively (Al-Mubarak and Amin, 1983); (10 – 12) m east of Rutbah town and increases to 23 m eastwards, then being the maximum 32 m in the northeastern part of the exposure area (Al-Azzawi and Dawood, 1996) and (60 – 80) m along wadi Hussainiyat (Hassan, 1984).

Fossils: The following fossils are recrorded by different authors: plant genus Cycus (Buday and Hak,1980); *Hydrobia* sp., small gastropods, little pelecypods, ostracods (Karim and Ctyroky, 1981); tree trunks, plant leeves, little gastropods, pelecypods, ostracods and rare algae (Al-Mubarak and Amin, 1983); *Nuculoma* sp., cf. *Nuculoma stoliczhai*, *Gervillela* sp. *Gervillela orintalis*, *Astarte* sp.,*Tancredia* sp., *Anisocardia* sp. *Isocyprina simplex, Pronocella* sp. and *Eomiodon* sp. (Hassan, 1984).

Age: The following authors suggested Lias age for the formation (Buday and Hak, 1980; Karim and Ctyroky, 1981 and Al-Mubarak and Amin, 1983), Bajocian (Hassan, 1984) and Lias (Hettangian – Pliensbachian) (Al-Jibouri, 1998).

Depositional Environment: The following depositional environments are suggested by different authors: Tidal flat, characterized by different conditions, including fresh, salt and hyper saline waters (Buday and Hak, 1980); eolian accumulation with lateritic dust (Skocek and Hussain, 1980); very shallow marginal sea with estuarine and fluviatile intercalations, strong influx of terrigenous clastics (Karim and Ctyroky, 1981); fluvial for the clastic unit and lagoon – bay condition of shallow depth (Jassim *et al*., 1984); continental for the clastics and very shallow marginal sea for the carbonates (Al-Mubarak and Amin, 1983)

and sea regression for the clastics and general transgression for the carbonates (Hassan, 1984).

Lower Contact: The Hussainiyat Formation is underlain unconformably by the Ubaid Formation; all the aforementioned authors confirm that. The contact is based either on the top of the last carbonate bed of the Ubaid Formation, or on the base of a ferruginous (iron ore) bed, within Hussainiyat Formation.

2.2.3. Amij Formation (Early Jurassic, Lias)

The Amij Formation is recently added to the stratigraphic column of Iraq. Previously, the involved sequence was included within the Muhaiwir Formation. It represents the third Jurassic sedimentary cycle. The formation was recognized and described for the first time by Buday and Hak (1980). However, Al-Mubarak and Amin (1983) also recognized the formation, but they named it as Upper Butmah Formation, then they abandoned the name and used Amij Formation. The formation was announced officially by Al-Azzawi (1997).

Type Locality: It is NE of K160, 10.4 km SE of Al-Hussainiyat Dam and defined by the following coordinates (Fig.5) (Al-Azzawi, 1997):

Longitude 41° 34' 00" E
Latitude 33° 20' 00" N

Exposure Area: It is exposed just west of the crossing of the High way No.1 and the old Baghdad – Rutbah road, between wadi Amij and wadi Al-Hussainiyah and extends northeastwards for about 90 Km in a narrow strip with width of (3 – 20) Km. It pinches out bellow Muhawir Formation in wadi Hauran, northeast of Qasir Muhawir for about 7 Km (Fig. 2). The subsurface extension is unknown, since the formation is not struck in the deep wells, nearby to the exposure areas.

Lithology: The following descriptions are given by different author from different localities: In the type locality, Buday and Hak (1980) described it as fine-grained quartz sandstone, followed by reddish marlstone, siltstone, fine sandstone, with several fossiliferous limestone horizons in the lower part. The upper part consists of white and yellowish pink muddy dolomitic limestone and muddy limestone. Al-Mubarak and Amin (1983) divided it NW of Kilo 160 vicinity into two members: **(1) Lower Clastic Member** consists of three to four sub cycles. Each sub cycle consists of alternation of red claystone and limestone.The limestone is interbedded with yellow marl. **(2) Upper Carbonate Member** (24 – 32 m) consists of dolomitic marl and fossiliferous limestone, with common yellow and pink colors. This sequence is in the northeastern part of the exposure area. Southwestwards, the main limestone changes to yellow and red limestone, followed by interbedding of yellow sandstone, occasionally quartzitic and yellow dolomitic marly limestone. The upper part consists of yellow dolomitic, fossiliferous and partly marly limestone. Al-Naqib *et al.* (1986) divided it east of Rutbah town into two units: **(1) Lower Clastic Unit** (21 m) consists of sandstone, siltstone and claystone, with thin beds of limestone. The common color is reddish brown and yellow, with some quartzitic concretions and iron pisolites**. (2) Upper Carbonate Unit** (15 – 30 m) consists of dolostone, dolomitic and marly limestone with rare marl. The common colors are yellow, redish brown, grey, pink and violet, with rare chert nodules. Qaser *et al.* (1992) divided it in the Hussainiyat vicinity into two units: **(1) Lower Clastic Unit** (20 – 25 m) consists of alternation of claystone, siltstone, sandstone and limestone, as one cycle, maximum four cycles are recorded. The common color is red and pale brown. **(2) Upper Carbonate Unit** (20 m) consists of marl, dolomitic limestone and limestone. The common color is pale yellow, brownish grey and violet, with rare chert nodules. Al-Azzawi and Dawood (1996) divided it NW of Kilo 160 vicinity into two units: **(1) Clastic – Carbonate Unit** consists of varicolored calstics, dolostone and dolomitic limestones, in

cyclic nature, usually (3 – 4) cycles are developed. The calstics are calcareous claystone overlain by marly dolomitic limestone and white dolomitic limestone. **(2) Carbonate Unit** (33 m in the northeast, decreases to 8 m in the southwest) consists of alternation of dolostone and marl with dolostone and limestone, with common yellow and grey colors.

Thickness: The following thicknesses are recorded by different authors from different localities: In the type locality it is 22 m (Buday and Hak, 1980); (34 – 54) m NW of Kilo 160 vicinity (Al-Mubarak and Amin, 1983); 51 m east of Rutbah town (Al-Naqib *et al*., 1986); 45 m in Hussainiyat vicinity (Qaser *et al*., 1992) and 50 m in the northeastern part decreases to 21 m southwestwards of Kilo 160 vicinity (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils are recorded by different authors: *Tancredia* sp., *Pleiromya* sp., *Plagiostroma* sp. and *Mytilus* sp. (Buday and Hak, 1980); *Grammatadone* sp., *Oxytoma* sp., *Pinna* sp. and *Corbulomya* sp. and stramotolites (Karim and Ctyroky, 1981) and *Glomospira* sp. and *Modiolus* sp. (Al-Azzawi and Dawood, 1996).

Age: The Lias age is agreed upon by Karim and Ctyrocky (1981); Al-Mubarak and Amin (1983) and Al-Azzawi and Dawood (1996)

Depositional Environment: The following depositional environments are suggested by different authors: Complex coastal environment (Buday and Hak, 1980 and Al-Mubarak and Amin, 1983); Terrigenous deltaic, probably coastal lagoon either of brackish or hypersaline (Buday and Hak, 1980); near shore quiet marine of very shallow depth (Al-Azzawi and Dawood, 1996).

Lower Contact: All the aforementioned authors confirm that the Amij Formation is underlain unconformably by the Hussainiyat Formation, the contact is based on the first clastic bed, which overlies the last carbonate bed if the Hussainiyat Formation.

2.2.4. Muhaiwir Formation (Middle Jurassic, Bathonian)

Type Locality: The upper part is in tributary of wadi Hauran, 13 Km east of Muhaiwir, defined by the following coordinates (Bellen *et al.*, 1959):

Longitude 41° 14' 00" E
Latitude 33° 33' 29" N

and the lower part is 15 Km east of Muhaiwir on road to Qasir Amij, defined by the following coordinates (Fig.5) (Bellen *et al.*,1959):

Longitude 41° 15' 20" E
Latitude 33° 30' 20" N

Exposure Area: It is exposed in wadi Hauran, 10 Km east of Qasir Muhawir and extends southwards as a narrow strip (3 – 5) Km, between wadi Hussainiyat and wadi Amij, for about 65 Km, then swings westwards for about 15 Km, near the crossing of Highway No.1 with the old Ramadi – Rutbah road (Fig.2).

Lithology: The following descriptions are given by different authors from different localities: In the type locality Bellen *et al*. (1959) divided it into two parts: **(1) Lower part** consists mainly of limestone, with thin bands of sandstone. **(2) Upper part** consists of limestone alternated with sandstone and marly limestone, limestone with chert and corals. Antonents *et al.* (1963) described it in wadi Hauran as marly limestone alternated with sandstone, claystone with lenses of limestone and crystalline limestone. Buday and Hak (1980) described it in wadi Hauran as coarse ferruginous sandstone, overlain by limestone. Al-Mubarak and Amin (1983) divided it NW of Kilo 160 into two units: **(1) Lower Unit** consists of yellow marl, red sandstone (ferruginous), yellow calacareous sandstone, yellow and pink limestone and yellow – pink marly limestone. **(2) Upper Unit** consists of ferruginous sandstone, yellow dolomitic and marly limestone, with large lateral and vertical variations in different parts of

the formation. Al-Naqib *et al.* (1986) divided it east of Rutbah town into two parts: **(1) Lower part** consists of clastics overlain by carbonates, two cycles are developed. The calstics consist of yellow sandstone, with calcareous cement. The carbonates consist of yellow limestone and dolostone. **(2) Upper part** also consists of clastics and carbonates, two cycles are developed. The clastics consist of yellow sandstone and green marl. The carbonates consist of dolostone and yellow – pink limestone. Al-Azzawi and Dawood (1996) divided it NW Kilo 160 vicinity into two units: **(1) Clastic – Carbonate Unit**, consists of yellow sandy dolostone alternated with yellow sandstone. Occasionally yellow marls and orhtoquarzite occurs too. **(2) Carbonate Unit** consists of dolomitic limestone, yellow dolostone with chert nodules, overlain by yellow limestone.

Remarks:

- From reviewing the lithological descriptions of different authors, the present authors believe that the main differences are attributed to:
  - facial changes
  - different geographical locations
  - different field terminology for the rocks
- The present authors, can brief the main lithology of the Muhawir Formation as yellow clastics, mainly sandstone, occasionally pebbly, limonitic and ferruginous, in the lower part. Carbonates, mainly yellow – pink limestones and dolostones, with subordinate marls and rare chert nodules, in the upper part.

Thickness: The following thicknesses are recorded by different authors: In the type locality 47.7 m (Bellen *et al*., 1959); 54 m in Ga`ara (Antonents *et al*., 1963); 20 m in Ga`ara wedging out rapidly, westwards (Buday and Hak, 1980); 94 m NW of Kilo 160 vicinity (Al-Mubarak and Amin, 1983); (5 – 12) m east of Rutbah town (Al-Naqib *et al.*, 1986) and (21 – 38) m between Rutbah and Hussainiyat area (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils are recorded by different authors: *Diamorphoseris* sp., *Stylina* sp., *Amphiastrea* sp., *Echinobrissus orbicularis* (PHILLIPS), *Holectypus sarthacenses* (COTTEAU), *Sphonerhynchia plicatella* (DESOW), *Stomechinu polyporus* (AGASSIZ), *Nautieloculina oolithia* MOHLER, *Pfenderina* sp., *Haurania amiji* HENSON and *Haurania deserti* Henson (Bellen *et al.*, 1959); *Haurania amiji* Henson, *Haurania* sp., *Nodosaria* sp., *Daghanirhynchia* sp. and *Ammonites micromphalites* (Karim and Ctyroky, 1981).

Age: The following ages are suggested by different authors: Bathonian (Bellen et al., 1959; Buday, 1980; Jassim *et al.*, 1984; Al-Azzawi and Dawood, 1996 and Kaddouri, 1988); Dogger – Bathonia (Buday and Hak, 1980); Early – Middle Bathonian (Karim and Ctyroky, 1981 and Al-Mubarak and Amin, 1983).

Depositional Environment: The following depositional environments are suggested by different authors: Neretic, with normal salinity (Buday, 1980); intertidal and supratidal, with depth of (10 – 15) m (Buday and Hak, 1980); shallow litoral marine, for the lower clastics and shallow reef marine, for the upper carbonates (Karim and Ctyroky, 1981 and Al-Mubarak and Amin, 1983), shallow beach, changes upwards to shelf – inner shelf (Al-Azzawi and Dawood, 1996).

Lower Contact: It is described as follows by different authors. In the type locality, the lower contact is not exposed (Bellen *et al*., 1959); in wadi Hauranit is underlain unconformably by the Ubaid Formation and the contact is not clear (Antonents *et al*., 1963); south of Ga`ra Depression it is underlain unconformably by Amij Formation (Buday and Hak, 1980); NW of Kilo160 it is underlain unconformably by upper Butmah Formation, the contact is marked by varicolored ferruginous sandstone (Al-Mubarak and Amin, 1983); East of Rutbah it is underlain unconformably by the Amij Formation, the contact is marked by ferrigenous sandstone (Al-Naqib *et al.*, 1986) it is underlain unconformably by the Amij

Formation, the contact is marked by yellow sandy limestone, in wadi Duwaikhlat Amij and by calcareous sandstone with iron oxides in wadi Mua`ishir vicinity (Al-Azzawi and Dawood, 1996).

2.2.5. Najmah Formation (Late Jurassic)

The formation was not recognized previously in the Iraqi Western Desert. It is recognized during the regional geological survey (Al-Mubarak and Amin, 1983) and ascertained during detailed geological survey (Al-Azzawi and Dawood, 1996). Jassim and Buday (2006) in Jassim and Goff (2006) considered all exposures of Najmah Formation, except those in Wadi Hauran, as Saggar Formation.

Type locality: It is in M.P.C. well Najmah No.29, defined by the following coordinates (Fig.5) (Bellen *et al*., 1959):

Longitude 43° 09' 21" E
Latitude 35° 53' 14" N

Exposure Areas: It is exposed east of Rutbah town for about 75 Km, near the crossing of Highway No.1 to wadi Amij and extends northeast wards for about 90 Km, as a narrow belt, with a width of few kilometers to 20 Km, then crosses wadi Hussainiyat, east of Qasir Muhaiwir, then extends along both banks of wadi Hauran till 25 Km south of H_1 (Figs.2 and 3). According to Al-Mubarak and Amin (1983), the Najmah Formation is exposed south of Ramadi – Rutbah road. This difference, according to the author`s opinion is due to a difference in one sedimentary cylse. GEOSURV adopted the results of the detailed geological survey (Al-Azzawi and Dawood, 1996) and as it is presented by Sissakian (2000). It is worth to mention that Jassim and Buday in Jassim and Goff (2006) considered some outcrops of the Najmah Formation, in Hussainiyat vicinity as the Saggar Formation and extended it westwards .The supposed coverage area by Saggar Formation is covered, actually by many Cretaceous formations (Sissakian, 2000). The subsurface extension is almost uniform; it extends south and northeastwards from the exposure area.It is struck in wells Awazil 5, Kifl 1, Samawa. Safawi, KH 12/7 and KH 9/7.

Lithology: The following descriptions are given by different authors from different localities: Al-Mubarak and Amin (1983) divided it NW of Kilo 160 vicinity into two members: **(1) Lower Clastic Member** consists of conglomerate with laterite and yellow marl, overlain by yellow sandstone alternated with yellow marl. **(2) Upper Carbonate Member** consists of reddish brown limestone, marly limestone and yellowish pink limestone in the top. Al-Naqib *et al*. (1986) divided it east of Rutbah town into to two members: **(1) Lower Clastic Member** consists of white quartzitic sandstone, clayey siltstone and claystone**. (2) Upper Carbonate Member** consists of pink and violet dolomitic limestone, very rarely secondary gypsum occurs in fractures. Al-Azzawi and Dawood (1996) divided it along wadi Hauran into two members: **(1) Lower Clastic – Carbonate Member** consists of yellow sandy limestone, yellow calcareous sandstone, yellow and red limestone and dolomitic limestone, yellow coralline limestone and yellowish white limestone. **(2) Upper Carbonate Member** consists of yellow limestone, white dolomitic limestone and white limestone.

Remark: It is clear from the descriptions of the aforementioned authors that the Najmah Formation consists of two parts; the lower part is clastics with dominant yellow color and the upper part, which consists of carbonates with dominant white color.

Thickness: The following thicknesses are recorded by different authors from different localities: In the southwestern part of the exposure area it is 30 m and increases northeast wards to 100 m NW of Kilo 160 vicinity, respectively (Al Mubarak and Amin, 1983); 7 m near Rutbah and increases eastwards to 10 m (Al-Naqib *et al.,* 1986); 45 m NW of Kilo 160 and decreases to 24 m southwestwards, then decreases again to 8 m and disappears totally

along Ramadi – Rutbah road, 10 Km east of Amij (Al-Azzawi and Dawood, 1996); 354 m in KH 12/7 (Yousif and Raji, 1989) and 403 m in KH 9/7 (Karim, 1993).

Fossils: The following fossils are recorded by different authors: *Valvulinella cf. jurassica* HENSON, *V. wellingsi* HENSON, *Nautiloculina oolithia* MOHLER, *Pfenderina* sp., *Trochammina* spp., *Glomospira* sp., *Pseudochrysalidina* sp., *Trocholina* sp., *T.* cf. *elongate* (LEUPOLD), *Haurania amiji* HENSON, *Haurania* sp., *Lituola* sp., *Paleotrix* sp. and *Rhynchonella* sp. (Bellen *et al*., 1959); *Haurania amiji* HENSON , *H. deserti* HENSON, *Pfenderina salarniana* SART ET CRESC, *Triloculina* sp., *Nautiloculina oolithica*, *Protoglobigerina* sp., *Choffatella* sp. and *Bigenerina* sp. (Al-Mubarak and Amin, 1983); *Protoglobigerina* sp., *Kurnubia* sp. and *Nautiloculina oolithica* MOHLER (Isho and Raji, 1989) and *Kurnubia Palastiniesis* HENSON, *Pfenderina trochoidia* SMOU, *P. salernitana* SART ET CRESC, *Anchispioocyclina* sp., *Haurania amiji* HENSON, *H. deserti* HENSON, *Trocholina elongate* (LEUPOLD), *Textularia jurassica* HENSON, *Pseudochrysalidina* sp., *Epistomia* sp., *Protoglobigerina jurasica* HAEUSLER, *Clypiena jurassica* FAVER, *Calponella* sp., *Cosinnoconus alpinus* LEOPOLD, *Cylindroporella elliptica* ELLIOT, *Salpingoporella pygma* GUMBEL and *Thanmatoporella* sp.(Al-Azzawi and Dawwod, 1996).

Age: Late Jurassic age is claimed by the following authors: Bellen *et al*., (1959); Buday (1980); Al-Mubarak and Amin (1983); Isho and Raji (1989); Karim (1993) and Al-Azzawi and Dawood (1996).

Depositional Environment: It is neritic with some shoal and restricted lagoonal episodes (Buday, 1980); littoral marine, for the lower part and back reef for the upper part of the Upper Member, changes upwards to deeper marine of shelf – outer shelf depth of (50 – 200) m (Al-Mubarak and Amin, 1983) and very shallow beach, for the Lower Member and continental for the Upper Member (Al-Azzawi and Dawood, 1996).

Lower contact: The Najmah Formation is underlain unconformably by many formations (Fig. 2 and 3).

2.3. CRETACEOUS

The Cenomanian Sea transgressed onto the Rutbah High, due to deformation along NE Tethyan margin, which led to reactivation of longitudinal ridges and transversal blocks. The basin was divided into smaller basins, by NW – SE trending ridges, causing facial variations. The tectonic activity at the Arabian Plate margins and narrowing of the Tethys Sea led to development of phosphorites within Late Cretaceous formations. The formations of the Cretaceous Period are exposed mainly in the middle part (Fig.1) of the Iraqi Western Desert and locally in its western margin of the eastern part, mainly due to Rutbah Uplift. Five sedimentary cycles represent the Cretaceous Period, which includes seven formations and Marbat Beds. The first two cycles include four formations, both of them consists of clastics overlain by carbonates, which define four formations, not like the sedimentary cycles of the Jurassic Period. From the seven exposed formations, three were recognized and mapped during the regional and detailed geological surveys. The exposed formations are described hereinafter (from the oldest to youngest).

2.3.1. Nahr Umr Formation (Early Cretaceous)

The formation was recognized in the Iraqi Western Desert for the first time by Al-Mubarak and Amin (1983). It represents the lower part of the first sedimentary cycle of the Cretaceous Period.

Type Locality: It is in B.P.C. well Nahr Umr No.2, defined by the following coordinates (Fig.5) (Bellen *et al*., 1959):

Longitude 47° 41' 45" E
Latitude 30° 44' 15" N

Exposure Area: It is exposed east of Rutbah town for about 17 Km and extends eastwards till the crossing of Highway No.1 and the old Ramadi – Rutbah road, then extends northwards for about 22 Km, then extends northwards crossing wadi Amij and along eastern bank of wadi Hussainiyat and Hauran till south of H_1 (Figs.2 and 3). The subsurface extensions of the Nahr Umr Formation are very clear.It extends eastwards to Basrah vicinity, northeastwards to the Mesopotamian Plain and it is widely correlated in the neighbouring countries (Sissakian, 2000).

Lithology: The following descriptions are given by different authors from different localities: In the type locality, Bellen *et al.* (1959) described it as black shales interbedded with medium and fine-grained sands and sandstones with lignite, amber and pyrite. Al-Mubarak and Amin (1983) divided it NW of Kilo 160 vicinity into two parts: A lower part that consists of white, yellow, greenish grey, pink and brown sandstone, occasionally pebbly. An upper part, which consists of yellow and pale green, fossiliferous marl interbedded with (2 – 3) horizons (1 – 1.5 m, each) of fossiliferous, yellow and brown limestones, which include geodes and ferruginous concretions. Towards northeast, the sandstone becomes quartzitic with desert varnish. Whereas, the upper part includes only one horizon (0.5 – 1.0 m) of fossiliferous limestone and one horizon of green sandy marl (0.5 – 1.0 m) and two horizons (0.2 – 0.3 m) of dark violet iron concretions. Jassim *et al*. (1984) grouped the Nahr Umr Formation with the overlying Mauddud Formation. Al-Naqib *et al.* (1986) did not recognize the formation, east of Rutbah town and considered it as the clastics of the Ubaid Formation. Al-Azzawi and Dawood (1996) desribed it NW of Kilo 160 as yellow, white and red sandstone, which is occasionally pebbly overlain by sandy claystone, with common white color.

Remark: Due to large lithological similarity of the Nahr Umr and Rutbah formations and their overlying two formations, Mauddud and Ms`ad, respectively and due to large flat, covered areas and some tectonic disturbances, beside the karstification complexities, some contradictions occured between different authors, in the involved areas. Therefore, some misleading occurred between different mapping projects and even within the same project. The authors adopted the mapping of Al-Azzawi and Dawood (1996), which represents GEOSURV`s opinion.

Thickness: The following thicknesses are recorded by different authors from different localities: In the type locality it is 193m, in NW of Kilo 160 it is 23 m increases to 27 m in the central part and to 54 m in the extreme northeastern part (Al-Mubarak and Amin, 1983) and it is only 3 m in the exreme northeastern part, increases to 19 m in the southwestern part, as exposed thickness, whereas the total thickness is 35 m (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils are recorded by different authors: *Orbitolina cf. discoidea* GRAS, *Haplophragmoides* sp., *Plicatula cf. auressensis, Neithea cf. dutrugi* and *Exogyra cf. dieneri* (Bellen *et al.*, 1959) and *Modiolus tansjordanicus, Pycnodonta vesicularis vesiculosa and Spiroplectamina sp*. (Karim and Ctyroky, 1981).

Age: Albian (Bellen *et al.*, 1959, Karim and Ctyroky, 1980 and Al-Mubarak and Amin, 1983).

Depositional Environment: Shallow coastal marine, for the clastic unit (Karim and Ctyroky, 1981).

Lower Contact: The Nahr Umr Formation overlies unconformably all Jurassic formations. In all cases the contact is based on the bottom of the first clastic horizon that overlies the last carbonate horizon of Ubaid, Hussainiyat, Amij, Muhaiwir and Najmah formations

(Figs.2 and 3). For this reason many misleading mapping results were achieved, locally by different authors.

2.3.2. Mauddud Formation (Early Cretaceous)

The formation was recognized in the Iraqi Western Desert for the first time by Al-Mubarak and Amin (1983). It represents the upper part of ther first sedimentary cycle of the Cretaceous Period.

Type Locality: It is in Dukhan well No.1, in Qatar (Henson, 1940 in Bellen *et al.*, 1959). A supplementary type section was chosen by Owen and Nasir (1958) in Bellen *et al*., (1959), in oil well Awasil 5 (Fig.5).

Exposure Areas: It is exposed east of Rutbah town by 11 Km and extends eastwards till about 70 Km, near Jabal Arainbah and extends northeastwards till Faidhat Tlaihah. There it disappears due to tectonic reason and appears again north of Faidhat Tlaihah and extends northwards for about 45 Km as dissected segments by NW – SE trending faults (Figs.2 and 3). The subsurface extension of the formation is very clear, it is found towards southeast in Basrah vicinity and northeastwards till Makhul, there it is totally replaced by Qamchuqa Formation, which is almost similar and identical (Chatton and Hart, 1960).

Lithology: The following lithological descriptions are given by different authors: In the type section it consists of grey limestone, with much fossils and pellet debris in the upper part (Bellen *et al*., 1959). Al-Mubarak and Amin (1983) described it NW of Kilo 160 vicinity as alternation of thick horizons of fossiliferous marl to marly limestone with thin horizons of fossiliferous limestone. Both of them have common yellow color. This succession changes laterally eastwards from the exposure area into three parts: **(1)** The lower part (7 – 9 m) consists of white, pink and violet fossiliferous limestone. **(2)** The middle part (16 – 20 m) consists of yellow and pink fossiliferous limestone rich in orbitollina, overlain by (5 – 6) m of yellowish brown and pink coralline limestone. **(3)** The upper part (20 – 22 m) consists of alternation of yellow marl and yellow and pink highly fossiliferous limestone. Al-Naqib *et al.* (1986) did not recognize the Mauddud Formation, east of Rutbah town; they considered it as the Carbonate Member of the Ubaid Formation. Al-Azzawi and Dawood (1996) described it between Rutbah town and Kilo 160 vicinity as sandy dolostone or dolostone of yellow and red colors, overlain by yellow, pink, red and grey dolostone or dolomitic limestone.

