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Facies Architecture and Diagenetic Features Development of Albian-Early Turonian Succession in Luhais Oil field, Southern Iraq

Noor Jawad Abid, Saad S. Al-Shaikhly*, Aiad Ali H. Al-Zaidy
Department of Geology, College of Science, Baghdad University, Baghdad, Iraq

Abstract

Clastic-carbonate succession which including the Nahr Umr and Mauddud Formations are represented a part of Albian-Early Turonian Sequence (Wasi`a Group). The present study includes Petrography, microfacies analysis, depositional environment, digenetic development, and reservoir characterization for seven boreholes (Lu-2, Lu-4, Lu-5, Lu-8, Lu-13, Lu-14 and Lu-39) within Luhais Oil field South Iraq.

There are six type of carbonate microfacies were recognized in the Mauddud Formation:- *Orbitolina* - Milliolids wackestone to packstone *Orbitolina* wackestone to packstone, miliolids wackestone, Peloidal wackestone to packstone, Ooides to Peloids grainstone and bioclastic Wackestone - Packstone. These microfacies are represented three depositional environments: restricted shallow marine environment, semi-restricted shallow marine environment and Shoal environments. While the Nahr Umr Formation characterized by six lithofacies; Lithofacies I (Mudstone), Lithofacies II (Siltstone - Claystone), Lithofacies III (Lenticular Bedded Sandstone-Mudstone), Lithofacies IV (Falser Bedded Mudstone - Sandstone), Lithofacies V (Parallel Lamination Sandstone - Siltstone) and Lithofacies VI (Well sorted sandstone). These lithofacies are suggested four depositional environment of Nahr Umr Formation: Active channel environment, channel fill environment, delta plain environment and delta front and shore face environment.

The most common diagenetic features observed and distribution in the studied sections includes Micritization, Cementation, Leaching (dissolution), dolomitization and Compaction fabrics. The most effective diagenetic processes were cementation, dissolution and dolomitization processes which have direct affect upon the study sections.

The Nahr Umr and Mauddud sequence can be divided by the gamma ray and shale value into three zones (A, B and C); therefore we have interpretation of the logs porosity and porosity evaluation according to these divisions.

Keywords: Facies Architecture, Diagenetic Development, Albian-Early Turonian and Luhais Oil field

البنية السحنية وتطور المظاهر التحويرية لتتابع الابين– التوروني المتقدم في حقل اللحيس النفطي جنوب العراق

نور جواد عبد، سعد سامي الشيخلي*، اياد علي حسين الزيدي
قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق[1]

*Email: aiadgeo@yahoo.com

الخلاصة

أن التتابع ألفتاتي _الكاربوني الذي يتألف من تكويني نهر عمر ومودود يمثل جزء من دورة الالبين _التوروني المتقدم (مجموعة وسيعة) أما الدراسة الحالية تتضمن دراسة طبوغرافية وتحليل سحنات وبيئة رسوبية وتطور العمليات التحويرية ودراسة الخواص المكمنية لسبعة أبار نفطية (2,4,5,8,13,14,39) في حقل اللحيس النفطي في جنوب العراق.

تم تمييز ستة أنواع من السحنات الصخرية في تكوين مودود:-

(*Orbitolina* - Milliolids wackestone to packstone *Orbitolina* wackestone to packstone, miliolids wackestone, Peloidal wackestone to packstone, Ooides to Peloids grainstone and bioclastic Wackestone-Packstone).

وهذه السحنات تمثل الترسبات في ثلاث بيئات ترسيبية : البحرالمفتوح الضحل وشبه الضحل المحجوز وبيئة الحاجز الرمليK بينما يتميز تكوين نهر عمر بستة سحنات صخرية: -

Bedded (Mudstone Lithofacies, Siltstone-Claystone Lithofacies, Lenticular Sandstone – Mudstone Lithofacies and Falser Bedded Mudstone – Sandstone Lithofacies).

حيث تمثل هذه السحنات الترسيب في بيئة القناة الفعالة وترسبات ملئ القناة ومقدمة الدلتا وواجهة الساحل.

فإن الخواص التحويرية الأكثر شيوعا في التتابع المدروس هي المكرتة والسمنتة والاذابة والدلمتة والتراص. والأكثر تأثيرا هي السمنتة والاذابة والدلمتة والتي تؤثر بشكل مباشر وواضح في الخواص البتروفيزياوية للتتابع المدرس.

Introduction

Clastic-carbonate succession which including the Nahr Umr and Mauddud Formations are represented a part of Albian-Early Turonian Sequence (Wasi`a Group).

The Nahr Umr Formation was defined by Glynn Jones 1948 in [1] from the Nahr Umr structure in South Iraq. The two major depocentres in central and South Iraq correspond to areas which received elastics from the Rutba Uplift and the Arabian Shield. In its type area in Southern Iraq, the Nahr Umr Formation comprises black shale sinter bedded with medium to fine grained sandstones with lignite, amber, and pyrite [1].

The Mauddud Formation includes the Upper part of Qamchuqa Formation and is the most widespread Lower Cretaceous formation in Iraq. Its thickness varies due to lateral facies changes and erosional truncation. At outcrop in NE Iraq the Qamchuqa Formation comprises organodetrital, detrital and locally argillaceous limestones with variable degrees of dolomitization [1]. In some areas fresh- or brackish-water limestone beds were reported [1]. In Southern Iraq, the Mauddud Formation comprises frequently dolomitised organodetrital limestone.

