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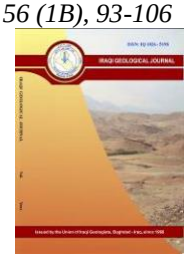

Depositional Architecture and Stratigraphic Framework of Albian Succession in Balad and Nasiyia Oil Fields

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Abstract

The Albian Carbonate-clastic succession in the present study is represented by the Mauddud and Nahr Umr formations were deposited during the Albian stage within the Wasia Group More than 200 thin sections of cores and cuttings in addition to well logs data for Nahr Umr and Mauddud formations from 4 boreholes within two oil fields (Ba-4, Ba-8, Ns-2 and Ns-4) were used to interpret the different associations facies as well as the facies architectures to describe the sedimentary framework of the basin and development the petrophysical properties. Seven major microfacies were diagnosed in the carbonate succession of the Mauddud Formation, while the Nar Umr Formation includes five lithofacies; their grain types characteristic and depositional textures enabled to recognize of paleoenvironments. These microfacies were deposited in restricted, shallow open marine, back-reef, slope and deep open marine for the Mauddud succession. While in Nahr Umr, the lithofacies were deposited in bay fill, back-shore and distributary channel. The studied succession in Balad oil field which represents two 3rd order and four 4th order cycles (A1, A2, A3 and A4). These cycles are asymmetrical and starts with cycle A1 where the Backshore facies in Lower Mauddud Formation represents the transgressive systems tract and then appear the hightstand systems tract bounded below by a transgressive surface which coinside with the unconformable surface with the underlying Shuaiba Formation.
In Nasyria oil field the studied succession represents two 3rd order cycles and three 3rd order cycles (A1, A2 and A4) with absence of A3 cycle. These cycles are asymmetrical and starts with cycle A1 where the distributary channel in the lower part of Nahr Umr succession represents the transgressive systems tract bounded below by unconformable surface with the underlying Shuaiba Formation. The highstand systems tract of cycle A1 is reflected by shallowing upward for distributary channel, bay fill and back-sore facies of the Nahr Umr Formation. This relatively thick parasequence reflect time of sea level stillstand where tectonic subsidence is the major controlling factor on producing the necessary accommodation for thick aggregational to progradation clastic succession to deposit.

Keywords: Depositional architecture; Stratigraphic framework; Albian succession; Balad oil field; Nasiriya oil field

1. Introduction

The Albian Carbonate-clastic sequence in the present study is representing by the Mauddud and Nahr Umr sucessions which deposited during Albian stage within the Wasia Group. The Nahr Umr Formation was explained at the first time by Bellen et al. (1959) in structure of Nahr Umr within southern

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Iraq. The basin of this succession is characterized by two major sedimentary basins in center and south of Iraq are corresponded to area which received the clastic sediments from the Rutba Uplift and the Arabian Shield. In the type area at Southern part of Iraq, the Nahr Umr succession including black shale bedded with sandstones (medium to fine grained) and lignite, ambers, and pyrite mineral (Bellen et al., 1959). The sand values in this succession are increasing towards the Salman Zone. The Mauddud Formation is the most widespread of the Early Cretaceous succession in Iraq. The thickness of this succession varies due to lateral changing of the facies and erosion truncation. The outcrops in northeast Iraq include Qamchuqa succession which comprising of organo-detrital, detrital and locally including argillaceous limestone with variable dolomitization stages. In Southern Iraq, Mauddud succession comprises frequently dolomitized organo-detrital limestones (Bellen et al., 1959).

The current study focused on Mauddud and Nahr Umr formations in two oil fields (Balad and Nasiriyah oil fields). The Balad oil field is sited in the middle part of Iraq within Salah Al-Din approximately 60-70Km along the Tigris River, north of Baghdad within the northren part of Mesopotamian Zone. While Nasiriyah oil field is sited in the south part of Iraq it is situated 38 Km, North West of Nasiriyah city. This oil field is represented a subsurface structural anticline with genetral direction N-S at the Mesopotamian Zone (Fig.1).