Thickness: The following thicknesses are recorded by different authors: It is (5 – 8) m east of Rutbah town, increases eastwards to 14 m, then in the extreme northeastern part is 52 m, as maximum thickness (Al-Mubarak and Amin, 1983); NW of Kilo 160 vicinity it is 9 m, decreases to (4 – 5) m, in the southwestern part (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils are recorded by different authors: *Iraqia simplex* HENSON, *Trocholina altispira* HENSON, *T.arabica* HENSON, *T.lenticularis* HENSON, *Orbitollina cf. concava* (LAMARK), *Cyclamina white* HENSON, *Rabanitina basraensis* SMOUT (Bellen *et al*., 1959); *Orbitollina cf concave* LAMARK, *O.concava sefini* HENSON, *O.lenticlaris* HENSON, *Tochalina altispira* HENSON, *Quncolina* sp., *Permocalculus inopinatus* ELIOT, *Cylammina* sp., *Nerina* sp. and *Strombus* sp. (Buday, 1980); *Orbitollina concave sefini* HENSON, *O.concava* HENSON, *Textularia sp.Eoradiolites cf syriacus* CONRAD, *Ceratosteron* sp., *Strombus peretus* CONRAD, *Nerina* sp. and *Conus* sp. (Karim and Ctyroky, 1980); *Praealveolina* sp., *Hedbergella Wasitensi* (GARSEY), *Dictyoconus* sp., *Pseodocherysalidina* sp., *Mullisprina iranesis* REICHEL, *Nezzazata* sp., *Textularia* sp., *Bacinello annulate* (CAROZZI), *Permcalc ulus inopinatus* ELLIOT, *Cuneolina hensoni* DALBIEZ, *C. pavonia* D`ORBEGNY, *Pithonella* sp., *Orbitolina concava* (LAMARCK), *O.kurdica* HENSON, *Dictyoconus Arabica* HENSON, *Iraqia simplex* HENSON,

Pseodolituonella sp., *Spiroplectamina* sp. and *Neomerise cf. pfenderi* KONISHI (Al-Mutter, 1988).

Age: Albian, according to Bellen *et al.* (1959); Buday (1980) and Jassim *et al.* (1984). Albian – Cenomanian, according to Al-Mutter (1988 and 1992); Al-Mubarak and Amin, (1983); Basi *et al*. (1987); Yousif and Raji (1989) and Al-Azzawi and Dawood (1996).

Depositional Environment: Marine, tropical to subtropical, central shelf – innershelf (50 – 100) m depth, reef – backreef facies with normal salinity (Karim and Ctyroky, 1981).

Lower Contact: The lower contact of the Mauddud Formation with the underlying Nahr Umr Formation is a matter of contraversy. It is conformable and gradational, as indicated by the presence of some silt and shale admixture, in the lower part (Buday, 1980); It is unconformable, as indicated by the presence of (1 – 2) m breccia or ferruginous pebbly sandstone (Al-Mubarak and Amin, 1983) and it is conformable, marked by the first appearance of dolostone horizon (Al-Azzawi and Dawood, 1996).

Remark: The authors believe that this contraversy is due to non-considering the same succession, by the aforementioned authors, for Mauddud and Nahr Umr formations.

2.3.3. Rutbah Formation (Late Cretaceous, Cenomanian)

It represents the third formation within the second sedimentary cycle of Cretaceous Period. In different localities of the exposure areas the Nahr Umr Formation was mapped, previously, as Rutbah Formation, like south of H_1 in wadi Hauran (Tyracek and Youbert, 1975); near Qasir Muhaiwir (Bellen *et al.*, 1959) and along wadi Hauran and eastwards (Buday, 1980).

Type locality: It is 4 Km northwest of Rutbah town, defined by the following coordinates: (Bellen *et al*., 1959) (Fig.5):

Longitude 40° 12' 50" E
Latitude 33° 04' 20" N

Exposure Areas: It is exposed in wadi Hauran, south of Rutbah town for about 20 Km, it extends in wadi Hauran (northwards) till Rutbah town, then extends eastwards parallel to the underlying Cretaceous formations for about 85 Km, then extends northeast wards crossing Tlaiha vicinity, then wadi Amij, then more northeastwards for about 36 km from Tlaiha, as dissected segments due to NW – SE trending faults. North of Rutbah town, it is exposed as isolated exposures like in Tal Al-Nasir. It is also exposed along the western rim of Ga`ara Depression (Fig.2).

Lithology: The following descriptions are given by different authors from different localities: In the type locality it consists of vari colored, white and ferruginous fine sands and sandstones, locally cemented to quartzites (Bellen *et al*., 1959). The same lithology is recognized, almost everywhere, with exception of missing of vari colored parts, which are often missing or occupy negligible parts of the sequence only (Buday, 1980). Buday and Hak (1980) described it near Rutbah town as white coarse grained sandstone, occasionally conglomeratic and quartzitic, passes upwards to yellow marly siltstone, locally dolomitic and silty sandy limestone with oysters. Above this cycle there is another cycle, which consists of coarse sandstone with limestone, topped by dolomitic limestone, silicified sandstone and sacharoidal dolostone. Locally, three to four cycles are developed within the Rutbah Formation. Al-Mubarak and Amin (1983) described it NW of Kilo 160 vicinity as mainly ferruginous sandstone, partly quartzitic, yellowish grey with desert varnish, occasionally cemented by siliceous, calcareous and ferruginous materials. Al-Naqib *et al.* (1986) divided it east of Rutbah town into three units**: First unit** (8.5 m) consists of white quarzitic sandstone. **Second unit** (18.5 m) consists of yellow and yellowish brown sandstone, including two fossileferous dolomitic limestone horizons, topped by 2.25 m of yellowish grey calcarenite with limonite nodules. **Third unit** (5.9 m) consists of sand volcanoes. Al-Azzawi and

Dawood (1996) described it NW of Kilo 160 vicinity as yellow and white sandstone, occasionally contains fine pebbles, overlain by white and grey sandstone, which includes sand balls (poikiloblastic texture), occasionally they change laterally to orthoquartzite with clear desert varnish, overlain by white, violet, brown and red sandstone, which contains iron oxides, in the upper parts. Occasionally, thin horizons of claystone and sandy marl occur in the uppermost part.

Remark: It is clear from the aforementioned descriptions that locally the Ms`ad Formation is included within Rutbah Formation, by some authors; therefore differences in lithology and thickness are recorded. The present authors adopted the description of Al-Azzawi and Dawood (1996), which represents GEOSURV`s opinion.

Thickness: The following thicknesses are recorded by different authors from different localities: In the type locality it is 23 m (Bellen *et al.*,1959); (20 – 30) m NW of Rutbah town (Buday and Hak, 1980); (4 – 5) m NW of Kilo 160 vicinity, increasing westwards (Al-Mubarak and Amin, 1983); 33 m south of Rutbah town (Al-Naqib *et al*., 1986) and it is 9 m NW of Kilo 160 vicinity increases to 54 m east of Rutbah town (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils are recorded by different authors: *Ceratostream spionsum*, *Strembus incertus* D`ORBIGNY and fragments of gastropods and oysters (Bellen *et al.*, 1959; Al-Mubarak and Amin, 1983 and Jassim *et al*., 1984); *Pinna* sp. and *Plicatula bathnensis* (Buday, 1980) and *Pterodont cf germeri* (Hassan, 1998).

Age: The following ages are claimed by different authors: Cenomanian (Bellen *et al.*, 1959; Buday, 1980; Al-Mubarak and Amin, 1983 and Al-Azzawi and Dawood, 1996); Cenomanian – Turonian (Buday and Hak, 1980 and Jassim *et al*., 1984) and Aptian – Middle Albian (Hassan, 1998).

Remark: The main difference in the recorded age is that of Hassan (1998), it is attributed to including Nahr Umr, Mauddud and Ms`ad Formations with the Rutbah Formation

Depositional Environment: The following depositional environments are suggested by different authors: Continental, exceptionally littoral marine (Byday, 1980); beach shelf, influnced by fresh water, locally very shallow sea and near coast, being of fluvio lacustrine origin (Buday and Hak, 1980); continental fresh water marginal lakes or estuarine, most probably deltaic (Al-Mubarak and Amin, 1983); beach, shallow marine, exceptionally fluvial or fluvio – lacustrine, with local lagoon influenced by brackish and local hyper saline water (Jassim *et al*., 1984); very shallow beach (shoal), locally changes to fluvial (Al-Azzawi and Dawood, 1996) and fluviatile with marine influence (Hassan, 1998). Most of the authors agreed upon continental depostioinal environment with marine influence.

Lower Contact: The Rutbah Formation overlies unconformably in the western rim of the Ga`ara Depression many formations, starting from Ga`ara, then Mulussa and Zor Hauran formations (Fig.2). It overlies unconformably the Mulussa Formation (Bellen *et al.*, 1959); it overlies unconformably the Muhaiwir Formation (Buday, 1980 and Buday and Hak, 1980); it overlies the Mauddud Formation only in the extereme western parts of the exposure area, the contact is covered by thick Quaternary sediments (Al-Mubarak and Amin, 1983); it overlies unconformably both Mulussa and Zor Hauran formations, moreover it overlies disconformably the Najma Formation (Al-Naqib *et al*., 1986) and it overlies many formations, the contact is unconformable, marked by the first appearance of sandstone horizon, which occasionally contains iron oxides (Al-Azzawi and Dawood, 1996) (Figs.2 and 3).

Remark: It is worth to mention that there are many differences in the description of the lower contact of the Rutbah Formation. The main reasons for this discrepancy are:

- The introducing of the Nahr Umr Formation, instead of the Rutbah Formation, in different areas.

- The introducing of the Mahliban Formation by Al-Mubarak and Amin (1983) to include Rutbah and Ms`ad formations.
- The introducing of the Najmah Formation and its misleading with other Jurassic formations.
- The mutual relation between Nahr Umr, Mauddud, Rutbah and Ms`ad formations, in different parts of the exposure areas.
- The flat and covered nature of large parts of the exposure areas.

2.3.4. Ms`ad Formation(Late Cretaceous,Cenomanian – Turonian)

The Ms`ad Formation represents the fourth formation in the second sedimentary cycle of the Cretaceous Period.

Type locality: It is 36 km north of Jabal Tayarat, in wadi Ms`ad Al-Rutbah when joining wadi Hauran (Fig.5) (Bellen *et al*., 1959), it is defined by the following coordinates:

Longitude 40° 17' 00" E
Latitude 32° 46' 00" N

Exposure Areas: It is exposed in wadi Hauran, south of Rutbah town for 35 Km, it extends along wadi Hauran (northwards) for about 18 Km, then extends eastwards parallel to the older Cretaceous formations for about 130 Km, till near Tlool Al-Amghar, there it extends northeastwards to cover Tlaiha and K160 vicinities, extending more eastwards for about 33 Km, then is terminated by a main NW – SE trending fault, even in wadi Ghadaf. Towards west of Rutbah town it extends for about 8 Km and terminates due to erosional surface (Figs. 2 and 3). The subsurface extension is not clear, because it is totally replaced by either Mahliban Formation or is considered as a facies of Mishrif Formation (Buday, 1980). However, it is present to the west of Abu Jir Subzone.

Lithology: The following descriptions are given by different authors from different localities. In the type locality it consists of alternating of shallow marine limestone, reef limestone, shell breccia, white and pink marls, sandy marls and sands, with a thin sandstone tongues near the base (Bellen *et al*., 1959). Buday and Hak (1980) described it in Rutbah vicinity and eastwards as clastics with mudstone, siltstone, sandstone and marl, in the lower part. This succession passes gradually, upwards to dolomitic limestone, dolostone with sandstone, siltstone and marly interlayers. Al-Mubarak and Amin (1983) didvided it NW of Kilo 160 into two parts: The lower part (50 m), consists of alternation of thick (1 – 10 m) horizons of yellow fossileferous marl ro marly limestone with thin (1.5 – 2 m) horizons of yellow and yellowish grey fossileferous limestones. Occasionally, the marl horizons contain lenses or thick (2 – 5 m) horizons of yellowish and greenish grey and pink sandstones, which are locally pebbly and glauconitic. The upper part (15 m) consists of yellow and white, highly fossileferous limestone. Al-Naqib *et al.* (1986) described it east of Rutbah town as yellowish grey and pink dolostones. Al-Azzawi and Dawood (1996) described it between Hussainiyat and Rutbah town as pink, grey, yellow and red sandy dolostone, dolostone and sandy fossileferous marl, overlain by white, pink and yellow dolostone, interbedded with white dolostones, overlain by yellow grey and brown sandy limestone, occasionally pebbly, overlain by yellow dolostone and sandy dolostone, which include ammonites, occasionally includes petrified trunks, in the upper part there are white and pink dolostone and dolomitic limestone. This succession changes to yellow and brown sandy limestone, overlain by dolostone , which intercalate with yellow and white dolomitic marl, overlain by yellow white dolostone, which interbeds with grey dolostone.

Remarks:

- Al-Mubarak and Amin (1983) mapped Mahliban Formation as equivalent to Rutbah and Ms`ad formations, in the eastern part of Kilo 160.

– Jasim *et al*. (1984) and Al-Naqib *et al.* (1986) considered Rutbah and Ms`ad formations as one formation; they named it as Rutbah – Ms`ad Formation.

Thickness: The following thicknesses are recorded by different authors: In the type locality it is about 65 m (Bellen *et al*., 1959); (20 – 50) m near Rutbah town increasing northwards (Buday and Hak, 1980); 65 m NW of Kilo 160 vicinity (Al-Mubarak and Amin, 1983); (3 – 8) m east of Rutbah town (Al-Naqib *et al.,* 1986) and (11 – 19) m between Rutbah town and Kilo 160 (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils are recorded by different authors*: Neinea cochleaeformis* CONRAD*, Caprinula sp., Eoradiolites liratus* CONRAD*, Nerinea cf.gemmfira, Meandropsina cf vidali* SHLUMBERGER, *Cuneolina cf,cylindrica* HENSON, *Dicyclina cf. quatarica* HENSON, *Pseodochrysalidina conica* (HENSON), *Taberina cf. bigistani* (HENSON) (Buday and Hak, 1980); *Protocardia cf. coquandi, Cyprimeria delettcei* COQUAND, *Barbatia sp., Pinna sp., Trigonia sp., Praeradiolites sp., Eoradiolotes syriacus* CONRAD*, Nerinea cochlaeformis* CONRAD*, Quicquiloculina* sp., *Rotalia* sp., *Pseudolituonella cf. reichelli* MARIE, *Spiroplectammina* sp., *Nezzazata* sp., *Dorthia* sp., *Medbergella cf. brotoneusis, Ovalveolina* sp., *Marsonella* sp., Hetroporella sp. and *Pithonella ovalis* KAUFMAN (Buday and Hak, 1980*); Exogyra flabellate* SOWERBY, *Rhynchostreon cf. Columbum* (NEETTLINK), *Lopha cf. dichotoma* (BAYLE), *Protocardium hillanum* (SOWERBY), *Ceratostrcom cf. flabellatatum* (GOLDFUS) and *Ceratostreom spinosum* (MATHERON) (Al-Mubarak and Amin, 1983); *Ovalveolina ovum, Iraqia* sp., *Dicuclina* sp., *Nummoloculina* sp. and *Guneolina* sp. (Al-Azzawi and Dawood, 1996); *Knemiceras syriacum, Engonoceras gracile, Nucula* (*N.*) *cf.gualtina, Yodia ovata, Isoarea agassizi , Arca cf. trigeri , Bachia cf. Keysertingiana , Theris minor, T. laevigata, Mutiella exigieri and Rostrocardia papieri* (Hassan , 1998).

Age: The following ages are suggested by different authors: Cenomanian (Bellen *et al.,* 1959; and Al-Mubarak and Amin, 1983); Cenomanain? – Turonian (Jassim *et al*., 1984) Late Albian – Cenomanian (Hassan, 1998).

Remark: It is worth to mention that the suggested age by Hassan (1998) is due to incuding of the Mauddud Formation within the Ms`ad Formation.

Depositional Environment: The following depositional environments are suggested by different authors: Shalow marine with local reef (Bellen *et al*., 1959 and Buday, 1980); shallow sea with high organic activity (Buday and Hak, 1980); shallow marine, reef – back reef (Al-Mubarak and Amin, 1983); reef near shore, in the west of Rutbah it is near shore, inner shelf facies, whereas in the east of Rutbah it is marine, warm of normal salinity (Jassim *et al.,* 1984); marine inner shelf, warm and subtropical (Al-Azzawi and Dawood, 1996) and transgressive marine phase, in the lower part, marginal marine, in the middle part and deep marine, in the upper parts (Hassan , 1998).

Lower Contact: The Ms`ad Formation overlies Rutbah Formation, gradationally and conformably (Bellen *et al.* 1959; Buday and Hak, 1980; Al-Mubarak and Amin, 1983 and Al-Azzawi and Dawood, 1996).

2.3.5. Hartha Formation (Late Campanian – Early Maastraichtian)

The formation was recognized in the Iraqi Western Desert for the first time by Al-Mubarak and Amin (1983). It represents the fifth formation in the third sedimentary cycle of the Cretaceous Period.

Type Locality: It is in Zubair oil well No.3 (Fig.5) (Bellen *et al.,* 1959) and it is defined by the following coordinates:

Longitude	47°	43'	29"	E
Latitude	30°	23'	01"	N

Exposure Areas: It is exposed in wadi Al-Raggas and wadi Ms`ad Al-Rutbah for 65 Km and 33 Km south of the Rutbah town, respectively.Then extends in both vallies northwards for 30 Km and 11 Km, respectively, then extends eastwards parallel to the older Cretaceous formations for about 140 Km till Tlool Al-Amghar, there it is terminated by a main NW – SE trending fault. Northwards from Rutbah town, it is exposed along the western rim of Ga`ara Depression for about 45 Km (Figs.2 and 3). The subsurface extensions are clear, it extends to the southeastern parts of Iraq, in Basra vicinity, also towards north and northeast to Kifl area (Al-Naqib, 1960), where it intertonges with the Shiranish Formation (Buday, 1980). It is also struck in Anah 2 and Khlesia 1 oil wells (Sissakian, 2000).

Lithology: The following descriptions are given by different authors from different localities: Al-Mubarak and Amin (1983) divided it NW of Kilo 160 vicinity into two members: **(1) Lower Clastic Member** (20 – 32 m), consists of two parts, the lower part (1 – 5 m), consists of conglomerate to conglomeratic sandstone. The upper part consists of calcareous sandstone (in the west) and sandy dolostone (in the central part) with common yellow and pale green color. Occasionally, the uppermost part of the sandstone is alternated with green, fossileferous sandy marl or fossileferous limestone. **(2) Upper Carbonate Member** (60 m in the east and 130 m in the west), consists of alternation of fossileferous dolostone, marl and marly dolostone, occasionally sandstone alternates with the marl. Lateral changes are common, from east towards west. The lower part (15 – 30 m) of this member consists of brown fossileferous dolostone, which changes to marly dolostone. Towards west, the upper part contains 10 m of green marl. Eastwards, the dolostone includes coarse grained sandstone. The middle part (20 – 40 m) of this member consists of alternation of whitish grey dolostone and grey slightly fossileferous marly dolostone. The upper part (50 – 60 m) of this member consists of alternation of yellowish and brownish grey fossileferous dolostone and yellowish green and grey marly fossileferous dolostone. The uppermost part (8 – 12 m) of this member consists of massive dolostone rich in chert and geodes, laterally changes to red dolostone, overlain by marl horizon rich in chert nodules. The massive dolostone changes eastwards to fossileferous sandy dolostone, interbedded with yellow marl to marly limestone and brownish grey calcareous sandtone

Remark: The present authors believe that this change in the lithology is due to interfingering of Hartha and Tayarat formations and locally the Digma Formation, in the uppermost part.

Thickness: The following thicknesses are recorded by different authors: In the type locality it is 437 m (Bellen *et al*., 1959), 85 m in the eastern parts, increases to 162 m in the western parts of Kilo 160 vicinity (Al-Mubarak and Amin, 1983) and is 37 m between Rutbah and Kilo 160 (Al-Azzawi and Dawood, 1996).

Fossils: The following fossils were recorded by Bellen *et al.* (1959) and Karim and Ctyrocky (1981) :*Valvulammina* sp, *Monolepidorbis* sp., *Pseudodomia complanata* sp., *Ammobaculites* sp., *Globotruncana stuarti* (DELAPARRENT), *Omphalocyclus macroporus* LAMARCK, *Orbitoides media* DE ARCHIAC, *Praeradiolites* sp. and *Nethea* sp.

Age: All authors agreed upon the age as Late Campanian – Early Maastrichtian.

Depositional Environment: It is reef, tropical and warm marin.

Lower Contact: The Hartha Formation overlies unconformably different formations. In the western rim of Ga`ara Depression it overlies (from north to south) Rutbah and Zor Hauran formations. West, south and east of Rutbah town it overlies Ms`ad Formation (Figs.2 and 3). According to Al-Mubarak and Amin (1983), the contact is disconformable marked by (1 – 5) m conglomerate or conglomeratic sandstone rich in glauconite, clay balls, chert and shell fragments and occasionally ferruginous materials.

2.3.6. Marbat Beds (Late Cretaceous, Campanian – Maastrichtian)

Al-Bassam *et al.* (1990) introduced these beds for the first time in the Iraqi Western Desert. Previously they were included within the Ga`ara Formation.

Type Locality: In the northern rim of the Ga`ara Depression, at Marbat Al-Hasan hill, it is defined by the following coordinates:

Longitude 40° 08' 04" E
Latitude 33° 36' 24" N

Exposure Area: The Marbat Beds are exposed only along the northern rim of the Ga`ara Depression. From Qasir Al-Halgoom westwards to Marbat Al-Hasan (Fig.2).

Remark: The authors believe that Marbat Beds could be present within the Ga`ara Formation in different parts of the Ga`ara Depression and may be elsewhere.

Lithology: The Marbat Beds consist of brown pebbly sandstone and yellow sandy dolostone. Southwestwards of Marbat Al-Hasan they change to coarser clastics, with conglomerate at the base passing upwards to pebbly sandstone, silty claystone, claystone and sandy conglomerate and rare fossiliferous detrital limestone (Al-Basam *et al.,* 1990).

Thickness: Varies from 29 m, in the south to 50 m in the north, from exposure area (Al-Bassam *et al.,* 1990)

Fossils: The following fossils are recorded by Al-Bassam *et al.* (1990):

Rugoglobigerina sp., Gumbleritria sp., Bulimina sp.

Age: Late Cretaceous (Campanian – Maastrichtian)

Depositional Environment: Fluvial and fluviomarine.

Lower Contact: The Marbat Beds are underlain unconformably by the Ga`ara Formation and the contact is tacken at the first appearance of pebbly calcareous sandstone or conglomerate (Al-Basam *et al.,* 1990).

2.3.7. Tayarat Formation (Late Maastriachtian)

It represents the sixth geological formation within the fifth sedimentary cycle of the Cretaceous Period.

Type Locality: It is in Jabal Tayarat, about 36 Km south of Rutbah town and is defined by the following coordinates (Fig.5) (Bellen *et al.,* 1959):

Longitude 40° 17' 00" E
Latitude 32° 46' 00" N

Exposure Areas: The Tayarat Formation is widely exposed in the middle part (Fig.1) of the Iraqi Western Desert**.** It is exposed in Traifawi, 75 Km south of Rutbah town, along both sides of wadi Hauran and extends northwards crossing Highway No.1 and more northwards along the western rim of Ga`ara Depression, then extends eastwards along the northern rim of Ga`ara depression, for about 14 Km. Esat of wadi Hauran, it extends for about 170 Km, where it is truncated by a major NW – SE trending fault. Towards south, it extends about 100 Km till the Iraqi – Saudi Arabian borders, near Muger Al-Na`am and extends eastwards, where it is exposed in deeply cut valleys, but it is truncated (in all valleys) by a major N – S trending fault. It is also exposed near Jdaidat Ar`ar in deeply cut valleys, where it is also truncated by NNW – SSE trending fault. North of wadi Ghadaf it extends till Al-Awaj (Figs.2 and 3). The subsurface extension of the Tayarat Formation is clear. It extends northwards till Euphrates River, north of the river it is replaced by Hartha and/ or Shiranish formations. Eastwards from the exposure areas, it extends almost parallel to the Euphrates River.