The study area is located in the Southern of Iraq (Luhais oil field), within the Mesopotamian basin at the stable shelf figure 1. The studied oil field is located in the southern desert, about 90 km south-west of the city of Basra, which lies about of 50 km southwest of the Northern Rumaila oil field.

The present study involves Facies analysis and depositional environment interpretation, Study of the petro physical properties of the Mauddud and Nahr Umr Formations, and the effects of diagenetic development on reservoir properties, with construction of a reservoir model for these formations.

Methodology

This include many stages of work

- **a-** Sampling for the collected borehole(Lu-2, 4, 5, 8, 13, 14 and 39), as core and cutting.
- **b-** Filed description as well as detailed core and cutting examination
- **c-** Thin section examination and microfacies analysis.
- **d-** Study of the available well logs and relate the log response to facies and digenetic changes.

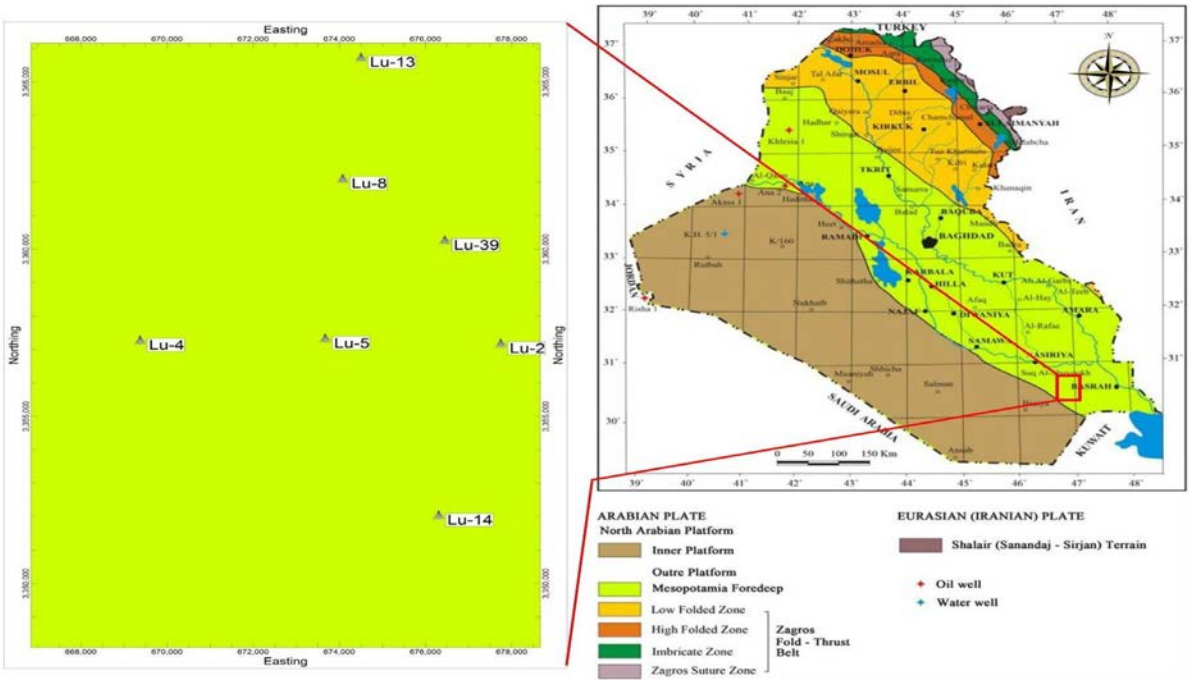

Figure 1- location and tectonic map of studied area

Microfacies Analysis

There are several types of microfacies were recognized in the succession of the Mauddud and Nahr Umr Formation; their characteristic grain types and depositional texture enabled the recognition of paleoenvironment.

Microfacies (1)

Orbitolina- miliolids wackestone to packstone this facies is mainly composed of *Orbitiolina* and miliolids in addition to shell fragments (mollusk), echinoderms, pellets and calcareous algae. The *Orbitolina*- Milliolids wackestone to packstone is the main microfacies which reflect open marine conditions [2 and 3], (Plt. 1f).

Microfacies (2)

Orbitolina wackestone to packstone the second most common microfacies is the *Orbitolina*–bearing limestone. With few shell fragments (mollusk &rudist), echinoderm and calcareous algae, but the microfacies with the Milliolids as the major component may refer to a more shallow environment [4]. This may reflect open marine environment (Plt. 1a).

Microfacies (3)

Miliolids wackestone the main constituents are miliolids, with few *Nezzazata* and small benthic foraminifera, and echinoderm fragments and algae. This microfacies reflects a restricted shallow environment (Plt. 1b). , but the microfacies with the *Orbitolina* as the major component may refer to more shallow environment [4].

Microfacies (4)

Peloidal wackestone to packstone with limited diversity it may reflect a very low energy environment [3], (Plt. 1c). Peloidal wackestone to packstone rounded grains are inferred, from their biform size, ovoid shape where the dominance of relatively coarse to fine (sand sized) and moderate sorted peloids and Pelletal wackestone to packstone is characterized by the abundance of the uniformly small particle size and consistent shape of these grains (silt sized well sorted pellets) .