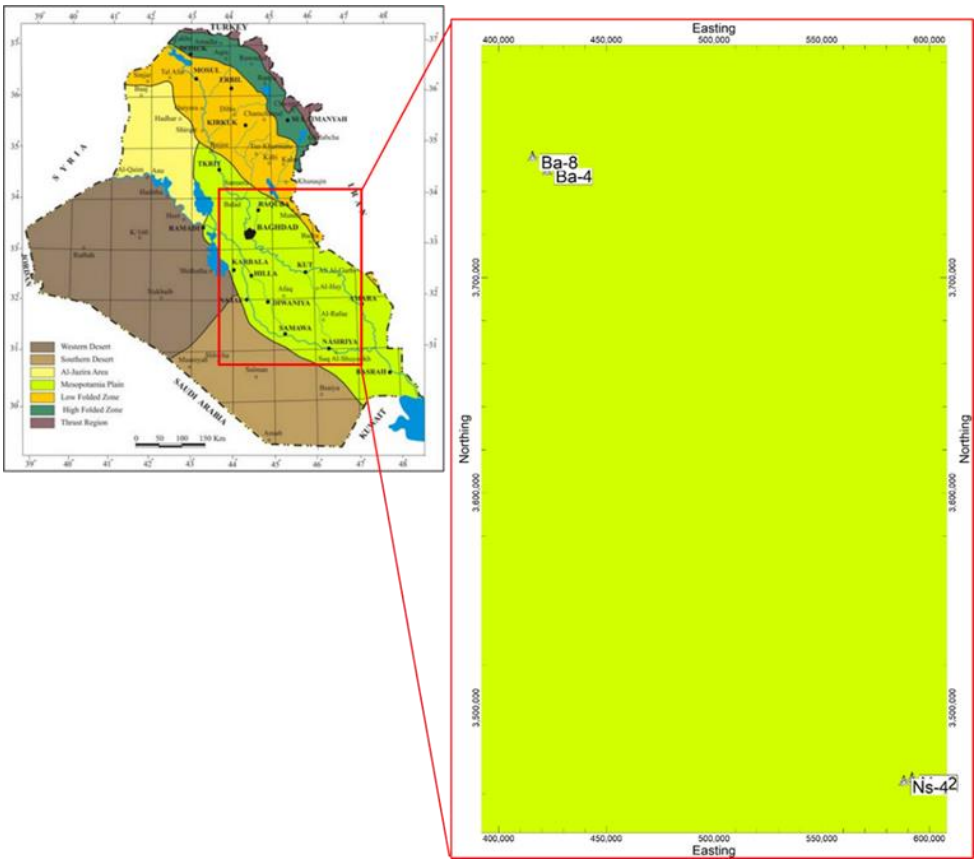

Fig.1. Location map of the studied area with tectonic framework

Abid et al. (2015) and Al-Zaidy and Amer (2015) studied the facies associations and development the diagenetic features during the Albian-Early Turonian period in Luhais and West Qura Oil fields, Southern Iraq. Khudhair and Al-Zaidy (2018) explained the petrophysical charactrization and reservoir evaluation for the Albian succession in Nasiriyah oil field in Southern Iraq. Amer and Al-Zaidy (2021) are studied the lithofacies and microfacies analysis and the depositional development during the Albian-Aptian Stage in Balad Oil Field. Where suggested that the Albian-Aptian sucession was deposited during

three stratigraphic cycles overlying the regional unconformity between Shuaiba and Zubair formations. At the final stage of this succession was ended with local unconformity underling the Ahmadi Formation. Al-Qayim et al. (2021) studied the reservoir fluids mobility evaluation of the Mauddud Formation (Albian) in Khabbaz oil field. The aim of the present study is to analyze microfacies to understand the depositional development and stratigraphic sequence of Nahr Umr and Mauddud succession in selected wells from Balad and Nasiyia oil fields.

2. Materials and Methods

The stages of current study is divided into :-

- Filed observations and sampling stage, this stage is including the going to the South Oil Company (SOC) where the collecting of core and cuttings samples (Table1).
- Laboratory stage
- Included thin section preparation to study the petrography and microfacies analysis and microfossils.
- Description and interpretation the available well logs related the log response to facies

Table 1. The succession interval and thickness with number of sample and well log types.

Well No.	Formation	Thickness	Sample no.	Well log type
Ba-4	Nahr Umr Mauddud	155m 129m	20 core 40 cuttings	GR and DT
Ba-8	Nahr Umr Mauddud	282m 115m	10 core 30 cuttings	GR and DT
Na-2	Nahr Umr Mauddud	153m 122m	50 cuttings	GR and DT
Na-4	Nahr Umr Mauddud	156m 122m	50 cuttings	GR and DT

3. Geological and Tectonic Settings

According to the geologic map of Iraq, issued by the State Establishment of Geological Survey and Mining in 1990, the area of study is a flat area with some simple uplands which range from 48m to 58m. The elevation of the studied area is increasing towards the north to east direction. This area is characterized by the agricultural regions where it has many irrigation projects, orchards, swamps and marshes, as well as the presence of areas of residential, civilian and military establishments. The studied area is charactrized by recent and Pleistocene sediments represented by river terraces and alluvial deposits coverd, where the studied sequence became thicker in Blad oil field. The ridge of Qamchuqa plunging towards the southeast across the Anah - Qalat Dizeh Fault system; the basinal depositional environment continued within Kirkuk city to the southwest. In the Jambur oil field, facies changes can be seen; a neritic depositional environment occurred in the northwest, and basinal limestone occurred in the southeast (Aqrawi et al., 2010) (Fig.2). Clastics-carbonates succession for Albian stage are characterized by inner shelf facies which covered the Stable Shelf. A carbonate ramp was developed within the east of Mesopotamian Zone (Tigris Subzone) over the Tikrit-Amara paleo-ridge. The Mosul High was subsided at the Albian Stage with the deposition of carbonates and evaporites for Jawan succession, in addition to the argillaceous lagoonal environment of the Upper Sarmord succession (Jasim and Goff, 2006).

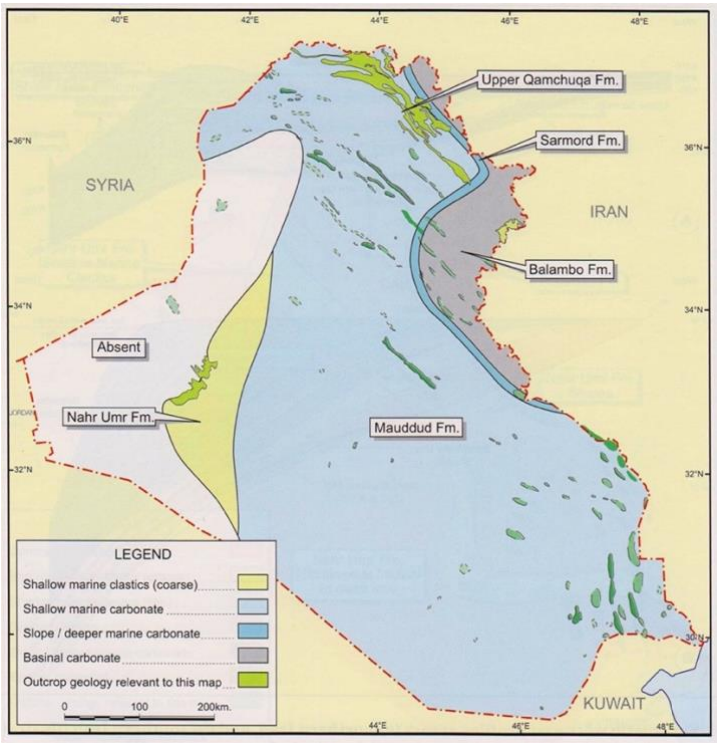

Fig.2. Late Albian paleogeography by Aqrawi et al. (2010)

The Mesopotamian and Salman zones were characterized by the deposition of clastics inner shelf of the Nahr Umr succession, which was later was covered by the carbonate platform of Mauddud succession at the Albian stage. Chatton and Hart (1960) described the Nahr Umr sandstone and Shale with Mauddud carbonate succession.