Lithology: The following descriptions are given by different authors from different localities: In the type locality it consists of ruby, porous, white, buff and rather chalky and pink fossiliferous, dolomitized, sandy limestone (Bellen *et al*., 1959). Buday and Hak (1980)

divided it in the Rutbah vicinity into two parts: The lower part consists of conglomerate; when it is absent, rusty sandy siltstone with hematitic concretions occur, instead. Overlain by marl, siltstone and sandstone with chert nodules. Followed by reddish or varicolored detrital limestone with Loftusia.The upper part consists of sandstone, overlain by alternation of marl and papery calcareous mudstone, containing geodes. Al- Mubarak and Amin (1983) divided it in Kilo 160 vcinity into two members: **(1) Lower Carbonate Member** (116 – 125 m), consists of yellowish grey fosiliferous dolostone, with chert nodules. Overlain by dolostone and fossileferous dolostone. Followed by alternation of fossileferous limestone and dolostone, with marl and silt intercalations. Near Suwihat Al-Ahemir and Tel Al-Amghar, this member consists of grayish brown dolostone, partly fossileferous, changes upwards to chalky limestone. **(2) Upper Clayey – Carbonate Member** (24 – 35 m), consists of yellowish green fossileferous marl, overlain by fossileferous dolostone, followed by interbedding of fossileferous dolostone and fossileferous marl. Al-Azzawi and Dawood (1996) described the formation as yellow marl with thin iron oxides, overlain by brown dolostone; this succession is southeast of Kilo 160 vicinity, whereas towards west it consists of yellow and red marl overlain by white dolostone, interbedded with yellow marl. Hassan (1998) described it as creamy marl or dolostone, overlain by dolostone, limestone and dolomitic limestone, with charaphyte and rare oystrers. This succession is developed along the western rim of Ga`ara Depression. South and southwestwards, intraclastic phosphorite, geodes and chert are encountered. This succession is capped by silicified, slightly phosphatic limestone. In Rutbah vicinity, the succession starts with yellow marl, overlain by limestone with fenestral porosity, then dolostone and dolomitic limestone, capped by silicified and phosphatic limestone. Al-Haz`za (2001) described it as shelly limestone, white dolostone, marl, occasionally sandy phosphatic limestone and fossileferous limestone. This succession is capped by Laftusia bearing carbonate bed. Al-Bassam *et al.* (1990) named the Tayarat Formation as "Na`aja Beds", which is considered as Tayarat Formation in compilation of the Geological Map of Iraq, scale 1: 1 000 000 (Sissakian, 2000). The Na`aja Beds consist of sandstone, passes laterally to dolomicrite, occasionally with chert nodules, overlain by creamy dolostone with charaphyte bearing dolomitic limestone (1 – 2 horizons) with oyster rich limestone, geodes and chert nodules. Locally, large pieces of tree trunks are common. The upper part consists of dolomicrite, with phosphatic horizons, which may pass laterally to phosphorite; this succession is capped by shelly limestone. South of Highway No.1 a limestone bed with hippurites occurs at the top of the middle part. The uppermost part consists of shelly, silicified limestone.

Thickness: The following thicknesses are recorded by different authors from different localities: In the type locality it is 30 m (Bellen *et al*., 1959); 45 m west of wadi Hauran, decreasing eastwards to (30 – 35) m in Jabal Tayarat and further eastwards to 10 m (Buday and Hak, 1980); 190 m decreasing eastwards to 30 m and further more to 15 m (Al-Mubarak and Amin, 1983); (10 – 25) m in Kilo 160 vicinity (Al-Azzawi and Dawood, 1996); 17 m in the western rim of Ga`ara Depression and 45 m in Rutbah vicinity (Hassan, 1998); (13 – 50) m in wadi Hauran, increasing eastwards to 100 m (Al- Haz`za, 2001) and (15 – 20) m along the western rim of Ga`ara Depression and southwards (Al-Bassam *et al.*, 1990).

Fossils: The following fossils are recorded by different authors: *Loftusia morgani* DOUVILLE and *Omphalocyclus macropora* (LAMARK) (Bellen *et al.,* 1959); *Ammobaculites* sp., *Anomalina ammonoides*, *Crstellina* sp., *Cuncolina cylindrical, Globigerina cretacea, Globotruncana stuarti, Glt. lapparenti tricainata, Glt. lapparenti, Glt. lapparenti bulloides, Lpidorbtiodes minor, Loftusia morgani, Monolepidorbis douville, Ompholocyclus macroporous, Orbitoides media, O. apiculata* and *Pseudedomia complanata* (Buday, 1980)*; Agerostrea ungulate* SCHIOTHEIM, *Aretostrea bomilcaris* COQUAND,

Ceratostreon cf. *laciniatum* (NILSSON), *Lopha (Actiostreon) villei* COQUAND, *Trgonoarca sheeinfurthi* (ZITTEL) and *Trachycardium productum* SOWERBY (Buday and Hak, 1980); *Omphalocyclus* cf. *macroporus, Orbitoides* sp., *Coskinolina* sp., *Carpinitidae* sp., *Modiolus* sp., *Cardita* sp., *Sptifer* sp., *Globotruncana* sp., *Heterohelix* sp., *Hedbergella* sp., *Loftusia elongate* COX, *Orbitoides* sp., *Anomalina* sp., *Gyroidina* sp. and *bolivina incrassate* (REUSS) (Al-Mubarak and Amin, 1983); *Loftusia* sp. and miloilids (Al-Azzawi and Dawood, 1996) and *Orbitoides media, O. opiculata browni* (ELSIS*), Lpidorbitoides* cf. *yurnaguensis* CUSHMAN, *Omphalocyclus macropora, Sulcoperculina* sp. and *Dicyclina* sp. (Ma`ala *et al*., 1999)

Age: The following ages are suggested by different authors: Late Maastrichtian (Bellen *et al*., 1959; Buday, 1980; Buday and Hak, 1980; Al-Mubarak and Amin, 1983; Al-Azzawi and Dawood, 1996 and Ma`ala *et al*., 1999)? Middle – Late Maastrichtian (Jassim *et al.*, 1984) and Late Campanian – Early Maastrichtian (Hassan, 1998).

Depositional Environment: The following depositional environments are suggested by different authors: Shalow marine (Bellen *et al.*, 1959); shallow sea with clastics influx (Buday and Hak, 1980); warm marine environment of (50 – 100) m depth, for the Lower Member and marine, reef facies of tropical subtidal conditions, for the Upper Member (Al-Mubarak and Amin, 1983); marine, shallow, warm, changes upwards to marine subtidal shelf (Jassim *et al*., 1984) and marine, warm, inner shelf (Al-Azzawi and Dawood, 1996).

Lower Contact: The following lower contact cases are recorded by different authors from different localities: In the type locality it is underlain by Ms`ad Formation, the contact is taken at the base of a localized conglomerate (Bellen *et al*., 1959). South of Rutbah, it is underlain by Digma Formation, the contact is marked by a basal conglomerate, breccia or coquina and organodetrital limestone, locally rusty sandy siltstone horizon with rare hematite concretions occur (Buday and Hak, 1980). SE of Kilo160, it is underlain conformably by Hartha Formation; the contact is taken at the top of the last marl horizon, with chert nodules and carnotite, or calcareous sandstone horizon with scattered chert fragments. To the east of Suwihat Al-Ahemir and Tal Al-Amghar, the Tayarat Formation is underlain unconformably by the Mahliban Formation; the contact is taken at the base of ferruginous sandstone, with chert nodules (Al-Mubarak and Amin, 1983). It is underlain unconformably by Ms`ad Formation, west of Kilo 160 vicinity, the contact is taken at the base of a yellow marl horizon with iron oxides, followed by a dolostone with fenestral porosity (Al-Azzawi and Dawood, 1996). It is underlain unconformably by Ga`ara Formation at the northwestern rim of Ga`ara Depression, the contact is taken at the top of cross bedded, varicolored quartzitic sandstone. At the northern rim, it is underlain by "Marbat Beds" and it is based at the first appearance of thick, creamy dolomicrite and the top of the ferruginous, cross bedded sandstone. At Al-Samhat and further southwards to Traifawi, it is underlain conformably by Hartha Formation and it is based at the top of a coralline limestone (in the south) or a limestone with fenestral porosity (at Al-Semhat) or the first appearance of creamy dolomicrite, occasionally with chert nodules (Al-Bassam *et al.*, 1990).

Remark: Buday and Hak (1980) considered that the Tayrat Formation is underlain by Digma Formation. This is because the considered Digma Formtion is not the true one, they have missed the true succession, see the details in the Digma Formation.

2.3.8. Digma Formation (Late Cretaceous, Maastrichtian)

The presence of the Digma Formation in the Iraqi Western Desert was mentioned for the first time by Sattran and Mansour (1975) in Buday (1980). Al-Bassam *et al.* (1990) however, mapped the formation as "Safra Beds" for the first time in the Western Desrt. The Digma Formation represents the sixth sedimentary cycle of the Cretaceous Period.

Type Locality: A supplementary type section is proposed by Al-Bassam *et al.* (1990) at Er Radhuma Al-Safra, about 10 Km southeast of Akashat mine. Whereas, the original type locality is in oil well Anah 1 (Bellen *et al*., 1959) (Fig.5), it is defined by the following coordinates:

Longitude 41° 15' 48" E
Latitude 34° 20' 24" N

Exposure Areas: The Digma Formation is exposed along the northern rim of Ga`ara Depression, from Marbat Al-Hasan hill and extends westwards, then extends along the western rim, farther southwards crossing the Highway No.1 and extends to the Iraqi – Saudi Arabian borders. In Traifawi vicinity, it extends eastwarsd for about 60 Km and northwards to about 35 Km, moreover towards southeast to Muger Al-Na`am vicinity (Fig.2). The subsurface extension of the Digma Formation is clear. It extends northwards from exposure areas to Khlesia passing through Anah trough, and west and eastwards along sides of the Rutbah Uplift.

Lithology: Buday and Hak (1980) described it as basal conglomerate, sandstone, siltstone, marlstone and organic limestone, beside yellow and green marlstone, thinly bedded calcareous claystone and calcareous siltstone are present in the north and nortwestern parts of the Ga`ara Depression. Al-Bassam *et al.* (1990) described the Digma Formation, which they called it as "Safra Beds" as white to creamy limestone, dolostone with phosphorite horizon and green to ocher pappery shale, with oyster shell horizon. Hassan (1998) divided it, in the Ga`ara vicinity into two units: **(1) Lower Unit** consists of white, creamy dolomicrite, withthin phosphorite horizon, overlain by green papery shale and topped by phosphorite horizon. **(2) Upper Unit** consists of oyster rich limestone alternated with marl horizons. Southwards the fossiliferous limestone increases in thickness and passes laterally to shelly limestone, with chert nodules and geodes in the middle and upper parts of this unit. Al-Haz`za (2001) divided it into three parts: The lower part consists of dolostone with phosphorite horizon and porcelinite, in the base. The middle part consists of ocher marl, occasionally with oysters, whereas the upper part consists of oyster rich limestone (lopha bed) which alternates with dolostone. Southwards the upper shelly part increases in thickness and passes to bivalves rich limestone.

Remark: It is worth to mention that the mapped succession as Digma Formation by Buday and Hak (1980) and which was renamed as "Samhat Formation" by Jassim *et al*. (1984) is not the same succession considered by GEOSURV as the Digma Formation. The upper part of the so called Jeed Formation by Jassim *et al*. (1984) is identified as "Safra Beds" by Al-Bassam *et al*. (1990) and it is addopted by GEOSURV as the Digma Formation (Sissakian, 2000). Whereas, the lower part of the so called "Samhat Formation" is considered as Marbat Beds and the upper part as Tayarat Formation. Moreover, the lower part of the so called "Jeed Formation" is considered, by GEOSURV, as the upper part of the Tayarat Formation.

Thickness: The following thicknesses are recorded by different authors. In the supplementary type section it is 23 m and 15 m in the northern rim of Ga`ara depression (Al-Bassam *et al*., 1990). It is (12 – 20) m west of Ga`ara depression and increases to more than 40 m (Al-Haz`za, 2001).

Fossils: The following fossils were recorded by different authors: Bellen *et al*. (1959) *Corax pristadontus* AGASSIZ, *Lammina* c.f. *appendiculata* AGASSIZ, *Globotruncan*a *stuarti* (DE LAPPARENT), *Glt. lapparenti bulloides* VOLGER, *Glt. Lapparenti*, *Globugerina cretacea* DE ORBIGNY, *Gumbelina globulosa* (EHRENBERG), *Vaginulina plummerae* (CUSHMAN). Al-Bassam *et al.* (1990) recorded *Rugogleobigerina macrocephala* BRCNNIMA, *Ruge. Bronnimanni* EL-NAGGAR, *Pseudotextularia elegans* RZEHAK,

Heterohlix striata (EHRENBERG), *H. glbosa* (EHRENBERG) and *Guembelitria cretacea* CUSHMAN. Hassan (1998) recorded mainly oysters (Lopha and Ostrea).

Age: The following ages are claimed by different authors: Maastrichtian (Bellen *et al*., 1959 and Hassan, 1998), Early Maastrichtian (Buday and Hak, 1980) and Late Maastrichtian (Al-Bassam *et al.*, 1990 and Al-Haz`za, 2001).

Depositional Environment: The following depositional environments are recoreded by different authors: Shallow water, littoral neritic condition (Buday, 1980), shallow marine (Hassan, 1998), shallow water (mostly back reef and lagoon), in the east and deep water, in the west of the exposure area (Al-Haz`za, 2001).

Lower Contact: The Digma Formation is underlain unconformably by Ms`ad Formation (Buday and Hak, 1980). It is underlain conformably by the Tayarat Formation (Na`ja Beds), the contact is based at the top of a shelly limestone and first appearance of white siliceous micrite, with phosphorite horizon. In a very small part of the exposure area, east of Marbat Al-Hasan hill, it is underlain by "Marbat Beds" and is based at the top of last clastic horizon (Al-Bassam *et al*., 1990). It is underlain conformably by the Tayarat Formation and it is based at the top of silicified limestone and first appearance of a yellow marl or pale grey dolomicrite, with phosphorite horizon (Hassan, 1998). It is underlain unconformably by the Ga`ara Formation, along the northern rim of the Ga`ara Depression, and marked by sandy, pebbly, phosphatic limestone or conglomerate, above cross bedded sandstone of the Ga`ara Formation (Al-Haz`za, 2001)

3. CENOZOIC

The Cenozoic formations are widely exposed in the Iraqi Western Desert, especially the eastern and western parts (Fig.1). The exposed formations are divided, age wise and described hereinafter:

3.1. PALEOCENE

The Neo-Tethys was closed finally due to renewed subduction. The deep basin shallowed during Middle – Late Paleocene, with deposition of phosphatic oolites in innershelf. The phosphatic facies was formed due to upwelling of cold nutrient water from the narrow closing of Neo-Tethys. The formations of Paleocene Epoch are the most widespread formations in the eastern part of Iraqi Western Desert, as compared to formations of other periods. These are Umm Er Radhuma and Akashat formations.

3.1.1. Umm Er Radhuma Formation (Middle – Late Paleocene)

Type Locality: The type locality of Umm Er Radhuma Formation is in Saudi Arabia. A supplementary type section was proposed by Own and Nasr (1958) from Zubair oil well 3 (Fig.5), depth 2980 ft (703 m) to 4482 ft (1358 m) (Bellen et al., 1959). It is defined by the following coordinates:

Longitude	47 °	43'	29"	E
Latitude	30 °	23'	01"	N

Exposure Areas: The Umm Er Radhuma Formation crops out widely in the eastern part of the Iraqi Western Desert. It crops out south of Al-Sahin, along the Iraqi – Saudi Arabian borders and extends northwards till north of wadi Ubaidh, also extends northwestwards to Muger Al-Na'am vicinity, crossing Al-Bireet, Jdaidat Ar`ar, Al-Nukhaib and extends further northwestwards till wadi Al-Meera, where Cretaceous rocks crop out (Figs.2 and 3). It is worth to mention that in the western part of the Iraqi Western Desert, the exposures of the Umm Er Radhuma Formation are included within the Akashat Formation (Fig.2).The subsurface extension of the formation is clear, it extends south and southeastwards, as

indicated in all drilled wells. Northwards, it extends slightly north of oil well Akaaz 1, then it wedges out, either due to erosion or non-deposition.

Lithology: In the supplementary type section, the Umm Er Radhuma Formation consists of anhydritic and dolomitic limestones, mostly dull, white or buff, microcrystalline and porous. Chert occurs in the higher part of the formation (Bellen *et al.*, 1959). (Al-Mubarak and Amin, 1983) divided it in the eastern part into two members: **(1) Lower Member** is divided into two lithological rock units, these are: **(a) Lower Chalky Unit** (15 – 45 m), consists of alternation of thick horizons of white, slightly fossiliferous chalks with thin horizons of white, slightly fossiliferous dolostone, with few chert lenses and geods. This alternation is overlain by intercalations of thick horizons of white, slightly fossiliferous chalky limestone and thin horizons of whitish grey, calcareous dolostone, with chert lenses and geods. **(b) Lower Shelly Unit** (20 – 30 m), consists of grey shelly dolostone with chert lenses, which are concentrated in the middle part. Towards northeast of Al-Nukhaib, the chert is replaced by coarse calcite crystals, which are concentrated in the upper 1.5 m, too. **(2) Upper Member** is divided into three lithological units: **(a) Shelly – Chalky Unit** (42 – 45 m), consists of yellowish grey dolostone with chert lenses and nodules, followed by interbedding of white, bedded, shelly calcareous dolostone and white, slightly fossiliferous chalky limestone, with chert layers, overlain by white slightly fossiliferous chalky dolostone, the top of this unit is highly silicified, locally forming residual boulders, up to 50 cm in size. **(b) Upper Chalky Unit** (13 – 35 m), consists of alternation of thick horizons of white, slightly fossiliferous, marly and chalky limestones with whitish grey, marly and chalky, shelly dolostone, overlain by white, slightly fossiliferous chalky limestone, with black chert in the uppermost parts. Locally, the top of this unit is capped by pink limestone. **(c) Upper Shelly Unit** (30 – 45), consists of grey shelly dolomitic limestone, with some quartzitic sandstone at the base, overlain by light grey shelly limestone, followed upwards by grey, brown and violet, highly fossiliferous dolomitic limestone. Buday and Hak (1980) described it in the middle part of the Western Desert (Fig.1) as different types of limestones, sometimes dolomitized or silicified. At the base there is a basal conglomerate, which contains layers of claystone and shark teeth. This succession is north of Ga'ara Depression. To the south of wadi Huaimi, it consists of whitish to creamy limestone, often recrystallized and dolomitized. Followed by interbedding of chalky limestone and dolomitized limestone, with numerous chert nodules.

Thickness: The thickness of the Umm Er Radhuma Formation in the suplementary type section is 458 m (Bellen *et al*., 1959). The Lower Member is (35 – 65) m thick, whereas the Upper Member is (85 – 115) m, which means the total thickness is (120 – 180) m (Al-Mubarak and Amin, 1983), it is (35 – 45) m south of Ga`ara Depression (Buday and Hak, 1980).

Fossils: The following fossils are recorded by Buday and Hak (1980);Yousif (1983) and Shakir (1983): *Dorthia oxycona* (REUSS), *Coskinolina* sp., *Nummulites deserti* DE LA HARPE, *N. frassi* DE LA HARPE, *Saudi labyrinthica* GRIMSDALE, *Alveolina primeava* REICHEL, *Dictyoconus* sp., *Miscellanea* sp., *Spiroloculina* sp.and *Cardita malticostata* LAMARK.

Age: The following ages were claimed by different authors: Paleocene –? Early Eocene (Bellen *et al*., 1959), Paleocene (Al-Hashimi, 1974 in Jassim *et al*., 1984) Middle – Late Paleocene (Jassim *et al*., 1984 and Al-Mubarak and Amin, 1983).

Depositional environment: The studied authors agreed for inner shelf hypersaline marine to very shallow marine environment.

Lower Contact: The Lower contact of the Umm Er Radhuma Formation, with the underlying Tayarat Formation is unconformable (Bellen *et al*., 1959). The Umm Er Radhuma Formation, in the eastern part is underlain unconformably by Tayarat Formation. The contact is based at

the bottom of the first appearance of black and brown chert or the last Loftusia bearing limestone horizon. Locally, the contact is marked by yellow and pink cross bedded sandstone, or yellow, brown, red and violet gypsiferous claystone, or yellowish orange, pinkish grey, yellowish brown limonitic limestone. (Al-Mubarak and Amin, 1983). South of the Ga`ara Depression, the contact with the underlying Tayarat Formation is not distinct but conformable. However, due to erosion, only the lower part of Umm Er Radhuma Formation, with maximum thickness of about 10 m, is exposed (Buday and Hak, 1980).

Remark: According to Al-Mubarak and Amin (1983) the lower part of the Umm Er Radhuma Formation is included within the Tayarat Formation (South of Ga`ara) by Buday and Hak (1980). Therefore, conformable contact is considered with the underlying Tayarat Formation.

3.1.2. Akashat Formation (Early – Late Paleocene)

The Akashat Formation is recently added to the stratigraphic column of Iraq. Formerly, the succession was considered as Umm Er Radhuma Formation. The difference in lithological composition, facial development and paleogeographical distribution between Akashat and Umm Er Radhuma Formations were recognized by Bellen *et al*. (1959); Al-Naqib (1960) and Powers *et al*. (1967) called it as Hibr Formation, Buday (1980) and Buday and Hak (1980) called it as phosphatic facies of Umm Er Radhuma Formation, Jassim *et al*. (1984) called it as Akashat Formation and Al-Bassam and Karim (1997) announced it officially as Akashat Formation. It is worth to mention that GEOSURV was using the name of Akashat Formation instead of Umm Er Radhuma Formation since 1990.

Type Locality: The type locality of the Akashat Formation is located by Al-Bassam *et al*. (1990) in wadi Samhat, along the western rim of Ga'ara Depression, which is located 7 Km south of Akashat phosphate mines (Fig.5). It is defined by the following coordinates:

Longitud 39° 50' 06" E
Latitude 33° 37' 30" N

Exposure Areas: The Akashat Formation is exposed, only in the western and middle parts (Fig.1) of the Iraqi Western Desert. It crops out in Qasir Al-Halqoom, along the northern rim of Ga'ara Depression, extends westwards (along the rim) till Akashat, then southwards to the Iraqi – Saudi Arabian borders, crossing Jabal Al-Hirri, in a form of narrow strip (2 – 10 Km) till the Highway No.1, ther it becomes (10 – 30) Km wide (Fig.2). The subsurface extension of Akashat Formation is almost uniform, it extends north and westwards. It is struck in oil wells Akkas 1, Risha 1 (in Jordan). Towards north it passes to Aaliji Formation and towards east and northeast it is replaced by Umm Er Radhuma Formation, east and northeast of Rutbah Uplift.

Lithology: The Akashat Formation, in the type locality consists of alternation of grey phosphorites and limestones (Al-Bassam *et al.*, 1990); it consists of phosphatic conglomerate or breccia, followed by oyster bed (biolitite), overlain by a sequence of calcareous siltstone, with layers of silty limestone and calcareous mudstone, locally phosphatic. Another fossiliferous limestone or coquina bed occurs. Followed by calcareous siltstone, with interbeds of limestone and chalky limestone, with abundant chert nodules, rare geodes and lenses of phosphorites, capped by violet, papery shale (Buday and Hak, 1980).

Remark: According to Al-Mubarak and Amin (1983) the lower part of Akashat Formation is included within the Hartha Formation by Buday and Hak (1980).

The Akashat Formation is divided into three members by Al-Bassam *et al.* (1990):
(1) Traifawi Member consists of alternation of lime mudstone, shale and phosphorite. The cycle, which is repeated (2 – 3) times, consists of coarse grained phosphorite, green to ochue, fissile, shale or marl, followed by creamy, siliceous lime mudstone, usually with small chert

nodules. South of Highway No.1, yellowish, quartzitic sandstone occurs in the middle part. **(2) Hirri Member** consists of alternation of phosphorite, shelly limestone and lime mudstone. The cycle is repeated (2 – 3) times. In Akashat – Ga'ara area, the upper part of Hirri Member consists of shelly (cardita) limestone, which reaches in thickness to 10 m. **(3) Dwaima Member** consists of alternation of grey phosphorite, grey and pink, fissile, siliceous marl and phosphatic, recrystallized limestone, with shark teeth.

Thickness: The thickness of the Akashat Formation, in the type locality is 27 m (Al-Bassam *et al*., 1990), it is (25 – 35) m along the northern rim of the Ga`ara Depression (Buday and Hak, 1980), it is (23 – 30) m (Jassim *et al.*, 1984), it is 15 m in Tel Samhat, (25 – 30) m in Akashat, 54 m in Traifawi and increases gradually towards north and west of the exposure areas (Al-Bassam *et al*., 1990).

Fossils : The first paleontological study for the Akashat Formation was from subsurface sections, around Akashat, the following fossils were recognized by different authors: Karim Ctyroky and (1978); Karim and Jassim (1985) and Karim in Al-Bassam *et al*. (1990): *Globigerina daubjergens*, *Globorotalia compresa* (PLUMMER), *Glt. Pseudobulloides* (PLUMMER), *Glt. Trinidodensis* BOLY, *Glt. Imitata* SUBBOTINA, *Glt. Vncinata* BOLY, *Globigerina haynesi* EL-NAGGAR, *G. triloculinoides* (PLUMMER), *Chilogucmbelina midawyensi* (CUHMAN), *Guembelitria cretacea*(CUHMAN), Benthenic fauna asociación age: *Gabonella sp., Lenticulina turbinate* PLUMMER, *Valvulinaria ravni* REUSS and *Anomalinoides midwayensis* BROTZEN.All these fauna are indicative of Danian age (Al-Bassam *et al*., 1997).

The following fauna are recorded by Karim in Al-Bassam *et al*. (1990) from the Middle Paleocene: *Globokotalia angulata*, *Glt. Psendobulloides* PLUMMER, *Glt. Quadrata* WHITE, *Glt. Haynesi* EL-NAGGAR, *Glt. Triloculinoides* PLUMMER, *Lenticulina midwayensis* TENDAM, *Valvulinaria ravni* RUSS. They (op. cit) recorded the following fauna from the Late Paleocene: *Globorrotalia velascensis*, *Globorotalia acuta* TOUIMIN, *Glt. Aequa* CUSHMAN and RENZ, *Glt. Esnaensis* (LEROY), *Glt. Irrerata* LOEBLICH and TAPPAN, *Glt. Woodi* EL-NAGGAR, *Glt. Occulosa* LOEBLICH and TAPPAN. The recorded benthonic fauna are, *Frondioularia phesphatica* (REUSS) *Vaginulopsis midwayensis* (Fox and ROSO), *Lenticulina midwayensis* (KUSHMAN and PONION).

Age: Jassim *et al*. (1984) claimed late Early Paleocene age for the Akashat Formation. However, surface section revealed Middle and Late Paleocene only the Early Paleocene is encountered west of outcrop area of Akashat Formation. Later on Al-Bassam *et al*. (1990) confirmed that the age of Akashat Formation ranges from Early – Late Paleocene depending on the formation biozones.

Depositional Environment: It is deeper and cooler shelf environment relative to that of Late Cretaceous (Al-Bassam and Karim, 1997). The middle Paleocene was more transgressive started in the early stages by central-shelf shoal facies to a deeper outer shelf peloidal phosphorite facies (Al-Bassam and Karim, 1997). The Dwaima Member indicates inner shelf, central shelf, and outer shelf to shelf edges, under subtidal and warm conditions The Late Paleocene cycle come to end by the development of inner shelf – shoal intertidal coprolitic shelly limestone (Al-Bassam *et al*., 1990).