Microfacies (5)

Ooides to Peloids grainstone. In addition to oolite and peloids it consists of intraclasts, shellfragments, benthic foraminifera and others. This microfacies is representing the shoal environment.

Microfacies(6)

Bioclastic Wackestone – Packstone**,** these assemblages with benthonic foraminifera, which representing Orbitolina. This facies is recognized by echinoid spines, molluscan shell fragments, Bryozoa, Rudestand some algal debris, this microfacies reflects an open marine environment (Plt. 1d).

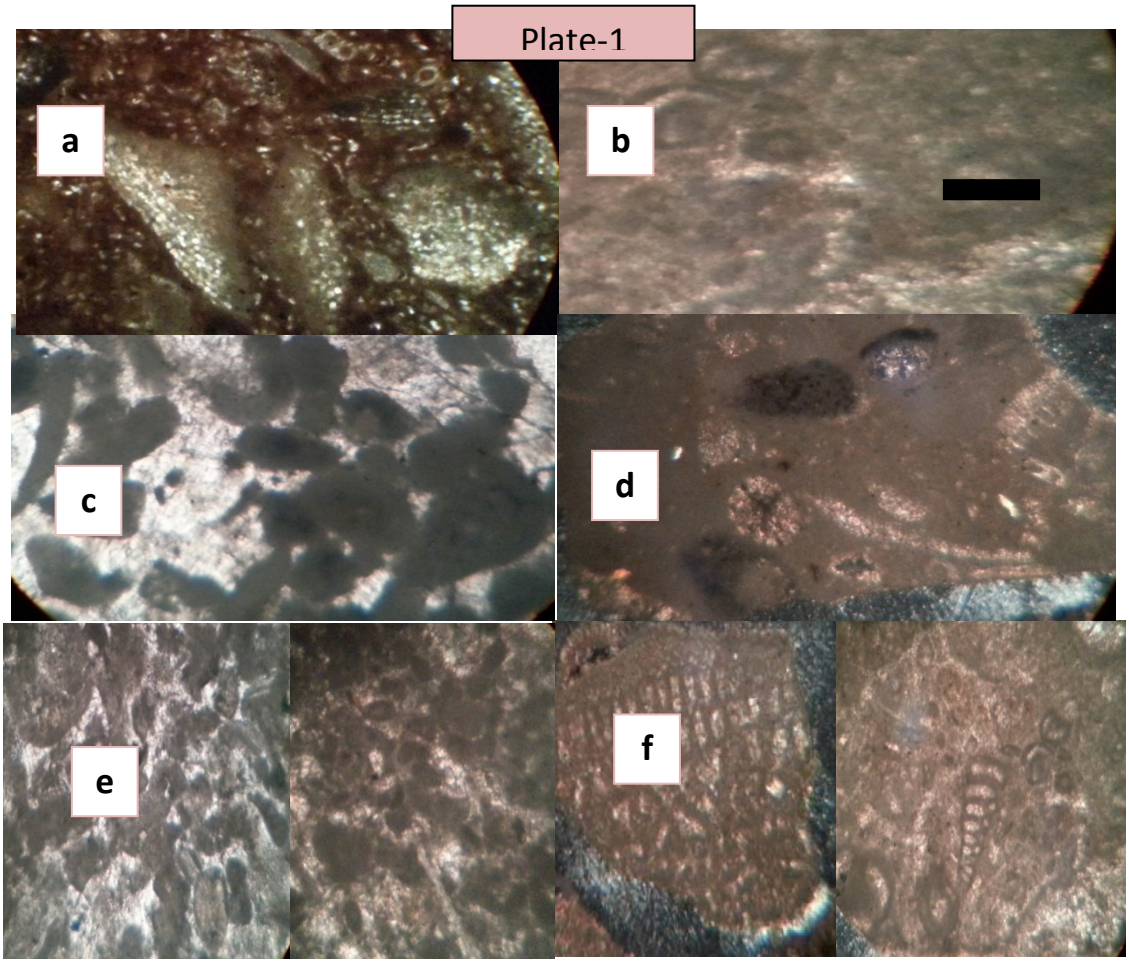

Figure 2- Show the digenesis process and porosity percentage for A. Lu-**13-** and B. Lu-**14-**
a- *Orbitolina*wackestone to packstonemicrofacies.(NahrUmrFormtion,Luhais-2, 2535m).
b- Miliolidswackestonemicrofacies.(Mauddu Formation,Luhais-2,2430m).
c- Peloidalwackestone to packstonemicrofacies.(Mauddud Formation,Luhais-14, 2450m).
d- BioclasticWackestone – Packstonmicrofacies. (Mauddud Formation,Luhaise-13, 2440m).
e-Peloidalwackestone to packstonemicrofacies.(Mauddud Formation,Luhais-8, 2430m).
f- *Orbitolina* - miliolidswackestone to packstonemicrofaices.(Mauddud Formation, Luhais-14,2430).