The upper boundary is represented by a conformable surface. However, in the structure of Butmah the Nahr Umr succession is disconformable, overlain by the bed of basal conglomerate for the Mauddud succession (Jassim and Goff, 2006) (Fig.3).

In Kuwait the Mauddud succession represented the deposition during the highstand stage in a carbonate inner shelf shallow environment during the Late Albian stage and developed during the transgressive cycle of the Burgan succession (Douban and Medhadi, 1999; Jassim and Goff, 2006; Aqrawi et al., 2010).

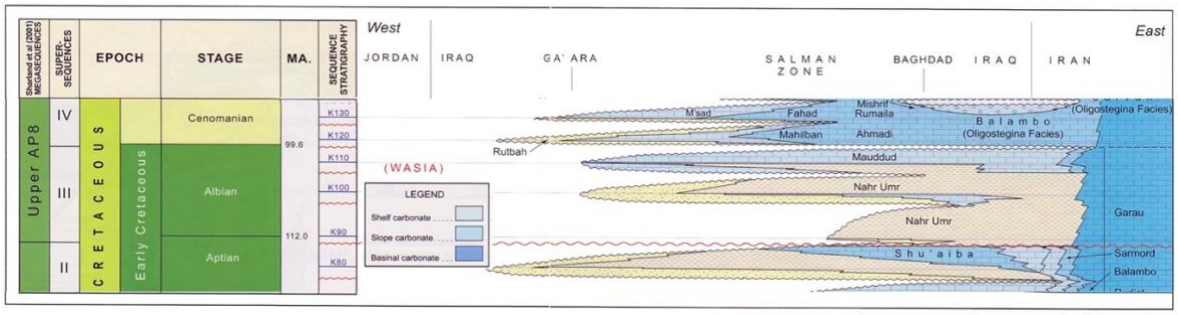

Fig.3. stratigraphic correlation of formation of megasequence Ap8 (Aqrawi et al., 2010)

4. Mauddud Microfacies Analysis

The information from the detailed study are more than 200 thin sections from core and cutting samples for the Mauddud succession, which were selected from 4 boreholes within two oil fields (Ba-4, Ba-8, Ns-2 and Ns-4). In the present study, they were used to interpret the different depositional

environments in the present study as well as the microfacies analysis to identify the sedimentary and stratigraphic frameworks of the sedimentary basin. Seven mainly microfacies were diagnosed in the Mauddud sequence; their characteristic the type of grains and sedimentary textures enabled to identified of paleoenvironments, according to Dunham (1960); Wilson (1975) and Flugel (2010).

4.1. Microfacies A: Orbitolina Wackestone-Packstone

The first microfacies is including the *orbitolina* sp. with some bioclasts of mollusk and rudist, in addition to echinoderm and calcareous green algae. This may refer to deposition in the shallow open marine environment (Plt. 1.A and 1.B). The microfacies A distribution is observerd in middle and upper parts of studied succession within Balad and Nasiriyah oil fields (Tables 2 and 3).

4.2. Microfacies B: Orbitolina with Miliolids Wackestone

This microfacies is consisting mainly of orbitiolina with miliolids in additional to bioclasts of mollusks, echinoderm and pellets with calcareous green algae. The facies B refer to deposition in shallow open marine environment (Plt.1.C and 1.D). This microfacies is appered in lower part of studied succession within Balad and Nasiriyah oil fields (Tables 2 and 3).

4.3. Microfacies C: Bioclast Mollusk and Echinoderms Wackestone-Packstone

The main compounds in this facies are bioclasts of mollusk and echinoderm, with *Nezzazata* sp. and other bioclasts. This microfacies is reflecting the deposition in restricted to semi-restricted environment (Plt. 1.E and 1.F). This microfacies is showed in middle and upper parts of Mauddud in studied wells (Tables 2 and 3).

4.4. Microfacies D: Peloidal / Pelletal - Echinoderm Wackestone-Packstone

The microfacies D is mainly composed of peloid, rudist bioclasts, calcareous green algae with less abundant of miliolids (Plt.2.G and 2.H). There are two submicrofacies in microfacies:

- Peloids wackestone to packstone with good rounding grains, which are characterized by biform sized and ovoidal shaped, with the predominance of coarse to fine particles sized and moderate sorting peloid.
- Pellets wackestone to packstone is characterizing by the dominance of the uniform small grain sized of the pellets and by their consisting of silt grain sized and well sorting pellets (Plt.2.D).

This microfacies indicate to deposition in the restricted environment, which evaluated the Mauddud succession deposition. This facies represents a lower part of the Mauddud Formation in Balad and Nasiriyah oil field (Tables 2 and 3)

4.5. Microfacies E: Milliolid-Peloidal Grainstone

There are two submicrofacies types in this microfacies were identified in this sequence, peloids grainstone, and ooidal and peloidal grainstone with quartz content. In addition to oolites and peloids it composed of intraclast particles, bioclasts, and benthonic foraminifera. This microfacies is representing the deposition in back-reef environment (Plt. 2.A and 2.B). the microfacies E is disappeared in Ba-8 and appeared upper most part in Ba-4, while in Nasiriyah oil field is observed in lower part (Tables 2 and 3).

4.6. Microfacies F: Bioclastic Wackestone - Packstone

This microfacies were observed in the succession as fragmented rudist bioclast , intraclasts and ehinoderms. In additional to small benthic foraminifera. Microfacies (E) is representing slope environment (Plt. 2.C and 2.D). This microfacies is showed in upper most of Mauddud Formation in Balad oil field, and its appeared in all part of this succession within Nasiriyah oil field (Tables 2 and 3).

4.7. Microfacies G: Planktonic Foraminifera Packstone

This is a less common which shows in the upper part of the Mauddud succession, which composed of ooze and calcisphere with shally and marly limestones (Plt. 2.E and 2.F). This faces is identify through high values of gamma ray well log reflection, in addition to diagnostic by thin sections. The microfacies F is representing the deposition in environments ranging from an open deep marine to basinal (Plt. 2.G and 2.H). The microfacies G is appeared in middle part of Mauddud Formation within Balad oil field, while in Nasiriyah oil fied is showed in lower part (Tables 2 and 3).