Lower Contact: The Akashat Formation is mainly underlain by Cretaceous rocks. In the northern rim of Ga'ara Depression it was considered to be underlain unconformably by the Ga'ara Formation, the contact was based on the top of last sandstone or conglomerate bed (Jassim *et al*., 1984). Al-Bassam *et al*. (1990) however recognized Marbat Beds instead of the Ga'ara Formation, the contact is unconformable. It is underlain unconformably by Mulussa Formation in the eastern rim of Ga'ara Depression and the Digma Formation in the northern and western rims (Buday and Hak, 1980). It is underlain by Safra Beds (Digma Formation)

south of the Ga`ara Depression, the contact is based at the last appearance of loftusia and lopha bearing limestone, or first appearance of ocher, siliceous lime mudstone or shale (Al-Bassam *et al*., 1990).

3.2. EOCENE

The Neo Tethys was narrowed and closed causing the development of phosphatic facies due to upwelling cold water currents. The formations of Eocene Period are well exposed in the Iraqi Western Desert, especially the eastern and western parts (Fig.1) where they cover almost the entire territory, represented mainly by Ratga and Dammam formations and partly by Jaddala Formation? (Figs.2 and 3). Three formations are encountered within Eocene Period. These are described hereinafter.

3.2.1. Dammam Formation (Middle – Late Eocene)

Type Locality: The type locality of the Dammam Formation is on the Dammam dome in Saudi Arabia (Bellen *et al*., 1959). Although Barkamp (1941) in Bellen *et al.* (1959) described the formation for the first time, but Sandrey (1952) in Bellen *et al*. (1959) was considered the author (Bellen *et al*., 1959). A supplementary type section has been introduced by Owen and Nasr (1958) in Zubair oil well 3 (Fig.5), which is defined by the following coordinates:

Longitude 47° 43' 29" E
Latitude 30° 23' 01" N

Exposure Areas: The Dammam Formation is exposed only in the eastern part (Fig.1) of the Iraqi Western Desert. It is exposed in Al-Sahin vicinity and extends northwards to Garat Al-Shatub, crossing Al-Breet, Al-Lusuf and Al-Jithoom vicinities. Its exposures cross wadi Ubaiyidh for about 50 Km, northwards till 10 Km southeast of Garat Al-Shutub (Fig.3). It is also exposed in some deep cut valleys, as isolated outcrops, like Ghadaf, Thumail and Hauran. Small isolated outcrops are recorded from the Ga'ara Depression, on the top of Al-Afayif and in Qasir Al-Halgoom (oral communication with Dr. Mazin Y. Tamar-Agha, 2006). But, these are not presented on the geological maps due to scale limitations. The subsurface extensions of the Dammam Formation are clear; it is encountered in oil wells of south Iraq. Also in oil wells of Ali Al-Gharbi, Kut and Musaiyeb vicinities (I.P.C., 1963). Farther northwards it passes to the off-shore, open sea sediments of the contemporaneous Jaddala Formation.

Remark: It is worth to mention that the exposures of the Dammam Formation, west of Rutbah Uplift, i.e. western part of the Iraqi Western Desert, are excluded from Dammam Formation and included within the recently announced Ratga Formation.

Lithology: The Dammam Formation, in the type locality, consists of "whitish grey, porous, dolomitized limestone. The limestones are sometimes chalky. At or near the base of the drilled section a persistent grey – green waxy shale body is encountered" Owen and Nasr (1958) in Bellen *et al*. (1959). The Dammam Formation was divided by Hubber and Ramsden (1944 – 1945) in Bellen *et al*. (1959) into ten informal units, from surface exposures, which they didn't recognize them in subsurface sections. Although the typical development of the ten informal units is in the Southern Iraqi Desert, not in the Western Iraqi Desert, but they are mentioned hereinafter for data presentation purpose.

1- Tuqaiyid Beds
2- Ghnaimi Beds
3- Barbak Beds
4- Radhuma Beds
5- Chabd Beds
6- Shawiya Beds
7- Huwaimi Beds
8- Shabicha Beds
9- Sharaf Beds
10- Wagsa Beds

Because, these units (Beds) were not constant enough and were not suitable for the surveys made on extensive areas. Therefore, Ramsden and Andre (1953) in Bellen *et al.* (1959) introduced four informal units only; these are (from top to bottom):

1- Tuqayid – Ghnaimi – Barbak – Radhuma Unit: consists of bryozoan – peneroplid limestones and shelly limestones.
2- Chabd – Shawiya – Huweimi (nummulitic) Unit: consists of nummulitic – alveolina limestones.
3- Huweimi (chalky) – Shbicha – Sharaf Unit: consists of chalks and chalky limestones.
4- Wagsa Unit: consists of chalk, fossiliferous limestones.

Remark: The best detailed description for the lithology of the Dammam Formation in the Southern and Western Iraqi Deserts is given by Al-Mubarak and Amin (1983). The detailed description is briefed by Sissakian and Abdul Jabbar (2001).

The following lithological descriptions are given for the Dammam Formation by different authors, in different localities. Tyracek and Youbert (1975) described the Dammam Formation in wadi Hauran, south and east of H_1 as three main rock types: **(1)** Red, pink and yellow nummulitic limestone. **(2)** White and creamy detrital nummulitic limestone. **(3)** Yellow to creamy, bouldary or blocky limestone (in the top). Al-Mehaidi *et al.* (1975) described the Dammam Formation, southeast of Shithatha and Wadi Ubaiyidh, as grey, creamy and white nummulitic limestone. Buday and Haq (1980) divided the Dammam Formation north of Ga`ara Depression into three units**: (1) Dammam 1**, consists of white, creamy limestone, reddish and yellowish limestone, silicified, fossiliferous limestone with desert varnish (locally altered to quartzite), chalky limestone, with very rare chert nodules and phosphorite. Locally at the base, aggregate of coarse calcite crystals occur. **(2) Dammam 2** consists of oyster bed, fossiliferous limestone, capped by creamy or light grey limestone, interbedded with layers of chert nodules and lenses, which forms large fields of fragments and nodules spraid over the surface. **(3) Dammam 3** consists of large nummulitic limestone. Al-Mubarak and Amin (1983) divided the Dammam Formation into three members, however only two members are exposed in the eastern part of the Western Desert: **(1) Lower Member,** which is divided into two units: **(a) Ubaiyidh Unit,** consists of basal conglomerate, overlain by whitish grey fossiliferous (nummulites) limestone. This succession is in wadi Ubaiyidh vicinity. In Nukhaib vicinity, the lower part consists of brownish grey, quartizitic sandstone, with the same lithology of the upper part. **(b) Thumaily Unit** consists of yellowish and greenish grey limestone, alternated with grey, phosphatic limestone, with shark teeth. The upper part consists of yellowish grey limestone, with chert nodules. **(2) Middle Member** is not divided, but it is described from different localities. It is named as **Al-Faj Unit**, in the Amij and south of Hauran vicinities, it consists of yellow and yellowish grey, friable sandy marl, dark brown ferrigenous quartzitic or silicified sandstone, with abundant plant remains. Followed, upwards by yellow to creamy massive nummulitic (gizehensis) limestone, with oyster. In the eastern and southern parts, **Al-Faj Unit** is subdivided into three subunits: **(a) Lower Subunit,** it is exposed in Ubaiyidh, Ghadaf, Faj and Raggas wadies. It consists of white with pink patches, chalky nummulitic limestone. **(b) Middle Subunit,** it is exposed in the same localities of the Lower Subunit. It consists of white, massive shelly limestone; shells are mainly oysters with few small nummulites. Some chert fragments occur too. **(c) Upper Subunit,** it is exposed in different eastern and southern parts, of the exposure areas. It consists of creamy and whitish grey, massive, nummulitic (gezihensis) limestone.

Remark: According to Al-Mubarak and Amin (1983), the Thumaily Unit is equivalent to Sharaf, Shbicha and Lower Huweimi Units. Al-Faj Unit is equivalent to Shawiya Unit.

Thickness: The thickness of the Dammam Formation in the supplementary type section is 225 m (Bellen *et al*., 1959). The following thicknesses are recorded by different authors in

different parts of the exposure areas. According to Al-Mubarak and Amin (1983) the thickness ranges from (32 – 99) m. It is (18 – 28) m in H_1 vicinity (Tyracek and Yuobert, 1975). In Shithatha vicinity it is about 20 m (exposed part) (Al-Mehaidi *et al*., 1975).North of the Ga`ara Depression it is (20 – 45) m (Buday and Hak, 1980).

Fossils: Because the three members of the Dammam Formation have different fossil assemblages, therefore the recognized fossils within each member are listed alone, hereinafter:

Lower Member:

Nummulites frausi DE LA HARPE, *N.deserti* DE LA HARPE, *N. atacicus* LEYMERIE, *N. planulatus* (LAMARK), *Opericulina libyca* SCHWAGER, *Assilina* sp., *Lopha* c.f. *sifax* (OQUARD), *Ostrea* c. f. *multicatars* DE SHAYES, and *Mytilus* sp.

Middle Member:

Nummulites gizehensis zeitteli DE LA HARPE, *N. discarbinus* (SCHLOTHEIM), *N. perforatus* (MONTFORT), *N. perforatus var bayhariensis* (CHECCHIARISPOLI), *N. atacicus* LEYMERIE, *N. irregularis* (DE SHAYES), *Coskinolina basilliei* DAVIES, *Linderina baranensis* SHLUMBERGER, *Linderina brugesi* SHLUMBERGER, *Aiveolina elliphica* (SOWERBY), *A. lepidula* SCHWAGER, *A. palermitana* (HOTINGER), *Assilina spira* DE ROISS, *Dictyoconoides cooki* (CARTER), *Lockharira aleveolata* SILVESTRI, and *Rotalia trochidiformrs* LAMARK**.**

Age: The age of the Dammam Formation is another matter of contraversy between different authors. According to Bellen *et al*. (1959) the age in the supplementary type section is Middle Eocene. However, they have not excluded the possibility of being Early – Late Eocene. The age in H_1 Oil pumping vicinity (along wadi Hauran) is Early – Middle Eocene (Tyrack and Youbert, 1975); in Shithatha vicinity is Middle Eocene (Al-Mehaidi *et al*., 1975); in the eastern part of the Western Desert is Early – Middle Eocene (Early Ypresian – Late Lutetian) (Al-Mubarak and Amin, 1983); the age of the Dammam Formation (regionally) is Middle – Late Eocene (Lower Lutetian – Priabonian) (Jassim *et al*., 1984).

Remark: It is worth to mention that the differences in the mentioned ages are mainly due to different exposed parts of the formation, in different localities. The Early Eocene is excluded, because it is included within the Jil Formation.

Depositional Environment: The Dammam Formation is deposited mostly in shallow neritic environment (Buday, 1980); the nummulites indicate a shole facies of tropical –subtropical quite marine environments depth not more than 100 m (Al-Mubarak and Amin 1983 and Jassim *et al*., 1984); typical restricted marine platform (lagoon) (Al-Hashimi and Amer, 1985).

Lower Contact: In majority parts of the Western Desert, the Dammam Formation is underlain by Umm Er Radhuma Formation; in remaining parts the base is not exposed. The following details are given by Al-Mubarak and Amin (1983). The Ubaiyidh Unit of the Lower Member is unconformably underlain by the Umm Er Radhuma Formation. The contact in Wadi Ubaiyidh is based on the bottom of a basal conglomerate (3 – 3.5 m thick). In Nukhaib vicinity, it is based on a ferrigenous quartzitic sandstone bed (1.5 – 2.5 m thick). In the vicinity of wadi Amij and south of Wadi Hauran, the Middle Member of the Dammam Formation is underlain unconformably by the Nahr Umr, Mauddud, Rutbah and Ms`ad formations; in wadi Hauran, south of H_1 is underlain unconformably by Rutbah Formation (Tyracek and Youbert, 1975).

Remarks:

- It is worth to mention that in recent geological mapping, the aforementioned Rutbah Formation was changed in wadi Hauran area, near H_1, by Nahr Umr Formation (Al-Mabarak and Amin, 1983).

- According to Al-Mubarak and Amin (1983) the contact between Lower and Middle Members of the Dammam Formation is unconformable. The contact is marked by a breccia horizon (2 m thick).
- It is worth to mention that in the Iraqi Southern Desert, the contacts between the three members are unconformable. Moreover, in the Iraqi Western Desert, the Upper Member of the Dammam Formation is absent. In the author's opinion it was not deposited, due to effect of Rutbah Uplift, otherwise relics of the Upper Member should be found somewhere.

3.2.2. Jil Formation (Early Eocene)

The Jil Formation is recently added to the stratigraphic column of Iraq. Formerly, the involved sequence was included within the Lower Member of the Dammam Formation. The proposal of the Jil Formation was claimed by Tamar-Agha (1983) and Al-Mubarak and Amin (1983). The Jil Formation, however, was announced officially by Tamar-Agha, *et al*. (1997).

Type Locality: The type locality of the Jil Formation is near the Jil water wells (along Tar Wagsa, about 2 Km southwest of the wells) (Fig.5). It is defined by the following coordinates:

Longitude 44° 00' 00" E
Latitude 30° 23' 00" N

Remarks:

- The Jil Formation is exposed only in the eastern part (Fig.1) of the Western Desert. Because it is supposed by Tamar-Agha *et al*. (1997) to be the equivalent of the Lower Member of the Dammam Formation, therefore it will not be described as other Formations. Because, all required data are mentioned within the Lower Member of the Dammam Formation.
- Al-Mubarak and Amin (1983) proposed the announcement of three new formations instead of the three members of the Dammam Formation. Since, only the Lower Member is concerned and remaining two members are still included within the Dammam Formation, therefore the present authors prefer not to consider the Jill Formation until the announcement of other two members as new two formations.
- Al-Jibouri (2003) didn't recognize any difference between the Jil Formation, in the type locality, and the Lower Member of the Dammam Formation elsewhere. Therefore, she didn't recommend the sole announcement of the Jill Formation, as the other two members are concerned.

3.2.3. Ratga Formation (Early – Late Eocene)

The Ratga Formation is recently added to the stratigraphic column of Iraq. Formerly, the involved rock sequence was included within Dammam Formation. The name was introduced by Jassim *et al.* (1984), but officially was announced by Karim and Al-Bassam (1997).

Type Locality: The type locality of the Ratga Formation is distributed over four localities, since it is not possible to have complete sequence of the formation within one locality. These four localities are defined as follows (Karim and Al-Bassam, 1997) (Fig.5):

Swab Member, in wadi Swab, near Iraqi – Syrian borders, limited by:

Longitude 39° 45' 00" E
Latitude 33° 45' 00" N

Damluk A, in wadi Akash, northwest of Akashat mine, limited by:

Longitude 40° 07' 30" E
Latitude 33 ° 52' 00" N

Damluk B, in wadi Halgum, limited by

Longitude 40° 30' 00" E
Latitude 33° 52' 00" N

Muger Member, in wadi Ratga, near Muger Al -Dheeb vicinity, limited by:

Longitude 40° 10' 00" E
Latitude 34° 00' 00" N

Exposure Areas: The Ratga Formation is widely exposed only in the western part (Fig.1) of Iraqi Western Desert. It is exposed north of Qasir Al-Muhaiwir, along the northern bank of wadi Hauran and extends westwards till Iraqi – Syrian borders in form of a wide strip (35 – 45 Km) parallel to the northern rim of Ga'ara Depression. From Muger Al-Dheeb vicinity, it extends southwards covering the whole western plateau, which is called "Hamad" (Fig.2). The subsurface extension of the Ratga Formation, towards north is not so clear. The area where Ratga Formation is replaced by Dammam Formation is not defined. Since in oil well Akkaz 1, Dammam Formation is recorded, not Ratga Formation. But, mostprobaly it is Ratga Formation. However, the replacement of the Ratga Formation by Jaddala Formation is somewhere south of oil well Anah1 (Fig.5).

Lithology: The Ratga Formation, in the type locality consists of nummulitic limestone, phosphorite and phosphatic limestone, fine crystalline limestone, with several chert horizons (Karim and Al-Bassam, 1997). Hagopian (1979) divided the RatgaFormation in the extreme western part of the Western Desert into five units: **(1) Nhaidain Unit** (20 m), it consists of white to grey, either reddish or brownish, massive partly silicified limestone. **(2) Umm Chaimin Unit** (18 m), it consists of greyish white, massive, nummulitic limestone, partly silicified and phosphatic, overlain by white, fossiliferous limestone, white and grey, limestone with chert nodules and concretions of dark black or grey in color. **(3) Ethna Unit** (16 m), consists of alternation of fossiliferous limestone and phosphatic limestone, with chert bands**. (4) Al-Tinif Unit** (28 m), consists of pale brown and yellow chalky and dolomitic limestones, with chert nodules and layers of dark brown in color. **(5) A`naza Unit** (5 – 28 m), consists of white and creamy, cavernous, nummulitic (gezahensis) limestone, overlain by grey and white fossiliferous and dolomitic limestones, partly phosphatic. Buday and Hak (1980) divided the Ratga Formation (they called it Dammam Fotmation) west of the Ga`ara Depression and southwards into three parts. **(1) Dammam 1** (35 – 45 m), consists of white and creamy limestone, dolomitic limestone, slightly nummulitic. Some of the limestone beds are silicified, others are highly fossiliferous. **(2) Dammam 2** (25 – 30 m), consists of whitish to light grey limestone, with abundant chert nodules and lenses**. (3) Dammam 3** (25 m), consists mainly of fossiliferous limestone, with chert nodules, in the uppermost part. Al-Bassam *et al.* (1990) divided the Ratga Formation in Ga`ara Depression and southwards into two members, these are: **(1) Swab Member**, consists of shelly limestone, white nummulitic limestone, capped by shelly, slicified limestone, with desert varnish**. (2) Damluk Member**, it is divided into two parts: **Damluk**"**A**" consists mainly of limestones, partly phosphatic, silicified and nummulitic (at the top). **Damluk**"**B**" consists mainly of limestones, partly phosphatic, chalky, with oysters and nummulites. Karim and Al-Bassam (1997) divided the Ratga Formation , in the whole exposed area, into three members: **(1) Swab Member** (32 m), consists of grey, shelly, slightly phosphatic limestone, overlain by white, cavernous, nummulitic limestone, capped by grey (with desert varnish) partly silicified, shelly, slightly phosphatic limestone. **(2) Damluk Member,** which is divided into two parts: **(a) Damluk**"**A**" (28 m), consists of creamy, phosphatic limestone, creamy to yellow limestone, pink, orange and pale yellow partly silicified limestone, with chert nodules, capped by white nummulitic limestone, with oyster beds**. (b) Damluk**"**B**" (52 m), consists of pale brown to grey, occasionally silicified limestone, pinikish grey limestone, phosphatic at the top, white chalky dolomitic limestone, with chert nodules, grey shelly limestone, with oysters, white, chalky, dolomitic, nummulitic limestone, capped by white, nummulitic limestone. **(3) Muger**

Member (119 m) consists of white, hard, fine to coarse crystalline nummulitic limestone, with tongues of phosphatic micritic limestone and several chert horizons.

Remark: The five mapped units by Hagopian (1979) are the equivalents of the three members considered by Karim and Al-Bassam (1997) as follows:

Nhaidain and Um Chaimin Units are equivalent of Swab Member

Ethna Unit is the equivalent of Damluk "A"

Al-Tinif Unit is the equivalent of Damluk "B"

A`naza Unit is the equivalent of Muger Member

Thickness: The thickness of the Ratga Formation in the type locality is 231 m (Karim and Al-Bassam, 1997); it is (90 – 100) m north and west of Ga`ara Depression (Buday and Hak, 1980); it is (21 – 108) m in Naidain – Tinif area (Hagopian, 1979) and it is 112 m west of Ga`ar Depression (Al-Bassam *et al*., 1990).

Fossilis: The following fossils are recorded, by different authors:

Swab Member: The fauna determined by Al-Hashimi (1974), Shakir (1979); Karim and Ctyroky (1980) and Buday (1980) are:

*Nummulites frass*i DE LAHARPE, *N.deserti* DE LAHARPE, *Assilina* sp., *Rotalia trochidiformis* DESHAYS, *Opericulina libyca* SCHWAGER and *N. akashensi* AL-HASHIMI.

Damluk Member: The fauna recorded by Karim and Al-Bassam (1997) are**:**

Damluk A:

Nummulites planulatus LAMARK, *N.globules* LEYMERIE, *N.murchisoni* RUTMEYER, *N. gizehensis* FORSKAL, small *globorotalia bullbrooki* BOLLI, *Globigerapsis kugleri* BOLLI and *G. lehneri* CUSHMAN and JARVUS.

Damluk B:

Nummulites gizehensis FORSKAL, *N. bayheriensis* CHECCHIA RISPOLI, *N. beaumonri* DE ARCHICAC, *N. gizehensis lyelli* DE LAHARPE, *Chiloguembelina* sp., small *Globigerina* sp. and *Bulimina* sp.

Mugur Member: Fossils recorded by Al-Hashimi (1974) are:

Nummulites bouillei DE LAHARPE and *N. incrassatus* DE LAHARPE.

The planktonics are *Globorotalia cerroazulensis* COLE, *Glt. Centrulis* CUSHMAN and BERMUDES, *Globigerina ampliapertura* BOLLI, *G. officialis* SUBBOTINA and *G. venezvuelana* HEDBERG

Fossils recorded by Karim and Al-Bassam (1997) are:

Nummulites bouillei DE LAHARPE, *N. straitus* BRUGUIERS, *N. praefabiani* VARENTOF and MENNER, *Opericulina* sp., *Bolirina* sp., *Globorotalia cerroazulensi* COLE and *Glt. centralis* CUSHMAN and BERMODS.

Age: According to Karim and Al-Bassam (1997) the age of the Ratga Formation is Early – Late Eocene. The adopted ages for the subdivision of the formation are as follows:

1. Swab Member is Early Ypresian.
2. Damluk Member is Late Ypresian – Early Lutetian.
    a. Damluk "A" is Late Ypresian – Late Lutetian.
    b. Damluk "B" is Late Lutetian.
3. Mugur Member is Late Eocene.

Depositional Environment: The depositional environment of the Ratga Formation is normal marine tropical to sub tropical environment (Jassim *et al*., 1984). Swab Member indicates a shoal facies (nummulitic facies) of normal marine water with depth not more than 10 m. The Early Lutetian phosphatic facies of the Ethna Unit indicates a shallow marine environment of shelf zone. This unit passes into the Jaddala Formation (Al-Tinif Unit), which indicates very deep normal marine conditions. Karim and Al-Bassam (1997) stated that the Ratga Formation

represents a normal marine tropical to sub tropical environment of shelf – shelf edge slope affected by pulses of cool upwelling deep water currents.

Lower Contact: The Ratga Formation, in the type locality is underlain conformably by the Akashat Formation; the contact is based at the top of the copralitic phosphatic limestone of Herri Member (Karim and Al-Bassam, 1997), it is also underlain conformably by Akashat Formation, elsewhere.

3.2.4. Jaddala Formation? (Middle Eocene, Early Lutitian)

Although the presence of the Jaddalah Formation in the Iraqi Western Desert is obscure, but it is described in this paper to elucidate its vague presence or otherwise.

Type Loacality: The type locality of the Jaddalah Formation is near Jaddalah village in Sinjar mountain, it is defined by the following coordinates (Fig.5) (Bellen *et al.,* 1959):

Longitude 41° 41' 28" E
Latitude 36° 08' 00" N

Exposure Areas: According to Jassim *et al*. (1990) based on Hagopian (1979) the Jaddala Formation is exposed in the western part (Fig.1) of the Iraqi Western Desert. It is exposed in Traibeel vicinity and extends northwards to the Iraqi – Syrian borders, then northeastwards parallel to wadi Swab for about 20 Km. Then crops out again parallel to wadi Suwab and extends for about 35 Km along the Iraqi – Syrain borders for about 15 Km southwest of Damluk hill (Fig.5). Because the presence of the Jaddala Formation in the Iraqi Western Desert is obscure, therefore its subsurface extension is not mentioned here, but it is worth to mention that it is struck in oil wells of Khlesia, Anah 1, Abu Jir, Awasil 5, Falluja, Hit, Milh Tharthar (Fig.5).

Lithology: The Jaddala Formation, in the type locality consists of "marly to chalky limestone and marls with occasional thin intercalations of shoal limestone (Avanah limestone tongues)" (Bellen *et al*., 1959). Hagopian (1979) considered the Al-Tinif Unit of the Ratga Formation to be equivalent of the Jaddala Formation. It consists of thin to medium beds, upwards become pale brown, white to yellow, chalky limestone to dolomitic limestone, with occasional chert nodules, in the uppermost part. The lower part contains radiolarian chert and it is rich in planktonic and benthonic foraminifera. The lower part of Damluk "B" shows similarities to the Jaddalah Formation and it consists of chert bearing limestone and phosphorite (Al-Bassam *et al*., 1990).

Thickness: The thickness of the Jaddalah Formation, in the type locality is 342 m (Bellen *et al*., 1959); it is 28 m in Al-Tinif area decreasing southwards to few meters (Hagopian, 1979) and it is a tongue like, therefore the thickness is about 8 m (Al-Bassam *et al*., 1990).

Fossils: Hagopian (1979) recorded the following fossils within Al-Tinif Unit (Jaddalah Formation) in Traibeel – Al-Tinif vicinity:

Globorotalia renzi BOLLI, *Glt. Centralis* CUSHMAN and BERMUDEZ, *Glt. Bullbrooki* BOLLI, *Glt. Cocoanewsis* CUSHMAN, *Glt. kugleri* BOLLI, *Hantkenina maxicana* CUSHMAN and *Hantkenina alabamensis* CUSHMAN.

Age: The age of the Jaddalah Formation, according to the aforementioned fossils is Early Lutetian (Middle Eocene) (Hagopian, 1979).

Depositional Environment: The formation represents a typical basinal facies through out, a shelf margin facies (Al-Hashimi, 1974; Al-Bassam and Al-Hashimi, 1983 and Al-Hashimi and Amer, 1985).