Lithofacies of Nahr Umr Formation

Two types of rocks are observed within the Nahr Umr Formation; the first is the upper part which characterized by clay dominated rocks and the second (lower part) is characterized by sand dominated rocks. These rocks classified into six lithofacies according to the lithology, particle sizes and available sedimentary structures, which recognized by cutting and core observation, thin section description and well logs(Gamma ray, SP and resistivity logs) interpretation.

Lithofacies I (Mudstone)

This facies consists of shale rocks with black color, high fissile and organic material (plant remains). The most important characteristic of this facies is a high density with a high volume of shale (High Gamma ray). This lithofacies is represented the lower part of the clay dominated rocks of Nahr Umr Formation.

LithofaciesII (Siltstone-Claystone)

The siltstone-claystone lithofacies consists of overlying dark gray shale rocks with silt and fine sand, with plant remains, sometimes in red color. The volume of shale here is less than in the first

lithofacies and appeared in the gamma ray log as a rapid decreasing value Figure -2. This lithofacies is represented the upper part of the clay dominated rocks of NahrUmr Formation.

Lithofacies III (Lenticular Bedded Sandstone-Mudstone)

It consists of alternative of sand and mud rocks with agray color, with laminated of soft sandy rocks as a lenticular sand body. The volume of shale is showing increasing upward (fennel shape gamma ray). This lithofacies is described within the upper part of the clay dominated rocks of NahrUmr Formation.

Lithofacies IV (Falser Bedded Mudstone – Sandstone)

This lithofacies consists of sandy rocks (greywackes) with soft granules medium-sized interspersed with shale rocks in the form of flaser bedding. The volume of shale is showing increase immediately (serrated shape gamma ray). This lithofacies is shows in the sand dominated rocks of Nahr Umr Formation as a bar facies.

Lithofacies V (Parallel Lamination Sandstone – Siltstone)

This lithofacies consist mainly of quartz arenite sandstone with grain size ranging of medium-coarse, moderate sorted, rounded to sub-rounded grains. The parallel lamination is the important sedimentary structure which observed within the sand dominated part as fanning upward with the next lithifacies. The gamma ray and SP logs showing serrated shape.

Lithofacies VI (Well sorted sandstone)

This facies consists of coarse quartz arenite sandstone good sorting and showing changes color from light gray to brown. The small scale sedimentary structures are not clear in this lithofacies, exceptional of the grain size grading (finning upwared). This lead to believe that this facies and the previous facies are active channel succession. The SP log showing box shape.

Paleoenvironments

In the present study, there are **six** lithofacies have been recognized within Nahr Umr clastic succession. It represents two types of environments: fluvial and deltaic, According to [5], [6], [7], [8]. In addition to six microfacies with in Mauddud carbonate succession, which represents three depositional environments: open marine, semi-restricted, and shoal environment, figure 2.

Paleoenvironment of Nahr Umr Formation

The clastic units, where represented two types of environments: fluvial and deltaic in Nahr Umr Formation, these succession of Nahr Umr Formation in the study area consist (from bottom to top) of active channel deposit represented by lithofacies(VI- well sorted sand stone) then probable channel fill represented by lithofacies (III-lenticular bedded sandstone-mudstone, IV- falser bedded mudstone-sandstone and V-parallel lamination sandstone-siltstone), the top of the formation consist mainly of two lithfacies I-mudstone and II- siltstone-clay stone.

Active channel environment

Well sorted sandstone lithofacies is the main lithofacies in this environment addition to the well sorted sand stone. The active channel association lithofacies is distinguished and separated from the sand dominated by using the resistivity log (high values) addition to gamma ray and sp logs, figure -2

Channel fill environment

This environment characterized by low energy channl with mud dominated sediment, lenticular bedded sandstone-mudstone, falser bedded mudstone-sandstone and parallel lamination sandstone-siltstone lithofacies are represented this environment. The point par sub- environment is appeard as ahigh gamma ray values (Sp shale-line) within the two above environment.

Delta plain environment

The succession which composed of mudstone and siltstone-clay stone lithofacies is represented the part of delta plain association facies, where showing finning upword.

Palioenvironments of Mauddud Formation

Three main sub environments were recognized with in the Mauddud succession: Theses include open marine, sime-restricted shallow marine and shoal environments.

Open marine environment

This environment is characterized by Peloidal wackestone to packstone and pelletal wackestone to packstone with limited diversity it may reflect a very low energy environment . [3]. The major components are peloids and pellets with few micritized Milliolids and other fragments. It's

characterized by the occurrence of fenesteral porosity, where this reflects the deposition in restricted shallow marine environments.

Semi-restricted shallow marine environment

This environment is represented by Orbitolinawackestone to packstonemicrofacies and Milliolidswackestonemicrofacies. The microfacies with Orbitolinaas main components with few small benthic foraminifera may refer to the semirestricted environment (deep part for this environment), but the microfacies with the Milliolids as the major component may refer to more shallow environment [4].

Shoal environments

One major microfacies characterized the shoal environment, they include; the peloidal grainstone characterized by fine, well sorted peloids and ooidal to peloidal grainstone which consist mainly of ooids and peloids with some bioclasts and benthos. Shoal environment locates in the sixth facieszone (FZ-6) according to Flugel classification [3] that shows the setting of Platform-margin sand shoals above fair-weather wave base and within the euphotic zone and strongly influenced by tidal currents. The Shoal facies was formed in a high energy environment within intertidal conditions.