Table 2. Deposionl environments distribution for the Mauddud Formation in Balad oil field

Ba-4	From	to	Depositional environments
	2840	2845	Slope
	2845	2875	Shallow open
	2875	2923	Restricted
Maudud	2923	2925	Back reef
	2925	2945	Slope
	2945	2950	Deep open
	2950	2995	Shallow open
Ba-8	From	to	Depositional environments
	2870	2875	Slope
	2875	2895	Restricted
	2895	2965	Shallow open
	2965	2980	Slope
	2980	2990	Deep 0pen
Maudud	2990	3025	Shallow open
	3025	3050	Restricted
	3050	3095	Shallow open
	3095	3120	Slope
	3120	3150	Shallow open

Table 3. Deposionl environments distribution for Mauddud Formation in Nasiriyah oil field..

Na-2	From	To	Depositional environments
	2240	2245	Slope
	2245	2260	Shallow open
	2260	2265	Restricted
	2265	2305	Shallow open
	2305	2310	Restricted
Mauddud	2310	2340	Shallow open
	2340	2345	Back reef
	2345	2360	Restricted
	2360	2380	Back reef
	2380	2390	Shallow open
Na-4	From	To	Depositional environments
	2245	2250	Slope
	2250	2260	Shallow open
	2260	2275	Restricted
	2275	2325	Shallow open
	2325	2330	Restricted
Mauddud	2330	2340	Shallow open
	2340	2355	Back-reef
	2355	2365	Restricted
	2365	2390	Back-reef
	2390	2400	Shallow open