Lower Contact: The lower contact of the Al-Tinif Unit (Jaddala Formation) with the underlying rocks is always conformable. Because, it forms a tongue, therefore it is underlain by Ratga Formation. However, in northeastern part of Al-Tinif area, it is underlain by Akashat Formation (Hagopian, 1979).

3.3. OLIGOCENE

The rocks of Oligocene Epoch in the Iraqi Western Desert have very limited extensions. This is because the Noe-Tethys was a narrow seaway forming reef backreef and forereef basins; this was due to the tilting of West Arabia at the end of the Eocene. The outcrops are limited to Anah anticline, Muger Al-Dheeb vicinity and wadi Hauran. In all other areas, they are exposed only in deep cut valleys. They are represented by four formations, these are described, hereinafter.

3.3.1.Shurau and Sheikh Alas Formations (Early Oligocene)

Because the Shurau and Sheikh Alas formations, occur always together in the western and central parts (Fig.1) of the Iraqi Western Desert and they are not separated (almost impossible to separate them) during the regional geological mapping, therefore they are described, in this paper, together. Their interfingering is proved by Al-Hashimi (1974).

Type Locality: The type locality of the Shurau Formation is in Kirkuk structure, oil well K109, which is defined by the following coordinates (Bellen *et al*., 1959) (Fig.5):

Longitude 44° 18' 55" E
Latitude 35° 33' 08" N

The type locality of Sheikh Alas Formation is in Qara Chouq Dagh, Northern dome, near Sheikh Alas village, which is defined by the following coordinates (Bellen *et al*., 1959) (Fig.5):

Longitude 43° 35' 30" E
Latitude 35° 54' 38" N

Exposure Areas: The Shurau and Sheikh Alas Formations are exposed only in the western and central parts (Fig.1) of the Iraqi Western Desert. They are exposed in Muger Al-Dheeb area, along the Iraqi – Syrian borders, as a narrow strip (1 – 6 Km) extending southeastwards for about 30 Km, crossing wadi Swab and Akash, it wedges out almost west of Al-Qaim – Akashat railway, after crossing wadi Ratga. They are also exposed in wadi Hauran, east of Al-Midham village and extend down stream for about 35 Km (Figs.2 and 3). The subsurface extension of the Shurau and Sheikh Alas Formations is almost clear. They are struck in oil wells of Anah 2, Awasil 5 and more north and northeastwards to Ain Zala and Kirkuk structures.

Remark: Some parts of the mapped Ratga Formation in Muger Al-Dheeb vicinity (Al-Jumasily, 1974) may belong to Shurau and Sheikh Alas formations.

Lithology: The Shurau Formation, in the type locality consists of porous coralline limestone, followed by grey, dense limestone (Bellen *et al.*, 1959). Whereas, the Sheikh Alas Formation, in the type locality, consists of dolomitic and recrystallized limestone, generally porous and occasionally rubbly (Bellen *et al*., 1959). Al-Jumaily (1974) described Shurau and Sheikh Alas formations in Muger Al-Dheeb vicinity as white, fine crystalline, nummulitic limestone, locally recrystallized and cavernous. Nummulites are small in size (few millimeters). Tyracek and Youbert (1975) described the Shurau and Sheikh Alas Formations in Hadithah and wadi Hauran vicinities as creamy, yellowish white, porous, limestones, locally contain nummulites.

Thickness: The thickness of the Shurau and Sheikh Alas formations in their type localities is 18 m and 26 m, respectively; in Muger Al-Dheeb vicinity it is 15 m (Al-Jumaily, 1974), whereas in wadi Hauran it is 20 m (Tyracek and Youbert, 1975).

Fossils: The following fossils were recognized in Sheikh Alas Formation (Al-Hashimi, 1974 and Al-Hashimi and Amer, 1985).

Nummulites intermedium (D'ARCHIAC), *N. vascus* JOLY and LEYMERE, *Heterostigina assilinoides* BLANKENHORN, *Opericulina complanata* (SCHLUMBERGER), *Rotalia viennoti* GREIQ, *Borelis pygmae* HANZAWA, Cerals, algae and mollusca.

While the fossils recorded from Shurau Formation are (Op.cit).
Archias operculifermis HENSON, *Peneroplis evolutus* HENSON, *P. thomasi* HENSON, *Praerhapydionina delicate* HENSON, *Austrotrillina howchini* (SCHLUMBERGER), *A. Paucialveolata* GRIMSDALE, *A. globulina*. AL-HASHIMI and AMER, *Rotalia viennoti* GREIG, Miliolids and algae.
Age: Early Oligocene age is claimed by the following authors (Al-Hashimi, 1974, Jassim *et al*., 1984, and Al-Hashimi and Amer, 1985).
Depositional Environment: Sheikh Alas Formation represents deposition in normal warm marine environment of shoal facies (shelf depth). This facies changes laterally into the inner shelf facies of Shurau Formation. While the Shurau Formation is deposited in an inner shelf zone of warm quiet marine conditions (Bellen *et al.,* 1959)
Remark: Transition between Sheikh Alas and Shurau formations is the main facies present in the Muger Al-Dheeb area. It is therefore suggested by the present authors to use the term Sheikh Alas – Shurau Formation.
Lower Contact: The lower contact of Shurau Formation, in the type locality is conformable with the Sheikh Alas Formation. Whereas, the lower contact of the Sheikh Alas Formation, in the type locality with the underlying Palani Formation is unconformable. In Muger Al-Dheeb vicinity, the Shurau and Sheikh Alas formations are underlain conformably by the Ratga Formation (Al-Jumaily, 1974); this is attributed to continuous sedimentation. In wadi Hauran, the lower contact is also unconformable with the underlying Dammam Formation, but the contact is not sharp and clear. Locally, basal conglomerate is developed, but mainly it is based depending on the type and size of the nummulites and appearance of white limestone (Tyracek and Youbert, 1975).
Remark: Because the Upper Member of the Dammam Formation is not deposited or totally eroded, almost in all parts of the Western Desert, therefore an unconformable contact is recorded.

3.3.2. Baba Formation (Middle Oligocene)

Type Locality: The type locality of the Baba Formation is in Kirkuk structure, Baba dome, oil well K 109 (Bellen *et al.,* 1959) (Fig.5); it is defined by the following coordinates:

Longitude 44° 18' 55" E
Latitude 35° 33' 08" N

Exposure Area: The Baba Formation is exposed only in the central part (extreme northern margin) (Fig1) of the Iraqi Western Desert, with very limited outcrops in some deep cut valleys, Al-Khazgah Al-Sharji and Al-Gharbi, and wadi Al-Burkhiyah (Figs.2 and 3). The subsurface extension of the Baba Formation is almost clear; it is present in areas where other Oligocene formations are developed, like Awazil, Ain Zala and Kirkuk.
Lithology: The Baba Formation in the type locality consists of "ruby limestone and limestone containing lepidocyclina" (Bellen *et al*., 1959). In Anah vicinity it consists of white, porous, partly fossiliferous and chalky limestone (Al-Mubarak, 1974). Fouad *et al*. (1986) described the Baba Formation, near Anah town as light grey to whitish grey, fossiliferous dolomitic limestone, chalky appearance, with Lepidocyclina, which decreases in size upwards.
Remark: According to Said in Fouad *et al*. (1986) the upper part of the exposed Baba Formation in Anah vicinity belongs to Azkand Formation.
Thickness: The thickness of Baba Formation, in the type locality is 20 m; in wadi Al-Khazgah Al-Sharji it is 20 m (Al-Mubarak, 1974), it is 17 m in Anah vicinity (Fouad *et al*., 1986).

Fossils: The following fossils were recorded in Baba Formation by many authors (Bellen, 1956 in Bellen *et al*.,1959 ; Ctyroky and Karim, 1971; Salman in Mahdi *et al*., 1985 and Said in Fouad *et al*., 1986).
Nummulites fichteli, Lepidocyclina elephanta LEMOINE and DOUVILLE,*L. morgan* LEMOINE and DOUVILLE, *Rotalia viennoti* GREIC, *Heterostegina* sp., *Opericulina* sp., *Praerhapydionina delicate* HENSON, *Archaias kirkukensis* HENSON, *Borelis pygmae* HANZAWA, *Meandrepsina anahensis* HENSON and Coralline algae.
Age: Ctyroky and Karim (1971) had estimated late Middle or early Late Oligocene age to the Baba Formation. In Anah vicinity, the Baba Formation (upper part) would comprise the younger faunal zone of the formation, i.e. the Lepidocyclina Zone (Sensu Bellen, 1956). Said in Fouad *et al*. (1986) emphasized Middle to Late Oligocne age. The latter dating was based on the finding of the *Miogypsinoides complanatus, Lepidocyclina morgani* Zone. The latter zone correspondes to the Azkand Formation, which have recently introduced to the Oligocene succession of the Western Desert (Said, 1995). Al-Hashimi and Amer (1985) claimed Middle Oligocene age to the second cycle rock units.
Depositional Environment: The Baba Formation represents fore reef facies (Bellen, 1956 and Bellen *et al*., 1959). Ctyroky and Karim (1971) estimated shallow warm tropical sea with normal salinity, at depth (30 – 50) m. Said in Fouad *et al*. (1986) claimed shoal facies deposited on the reef slope in seaward direction, as indicted by the presence of *Lepidocyclina* (*Eulepidina*).
Remark: Recently, based on the sequence stratigraphic analysis of the Oligocene succession in Western Iraq, the Baba Formation represents a shelf margin edge deposited in the interior parts of a ramp-like setting, the crowded larger *Lepidocyclina* spp. qualify a stressed environment, prevailed during Early Chattian time and caused by lower rates of marine water invasion and lower rate of subsidence (Al-Twaijri, 2000).
Lower Contact: The Baba Formation in the type locality is underlain, unconformably by the Shurau Formation (Bellen *et al*., 1959). In the Iraqi Western Desert, the base of the Baba Formation is not exposed.

3.3.3. Anah Formation (Late Oligocene)

Type Locality: The type locality of the Anah Formation is located 15 Km east of Nahhiyah village, west of Anah, along the Euphrates River (Bellen *et al*., 1959) (Fig.5); it is defined by the following coordinates:

Longitude 43° 37' 25" E
Latitude 34° 58' 00" N

Exposure Areas: The Anah Formation is exposed in the extreme northern margin of the western and central parts (Fig.1) of the Iraqi Western Desert, in very small outcrops, except in the core of Anah anticline. It is exposed as a very narrow (1 – 3) Km and about 20 Km long strip, along the core of Anah anticline. It is also exposed in deep cut vallies like Chabab and other three vallies to the west, and Fhaimi to the east. Near Haqlaniyah, along the right bank of the Euphrates river, it is exposed as small patches, extending downstream to Al-Baghdadi (Figs. 2 and 3).The subsurface extension of the Anah Formation is clear, it extends as all other Oligocene formations, eastwards, in Awazil and northwards to Ain Zala and northeastwards to Kirkuk.
Lithology: The Anah Formation, in the type locality consists of "grey, breccious, recrystallized, detriatl and coralline limestone" (Bellen *et al*., 1959). Al-Mubarak (1974) described the Anah Formation, in the extreme western outcrop area, as brownish grey or creamy, massive, fossiliferous limestone, the uppermost part is highly fractured and cavernous. Mahdi *et al*. (1985) decribed it in Haditha vicinity as creamy and grey, very hard,

splintary, massive and cavernous limestone, locally coralline limestone may occur. Fouad *et al*. (1986) decribed it in Anah vicinity as creamy, massive, coralline and fossiliferous limestones, with thick interbeds of intraclastic, fossiliferous limestones. Overlain by creamy, intraclastic limestone and thinly bedded fossiliferous limestone, with thin interbeds of light green, marly limestone and calcareous marls.

Thickness: The thickness of the Anah Formation in the type locality is 45 m (Bellen *et al*., 1959). It is 40 m in exterme western exposure areas (Al-Mubarak, 1974), in Fhaimy, Haqlaniyah and wadi Banat Al-Hassan localities it is (1 – 6) m (Tyracek and Youbert, 1975). In Anah vicinity, it is (29 – 47) m (Fouad, *et al*., 1986).

Fossils: The following fossils are recorded by different authors:

Miogypsinides complanatus (SCHLUMBERGER), *Archias asmaricus* SMOUT and EAMES, *A. Henson* SMOUT andEAMES, *A. kirkukensis* HENSON, *Peneroplis thomasi* HENSON, *P. evolutus* HENSON, *Austrotrillina howohini paucialveotara* GRIMSDALE, *Borelis pygmae, B. schlumbergeri, Lepidocyclina* sp., *Rotalia viennoti* GREIG, *Meandropsina anahensis, Praerhapydionina delicate, Heterostigina assilinoides, Dentritina* sp., *Subterraniphyllum thomasi* and corals.

Age: According to Bellen *et al*. (1959) it is Late Oligocene; Ctyroky and Karim (1971) claimed Late or Uppermost Oligocene; Said in Fouad *et al.* (1986) claimed Late Oligocene age for the succession cropping out in Anah area; Al-Hashimi and Amer (1985) claimed late Middle – Late Oligocene age in wadi Khazgah and Al-Qaim area and Al-Twaijri (2000) designates that the Anah Formation to be developed during Late Chattian time in a successive superposition. This dating is acqiured from sequence stratigraphic analysis of the Oligocene succession in Western Iraq. The analysis is carriedout on surface and subsurface sections by means of biostratigraphy and microfacies.

Depositional Environment: Bellen (1956) in Bellen *et al*. (1959) inferred that Anah Formation represents reef – backreef facies. Ctyroky and Karim (1971) concluded that the Anah Formation is a complicated reef and back reef facies orginated in shallow warm tropical euhaline sea, under strong current energy. Said in Fouad *et al.* (1986) estimated that Anah Formation has three basic environments: reef (normal marine) in the lower part, back reef (hypersaline) in the middle part and very shallow (brackish water) facies. The Anah Formation originated in depth water about 50 m, decreased upwards to less than (10 – 12) m. The second Upper Oligocene Cycle, i.e., the Azkand Formation, followed by the Anah Formation was developed in a transgressive system tract (transgressive phase) in its lower part (Azkand Formation) and a high system tract (Anah Formation) in its upper part, where the filling of the shallowing basin is indicated by a maximum flooding surface which is indicated by colonial corals dominated sequence (Al-Twiajiri, 2000). The shallowing upward cycle could be inferred within the deposition of the Azkand Formation too, where it was developed through the older *Miogypsinides Lepidocyclina* faunal zone and the younger *Miogypsinoides* faunal zone of Bellen (1956) in Bellen *et al*. (1959).

Lower Contact: The Anah Formation, in the type locality is underlain conformably by Azkand Formation (Bellen *et al*., 1959). In the extreme western exposure area it is underlain conformably by Baba Formation (Al-Mubarak, 1974); in Anah vicinity it is underlain by Baba Formation, the contact is conformable and gradational (Fouad *et al*., 1986). Downstream, from Anah vicinity, the base of the Anah Formation is not exposed (Tyracek and Youbert, 1974 and Mahdi *et al*., 1985).

3.4. MIOCENE

The Savian movements caused development of broad and shallow basins in which carbonates were deposited, whereas in the coastal parts clastics were deposited. Both deposits

pass to each other laterally indicating irregular shore line of the basin. During Middle Miocene the marine transgression extended south and southwestwards forming shallow basins, with carbonate deposits, whereas in closed lagoons evaporates were deposited. Near Hit, identical case occur where the evaporates of the Fat`ha Formation pass to the carbonates of the Nfayil Formation. This is attributed most probably to the activity of the Abu Jir Fault. During Late Miocene, the marine phase was changed to continental and only clastis were deposited. This is attributed to collision of the Neo-Tethys with the Arabian Plate. The formations of this epoch are exposed in all parts of the Iraqi Western Desert (Figs.2 and 3), they are represented by five formations, these are:

3.4.1. Ghar Formation (Early Miocene)

Type locality: The type locality of the Ghar Formation is in B. P. C. oil well Zubair 3 (Bellen *et al.*, 1959), which is defined by the following coordinates (Fig.5):

Longitude 47° 43' 29" E
Latitude 30° 23' 01" N

Exposure Areas: The Ghar Formation is exposed only in the centarl and western parts (Fig.1) of the Iraqi Western Desert. It is exposed along the Iraqi – Syrian borders, 10 Km north of Muger Al-Dheeb and extends southeastwards, as a strip (5 – 18 Km) crossing Akash, Ratga and Mana`i valleys, till wadi Hauran, southwest of H_1. Then, it is exposed east of wadi Hauran as a small patch with crescentic shape (Figs.2 and 3). In the extreme eastern exposure area, the Ghar Formation interfingers with the Euphrates Formation. The subsurface extension of the Ghar Formation southeastwards is clear, since it is struck in almost all oil wells of Basrah vicinity. Towards east and northeast, most probably it passes totally to the Euphrates Formation

Remark: It is worth to mention that some outcrops of the Zahra Formation in Ashwa vicinity (Fig.3) are considered as Ghar Formation by Ma'ala *et al.* (1999).

Lithology: The Ghar Formation in the type locality consists of sands and gravels, rare sandy limestone, rare clay and anhydrite (Bellen *et al*., 1959). Al-Jumaily (1974) described the Ghar Formation, north of Muger Al-Dheeb vicinity and southeastwards as white, pink and pale reddish brown calcareous sandstone, very rarely thin horizons (0.2 – 1.0 m) of limestone are developed, which increase in thickness and abundance, northwards, changing to alternation of sandstone and limestone, the limestones are white, grey, rarely pink, slightly fossiliferous and burrowed. In the lowermost part basal conglomerate is devloped. The pebbles are mainly derived from Ratga Formation.

Remarks:

▪ It is worth to mention that Al-Jumaily (1974) named the Ghar Formation as "Littoral Sandstone Facies", of the First Miocene sedimentary cycle.

▪ Al-Jumaily (1974) recognized a horizon of conglomerate at the right bank of wadi Ratga, capping the Ghar Formation. Sissakian and Abdul Jabbar (2001) considered the conglomerate as relics of terraces of wadi Ratga. The authors confirm this assumption.

Al-Mubarak and Amin (1983) described the Ghar Formation, in wadi Hauran vicinity, as pebbly sandstone, followed by interbedding of pink and yellowish grey, slightly fossiliferous and sandy limestone with soft marly sandstone. Folloewd by alternstion of yellow thick beds of sandy marl with thin yellow and pink burrowed limestone, which contains small gastropods. Overlain by yellow, pink and white calcareous snadstone, intercalated with one or two beds of sandy limestone, which contain few small pelecypod shells. In Al-Faj vicinity and wadi Ghadaf, the Ghar Formation consists of reddish brown claystone, followed by green claystone or calcareous claystone and whitish gery, calcareous sandstone, overlain by intercalation of claystone and limestone. The limestone is whitish grey, slightly sandy and

fossiliferous. The middle part consists of reddish brown calcareous sandstone. The Upper part consists of white to light brown calcareous sandstone, intercalated with one or two horizons of brown and greenish grey silty claystone. Capped by greenish grey and whitish grey sandy limestone.

Remark: According to the author's opinion, the upper part of the aforementioned succession may belong to the Nfayil Formation?

The Ghar Formation, west of wadi Hauran and north of Muhaiwir vicinity, consists of conglomerate, followed by pebbly sandstone and calcareous sandstone, with thin horizons of burrowed limestones (Qaser *et al.*, 1992); north of wadi Hauran, it consists of brown and white, calcareous sandstone, with pebbles, laterally changes to white and brown calcareous or clayey sandstone, which locally includes reddish brown sandstone, overlain by red claystone, rich in iron oxides, capped by calcareous sandstone (Al-Azzawi and Dawood, 1996) and in Ashwa vicinity it consists of sandy limestone, interbedded with calcareous sandstone, capped by pink, burrowed limestone(Ma'ala *et al*., 1999).

Remark: According to authors opinion, the aforementioned succession, in Ashwa vicinity, belongs to the Zahra Formation, which is underlain (in subsurface section) by the Ghar Formation, in the involved vicinity. This is believed so, because the surrounding areas are built up by Zahra Formation.

Thickness: The thickness of the Ghar Formation in the type locality is 129 m (Bellen *et al*., 1959). In Muger Al-Dheeb vicinity is (10 – 30) m, in wadi Ratga is (40 – 50) m (Al-Jumaily, 1974), in wadi Hauran is (9 – 13) m (Al-Azzawi and Dawood, 1996), in Hussainiyat vicinity is 22 m (Qaser *et al*., 1992), in Al-Faj vicinity is (30 – 40) m (Al-Mubarak and Amin, 1983) and in Ashwa vicinity is (15 – 25) m (Ma'ala *et al*., 1999).

Fossils: According to Owen and Nasr (1958) in Bellen *et al*. (1959), and Buday (1980) no fossils were recorded in the Ghar Formation. Karim in Jassim *et al*. (1984) recorded the following fossils:

Abundant shell fragments, fragments of peneroplis and Ammonites, miliolids, charaphytes, reworked planktonics and large amount of organic matter.

Qaser *et al.* (1992) and Al-Azzawi and Dawood (1996) recognized the following fauna: charaphytes, fresh water gastropeds, peneroplis, miliolids, and ostracods. Kadoori in Ma'ala *et al*. (1999) recorded the following fossils at Ashwa vicinity:

Spirolina austrica D'ORBIGNY, *Ammonia beccarii var parkinsoniana* D'ORBIGNY, *Peneroplis evoluties* HENSON, *P. frasensis* HENSON, *Elphidiun* sp. And *Dentritina rang.*

Remark: According to author's opinion the majority of the aforementioned fossils are of Early Miocene and are good indication of marine environment, which is not the environment of the Ghar Formation, therefore, we believe that the recorded fossils belong to Euphrates Formation with common interfingering with Ghar Formation. Moreover, no fossils were recored in the Ghar Formation by all previous workers, since the announcement of the Ghar Formation in 1958 untill 1999, except few fossils recorded by Qaser *et al*. (1992) and Al-Azzawi and Dawood (1996) from interfingering areas with the Euphrates Formation.

Age: The original age of the Ghar Formation, as given by Owen and Nasr (1958) is Oligocene – Miocene. Bellen *et al*. (1959) claimed Middle Miocene age; Al-Naqib (1967) in Buday (1980) cliamed Early Miocene; Ditmar *et al.* (1972) in Buday (1980) considered the original age as Oligocene – Early Miocene; Buday (1980) claimed late Early Miocene age depending on the age of the Euphrates Formation; Al-Jumaily (1974) claimed Middle Miocene age; Jassim *et al*. (1984) claimed Early – early Middle Miocene, depending on the presence of sand tongues in the "Kherish Beds" of Middle Miocen, moreover they stretched the age to Oligocene depending on the presence of sandy interbeds in Oligocene of Misan Oil wells. The cliamed Late Oligocene age, to the Ghar Formation by Ditmar *et al.* (1971) in

Buday (1980) depends on the equivalents of the formation to Anah – Azkand formations, which are proved to be of Late Oligocene; Buday (1980) stated that according to Al-Jumaily (1974) the Ghar Formation was clearly proved to change laterally into "Euphrates Formation" in the Western Desert. Qaser *et al*. (1993) and Al-Azzawi and Dawood (1996) claimed Early Miocene age, depending on the recognized fossil assemblages.

Remarks:

▪ It is worth to mention that according to Al-Jumaily (1974) the Ghar Formation changes laterally into the informal "Unit B" and not to the Euphrates Formation and "Unit B" was proved to be a new formation, called Nfayil (Sissakian *et al*., 1997).

▪ According to Ma'ala *et al*. (1999) the age of the Ghar Formation is Middle Miocene, based on the recognized interfingering with Nfayil Formation. However, Kaddoori in Ma'ala *et al*. (1999), claimed Early Miocene age to the Ghar Formation depending on faunal assemblages.

▪ From reviewing the aforementioned assumptions concerning the age of the Ghar Formation, the authors believe that the age of the formation is Early – Middle Miocene, based on the interfingering of the lower part of the Ghar Formation with the Euphrates Formation (Early Miocene) and its upper part with the Nfayil Formastion (Middle Miocene). The subsurface sections, however, have Oligocene age. But, no such data are recorded from surface sections, although in different localities in Iraq, the Ghar Fornation is underlain by Eocene rocks (Dammam and Ratga formations) and rarely by Oligocene rocks (Shurau and Sheikh Alas formations), N of Muger Al-Dheeb vicinity.

Depositional Environment: The depositional environment of the Ghar Formation, as stated by the majority of the authors is deltaic, marine (intershelf) environment, however marine environment also is encountered, only when the Ghar Formation interfingers with Euphrates Formation. Buday (1980); Al-Mubarak and Amin (1983) considered the depositional environment of Ghar Formation is littoral and deltaic. Jassim *et al*. (1984) claimed fluvial marine possibly of deltaic origin, ranging from delta top to innershelf. Al-Azzawi and Dawood (1996) claimed very shallow environment near to river origin. Ma'ala *et al*. (1990) recorded the environment as marine (shore).

Remark: According to the authors opinion, depending on the lithology and fossil assemblages, the depositional environment of the Ghar Formation is continental (deltaic) only. All the encountered and claimed environments by different authors, especially concerning marine, belong to that part of the Ghar Formation which interfingers with the Euphrates Formation. Some marine influences, however, could be found in some parts of the formation, depending on the area of the deposition from the basin.

Lower Contact: The Ghar Formation is underlain unconformably by Ratga, Shurau and Sheikh Alas formation, in Muger Al-Dheeb vicinity and northeastwards, the contact is marked by a basal conglomerate, Al-Jumaily (1974). In wadi Hauran, Hussainiyat and Qasir Muhaiwir vicinities, it is underlain unconformably by Najmah, Nahr Umr, Mauddud and Rutbah formations, the contact is always sharp and clear, either due to presence of basal conglomerate and/ or lithological difference (Al-Azzawi and Dawood, 1996).