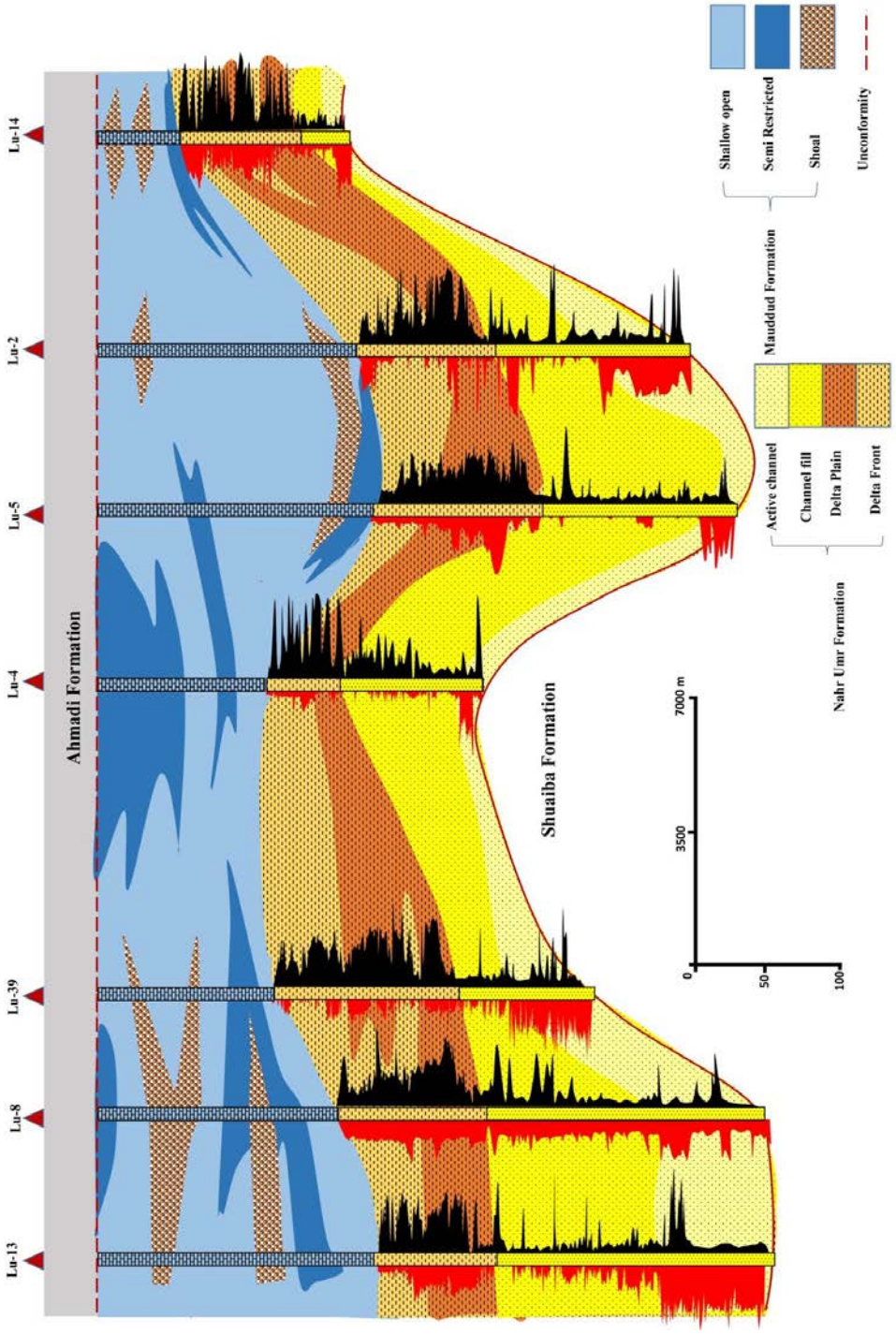

Figure 2- Deposition model of the study area gamma ray (black color)and resistivity (red color)

Digenesis

The term digenesis is used to describe the processes by which unconsolidated sediment is transformed into a rock. So, diagnosis may involve all the changes (textural, physical, chemical and biological) in sediments or sedimentary rocks which occur during and after deposition, but excluding processes involving high enough temperature and pressure to be called metamorphism [9]. The most common diagenetic features observed in the studied sections include Micritization, Cementation, Leaching (dissolution), Dolomitization and Compaction fabrics. The most effective diagenetic processes were cementation, dissolution and dolomitization processes which have direct effect upon the study sections figures -3,-4,-5 and -6.

The digenesis features are development from early to late digenesis stage according to location of each studied wells. Therefore we observed the following:-

Nahr Umr succession

The volum of shale in the Nahr Umr is the major control upper the porosity within the shale (mud) dominated part.

The late cementation is distinguished the sand member in this succession, addition to compaction process at the southern part of studied area (Lu-4, Lu-14). While in the north part shoes the early-moderate digenesis stage which represented by clay and calcite cement (coated grain cement) with high porosity without connected (low permeability).

The digenesis features in the north part of the studied area not clear because the increasing of shale volume which effecting upon the porosity and permeability.