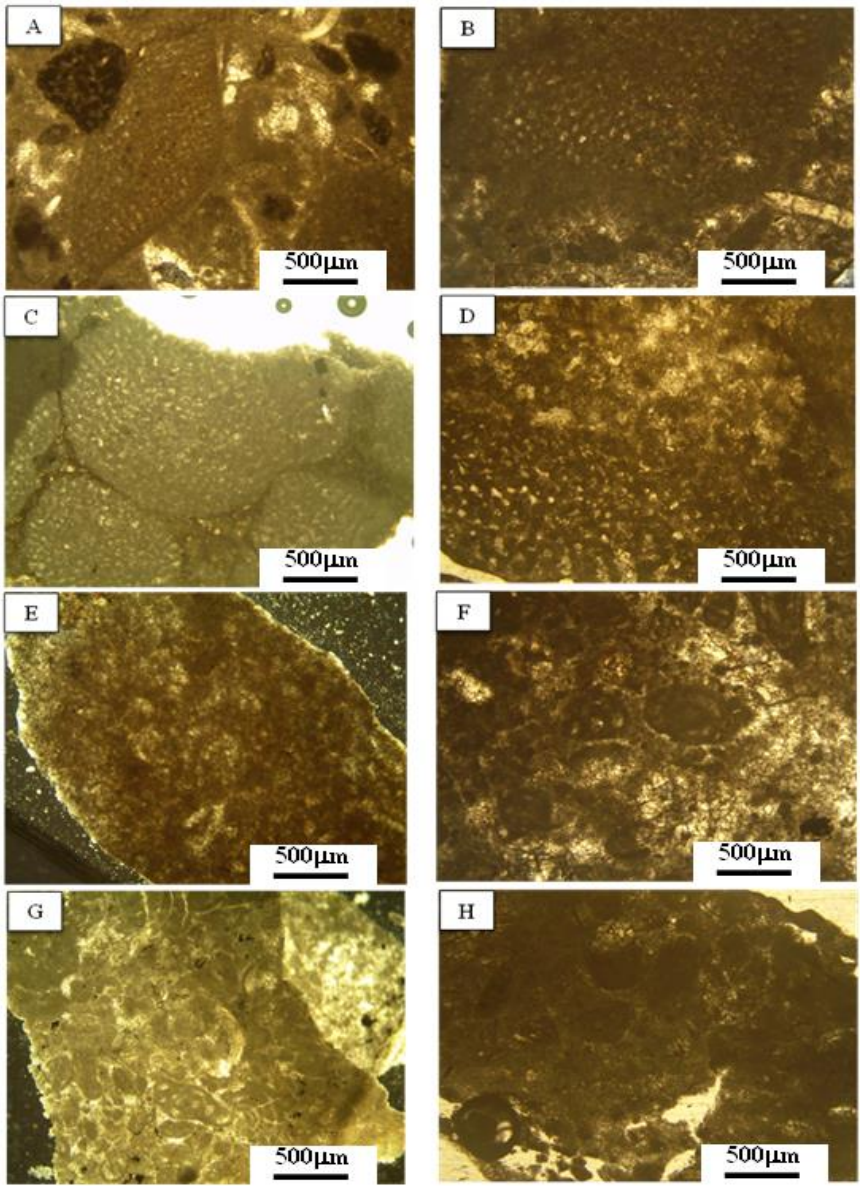

Plate 1. Microfacies types of the Mauddud Formation

A. Orbitolina - miliolids wackestone to packstone, Mauddud Formation, Ba-4 (3108-13 m)

B. Orbitolina - miliolids wackestone to packstone, Mauddud Formation, Ns-2 (2290 m)

C. Orbitolina wackestone to packstone (Mauddud Formation, Ba-8(2896 m)

D. Orbitolina wackestone to packstone (Mauddud Formation, Ns-4(3127 m)

E. Miliolids wackestone (Mauddud Formation, Ba-4(2885 m)

F. Miliolids wackestone (Mauddud Formation, Ns-4 (2290 m)

G. Peloidal wackestone to packstone, Mauddud Formation, Ba-8(2925 m)

H. Peloidal wackestone to packstone, Mauddud Formation, Ns-2 (2296 m)

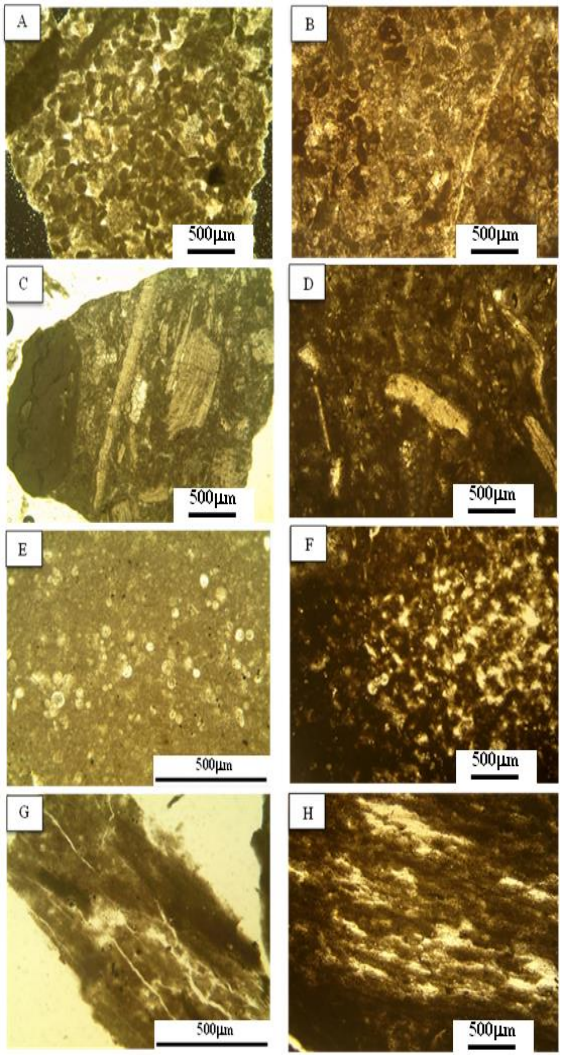

Plate 2. Microfacies types of the Mauddud Formation

A. Milliolid to Peloids grainstone (Mauddud Formation, Ba-8(3071 m)
B. Milliolid to Peloids grainstone (Mauddud Formation, Ns-2 (2280 m)
C. Bioclastic Wackestone - Packstone (Mauddud Formation, Ba-8(2965 m)
D. Bioclastic Wackestone - Packstone (Mauddud Formation, Ns-4 (2286 m)
E. Planktonic wackestone to packestone, Mauddud Formation, Ba-8(2970 m)
F. Planktonic wackestone to packestone, Mauddud Formation, Ns-4 (2341 m)
G. Basinal marl and green shale (Mauddud Formation, Ba-8(3314 m)
H. Basinal marl and green shale (Mauddud Formation Ns-2 (2220 m)

5. Nahr Umr Lithofacies Analysis

The sedimentology of the clastic succession based on interplaying of the tectonic activity, changes of sea level, accumulation rates of sediments supply, physical and biological processes of the sediments transportation and deposition, and climatic effects. These processes interact to produce the geometry arrangements and the distribution of varied depositional environments or sequence tracts through the times, known as the architecture stratigraphy of the sedimentary basin (Miall, 1991).

The first step in lithofacies analysis of clastics succession are the identification and interpretation of the available conventional samples of core (Siemers, and Tillman, 1981). The important results of the core descriptions are subdivided and classified of core samples into lithofacies, defined as sedimentary successions depending on the lithologic type, mode of grain size, physically and biogenetic of the

sedimentary structure and stratifications. That represented the direct relationships to the processes of deposition and environments those producing them. The lithofacies types and facies association are the rock units for the identification of the depositional environment (Fig.4).

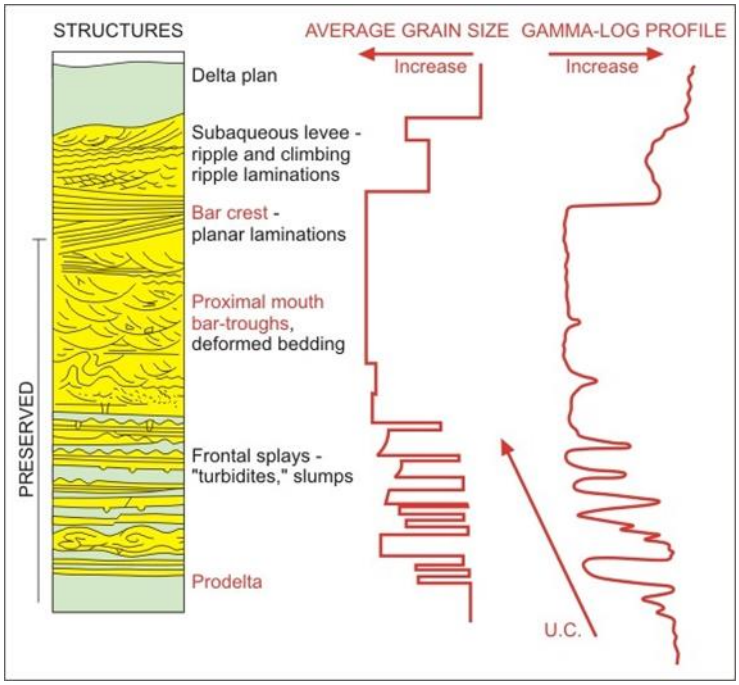

Fig.4. Vertical facies distribution from well logs or sample core or outcrop, modified from Galloway and Hobday (1996)

According to these parameters the Nahr Umr succession divided in to five lithofacies in the studied boreholes (Figs. 5 ,6 , 7 and 8).

5.1. Lithofacies I (Quartz Arenite Well Sorting Sandstone Lithofacies)

this lithofacies is characterized by fine grain sized, well sorted sandstones, with shape of grains which ranging from sub-angular to sub-rounded. The sandstones in this lithofacies are consist of more than 90% of quartz grains to classifying as quartz arenite sandstones. This lithofacies is observed in the middle part of Nahr Umr succession with recording a very low values of GR and high value of sonic log as a box shaped mode (Plt. 3.A).