3.4.2. Euphrates Formation (Early Miocene)

Type Locality: The type locality of the Euphrates Formation is along wadi Fhaimi, near the police post (Fig.5) (Bellen *et al*., 1959); it is defined by the following coordinates:

Longitude 42° 08' 09" E
Latitude 34° 15' 58" N

Remark: It is worth to mention that the type locality of the Euphrates Formation is inundated by Haditha Dam Lake. Moreover, the chosen type locality by Bellen *et al*. (1959) is not a

representative one. Jassim *et al*. (1984) recommended a supplementary type section in wadi Chab`bab, in Anah vicinity (Fig.5), for the Lower and Middle Units (A and B) and another supplementary type section, in wadi Rabi, in Anah vicinity (Fig.5) for the Upper Unit (C). But, the Upper Unit (C) was found to be another formation, which was named as Nfayil Formation (Sissakian *et al*., 1997).

Exposure Areas: The Euphrates Formation is widely exposed in the eastern, middle and western parts (Fig.1) of the Iraqi Western Desert. It crops out along the Iraqi – Syrian borders near Al-Qaim and extends eastwards, parallel to the Euphrates River, crossing Anah, Haditha and Heet vicinities; there it is covered by the Nfayil Formation. It is exposed south of the Highway No.1 only in deep cut valleys like Thumail and Ghadaf , west of Shithathta, for about 45 Km, it crops out again in a longitudinal form and extends southwards till Tlool Al-Mlootiyat and extends south of wadi Ubaiyidh in a narrow strip (few kilometers in width and length). Moreover, it crops out in deep valleys of Akash and Ratga, also along both sides of wadi Hauran in H_1 and Qasir Amij vicinities (Figs.2 and 3). The subsurface extension of the Euphrates Formation is clear, with very wide extension. Eastwards, from the exposure areas it exsists almost in all drilled oil wells and extends to Iran. Northeastwards it reaches till Qara Chouq and northwards till south of Dohuk. Towards south and southeast it passes to the Ghar Formation between Nasirriyah and Basrah.

Lithology: The Euphrates Formation in the type locality consists of "Shelly, chalky, well bedded recrystallized limestone" (Bellen *et al*., 1959). The type section proposed by Jassim *et al*. (1984) consists of: **(1) Lower Unit (A)** consists of 20 m of basal conglomerate, with subrounded limestone boulders and pebbles, mainly derived from Anah Formation. The conglomerate is followed by 10 m of recrystallized, fossiliferous limestone, changing to coralline limestone. **(2) Middle Unit (B)** consists of alternation of hard limestone and pseudoolitic limestone. Al-Mubarak (1974) divided the Euphrates Formation in Al-Qaim and Anah vicinities into three members: **(1) Lower Member** consists of basal conglomerate, followed by dolostone and dolomitic limestone. **(2) Middle Member** consists of white, fossiliferous limestone, alternated with pseudoolitic chalky like limestone. **(3) Upper Member** consists of alternation of grey limestone with green marl.

Remarks:

- Al-Mubarak (1974) considered the brecciated rocks, which overly the Middle Member as a part of the Fat`ha Formation. But, latter on the brecciated rocks were grouped with the Euphrates Formation (Jassim *et al*., 1984).
- The Upper Member is announced as a new formation and is called Nfayil Formation (Sissakian *et al.*, 1997).

In Al-Kherish vicintiy, south of Al-Qaim and southwards, Al-Jumaily (1974) mapped the Euphrates Formation as informal units, without considering them to belong to the Euphrates Formation, the informal units are: **(1) Unit A_1** consists of chalky limestone, well bedded, locally shows cross bedding, marked by fossils **(2) Unit A** consists of white, chalky, fossiliferous, well bedded limestone. This unit is exposed only in deep cut valleys like Akash, Ratga and Mana'i, also in T_1 vicinity. Tyracek and Youbert (1975) adopted the subdivisions of Al-Mubarak (1974) and Al-Jumaily (1974) of the Euphrates Formation, in the area extending from Anah till wadi Hauran, including, Haditha, K_3 and T_1 areas. They divided the Euphrates Formation into three members: **(1) Lower Member** consists of basal conglomerate, followed by grey, shelly dolomitic limestone, limestone and dolostone**. (2) Middle Member** consists of white, bedded, chalky dolostone and dolomitic limestone with horizons of green marl. **(3) Upper Member** consists of white, massive dolomitic limestone, highly deformed and brecciated, with thin horizons (2 – 5 cm) of silicified limestone. Followed by grey, well bedded, highly undulated limestone. Along wadi Hauran, some 30 Km from the junction with

the Euphrates river and upstream, the whole succession of the Euphrates Formation changes to grey and white, fossiliferous limestone, dolostone and dolomitic limestone, very rarely green marl horizon, may occur. But, the basal conglomerate is present, although it changes to fine clastics, where the Euphrates Formation is underlain by the Dammam Formation. In Heet and Kubaisa vicinities, Hamza (1975) divided the Euphrates Formation into the following informal units: **(1) Unit of Basal Conglomerate** consists of limestone pebbles (1 – 20 cm in size), pink and light grey in color. **(2) Unit of Limestone** consists of three parts. The lower part consists of light grey, burrowed dolomitic limestone. The middle part consists of grey, slightly fossiliferous and oolitic limestone. The upper part consists of grey fossiliferous, chalky limestone. **(3) Marly and Brecciated Unit** consists of white, light grey, massive, brecciated limestone. Eastwards from Khan Al-Baghdadi, the brecciation increases. In wadi Al-Mahmadi the unit is highly brecciated. Towards Qasir Al-Khabaz, the unit changes to limestone only, as in Shithatha vicinity. Al-Mehaidi *et al.* (1975) mapped the Euphrates Formation, in Shithatha – Rahaliyah – Tlool Al-Mlootiyat vicinity as "**Limestone Unit**", which consists of three members: **(1) Basal Breccia Member** consists of subrounded nummulitic limestone fragments. **(2) Um Sufaya Chalky Limestone Member** consists of chalky fossiliferous limestone. The unit wedges out near Shithatha town. **(3) Limestone – Marl Member** consists of fossiliferous, oolitic limestone, with some marl intercalations. In wadi Al-Ubaiyidh, the upper part is pink in color, whereas the lower part is formed of clausinella bearing limestone. In Tlool Al-Mlootiyat vicinity, the lower part is the same, but the upper part consists of grey, chalky and oolitic limestone. In Imam Ahmad vicinity, the upper part is the same, as that of Tlool Al-Mlootiyat, whereas the lower part consists of yellowish white limestone and olive green marl. In Thumail vicinity the upper part consists of whitish grey fossiliferous limestone, whereas the lower part consists of yellowish green marl.

Remark: It is clear that the last member changes, facially in different parts within the considered area and represents the recently announced Nfayil Formation (Sissakian *et al*., 1997).

In the eastern part (Fig.1) of the Iraqi Western Desert, Al-Mubarak and Amin (1983) divided the Euphrates Formation into three units: **(1) Lower Unit** consists of basal breccia or basal conglomerate, followed by chalky, partly fossiliferous and dolomitized limestone. **(2) Middle Unit** consists of thick limonitic marl, followed by fossiliferous limestone. The upper part consists of shelly, oolitic fossiliferous (coquina and oysters) limestone. **(3) Upper Unit** consists of silty calcareous claystone, followed by green soft marl. The upper part consists of dolomitic limestone, rich in oysters.

Remark: It is worth to mention that the Middle and Upper Units belong to the recently announced Nfayil Formation (Sissakian, *et al.*, 1997).

Mahdi *et al*. (1985) divided the Euphrates Formation, in Haditha – Hit vicinity into the following units: **(1) Fhaimi Unit** (corresponds to the Lower Member of Al-Mubarak, 1974), it is subdivided into three facies: **(a) Coralline Facies** consists of grey, yellow, fossiliferous dolomitic limestone, with corals. The lowermost part consists of corals. **(b) Fhaimi Facies** consists of grey, shelly dolomitic limestone and dolostone. **(c) Haditha Facies** consists of white chalky limestone and dolostone. **(2) Akhdar Unit** (corresponds to the Middle Member of Al-Mubarak, 1974) and is subdivided into four facies. **(a) Lower Akdhar Facies** consists of grey and white chalky like dolostone**. (b) Lower Haqlan Facies** consists of white and grey, fossiliferous dolostone. **(c) Upper Akhdar and Upper Haqlan Facies**, the two facies are almost similar to each other. They consist of grey, fossiliferous, chalky like dolostone. **(d) Uglat Horan Facies** consists of white, shelly limestone and dolostone. **(3) Ezghadan Unit** (corresponds to the Brecciated Unit of Al-Mubarak, 1974; Tyracek and Youbert, 1975 and Ibrahim and Sissakian, 1975). It is divided into three facies: **(a) Ezghadan Facies**

consists of intercalation of green marl, marly dolostone and white dolostone. **(b) Al-Waziyah Facies** consists of white, fossiliferous, chalky like dolostone. **(c) Hauran Facies** consists of green marl, white dolomitic limestone and white massive dolostone. **(4) Undulated Limestone Unit** consists of white, undulated and deformed limestone, locally slightly fossiliferous. **(5) Ahmar Unit** consists of ocher, fossiliferous, brecciated marly dolostone, with grey shelly limestone, overlain by bedded grey limestone.

Remark: The Ahmar Unit is equivalent to "Unit A" of Al-Jumaily (1974) and Tyracek and Youbert (1975). Most probably it is equivalent to the Jerribe Formation?

In Anah vicinity, Fouad *et al*. (1986) divided the Euphrates Formation into six units: **(1) Conglomeratic Unit** consists of basal conglomerate; pebbles are derived from Anah Formation. **(2) Shelly Unit** consists of dark grey, fossiliferous dolostone, dolomitic limestone, locally coral colonies occur. **(3) Lower Chalky Unit** consists of white massive, fossiliferous and chalky like dolostone. **(4) Upper Chalky Unit** consists of white, well bedded, fossiliferous, oolitic and chalky like dolostone**. (5) Brecciated Unit** consists of alternation of green marl, with white marly dolostone and dolomitic limestone. Overlain by highly warped and brecciated alternation of green layers of marl and marly dolostone. **(6) Undulated limestone Unit** consists of light brown and pale grey, thinly bedded, slightly fossiliferous, undulated limestone. In Qasir Muhaiwir vicinity, Al-Azzawi and Dawood (1996) mapped the Euphrates Formation along banks of wadi Hauran as one unit, which consists of white and pale brown, fossiliferous limestone, followed by brown, fossiliferous, thinly bedded limestone, overlain by clayey limestone. In Heet – Kubaisa vicinity, the "Brecciated Unit" which is well exposed in neighboring areas, is not developed and the "Chalky Unit" is overlain directly by the Fat`ha Formation (Hassan *et al*., 2000).

Remark: From reviewing the described Euphrates Formation in the Iraqi Western Desert, it is clear that there are large facial changes, which led to totally different lithological constituents of the formation, in different areas. The author`s believe it is due to the tectonic effect of Abu Jir Fault and the position within the depositional basin, or more than one formation may occur, i.e. another unidentified formation.

Thickness: The thickness of the Euphrates Formation in the type locality is 8 m (Bellen *et al*., 1959) and in the supplementary type section is 110 m (Jassim *et al*, 1984). In Al-Qaim vicinity is (128 – 145) m (Al-Mubarak, 1974), but part of this thickness belong to the Nfayil Formation (Sissakian *et al*., 1997). In Haditha and T_1 vicinities is (55 – 87) m (Tyracek and Youbert, 1975), in Heet and Qasir Al-Khubaz vicinity is (20 – 40) m (Hamza, 1974), in Akash, Ratga and Mana`i valleys is (20 – 30) m (Al-Jumaily, 1974), in the eastern part of the Western Desert is (40 – 57) m (Al-Mubarak and Amin, 1983).

Remark: Part of the mentioned thickness, in the eastern part of the Western Desert belongs to the Nfayil Formation (Sissakian and Abdul Jabbar, 2001).

Fossils: The following fossils are recognized by different authors in different areas:

Ctyroky and Karim (1971) determined the following fauna from Units A and B:

Peneroplis evolutus HENSON, *P. farsensis* HENSON, *Archias* sp., *Robulus* sp., *Quinueloculina aknariana* D'ORBIGNY, *Triloculina* sp., *Cythereis* sp., *Cyprideis* sp., *Hydrobia* sp., *Macoma* sp., *Miogypsina globulina* MICHELOTTI, *Miogypsina intermedia* and *Borelis melo melo* FICHTEL and MOU

Macrofossils are:

Turritella angulara BROCCHI, *Murex* sp., *Actcoina* sp., *Conus* sp., *Figus conditus* (BRONGNIART), *Glycymeris pilosus* LINNAEUS, *Arca Turonica* DUJARDIAN, *Phacoides* c. f. *Columbella* LAMARCK, *Divericella* sp., *Cardium* sp., *Chana gryphoidis* UNNAEUS, *Modiolus* c. f. *increassat* D'ORBIGNY.

Karim (1975) determined the following fauna from Unit C in Hit area:

Pentritina sp., Triloculina subinflata, T. asynetrica SALD, *T. asperula* CUSHMAN, *Quinueloculina acuta* HUSSEN, *Spiroloculina tergemiana, Elphidium advantum* CUSHMAN, *Bolivina shukrii* SOAYA, *Bolimina ovata* D'ORBIGNY, *Cibicides lobatulus* WALKER, *Borelis melo melo* FICHTEL and MOLL, *Miogypsina cushmani, Ostrea latimarginata* UREBENBURG, *Ostrea verieti* DESHAYES, *Clausinella* sp. and *Chlamus* c.f. *varia* LINNE.

Prazak (1974) found the following macrofaunal assemblages in the Euphrates Formation within the Western Desert:

Modiolus invrassatus D'ORBIGNY, *Tapes vetulus* BAST, *Troclus nefa* KCLESNIKOV *Corbula gibba* OLIVI, *Divercella ornate* AGASSUZ, *Cardium facetum* ZHIZHCHENKO, *Modiolus conditus* MAYER and *Glycymeris pilosus* LINNAEUS.

Age: The age of the Euphrates Formation, depending on the aforementioned fossils is Early Miocene (Early – Late Burdigalian) confirmed by the presence of *Miogypsina globulina* and *Miogypsina intermedia*. This age is agreed upon by all authors.

Depositional Environmet: The depositional environment of the Euphrates Formation is marine, warm tropical to subtropical, with reef – back reef, near shore (10 – 50 m depth), active very shallow innershelf (not more than 20 m depth), warm central shelf quiet, shallow and very shallow active conditions. The aforementioned conditions are distributed in different parts of the basins and as recognized and indicated paleontologically and petrographically. The abundant brecciated horizons, within the upper parts of the Euphrates Formation is explained by Bolton (1954) in Jassim *et al*. (1984) by slumping and escape of gases with possibiltiy of earthquakes triggering the slumping processes. The interfingering of the Euphrates Formation with the Ghar Formation indicates near shore areas, which are under the influence of fresh water sedimentation.

Lower Contact: The Euphrates Formation in the type locality is underlain unconformably by Anah Formation (Bellen *et al*., 1959). From Al-Qaim to Al-Baghdadi areas, it is underlain unconformably by Anah Formation; the contact is sharp and indicated by a basal conglomerate (Al-Mubarak, 1974, Tyracek and Youbert, 1975 and Hamza, 1975). In wadi Hauran it is underlain unconformably by Sheikh Alas, Shurau and Dammam formations (Tyracek and Youbert, 1975). In wadi Hauran, southeast of H_1, it is underlain unconformably by Nahr Umr Formation (Al-Mubarak and Amin, 1983).

Remark: It is worth to mention that Tyracek and Youbert (1975) considered the underlying formation in H_1 vicinity to be Rutbah Formation. The contact is sharp and clear, based on the top of the last sandstone horizon.

In Thumail, Ghadaf and Ubaiyidh valleys it is underlain unconformably by the Middle Member of the Dammam Formation, the contact is marked by a basal conglomerate (Al-Mubarak and Amin, 1983). In Qasir Amij vicinity it is underlain unconformably by Rutbah and Ms`ad formations, the contact is marked by basal conglomerate (Al-Mubarak and Amin, 1983 and Al-Azzawi and Dawood, 1996).

3.4.3. Jeribe Formation? (Middle Miocene)

Although the Jeribe Formation is not presented in any geological map of the Iraqi Western Desert, but it is reviewed in this paper aiming to clarify its doubtful presence in the Iraqi Western Desert. Buday (1980, p.278), however mentioned the presence of the Jeribe Formation in the Iraqi Western Desert, west of Haditha vicintiy and its doubtful presence in other parts of the Iraqi Southern and Western Deserts.

Type Locality: The type locality of the Jeribe Formation is in Sinjar Mountain, near Jaddala

village and it is defined by the following coordinates (Bellen *et al*, 1959) (Fig.5):

Longitude 41° 41' 00" E
Latitude 36° 18' 00" N

Exposure Areas: Because the Jeribe Formation is not presented in any geological map, of any scale, therfore its true exposure areas in the Iraqi Western Desert is obscure. In this paper, it is an attempt to demonstrate the exposure areas of the Jeribe Formation. The exposure areas of the following informal units: "Unit A" (Al-Jumaily, 1974 and Tyracek and Youbert, 1975) and "Ahmar Unit" (Mahdi *et al*., 1985) will be considered, for this purpose. However, this will not be the true coverage area, because in the adjacent parts of the involved areas, the Jeribe Formation is not recognized, or not even an equivalent informal unit is mentioned (by other authors). The Jeribe Formation? is exposed along Al-Kherish ridge, starting from Iraqi – Syrain borders (where it is called as Unit A by Al-Jumaily, 1974) and extends southeastwards, parallel to the main ridge, with extensions in the deep cut valleys like Akash, Ratga and Al-Mana`i; near T_1 vicinity it covers considerable areas and extends northeastwards to K_3 and Haditha vicinities (where it is called as Ahmar Unit, by Mahdi *et al*., 1985). Farther east and southwards its presence is obscure, either it is overlain by the Nfayil Formation or it wedges out, like the area slightly west of the junction of wadi Hauran with the Euphrates river, especially along the main road. There, the Nfayil Formation directly overlies the "Undulated Limestone Unit", which represnts the top of the Euphrates Formation, without the presence of "Ahmar Unit" (Mahdi *et al*., 1985) or Jeribe Formation. The subsurface extension in the Western Desert, as the surface, is obscure, for the same aforementioned reason. In the author's opinion, it may be present below the Nfayil Formation in the area between T_1 and H_1 vicinities.

Remarks: From the author's observations, it may be present in wadi Hauran, in H_1 vicinity, between the Euphrates and Nfayil formations.It may extend farther southwards?.

Lithology: The Jeribe Formation, in the type locality consists of "Limestone, recrystallized and dolomitized, generally massive, with beds of (3 – 6) feet (0.3 – 2.6 m) in thickness. The top is obscured; however it is capped by 50 feet (15.5 m) of gravels. The gravels almost certainly replace the anhydrite, which normally exist at the base of the Lower Fars Formation" (Bellen *et al*., 1959). Al-Jumaily (1974) and Tyracek and Youbert (1975) described the "**Unit A**" in Al-Kherish, T_1, K_3 and Haqlaniyah vicinities as "white chalky, fossiliferous, hard, well bedded, fine crystalline limestone". Mahdi *et al*. (1985) described the "**Ahmar Unit**" as "two asymmetrical cycles of khaki color, massive, soft to fairly hard, compacted, fossiliferous, brecciated marly dolostone, with thin, grey, very fine crystalline, fairly hard, shelly limestone. Fossils are gastropods and small spherical echinoids. This sequence is overlain by hard, bedded, grey limestone".

Thickness: The thickness of the Jeribe Formation, in the type locality is 73 m (Bellen *et al*., 1959). The thickness of "Unit A" in Al-Kherish vicinity is (15 – 20) m (Al-Jumaily, 1974) and it is (8 – 10) m in T_1 – K_3 vicinities (Tyracek and Youbert, 1975), south of K_3 the thickness of "Ahmar Unit" is (2 – 13) m (Mahdi *et al*., 1985).

Fossils: The following fossils are recorded from Jeribe Formation (the equivalent informal units):

Borelis melo melo (FITCHEL and MOLL), *Borelis melo curdica* REICHEL, *Peneroplis farsensis* HENSON, *Meandropsina anahensis* HENSON, *Amphistigina* sp., *Ammonia beccarii* (LINNE), *Dendritina* sp., *Milioleds, alga* and *shell fragments*.

Age: Middle Miocene, as agreed upon by all authors.

Depositional Environment: The Jeribe formation is homogenous in lithology and in faunal assemblage's content. It reflects a restricted environment on marine platform, mainly of lagoonal facies, of calm and warm water, with relatively high salinity.

Lower Contact: The Jeribe Formation in the type locality is underlain unconformably by the Serikagni Formation (Bellen *et al*., 1959). In majority parts of the supposed exposure areas in the western parts (Fig.1) of the Iraqi Western Desert, the base is not exposed. When it is exposed, however it is underlain conformably by the Euphrates Formation. The contact is based on the top of the "Undulated Limestone Unit" of the Euphrates Formation (Al-Jumaily, 1974; Tyracek and Youbert, 1975 and Mahdi *et al*., 1985). However, in Al- Kherish vicinity and eastwards the contact is based on the top of the last white limestone horizon, rich in clausinella, showing cross bedding (Unit A_1 of Al-Jumaily, 1974).

3.4.4. Fat`ha Formation (Middle Miocene)

Type Locality: The type locality of the Fat`ha Formation is in Makhul Range, it is defined by the following coordinates (Al-Rawi *et al.,* 1992)

Longitude 43° 21' 15" E
Latitide 35° 10' 00" N

Exposure Areas: The Fat`ha Formation is exposed in two small areas only, in the middle and western parts (Fig.1) of the Western Deasert. The first locality is in Hit – Kubaisa vicinity, whereas the second one is east of Al-Qaim (Figs. 2 and 3).

Lithology: The Fat`hah Formation, in both exposed areas consists of green marl, bedded limestone and gypsum, in cyclic nature. In Hit – Kubaisa locality (2 – 3) cycles are developed (Hamza, 1975 and Hassan *et al.*, 2000), whereas east of Al-Qaim only two cycles are developed (Al-Mubarak, 1974). According to Hassan *et al.* (2000) the Fat`ha Formation passes clearly to Nfayil Formation south of Heet vicinity.

Lower Contact: The Fat`ha Formation, in Al-Qaim vicinity is underlain conformably by the Euphrates Formation, the contact is based on the first green marl horizon (Al-Mubarak, 1974), in Heet – Kubaisa vicinity, it is underlain by the Euphrates Formation, the contact is based on the top of the last undalutaed limestone bed (Hamza, 1975).

Thickness: The thickness of the Fat`hah Formation in Al-Qaim vicinity is (5 – 9) m (Al-Mubarak, 1974), whereas in Heet – Kubaisa vicinity is (8 – 12) m (Hamza, 1975 and Hasan *et al.*, 2000).

Fossils: The following fossils were recorded *Ammonia beccarii* LINNE, *Quinquiloculina* sp., *Pergo* sp., *Spiroloculina* sp., *Cluseinella* sp., *Modiolus* sp.and *Paracypris* sp.

Age: Middle Miocene is agreed upon by all authors. Mahdi (2007) however, claimed Early Miocene (Burdigalian) age for the Fat`ha Formation.

Depositional Environment: The depositional environment of the Fat`hah Formation is agreed upon by all authors to be of closed lagoon of hypersaline condition.

3.4.5. Nfayil Formation (Middle Miocene)

The Nfayil Formation is recently added to the stratigraphic column of Iraq, previously, the involved sequence was included within Euphrates, Fat`ha and partly Injana formations. The Nfayil Formation was announced by Sissakian *et al*. (1997).

Type Locality: The type locality of the Nfayil Formation is of a composite type (Fig.5). The Lower Member is defined from "Garat Al-Nfayil", which is located 23 Km west of Haditha town and is defined by the following coordinates:

Longitude 42° 24' 10" E
Latitude 34° 07' 30" N

Whereas the Upper Member is located 3 Km south of Al-Habbaniyah lake (Fig.5) and is defined by the following coordinates:

Longitude 43° 27' 30" E
Latitude 33° 10' 00" N

Exposure Areas: The Nfayil Formation is widely exposed in the Iraqi Western Desert. It is exposed in Al-Kherish vicinity, along the Iraqi – Syrian borders and extends eastwards, crossing all deep valleys (Akash, Ratga, Mana'i) and passing T_1, Al-Midham, till longitude 42° (west of Haditha). There, it changes its direction southeastwards, crossing wadi Hauran, Highway No.1, and extends eastwards till Ramadi and Habbaniya Lake, then again southeastwards, passing through Rahaliyah, Shithatha, Qasir Al-Akhaidhir and continues off the Iraqi Western Desert, towards Iraqi Southern Desert (Figs.2 and 3). The subsurface extensions of the Nfayil Formation is clear, it passes, eastwards and southeastwards to the Fat`ha Formation, almost in a line alongside the Euphrates River. In majority of drilled oil wells, west of the Euphrates River, the described Fat`ha (Lower Fars) Formation contains no gypsum, therefore the struck sequnce belongs to the Nfayil Formation and not to the Fat`ha Formation, as mentioned in oil well records (I.P.C., 1963).

Lithology: The Nfayil Formation, in the type locality consists of two members (Sissakian *et al.,* 1997): **(1) Lower Member** consists of three cycles. Each cycle consists of green marl and grey fossiliferous limestone. The second cycle is characterized by oyster bed. **(2) Upper Member** consists of cyclic deposits; each cycle consists of reddish brown claystone, slitstone and sandstone, with thin limestone and green marl horizons. Al-Mubarak (1971) mapped the Nfayil Formation as "**Unit C**" of the Euphrates Formation, in the extreme western parts of the exposure areas; it consists of alternation of green marl and fossiliferous limestone, with chert horizons. Al-Jumaily (1974) mapped the Nfayil Formation as "**Unit B**" of Second Miocene sedimentary cycle; it consists of soft, green marl and fossiliferous white limestone, in cyclic nature. A distinct coralline horizon is developed in vicinity of Akash, Ratga and Mana'i valleys, with thickness of 13 m, which represents a large reef body with length of (50 – 70) Km and width of (5 – 7) Km, which is surrounded by intraformational breccia, with thickness of (0.2 – 5) m. Tyracek and Youbert (1974) adopted the mapped "**Unit B**" of Al-Jumaily (1974) in $T_1 - K_3$ vicinity. Hamza (1975) in Hit – Kubaisa vicinity, mapped the Nfayil Formation as "**Unit of alternation Marl and Limestone**". He described the marl as soft and green, whereas the limestone as white and fossiliferous, with oyster and corals (locally). Al-Mehaidi *et al*. (1975) mapped the Nfayil Formation as "**Shithatha Marl**"**,** which is green, changes upwards to reddish brown, alternated with yellowish light grey limestone rich in clausinella and oysters. Moreover, they proposed the announcement of a new formation. Al-Atia *et al*. (1981) described a thick gypsum bed (12 m) encountered in a borehole (B.H.6) within a set of boreholes drilled in Abu Jir vicinity.