Mauddud succession

The lower part of the Mauddud Formation is shown the late digenetic features, which represented by high cementation and saddle dolomite. This case causes destroyed the porosity within the lower part of Mauddud Formation.

This does not apply to the Lu-5 and Lu-2 which characterized by high porosity (low cementation of shoal deposits).

The upper part of Mauddud Formation is characterized by high dissolution (high porosity) during the moderate-late digenesis stage. This zone is distribution within all studied.

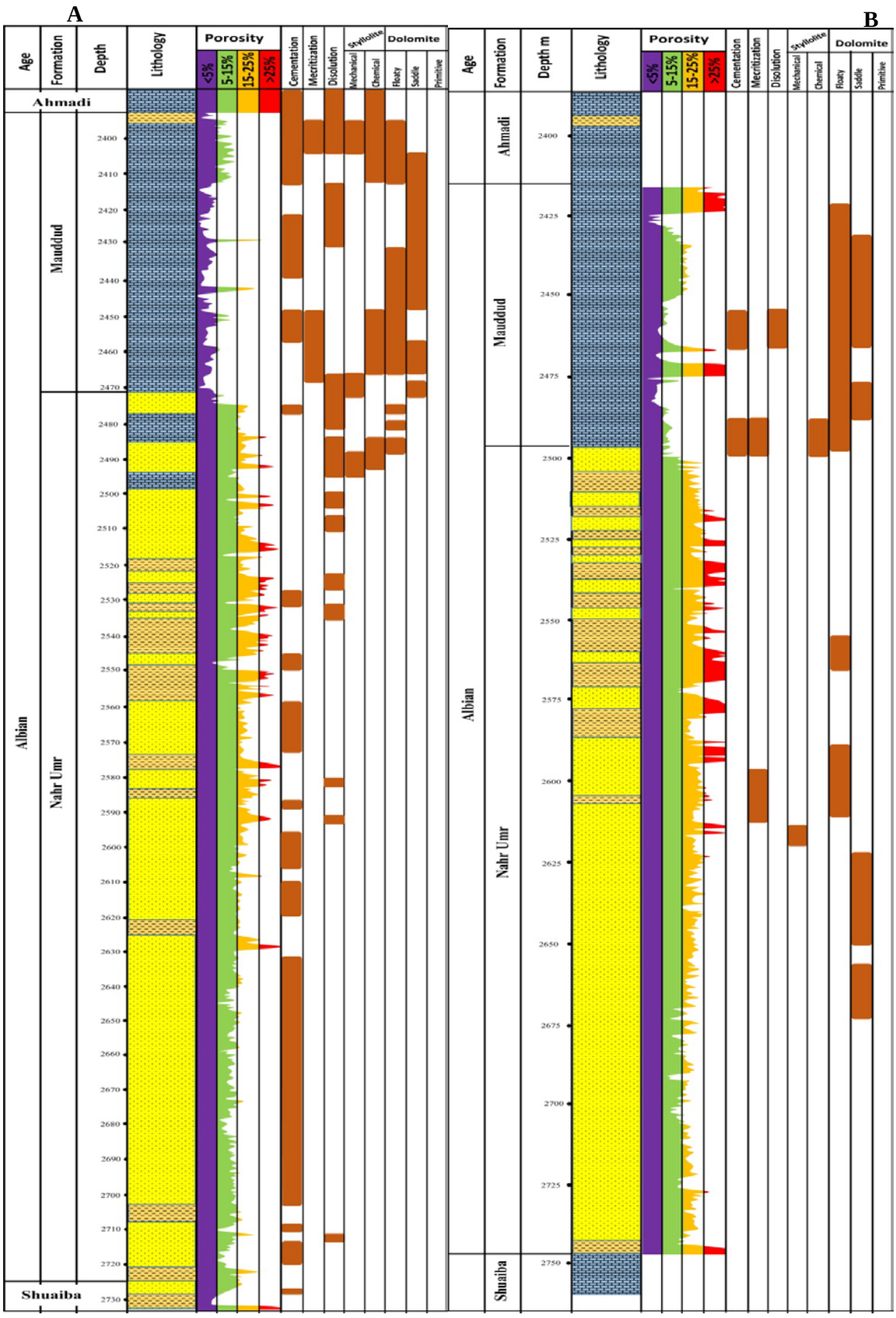

Figure 3- Show the digenesis process and porosity percentage for A. Lu-2 and B. Lu-4