5.2. Lithofacies II (Quartz Arenite Poorly Sorting Sandstones Lithofacies)

It is characterizing by wide grain size range of sand-sized which ranging from fine to coarse, with well rounding to sub-rounded shaped. The sandstones in this lithofacies is consist of more than 90% of quartz grains to classifying as a quartz arenite which showed in the upper rock unit of Nahr Umr succession. This is characterized by poorly sorted with very low amounts of GR which decreasing upward as a bell shape and low values of sonic well log (Plt. 3.B).

5.3. Lithofacies III (Graywacke Poorly Sorting Sandstones Lithofacies)

The third lithofacies is represented a mud-bearing sandstone dominated rocks which mainly including of quartz minerals, with characterizing by poorly sorting graywacke sandstones (Plt. 3.C). This appeared a moderate amounts of GR log as funnel shape. The lithofacies III is observed in the upper rock unit of the Nahr Umr succession.

5.4. Lithofacies IV (Sandy mudstone)

The fourth lithofacies is observed in the sandstones parts as shale lenses, which characterizing by high volume of shale as funnel shaped. The major components of this lithofacies is mudstone dominated rock units with grains of quartz which characterizing by angular shaped of grains (Plt. 3.D).

5.5. Lithfacies V (Shale/mudstone)

This facies is showed in all units of Nahr Umr sequence. It is characterizing mainly by shale rocks (Plate7- E) with high amounts of GR log as a bell shape.