Remark: According to authors opinion this might indicate a small isolated closed lagoon within the main depositional basin of the Nfayil Formation, which indicates the activity of the Abu Jir Fault.

Mahdi *et al*. (1985) mapped the Nfayil Formation in Haditha vicinity as "**Nfayil Unit**", which consists of alternation of green marl and fossiliferous limestone. This was adopted by Fouad *et al*. (1986) in Anah vicinity. Jassim *et al.* (1984) called the Nfayil Formation as "**Kherish Beds**". Sissakian (1994) and Sissakian *et al.* (1994) represented the Nfayil Formation as **Nfayil Member** of the Fat`ha Formation in Haditha and Ramadi Quadrangles (scale 1: 250 000). Hassan *et al*. (2002) called the succession (of the Lower Member) in Karbala – Najaf vicinity as **Nfayil Formation** and ignored the Upper Member of the Nfayil Formation; they considered it as Injana Formation. Al-Mehaidi *et al.* (1975) called the succession of the Upper Member as "**Claystone Unit**" in Rahaliyah – Shithatha vicinity, whereas Al-Mubarak and Amin (1983) called the succession as "**Unit C**" of the Euphrates Formation, west of Najaf vicinity.

Thickness: The thickness of the Nfayil Formation, in the type locality is 10 m and 8 m, for the Lower and Upper Members, respectively (Sissakian *et al*., 1997). In Al-Kherish vicinity it

is (15 – 20) m, in wadi Ratga it is 40 m, Near T_1 it is 30 m (Al-Jumaily, 1979). In Kubaisa, the Lower Member is (10 – 15) m (Hamza, 1975). In Shitha and Rahaliyah vicinities the thickness of the Lower Memebr is (6 – 15) m, whereas the Upper Member is (3 – 17) m (Al-Mehaidi *et al*., 1975). In Karbala vicintiy, the Lower Member is 15 m, whereas the Upper Member is 12 m. In Najaf vicinity the Lower Member is (10 – 16) m, whereas the Upper Member is (20 – 25) m (Al-Mubarak and Amin, 1983). In Anah vicinity the Lower Member is (5 – 8) m (Fouad *et al*., 1986).

Fossils: The following fossils were recorded in the Nfayil Formation from different localities, by different authors (Al-Jumaily, 1974; Hamza, 1975; Tyracek and Youbert, 1975; Al-Mehaidi *et al*., 1975; Mahdi *et al.*, 1985 and Fouad *et al*., 1986). *Orbulina* sp., *Elphidium* sp., *Ostrea virleti* DESHAYES, *Biloculina elongate* D'ORBIGNY, *Discorbis c. f. rehokrakensia*, *Peneroplis farsensis* HENSON, *Pyrgo inorata* D'ORBIGNY, *Nonion markobi*, *Quinqueloculina oblique* RUESS, *Q. akneriana*, *Ostrea latimarginata* VREDENBURG, *Borelis melo melo* FICHEL and MOLI, *Borelis melo curdica* (RECHEL), *Elphidium articulatium* (D'ORBIGNY), *E. incertium* (WILIAMSON) CUSHMAN, *Ammonia beccarii* LINNE, *Trachylebris* c.f. *exactemata* ULRICH and BASSIER, *Loxoconcha reticulates* EDWARD, *Paijenoporchellina* sp., *Turritella* sp., *Clausinella* sp., *Theodoxus* sp., *Hydro bia* sp. and *melanella* sp.

Age: The age of Nfayil Formation according to the aforementioned fossil assemblages is Middle Miocene. The age is claimed mainly depending on *Borelis melo melo* and *Borelis melo curdica.* All authores agreed upon the recorded age.

Depositional Environment: The Nfayil Formation is deposited in a shallow marine environment with normal to high saline water, with clear oscillation in the sea level. The upper part of the Upper Member may indicate near shore enviroment with some deltaic influences, as indicated by the type of the clastics (fining upwards and reddish brown color) of the uppermost part of the Nfayil Formation.

Lower Contact: The Nfayil Formation, in the type locality is underlain conformably by the Euphrates Formation. The contact is based on the base of the first green marl, above the undulated limestone horizon of the Euphrates Formation (Sissakian, *et al*., 1997). Due to west of the type locality and westwards the Nfayil Formation is underlain conformably by a thick limestone horizons, called "Unit A" by Al-Jumaily (1974) and "Ahmer Unit" by Mahdi *et al*. (1985). This thick succession is found to be the equivalent of the Jeribe Formation? (Mahdi *et al*., 1986). Towards south of Al-Kherish, the Nfayil Formation interfingers with the Ghar Formation, (Al-Jumaily, 1974). In all other exposure areas, the contact between the Nfayil Formation and the underlying Euphrates Formation is conformable and taken at the base of the first green marl (Hamza, 1975, Al-Mehaidi *et al*., 1975, Al-Mubarak and Amin, 1983 and Hassan *et al*., 2002).

Remark: Although in some localities, as aforementioned, the supposed Jeribe Formation is not present between the Euphrates and Nfayil formations, but still conformable contact is described by all authors.This could be attributed to a small hiatus, of very short time span, since both Jeribe and Nfayil formations have the same age, as indicated by the fossil assemblages, especially *Borelis melo melo* and *Borelis melo curdica*.

3.4. 6. Injana Formation (Late Miocene)

The Injana Formation was formerly known as the Upper Fars Formation. Jassim *et al*. (1984) introduced the name of Injana Formation, which was adopted by the geologists of GEOSURV. Al-Rawi *et al*. (1992) annouced, officially the name of Injana Formation.

Type Locality: The type locality of the Injana Formation is along the northeastern limb of Himreen South anticline at Injana, it is defined by the following coordinates (Jassim *et al*., 1984) (Fig.5):

Longitude	44°	38'	10"	E
Latitude	34°	32'	00"	N

It is worth to mention that Al-Rawi *et al*. (1992) adopted the same aforementioned type locality. The original type locality of the Upper Fars Formation is in Iran, Busk and Mayo (1918) in Bellen *et al*. (1959).

Exposure Areas: The Injana Formation has very limited exposure area in the eastern part (Fig.1) of the Iraqi Western Desert. It is exposed east of Habbaniyah Lake and extends southeastwards as a very narrow strip (not more 3 – 5 Km) parallel to the Euphrates River for about 65 Km downstream from Falluja. It is also exposed along the eastern and southeastern banks of Razzazah Lake, as very narrow strip (1 – 3) Km and as scattered outcrops within the main plateau, east of Habbaniyah and Razzazah lakes. It is also exposed along both Tars (cliffs) of Al-Sayed and Al-Najaf, as very narrow strip (1 – 3) Km (Fig. 3). The subsurface extension of the Injana Formation is clear. It extends eastwards and southeastwards, under the thick Quaternary sediments of the Mesopotamian plain, but it is not developed in Basrah vicinity, or it is totally eroded (I.P.C.,1963).

Lithology: The Injana Formation, in the type locality consists of alternation of red, brown and grey claystone, siltstone and sandstone, with rare fresh water thin limestone and gypsum horizons, in the lowermost part (Jassim *et al*., 1984 and Al-Rawi *et al*., 1992). In Habbaniyah vicinity, the Injana Formation consists of reddish brown, cross bedded sandstone, with green marl and red or green claystone, both fining upwards and coarsening upwards cycles were found. The uppermost sandstone beds contain clay balls, high organic layers containing carbonized leave prints occur, locally. White chalk; also occur in some horizons (Jassim *et al*., 1984). Jassim *et al.* (1984) introduced the name "**Habbaniyah Beds**" to the exposed sequence of the Injana Formation in Habbaniya vicinity and southwards. The main reason for that is the abundance of quartz arenites, which may indicate different source area. Moreover, more limestone and green marls are present too.

Remark: The authors believe that part of the Habbaniyah Beds, especially the lower parts; belong to the Upper Member of the Nfayil Formation. They also agree with Jassim *et al*. (1984) in recognizing a difference in the rock types as compared to those of the Injana Formation, as the green marl and limestone horizons, which indicate different depositional environment and source area,. But, they are not in accordance with Jassim *et al*. (1984) in defining "Habbaniyah Beds", because they include two formations (Nfayil and Injana) of different ages and depositional environments.

Hassan *et al*.(2002) divided the Injana Formation, in Tar Al-Sayed and Tar Al-Najaf into two units: **(1) Lower Clastic Unit** consists of alternation of brown and reddish brown claystone, sandstone and siltstone, with two thin (10 – 15 cm) limestone horizons. **(2) Upper Cave-Formaing Unit** consists of brown and reddish brown claystone, a greenish grey clayey limestone horizon (0.5 m) occurs in the upper part.

Remark: The authors believe that majority of the described sequence by Hassan *et al.* (2004) belongs to the Upper Member of the Nfayil Formation. Although Hassan *et al*. (2004) claimed fluvial environment (see details in the discussion, of this paper, p. 119).

Thickness: The thickness of the Injana Formation in the type locality is 620 m (Jassim *et al*., 1984 and Al-Rawi *et al*., 1992). It is 20 m in Habbaniya vicinity and Tar Al-Najaf (Jassim *et al*., 1984); it is (5 – 10) m in Tar Al-Sayed (Hassan *et al*., 2004).

Fossils: The fossils within the major parts of the formation are very rare or not well preserved. Gastropods and pelecypods are reported in the type locality (Al-Rawi *et al*., 1992).

No fossila are recorded from the Western Desert. However, *Venus* sp., *Chlamys multistriata* (POLI), *Osteria latimarginata* VREDENBURG and *Clausinella* sp. Are recorded fro the type locality.

Age: The age of Injana Formation is not definitely established. Al-Naqib (1959) and Bellen *et al*. (1959) assigned the formation to Late Miocene age. This age assignement was based on its stratigraphical position, rahter than on its fossils contnent. Al-Rawi *et al.* (1992) considered the age of the Formation as Late Miocene based on the stratigraphic position, too.

Depositional Environment: The lower part of Injana Formation has been interpreted as shallow water to subcontinental environment. This interpretation is based on the presence of limestone bearing pelecypods, gastropods and ostracods (Yakta, 1977 in Jassim *et al*., 1984). Algea and miliolids were also mentioned and a supratidal environment for the lower part of the formation has been suggested (Jassim *et al*., 1984). Thus, the lower part of the formation seems to be transitional between the marine evaporitic Fat`ha Formation and the continental (fluvial) Injana Formation. Jassim *et al*. (1984) have concluded that Injana Formation changes its facies, especially in the area between Ramadi and Najaf, where quartz arenites are present within the sequence of the formation. This indicates that the source is from the Stable Shelf and thus a mixed province is developed along the marginal area of the Stable Shelf.

Lower Contact: The lower contact of the Injana Formation in the type locality is conformable and gradational with the underlying Fat`ha Formation, it is based on the top of the last gypsum bed (Jassim *et al*., 1984). In Habbaniyah vicinity it is underlain conformably and gradationally by the Nfayil Formation, the contact is based on the bottom of the first thick reddish brown sandstone or claystone (Sissakian, *et al.*, 1997). In Tar Al-Sayed vicinity it is underlain unconformably by the Nfayil Formation, the contact is marked by the first appearance of brown to redish brown clastic sediments (claystone and sandstone) (Hassan *et al*., 2002).

Remark: The authors would like to pay attention that no unconformable contact between Middle and Late Miocene sediments is recorded in Iraq and neighboring countries, therefore they are not in accordance with Hassan *et al*. (2002). This confirms the assumption of Sissakian (2000) about considering a part of the sediments, in the lower parts of Tar Al-Sayed and Tar Al-Najaf to belong to the Upper Member of the Nfayil Formation, rather than to Injana Formation, as indicated by Hassan *et al*. (2002).

3.5. PLIOCENE

The whole Iraqi Western Desert was still (and continued so) uplifted area, due to collision of the Arabian Plate with the Neo-Tethys terrains. Therefore, continental, fluvial, deposits prevailed over the considered area. The Pliocene Epoch is represented by two formations, in the Iraqi Western Desert. These are Dibdibba and Zahra formations. The former has very restricted outcrops in a small area, only.

3.5.1. Dibdibba Formation (Pliocene – Pleistocene?)

Type Locality: The type locality of the Dibdibba Formation is in Birjisiya, south of Basrah, it is defined by the following coordinates (Macfadyen, in Bellen *et al*., 1959) (Fig.5):

Longitude 47° 38' 00" E
Latitude 30° 22' 00" N

But, Owen and Nasr (1958) in Bellen *et al.* (1959) claimed better surface and subsurface succesion, in Zubair oil well No.3, with much thicker development (305 m).

Exposure Area: The exposures of the Dibdibba Formation are restricted only to the Najaf – Karbala Plateau, within the whole Iraqi Western Desert (Fig.3). Because, the Dibdibba

Formation is one of the youngest formations in the stratigraphic column of Iraq, therefore it has no subsurface extensions.

Lithology: The Dibdibba Formation, in the type locality, consists of "mainly sandstone and gravel of igneous rocks, including pink granite, various liver-colored and slate-grey intrusives, dolerites, etc. and white quartz pebbles. Not infrequently the rock is cemented to hard grit"(Macfadyen, in Bellen *et al*., 1959). Hassan *et al*. (2002), described the Dibdibba Formation as brown, yellow, white and grey sandstone and pebbly sandstone.

Thickness: The thickness of the Dibdibba Formation, in the type locality is 354 m (Bellen *et al*., 1959). In Tar Al-Sayed it ranges from (3 – 15.5) m. (Hassan *et al*., 2002)

Fossils: No useful fossils were found except for some vertibrate remains, which are not identified yet. *Chara* sp., *Ostracods* and *Planorbis* sp. are recorded.

Age: The age of the Dibdibba Formation is not ascertained yet, it may be Pliocene – Pleistocene? (Sissakian, 2000), however Late Miocene – Pliocene or even early Pleistocene age is recorded by Buday (1980); Jassim and Buday in Jassim and Goff (2006) calimed post Middle Miocene age.

Remark: The authors did not accept Middle and Late Miocene ages for the Dibdibba Formation, because Dibdibba Formation is clearly underlain by Injana Formation of Late Miocene age.

Depositional Environment: The Dibdibba Formation represents fluvial sedimentation in extensive sheets probably as large old alluvial fans. From thickness studies it seems that at least two such fans may be considered (Jassim *et al*., 1984).

Lower Contact: The Dibdibba Formation, in the type locality is underlain conformably by the Lower Fars Formation (Bellen *et al*., 1959). In Tar Al-Sayed locality, the Dibdibba Formation is underlain unconformably by the Injana Formation, the contact is based on the first appearance of sandstone or pebbly sandstone (Hassan *et al*., 2002).

3.5.1. Zahra Formation (Pliocene – Pleistocene?)

Type Locality: The type locality of the Zahra Formation lies at Faidhat al Zahra, west of Busaiya, in the Iraqi Southern Desert (Fig.5) (Bellen *et al*., 1959); it is defined by the following coordinates:

Longitude	45°	27'	54"	E
Latitude	30°	13'	12"	N

Exposure Areas: The Zahra Formation has considerrable coverage areas in the Iraqi Western Desert. It is exposed in the eastern part (Fig.1), from Al-Sahin vicinity and extends north and northwestwards in a patchy character crossing Khibrat Shinana, Al-Nukhaib, Al-Habbariyah, till wadi Ghdaf. There, it changes its direction northwestwards, crossing Highway No.1 and Qasir Amij and terminates after 30 Km, northwestwards. Then it is exposed again northwest of H_1 for about 45 Km covering the whole plateau crossing northwestwards the Iraqi – Syrian borders. However, the plateau is dissected by deep valleys like Mana`i, Ratga and Akash, which cause the cropping out of older formations. It is also present as relics (cap rock) on almost all isolated hills and small plateaus, like south of T_1 and Al-Qaim (Figs.2 and 3).

Lithology: The Zahra Formation, in the type locality consists of "whitish and reddish limestone, locally sandy, red and purple sandy marls and calcareous sands" (Bellen *et al*., 1959). Al-Mubarak and Amin (1983) described the Zahra Formation as cyclic deposists; usually (1 – 10) cycles are developed, except in the southern part of Nukhaib Graben, where it consists of 26 cycles. Each cycle, in the western and centarl portions of the eastern part of the Iraqi Western Desert, consists of sandstone overlain by limestone, while in the eastern portion, it is characterised by lateral variation in lithology, from alternation of red claystone and limestone to alternation of red claystone, green marl and limestone. However, this general

description is not valid everywhere. Therefore, the following descriptions are given in different areas (Al-Mubarak and Amin, 1983):

- Amij area, it consists of one cycle, a basal conglomerate overlain by pebbly snadstone and capped by burrowed limestone.
- Suwihat Al-Ehaimer and Tal Al-Mughar (Amghar) area, it consists of one cycle, a reddish brown, calcareous terrafusca, which may contain 1 or 2 horizons of pink burrowed limestone. The terrafusca changes southwards to basal conglomerate. Both successions are capped by pinkish grey, slightly fossiliferous, sandy limestone.
- Wadi Hauran – wadi Ghadaf area, it consists of (4 – 5) cycles. Each cycle consists of reddish brown sandstone overlain by grey and brownish grey, slightly fossiliferous, clayey burrowed limestone.
- Northern part of Nukhaib Graben area, it consists of (3 – 5) cycles. Each cycle consists of light brown, reddish brown and white, partly pebbly, calcareous sandstone, overlain by red and reddish brown, slightly sandy claystone, which is followed by greenish grey, slightly sandy and gypseous marl, which is capped by whitish grey and brownish grey, slightly sandy, fossiliferous and burrowed limestone.
- Southern part of Nukhaib Graben area, it consists of 26 cycles. Each cycle consists of greenish grey, slightly calcareous and pebbly sandstoen, in the upper parts, reddish brown sandy claystone lenses occur. The sandstone is overlain by greenish and yellowish grey, pink, burrowed slightly sandy limestone.

Remark: The authors would like to pay attention that in this locality Jassim *et al*. (1990) and Jassim and Buday in Jassim and Goff (2006) renamed the Zahra Formation as Ghadaf Beads, due to this thick and abnormal succession.

- Al-Sahin area, it consists of (2 – 3) cycles. Each cycle consists of brown and whitish grey, slightly pebbly sandstone, at the base lenses of claystone occur. The sandstone is overlain by greenish brown and pinkish grey, slightly fossiliferous limestone.

Al-Jumaily (1974) described the Zahara Formation in Al-Khirish Plateau and near surroundings as "Unit D", within unknown succession, which he called as "Units A, B, C and D". It consists of grey sandstone, conglomerate, which form large isolated bodies, pebbles are (2 – 20) cm in size, heterogenous, pinkish sandy limestone, white, grey and brown breccia, which passes laterally to nodular limestone, capped by pink, very hard splintary limestone, which is occasionally alternated with sandy limestone or calcareous sandstone.

Thickness: The thickness of the Zahra Formation, in the type locality, is about 30 m (Bellen *et al*., 1959). Al-Jumaily (1974) recorded the thickness of the Zahra Formation (Unit D) as 15 m, in Al-Kherish area, which decreases to several meters towards south and southeast. Al-Mubarak and Amin (1983) reported the following thicknesses: (10 – 13.5) m in Amij area, (38 – 42) m in Suwihat Al-Ehamair and Tal Al-Mughar area, (20 – 25) m in wadi Hauran – wadi Ghadaf area, (30 – 40) m in north of Nukhaib area, (46 – 60) m in south of Nukhaib area, 76 m in wadi Ar`ar, 30 m in Al-Bireet, (12 – 18) m in Al-Sahin and (18 – 23) m in wadi Al-Faj.

Fossils: Bellen *et al*. (1959) and Salman (1993) recognized the following fossils from the type locality:

Chara sp., *Melanoides tuberculata* MUELLER, *Planorbis* sp., *Virapara* sp. and tubular holes probably of reedstalks

Age: The presence of a tongue of limestone similar to those of Zahra Formation in Dibdibba Formation suggests that the two formations are laterally equivalent at least in parts. Late Miocene or younger age is claimed by Bellen *et al*. (1959) and Late Miocene – Pliocene age is claimed by Field and Thompson (1957) and Huber (1944) in Bellen *et al*. (1959). However,

Salman (1993) claimed Pliocene – Pleistocene? age in Al-Kherish vicinity; Jassim and Buday in Jassim and Goff (2006) claimed Late Miocene – Pliocene age.

Remark: The authors did not accept Late Miocene age for the Zahra Formation, because it overlies clearly the Injana Formation, which is Late Miocene in age.

Depositional Environment: The depositional environment of the Zahra Formation is of fresh water origin, this is based on the recorded fossils (Bellen *et al*., 1959). All other authors adopted the fresh water origin.

Lower Contact: The Zahra Formation, in the type locality is underlain, unconformably by the Fat`ha Formation (Bellen *et al*., 1959).

Remark: The authors believe that the described green marls, which bear oysters, belong to the Nfayil Formation (Sissakian, 2000) and the younger clastics belong to the Injana Formation. Therefore, the Zahra Formation in the type locality is underlain by Injana Formation.

Al-Jumaily (1974) claimed that the Zahra Formation (Unit D) is underlain by "Unit B", which is equivalent to the Nfayil Formation, the contact is taken at the base of grey sandstone, in Al-Kherish area, or at the base of pink limestone; in T_1 vicinity it is taken at the base of a breccia horizon. Al-Mubarak and Amin (1983) reported that the Zahra Formation is underlain by different formations, in different areas. In Amij area, it overlies unconformably the Mauddud Formation. In Suwaihat Al-Ehaimer and Tal Al-Mughar area, it overlies unconformably the Mahilban (Rutbah and Ms`ad formations) and Hartha formations. In wadi Hauran and wadi Ghadaf area, it overlies the Euphrates and Ghar formations. In Nukhaib Graben area, it overlies unconformably the Umm Er Radhuma, Dammam and Ghar formations. In Al-Sahin area, it overlies unconformably the Umm Er Radhuma and Dammam formations.

3.6. Quaternary Deposits

The Quaternary deposits are well developed in the western part (Fig.1) of the Iraqi Western Desert, on contrary to the eastern part. Only the main types are reviewed, hereinafter:

− Habbariyah Gravels (Pleistocene)

Al-Mubarak and Amin (1983) introduced the Habbariyah Gravels for the first time.These are well developed in the middle part (Fig.1) of the Iraqi Western Desert (Fig.3). They are composed of loose, rounded to subrounded limestone pebbles with few chert, the size of the pebbles range from (12 – 20) cm, the thickness of this level ranges from (5 – 6) m, exceptionally reaches (8 – 12) m, in the northern bank of wadi Ghadaf. This horizon is capped by calcrete layer, semi bedded, with few pebbles and thickness of (0.5 – 1.5) m. The second (higher) gravelly layer is composed of loose, rounded to subrounded dolostone, limestone and chert pebbles, the size of the pebbles range from (0.5 – 3.0) cm, with thickness of (1 – 3) m, but occasionally may reach (4 – 5) m. The source and origin of the pebbles are obsure.

− Hauran Gravels (Pleistocene)

Al-Mubarak and Amin (1983) introduced the Hauran Gravels for the first time. These are well developed in the middle part (Fig.1) of the Iraqi Western Desert (Figs.2 & 3), especially near H_1 oil pumping station. They are composed of loose rounded pebbles of different sedimentary rocks, the size of the pebbles ranges from (1 – 10) cm, but locally reach up to 25 cm, with thickness of (2 – 3) m and occasionally may reach 7 m. The source and origin of the pebbles are obsure. The thickness reaches (0.5 – 1.5) m.

Remark: Tyracek and Youbert (1974) considered the gravels as terraces of wadi Hauran.

− Terraces (Pleistocene)

The Euphrates River has deposited three terrace levels, but they are not well developed, with limited areal extent. The pebbles are well rounded to rounded, mainly of limestone and

silicates, with rare igneous and metamorphic rocks, their size range from few cm, up to 15 cm and may reach to 35 cm, the thicknes of each level is variable, generally does not exceed few meters, cemented by gypsiferous and sandy materials.The main valleys, like Hauran, Swab, Ratga, Akash, Amij, Hussainiyat…etc. have also developed terraces. The pebbles are limestone and silicates, rounded to subrounded, their sizes is (0.2 – 10) cm, but may reach 25 cm, cemented by calcareous and sandy materials, the thickness is highly variable, depending on the valley, generally (1 – 3) m.

− Calcrete (Pleistocene – Holocene)

Although calacrete is well developed in different parts of the Iraqi Western Desert, but it is not well mapped and studied. The thickness may reach few meters, with different composition. Few meters are reported in Ga`ara Depression (Dr.Mazin Tamar-Agha, personal communication, 1987).

− Gypcrete (Pleistocene – Holocene)

It is well developed in the eastern part of the Iraqi Western Desert, especially in Fallujah, Habbaniyah, Karbala and Najaf vicinities (Fig.3). Locally, they are covered by thin venieer of sand sheets and scattered pebbles.The percentage of the SO_4 is highly variable, the thickness ranges from (0.5 – 2.0) m.

− Valley Fill Deposits (Holocene)

The main valleys are filled by different clastic deposits, which are highly variable in compositin, size and thickness. The main composition is carbonate with silicate; the pebbles are rounded to subrounded, with average size of (1 – 10) cm, but may reach to 25 cm. The thickness ranges from (0.5 – 2.5) m, but locally may exceed 5 m, or even more.

− Residual Soil (Holocene)

Large parts of the western part (Fig.1) of the Iraqi Western Desert are covered by residual soil, on contrary of the other two parts. The soil is brown to reddish brown, silty and clayey, very rarely sandy and calacareous, with small rock fragments, which increase in size and abundance depthwards. The thickiness ranges from (0.5 – 1.5) m, but exceptionally may reach few meters.