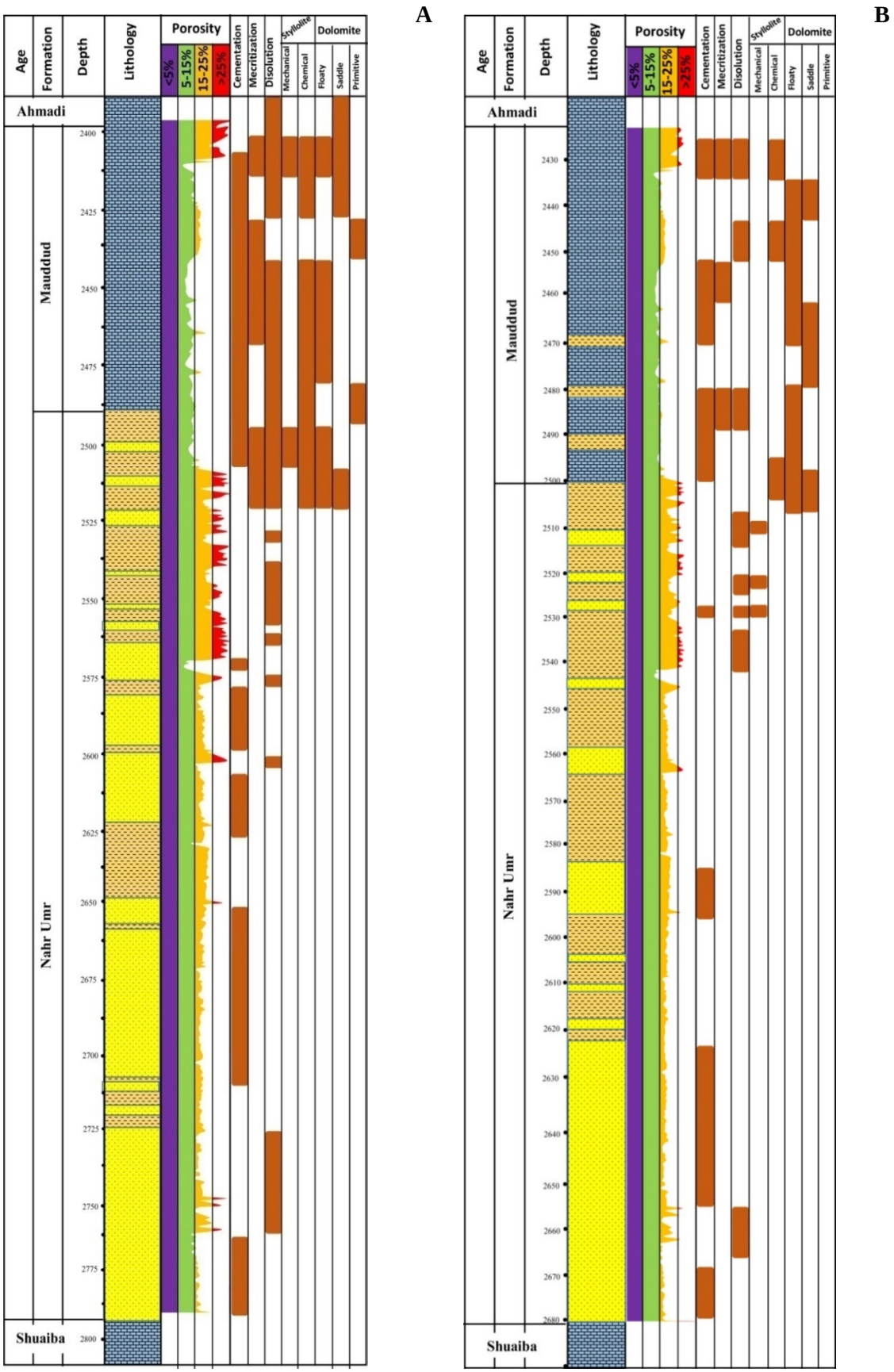

Figure 4- Show the digenesis process and porosity percentage for A. Lu- 5 and B. Lu-8