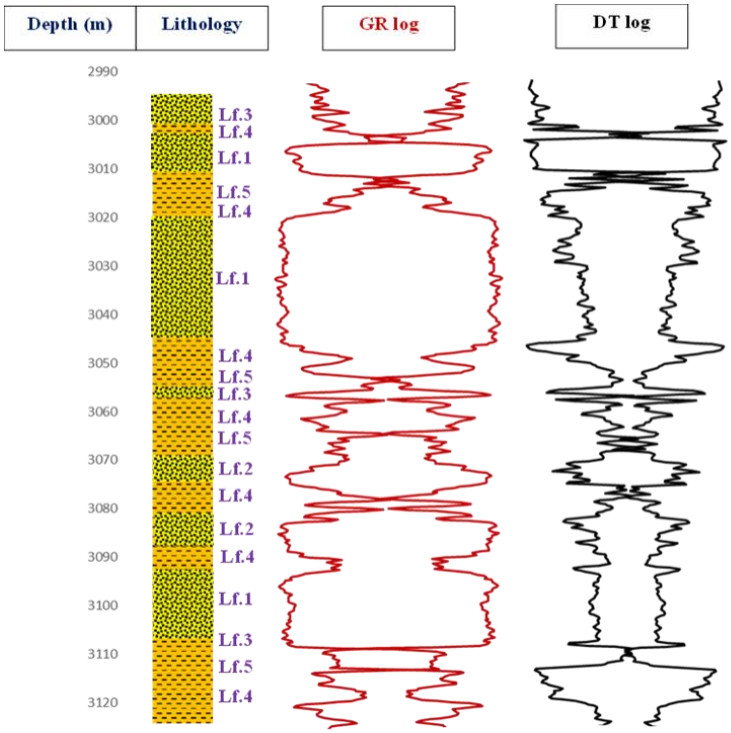

Fig.5. Lithofacies and electrofacies of Nahr Umr succession in Ba-4

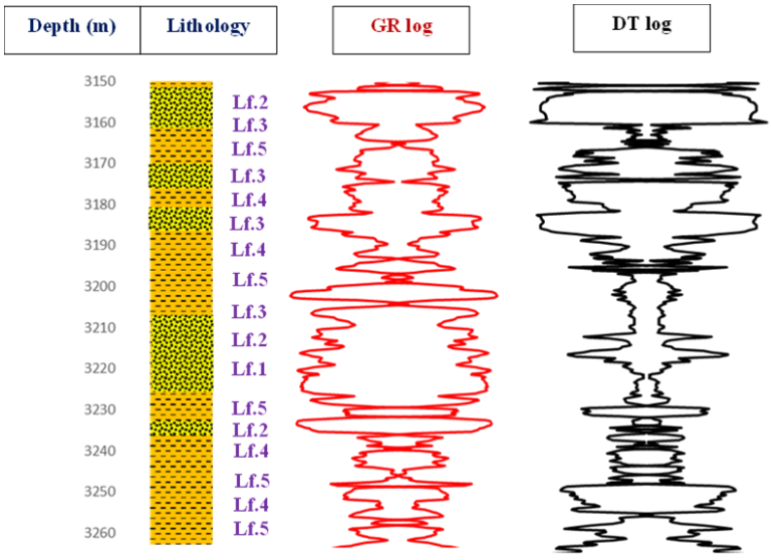

Fig.6. Lithofacies and electrofacies of Nahr Umr succession in Ba-8

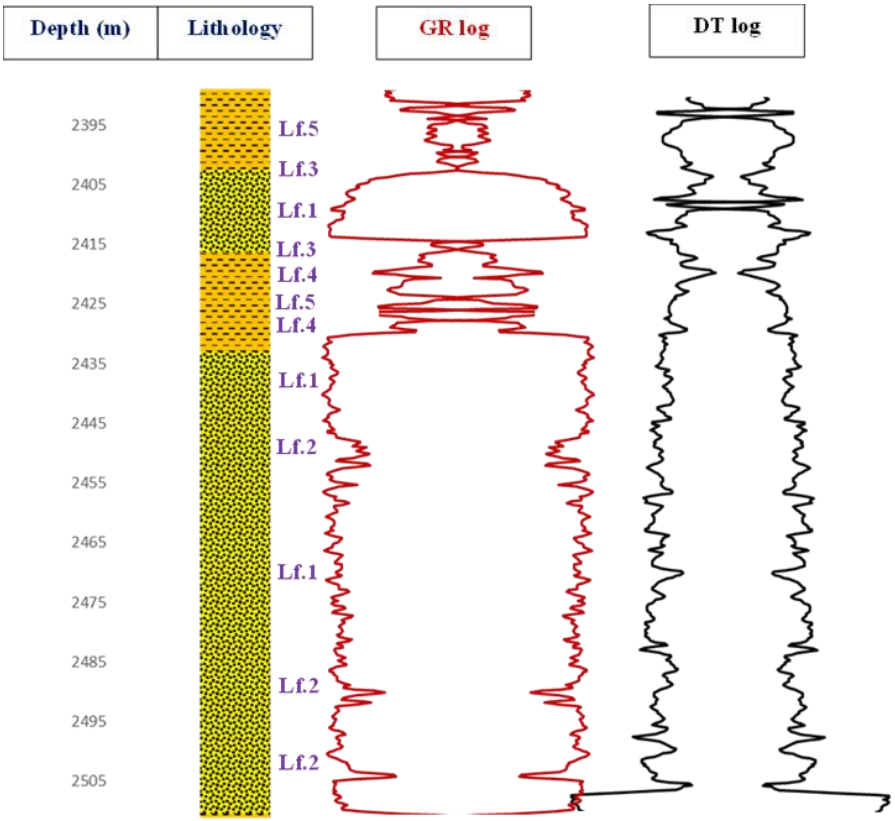

Fig.7. Lithofacies and electrofacies of Nahr Umr succession in Ns-2.

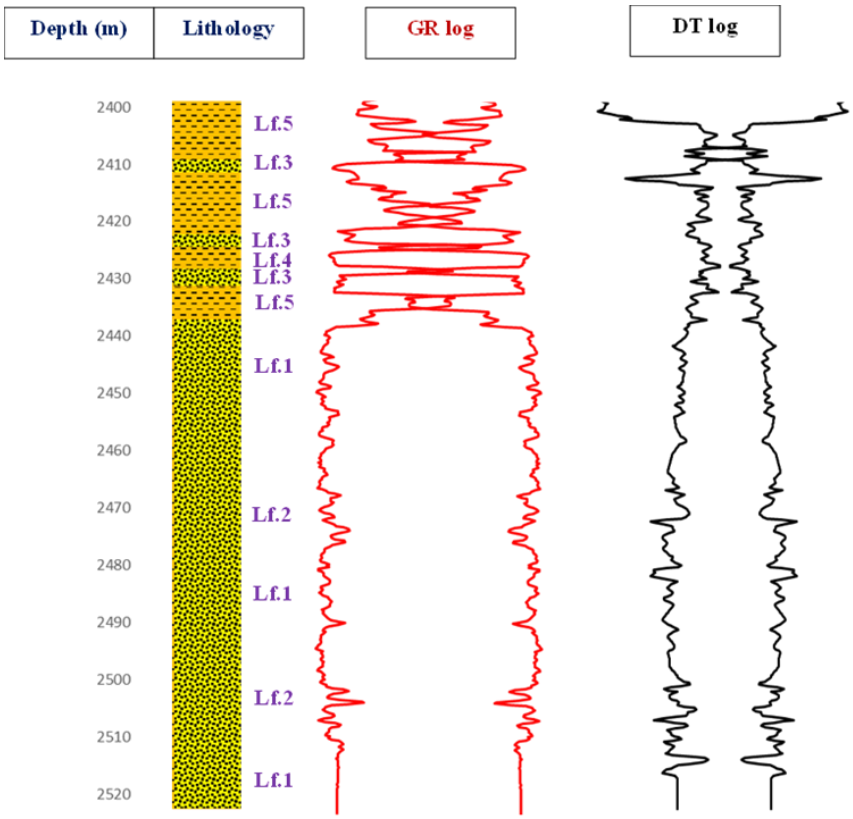

Fig.8. Lithofacies and electrofacies of Nahr Umr succession in Ns-4

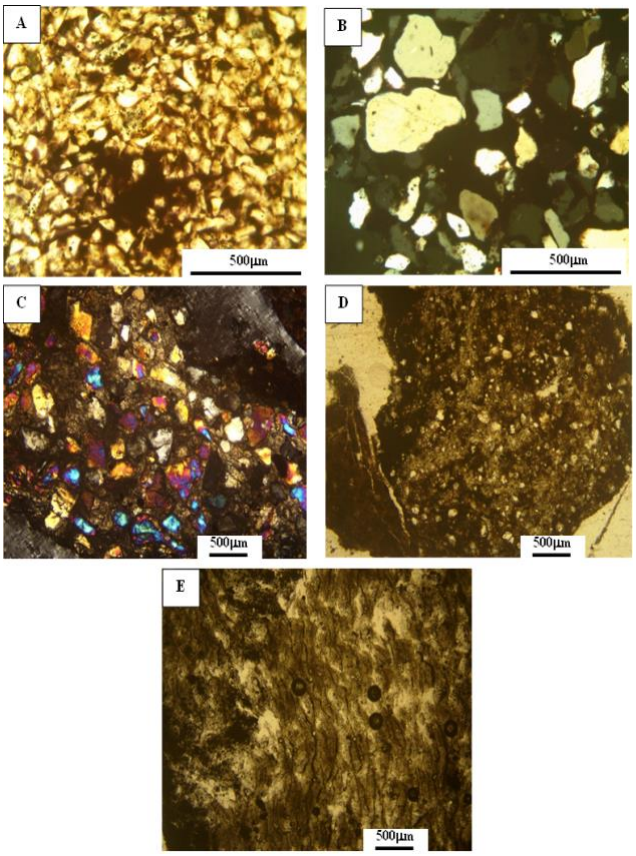

Plate 3. Lithofacies types of the Nahr Umr Formation
A. Well sorting quartz arenite lithofacies (Ba-4, 3064 m),
B. Poorly sorting Quartz arenite lithofacies (Ba-4, 3064 m),
C. Graywacke sandstone lithofacies (Ns-2, 2949 m),
D. Sandy shale Lithofacies (Ns-2, 2943 m),
E. Shale Lithfacies (Ns-4, 2278 m),

6. Stratigraphic Development

The studied succession in Balad oil field represents two 3rd order and four 4th order cycles (A1, A2, A3 and A4). These cycles are asymmetrical and start with cycle (A1) where the Backshore facies in Lower Mauddud Formation represents the transgressive system tract (TST) and then the highstand system tract (HST) bounded below by a transgressive surface (TS) which coinside with the unconformable surface (SB1) with the underlying Shuaiba succession. The highstand system tract of cycle (A1) is reflected by the distributary channel facies (Fig.9).