− Depression Fill Deposits (Holocene)

These are restricted to the western part (Fig.1) mainly, forming usually flat areas, which are called playa and locally as "Faidhah" or "Khibrah".The deposits are mainly of clay and silt, rich in SO_4. The thickness is (0.5 – 1.5) m and may exceed, whereas the average area is less than 1 Km^2 to more than few tens of square kilometers.

INTRODUCING AND CANCELLING OF ROCK UNITS

During regional and detailed geological surveys, which were carried out in the Iraqi Western Desert, many rock units were introduced to the stratigraphic column of Iraq and others were omitted. Only those rock units which are represented on the geological map of Iraq, scale 1: 1 000 000, the three editions (Jassim *et al*., 1986 and 1990 and Sissakian, 2000, respectively) are dealt with.

▪ Cancelled Rock Units

The following rock units are cancelled from the geological map of Iraq (1^{st} and 2^{nd} editions) (Jassim *et al*., 1986 and 1990) by Sissakian, 2000 (3^{rd} edition of the geological map of Iraq).

− Shalameej (Saggar) Beds

These beds were introduced by Jassim *et al.* (1986) on the geological map of Iraq, scale 1: 1 000 000. On the second edition (1990) they changed the name to Saggar Beds, claiming Late Jurassic – Early Cretaceous age. Moreover, Jassim and Goff (2006) renamed the beds as Saggar Formation and claimed Late Jurassic age. The beds crop east of Rutbah town, for

about 13 Km along the Highway No.1 and extends eastwards for about 80 Km, then extends northeastwards for about 50 Km, crossing the main road of Kilo 160 – Ga'ara. They are underlain by Jurassic formations and overlain by Nahr Umr, Mauddud, Rutbah and Ms`ad formations. No explanation is given by the authors for introducing these beds, and changing their names. Sissakian (2000), on the geological map of Iraq scale 1: 1 000 000 (3rd edition) cancelled these beds due to:

- No continuous sedimentation exists between Late Jurassic and Early Cretaceous rocks in the Iraqi Western Desert, due to Rutbah Uplift and the well known unconformity.
- The coverage areas for these beds (Saggar Formation) belong to the Najmah, Nahr Umr, Mauddud, Rutbah and Ms`ad formations, according to the regional and detailed geological mapping (Al-Mubarak and Amin, 1983 and Al-Azzawi and Dawod, 1996).

Therefore, the authors adopted the idea of Sissakain (2000) and are in full accordance with him.

− Samhat Formation

This formation was introduced by Jassim *et al*. (1984) from the northern rim of Ga'ara Depression. It consists of conglomerates overlain by carbonates and marls, of Late Cretaceous age, claiming interfingering with the Hartha Formation in very short distance (Fig.74, Jassim *et al*., 1984). Buday and Hak (1980) mapped the involved sequence as the Digma Formation. Al-Bassam *et al*. (1990) mapped the involved sequence as "Marbat Beds" and Tayart Formation. Because, the lower part (the conglomerate) has very restricted geographical distribution and the upper parts represents the Tayarat Formation, therefore the author`s are in accordance with Sissakian (2000) in cancelling the name "Samhat Formation" and adopting the Marbat Beds, partly instead.

− Jeed Formation

The formation was introduced by Jassim *et al*. (1984) and represented it on the geological map of Iraq (Jassim *et al*., 1986). They claimed it is the phosphatic and marly equivalent of the Tayarat Formation, west of Rutbah vicinity. The detailed geological mapping (Al-Bassam *et al*., 1990) revealed that the involved sequence belongs to two formations, Tayarat and Digma (Na'aja and Safra Beds, respectively of Al-Bassam *et al*., 1990). The author`s are in accordance with Sissakian (2000) in his assumption, which depends on the results of the detailed geological survey (Al-Bassam *et al*., 1990). Therefore the name "Jeed Formation" is cancelled. Moreover, Jassim *et al*. (1990) presented the Jeed Formation on the geological map of Iraq without marking the contact with Tayarat Formation. This is good indication for the uncertainty.

− Jaddala Formation

The formation was introduced by Jassim *et al*. (1986 and 1990) on the geological map of Iraq (1st and 2nd editions). Sissakian (2000) omitted it from the geological map of Iraq, due to inadequate information about its areal extent and lower and upper contacts. For details refer to **3.2.4**.

− Ghadaf Beds

These are introduced by Jassim *et al*. (1984) and presented on the geological map of Iraq (Jassim *et al*., 1986 and 1990), in the Nukhaib Graben area and wadi Ghadaf, claiming that the beds consist of sandstones and limestones, in cyclic nature, representing the continental part of the deltaic Ghar Formation. They claimed, however that the Ghadaf Beds are underlain by the Ghar Formation and they may have Miocene age?. The involved sequence is mapped by Al-Mubarak and Amin (1983) as the Zahra Formation; they mentioned that the Zahra Formation in the considered vicinity attains maximum development of 26 cycles, claiming this abnormal development to the Nukhaib Graben activity. This abnormal development of 26 cycles is considered by Jassim *et al*. (1984) in introducing the "Ghadaf Beds" and their

absence in other areas. The authors are in full accordance with Sisskian (2000) in canceling the name "Ghadaf Beds" and retaining the name Zahra Formation to the involved sequence, which was mapped by Al-Mubarak and Amin (1983) in all geological maps of scale 1: 25 000 of the eastern part of Iraqi Western Desert, and because all outcrops of the Zahra Formation, not only in Nukhaib Graben vicinity, are changed to "Ghadaf Beds" by Jassim *et al*. (1986 and 1990), which means cancelling of the Zahra Formation from the Iraqi Western Desert.

− Kherish and Najaf Beds

These beds were introduced by Jassim *et al*. (1986 and 1990) on the geological map of Iraq and Jassim and Goff (2006). They claimed the "Kherish Beds" consist of clastics in the bottom overlain by green marls and limestones, depending on the description of Al-Jumaily (1974). But, the description of Al-Jumaily (1974) contradicts with the mentioned sequence, because Al-Jumaily (1974) mapped the green marls and limestones as "Unit B", which is overlain by "Unit D" that consists of clastics and capped by limestone, which means the reversed (upside down) assumed succession by Jassim *et al*. (1984). Moreover, they considered that "Kherish Beds" and Najaf Beds" and Fat`ha Formation are interfingering with each other (Fig.50, Jassim *et al*., 1984). The detailed geological mapping revealed that the "Kherish Beds" are the same "Najaf Beds", but the lithological description of the "Kherish Beds" is missed upside down.

Remark: It is worth to mention that Hassan *et al*. (2002 and 2004) considered the Nfayil Formation during the detailed geological mapping of Karbala – Najaf area, which is the same succession called as "Najaf Beds" by Jassim *et al*. (1984). Sissakian *et al.* (1997) and Sissakian (2000) considered the so called "Unit B" as a new formation and named it as the Nfayil Formation. The so called "Unit D" is proved to belong to the Zahra Formation (Salman, 1993). Therefore, the "Kherish Beds" and "Najaf Beds" are cancelled by Sissakian (2000), because they represent two formations of different ages, lithologies and depositional environments. The authors adopted this assumption due to aforementioned reasons.

− Habbaniyah Beds

These beds are introduced by Jassim *et al*. (1984) for a succession of clastics in Habbaniyah and Tar Al-Najaf vicinities, claiming ?Middle – Late Miocene age and being special development of the Injana Formation, due to the presence of limestone horizons and green marls. This assumption was not adopted by Sissakian (2000) because the involved sequences (Kherish Beds and/ or Najaf Beds, with Habbaniyah Beds) represent the Lower and Upper Members of the Nfayil Formation and Zahra Formation; therefore the three terms (Beds) are cancelled by Sissakian (2000). The authors are in full accordance for canceling the three names, for the aforementioned reasones.

Remark: It is worth to mention that Hassan *et al*. (2002 and 2004) did not consider the Upper Member of the Nfayil Formation, which is the same succession of "Habbaniyah Beds" and instead they mapped Injana Formation, in Tar Al-Najaf and Tar Al-Sayid, ignoring the presence of green marls and limestones (even in the uppermost bed of the succession), which can not be deposited in the environment of the Injana Formation.

▪ Recently Introduced Rock Units

The following rock units are recently introduced and added to the stratigraphical column of Iraq and presented on the last (3rd) edition of the geological map of Iraq, scale 1: 1 000 000 (Sissakian, 2000):

− Hussainiyat Formation

The formation was previously included within the Ubaid Formation. It is Early Jurassic in age, consists of clastics and carbonates. For details refer to **2.2.2.**

− Amij Formation

The formation was previously included within the Muhaiwir Formation. It is Middle Jurassic in age, consists of clastics and carbonates. For details refer to **2.2.3.**

− Marbat Beds

The beds were previously included within the Ga`ara Formation. They are Late Cretaceous in age. For details refer to **2.3.6.**

− Digma Formation

The formation was previously included within the Tayarat Formation. Jassim *et al*. (1984) included part of the sequence to the "Samhat Formation". Sissakian (2000) adopted the Digma Formation from the "Safra Beds" introduced by Al-Bassam *et al*. (1990). The authors are in full accordance with this assumption. For details refer to **2.3.8.**

− Akashat Formation

The formation was previously known as Umm Er Radhuma Formation (west of Rutbah Uplift). It is Paleocene in age, consists of phosphatic marine carbonates and marls. For details refer to **3.1.2.**

− Ratga Formation

The formation was previously known as the Dammam Formation (west of the Rutbah Uplift). It is Eocene in age, consists of limestones and marls, with chert nodules. For details refer to **3.2.2.**

− Jil Formation

The formation was previously included within the Lower Member of the Dammam Formation. It is Early Eocene in age, consists of limestones, dolostones and marl, with chert nodules. For details refer to **3.2.3.**

− Jeribe Formation

The formation is introduced in this study, because the authors believe it is present in the Iraqi Western Desert, especially in the northwestern part. For details refer to **3.4.3.**

− Nfayil Formation

The formation is recently announced by Sissakian *et al*. (1997) and adopted by Sissakian (2000). The Formation was previously included within Euphrates, Fat`ha and Injana formations. Moreover, different authors considered different parts of the formation in different areas and used different names. For details refer to **3.4.5**.

DISCUSSION

Due to some contradictions in scientific opinions between different authors working in the Iraqi Western Desert, especially age wise and due to very large coverage areas of some formations, which cross different structural zones, consequently being affected in their depositional style, many contradictions and misleading opinions are achieved, by those authors. Therefore, the present authors did this attempt to discuss and highlight, as much as possible, these ambiguities, which are occasionally included with recommendations, for future studies. The exposed formations are reviewed and argued, hereinafter, from oldest to youngest.

Ga'ara Formation, the mutual relation with the encountered red clastics in oil well Akkaz 1 should be defined. The presence or otherwise of "Sufi Formation" is recommended for future studies. Jassim and Goff (2006) named "Bir Al-Rah Formation" instead of the "Sufi Formation".

Mulussa Formation, no comment.

Zor Hauran Formation, no comment.

Remark: The absence of the aforementioned two formations northwards of Ga'ara Depression should be studied. The authors believe it is due to structural effect, during early

Alpine Orogeny. The authors are not in accordance with Buday (1980) in assuming that the two formations pass northwards to Kura Chine and Baluti formations, respectively. Because, no Triassic rocks were encountered in oil well Akazz 1, which is north of Ga'ara Depression and they are not present in its northern rim, moreover Triassic rocks are encountered in oil well Khlesia 1.

Ubaid Formation
Hussainiyat Formation
Amij Formation
Muhaiuir Formation
Najmah Formation

The aforementioned five formations represent five Jurassic cycles. Each of them consists of lower clastic and upper carbonate units. The authors prefer to separate each formation into two formations, due to the following reasons:

- Each lithological unit, of each formation, has mappable areal distribution, in geological maps of scale 1: 25 000.
- Each lithological unit represents certain depositional environment, which might differ (widely) from its conjugate lithological unit's environment.
- Locally, unconformable contacts (with clear indication) are reported, by different authors, between the two units of the same formation.
- The age of the clastic unit is usually not well known, it depends on the age of the overlying carbonate unit. Detailed age studies may reveal different age of the clastic unit from the age of the overlying carbonate unit.
- To be in accordance with the Cretaceous formations, which have the same characters.

Nahr Umr Formation
Mauddud Formation
Rutbah Formation
Ms`ad Formation
Hartha Formation
Tayarat Formation
Digma Formation

The aforementioned seven Cretaceous formations, which represent five sedimentary cycles have large coverage areas and large lithological similarities, in both clastic and carbonate units (for the first four formations, which represent two cycles), beside local interfingering of the last three formations. These are the main reasons for having slight differences in the geographical and partly stratigraphical positions between different author`s, like Buday and Hak (1980); Al-Mubarak and Amin (1983); Jassim *et al*. (1984); Al-Azzawi and Dawood (1996); Hassan (1998) and Jassim and Goff (2006). Some of these contradictions led to claiming of different ages or extending the age younger and/ or older, by some authors, to some formations as compared to their original ages (as announced from the type localities). Hereinafter is a brief review for these contradictions:

- According to Al-Mubarak and Amin (1983) the Nahr Umr Formation in the central part of the Iraqi Western Desert is mapped as Rutbah Formation by Tyracek and Youbert (1975) and Buday and Hak (1980). GEOSURV adopted the assumption of Al-Mubarak and Amin (1983).
- Jassim *et al*. (1984) grouped Cretaceous formations, each two, using the hyphenated name for each cycle. The authors are not in accordance with this assumption, due to the same aforementioned reasons mentioned in the proposal of subdividing the Jurassic formations. Moreover, clear indications for unconformable contacts between some formations are

recognized by different authors, in different localities, therefore could not be grouped together, as one formation.

- The presence of the Ms`ad Formation east of Kilo 160 and east of Al-Awaj vicinities is problematic. Al-Mubarak and Amin (1983) mapped the involved sequence as Mahilban Formation. However, they disused this name and retained the Ms`ad Formation. According to Mrs. Sahira Abdul Karim (personal communication, 2006), the involved succession might belong to Hartha or Tayart Formation. The authors believe that the sequence belong to the Hartha Formation rather than Tayarat Formation, because in the normal succession, Hartha Formation overlies Ms`ad and the exposed thickness does not permit the exposure of Hartha and Tayarat formations, in the sequence, although Ma`ala *et al*. (1999) mapped in Ashwa site Tayarat Formation and not Ms`ad Formation. If this is true then there must be interfingering of Hartha and Tayarat formations in the vicinity, so Tayarat Formation overlies, locally, Ms`ad Formation.
- Hassan (1998) denied the presence of the Nahr Umr and Mauddud formations and included the succession within the Rutbah Formation. He also extended the age of the Rutbah Formation Aptian – Middle Albian, this contradicts the announced age of Rutbah Formation.

Marbat Beds, the areal distribution has to be studied more precisely in Ga'ara Depression. Because, Al-Bassam *et al*. (1990) mapped the western rim and part of the northern rim only. Therefore, the beds may occur in other areas of the depression, too.

Umm Er Radhuma Formation, no comment.

Dammam Formation, the large difference in the lithological constituents of the proper Dammam type and those exposed in the eastern part of Iraqi Western Desert, beside the unconformable contact between the three members of the Dammam Formation (Al-Mubarak and Amin, 1983) and the total absence of the Upper Member, in the Western Desert, encourages introducing of new three formations, instead of the three members, like the Jill Formation. Therefore, the authors highly recommend detail studies for introducing new formations. The details given by Al-Mubarak and Amin (1983) are very helpful in this concern.

Akashat Formation, no comment.

Ratga Formation, as the Dammam Formation, it is highly recommended to establish, at least two, new formations instead of the Ratga Formation. Because, the Ratga Formation is established to be the equivalent of the Dammam Formation, and because the authors recommend the establishment of new formations instead of Dammam Formation, consequently new formations should be established instead of the Ratga Formation and for the same reasons. Moreover, to confirm or otherwise the presence of the Jaddala Formation The detailed descriptions given by Hagopian (1979) and Al-Bassam *et al*. (1990) are very helpful in this concern.

Jil Formation, no comment, it is highly recommended to use this new name, but after establishing of other two formations to represent the Middle and Upper Members of Dammam Formation.

Jaddala Formation, the presence or otherwise and the geographical distribution and mutual relation with the overlying and underlying rocks are highly recommended for future studies.

Shurau and Sheikh Alas formations, no comment, but their geographical distribution in Muger Al-Dheeb vicinity is highly recommended for future studies, since they are not precisely distinguished from the Ratga Formation, during the Regiona Geological Survey (Al-Jumaily, 1974).

Baba Formation, no comment.

Azkand Formation, the presence or otherwise with Anah Formation, in Anah vicinity is highly recommended for future studies.

Anah Formation, no comment.

Ghar Formation, the interfingering of the uppermost part of Ghar Formation with the lowermost part of the Nfayil Formation in vicinity of wadi Ratgah and Man`ai, southeast of Al-Kherish, leads to extend the age of the Ghar Formation to Middle Miocene, which means the relevant age will be Early – Middle Miocene. It is highly recommended for future studies to confirm or otherwise this assumption.

Euphrates Formation, due to its very large coverage areas, which cross different structural zones, large differences in its main lithological constituents occur, which is not in accordance with the described type locality . Moreover, the informal units (Al-Mubarak, 1974) in Al-Qaim vicinity and southeastwards (down stream of Euphrates river) show very large changes, starting from wadi Hauran vicinity and southeastwards. The authors believe that the Euphrates Formation passes to another formation (not recognized), which covers almost the majority of the Iraqi Western Desert, except Al-Qaim – Alus vicinity. The large lithological changes mentioned by Al-Mubarak and Amin (1983) and Mahdi *et al*. (1985) support the authors opinion in establishing of a new formation, which will have shallower marine environment with influx of continental deposits, due to near shore areas of the main Early Miocene sea. The authors also believe that part of "Unit C", mapped by Al-Mubarak and Amin (1983) especially in the extreme southern edges of the exposure areas in eastern and middle parts (Fig.1) of the Iraqi Western Desert may belong to the Nfayil Formation, both Lower and Upper Members. The authors are in full accordance with Jassim *et al*. (1984) in choosing a new type locality for the Euphrates Formation, which depends on Al-Mubarak (1974). The main reasons for this proposal are:

- Inundation of the original type locality by Haditha Dam reservoir.
- The new selected type locality is more representative, lithologically, for the Euphrates Formation as compared to the original sellected type locality by Bellen *et al*., (1959).

Remark: The described informal units, of the Euphrates Formation, in the new selected and the original type localities, could not be followed southeastwards from Alus vicinity, although the same informal units are mapped by Al-Mubarak and Amin (1983) in all parts of the Iraqi Western and Southern Deserts, but with main differences in their lithological constituents and thickness.The authors believe that the main reason for these lithological variations is the activity of Abu Jir and Euphrates Fault Zones , which caused changes in the depth and extensions of the depositional basin(s).

Jeribe Formation, the presence of the formation in the Iraqi Western Desert is not ascertained yet, because it is not presented on the available geological maps. However, the informal unit mapped by Al-Jumaily (1974) as "Unit A" and Mahdi *et al*. (1986) as "Ahmar Unit" most probably represents the Jeribe Formation?. The contact with the underlying Euphrates Formation is sharp and clear. The same holds good with the overlying Nfayil Formation. This informal unit, wedges out southeastwards from Alus vicinity. It is also absent northwest of Haditha vicinity, but exist southwestwards from Haditha and extends farther westwards to Syria. This informal unit could be easily recognized in the field either by the presence of a clausenella bed or by the presence of small (0.3 – 0.5 cm) ball like echinoids. It might be present within the Euphrates Formation, but not recognized and differentiated due to large lithological similarity, especially when the basic informal units of the Euphrates Formation are not recognizable, like in wadi Hauran, H_1 vicinity and southwards, where the uppermost part of the Euphrates Formation consists of well bedded limestone, which resembles the lithology of Jeribe Formation. If this informal unit (Unit A or Ahmar Unit) represents Jeribe Formation, then a small hiatus exists between the Euphrates Formation and

the overlying Fat`ha and/ or Nfayil Formation, in areas where no Jeribe Formation is developed. For geographical distribution, see the Jeribe Formation (P.104).The study of presence or otherwise of Jeribe Formation and its areal distribution, in the Iraqi Western Desert is highly recommended.

Injana Formation, the presence of the formation in Habbaniyah, Karbala and Najaf vicinities is uncertain and problematic. If not all of the succession, part of it might belong to the Upper Member of the Nfayil Formation. Even if the formation is present, then its source should be known. These subjects are highly recommended for future studies.

Dibdibba Formation, the mutual relation with the Zahra Formation is still problematic. It is highly recommended to study this ambiguity and determine the precise age.

Zahra Formation, its presence as continueous outcrops in the western part of the Iraqi Western Desert, which contradicts the main outcrop pattern, in other exposure areas is problematic. Since it is known to be deposited in karst depressions. The maximum development, inform of 26 cycles, in wadi Ghadaf vicinity (Al-Mubarak and Amin, 1983) is also problematic, because in nearby areas and other exposure areas no such huge development is recorded.This is why Jassim *et al*. (1984) and Jassim and Buday in Jassim and Goff (2006) introduced "Ghdaf Beds" instead of the Zahra Formation. This abnormal deposition should be related to tectonic effect, i.e. a local neotectonic event, which caused continuous downwarping, most probably it might be the effect of Nukhaib Graben.These subjects are highly recommended for future studies.

Habbariyah and Hauran Gravels, the origin of these gravels and their depositional mode is still problematic, although they are attirbuted to Nukhaib Graben (Al-Mubarak and Amin, 1983). It might have the same origin of the aforementioned abnormal development of the Zahra Formation. This should be explained with the new structural concepts and regimes of the area. It is highly recommended for future studies, to overcome these ambugities and to discover if the gravel relics in Al-Kherish vicinity, on the top of the platue, have the same origin of the mentioned gravels, or otherwise.

CONCLUSIONS

From reviweing the presented data, which deals with the stratigraphy of the Iraqi Western Desert, the following can be concluded:

- The Mulussa and Zor Hauran formations were not deposited north and westwards of the Ga'ara Depression, most probably due to continuous Ga'ara Uplift, even before Triassic. The absence of the Triassic sediments in oil well Akkaz 1 proves this assumption.
- The absence of Jurassic sediments, north and west of the Ga'ara Depression, as indicated in oil wells Risha 1 and Akkaz 1, beside the trend and areal extent of the sediments, which is E – W, then changes to NE – SW, indicate the continuation of Ga'ara Uplift (Kimmerian Orogeny), but slightly eastwards as compared to Triassic Period.
- The two main lithological constituents of Jurassic formation, which consist of clastics overlain by carbonates, indicate continuous and cyclic regressions and transgression of the Jurassic sea, in the area, due to tectonic effect.
- The local absence of Cretaceous sediments in the northeastern rim of Ga'ara Depression, although the whole area was covered by Cretaceous sea, as indicated from oil wells Risha1 and Akazz 1, may indicate a slight uplifted area, which is the continuation of Jurassic Ga'ara Uplift that was terminated during Cretaceous.
- The termination of clastic – carbonate style of sedimentation during the third Cretaceous sedimentary cycle, the end of Ms`ad Formation and starting of Hartha Formation (Late Campanian), indicates quite neritic marine sedimentation, without interruptions, except

local influxes, to which some thin clastics are attributed in Late Campanian – Maastrichtian formations. Moreover, the phosphatic sediments indicate shallower basin, which was the last phase of Rutbah Uplift, the local interfingering of Hartha, Tayarat and Digma formations indicates the presence of small local isolated basins, within the main depositional basin.

- The absence of Paleocene sediments, Umm Er Radhuma and Akashat formations, in the Rutbah Uplift area, indicates that the area was still elevated, which was not covered during the Paleocene regression. Large parts, however of Paleocene sediments were eroded in northeastern and eastern parts of Ga`ara vicinity, where Miocene sediments cover Jurassic and Cretaceous sediments.
- The same holds good for Eocene sediments, Dammam and Ratga formations, but the erosion was less effective, since the northern rim of Ga`ara Depression is covered by Eocene sediments, and their relics are presented on Mulussa Formation on the top of Al-Afaif hills.
- The large lithological and thickness differences in three members of the Dammam Formation in both eastern and middle parts of the Iraqi Western Desert could be attributed to structural effects. Moreover, the recorded unconformity indications, between the three members confirm the structural effect, which caused changes in the depositional basin.
- The absence of the Oligocene sediments as continuous belt from Muger Al-Dheeb vicinity and southeastwards, indicates that the depositional basin was not continuous (or isolated basins) it is attributed to structural effect.
- The basin of Early and Middle Miocene was more uniform, as compared to formers. Since continuous sediments occur all over the Iraqi Western Desert, with clear indication for the shape of the basin, which is demonstrated by the Ghar and Euphrates formations (Early Miocene), and Fat`ha and Nfayil formations (Middle Miocene).
- The major changes in lithological constituents and thickness of the Euphrates Formation in Al-Qaim to Alus vicinity and southeastwards indicate either the presence of another formation or change in the depositional style in the basin due to structural effect. The authors postulate the former assumption.
- The change of the type of sediments between Lower and Upper Members of the Nfayil Formation, from marine to subcontinental, coincides with the style of the sedimentation, which was prevailing all over other parts in Iraq, i.e. the change of marine phase to continental during Late Miocene.
- The arc shape of outcrops of the Zahra Formation, starting from south of Nukhaib, passing through Habbariyah, Qasir Amij and Al-Kherish is highly attributed to structural effect, which caused the development of the depositional basin and which may indicate active contineous subsiding basin, Nukhaib Graben.
- The same holds good for Habbariyah and Hauran Gravels, which have the same outcrop pattern, although northwest of Hauran, in H_1 vicinity and more northwestwards, no gravels are present, but their relics are present in Al-Kherish plateau. This could be attributed to Nukhaib Graben. If it is true, then the age and extension of the graben should be changed to coincide with the age and geographic extensions of the Zahra Formation.
- The presence of dense valley terraces along both banks of the main valleys in Hit – Kubaisa vicinity indictes activity of the area, which is attributed to Abu Jir Fault activity.

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