The second cycle (A2) is reflected by the shallow open marine facies within Mauddud succession. represents thick TST and then appear HST which reflected by the restricted facies. abounded by a TS reflected by shallow open marine facies in the facies TST. Cycle (A3) is reflected by the shallow open marine facies. represents thick TST and then appear the HST which reflected by the restricted facies. Cycle A4 is reflected by the restricted facies and slope represents thick TST. In Nasyria oil field, the studied succession represents two 3rd order cycles and three 3rd order cycles (A1, A2 and A4) with absence of an A3 cycle (Fig.9). These cycles are asymmetrical and starts with cycle (A1) where the distributary channel in the lower part of Nahr Umr succession represents the TST bounded below by an unconformable surface (SB1) with the underlying Shuaiba succession. The highstand system tract of cycle (A1) is reflected by shallowing upward for distributary channels, bay fill, and back-sore facies of the Nahr Umr Formation. This relatively thick parasequence reflects a time of sea level stillstand where tectonic subsidence is the major controlling factor in producing the necessary accommodation for thick

aggregational to progradation clastic succession to deposit. The second cycle (A2) is also asymmetrical and represented by a relatively thin transgressive systems tract reflected by the shallow open marine of the lower part of Mauddud Formation, which is bounded below with Nahr Umr succession by TS. And above by maximum flooding with the overlying back-reef facies within Mauddud Formation as three cycle of HST. This reflected by restricted with alternative with shallow open an back-reef association facies bounded above by a TS which represent A4 cycle as slope facies. This cycles also reflects successive periods of sea level rise and stillstand where tectonism is also the major controlling factors on its development, it is bounded above by a transgressive surface with the upper part of Mauddud Formation.

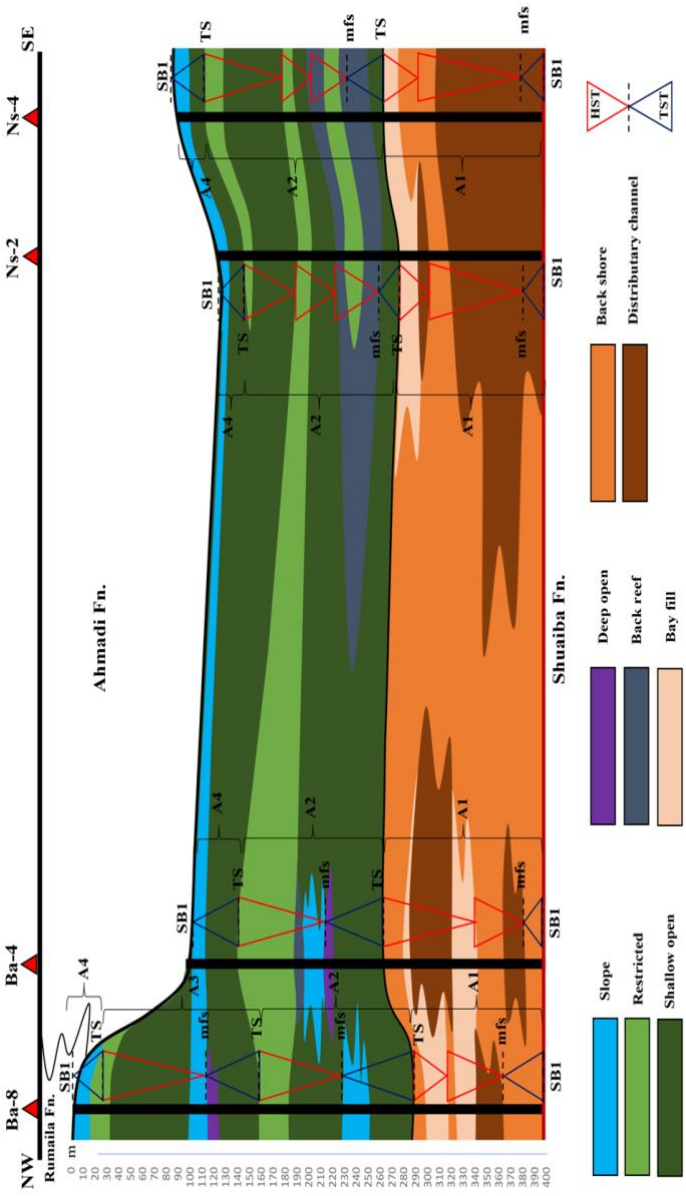

Fig.9. Stratigraphic cross section showing the facies distribution and sequence cycles for studied oil fields

7. Conclusions

Seven major microfacies were diagnosed in the Mauddud succession, while the Nar Umr Formation includes five lithofacies; their grain types characteristic and depositional textures enabled us to

recognize paleoenvironments. These microfacies were deposited in restricted, shallow open marine, back-reef, slope and deep open marine for Mauddud succession. While in Nahr Umr the lithofacies were deposited in bay fill, back-shore and distributary channel.

The studied succession in Balad oil field which represents two 3rd order and four 4th order cycles (A1, A2, A3 and A4). These cycles are asymmetrical and starts with cycle (A1) where the Backshore facies in the Lower Mauddud Formation represents the TST and then appear the hightstand systems tract HST bounded below by a TS which coinside with the unconformable surface (SB1) with the underlying Shuaiba Formation.In Nasyria oil field the studied succession represents two 3rd order cycles and three 3rd order cycles (A1, A2 and A4) with absence of A3 cycle. These cycles are asymmetrical and starts with cycle (A1) where the distributary channel in the lower part of Nahr Umr succession represents the TST bounded below by unconformable surface (SB1) with the underlying Shuaiba Formation. The highstand systems tract of cycle A1 is reflected by shallowing upward for distributary channel, bay fill and back-sore facies of the Nahr Umr Formation. This relatively thick parasequence reflect time of sea level stillstand where tectonic subsidence is the major controlling factor on producing the necessary accommodation for thick aggregational to progradation clastic succession to deposit.

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