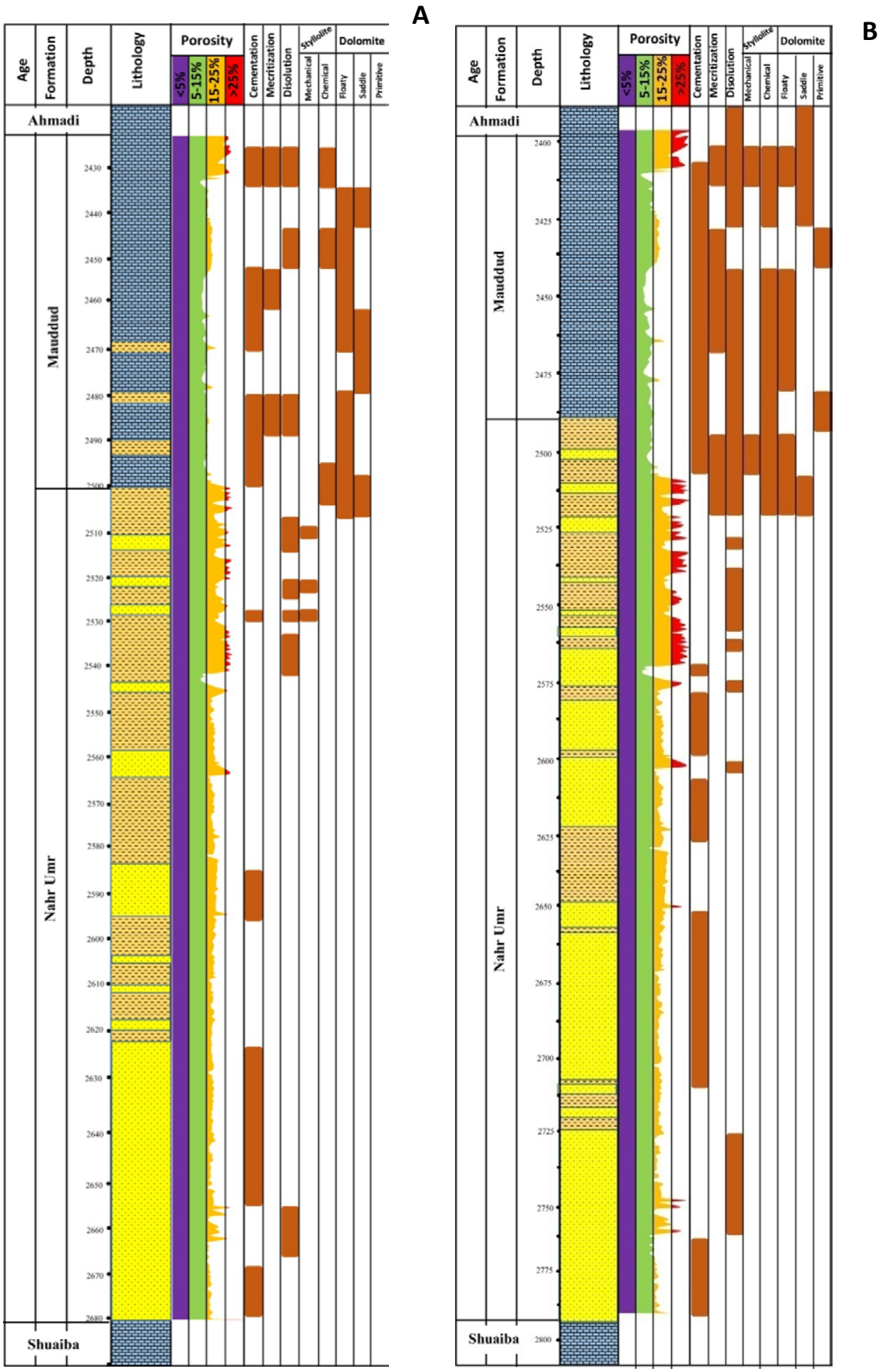

Figure 5- Show the digenesis process and porosity percentage for A. Lu-14 and B. Lu-13

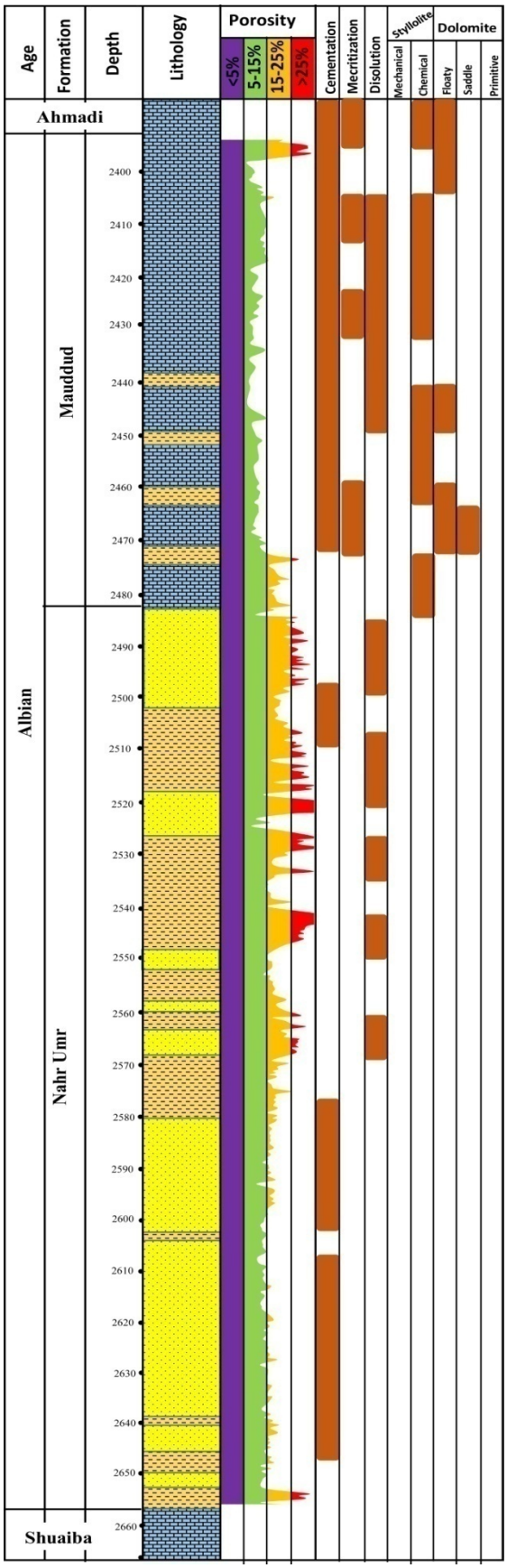

Figure 6- Show the digenesis process and porosity percentage for Luhais39

Conclusions

Clastic-carbonate succession which including the Nahr Umr and Mauddud Formations are represented as a part of Albian-Early Turonian Sequence (Wasi`aGroup).The present study include Petrography, microfacies analysis, depositional environment, digenetic development, and reservoir characterization for seven boreholes (Lu-2, Lu-4, Lu-5, Lu-8, Lu-13, Lu-14 and Lu-39) within the Luhais Oil field, Southern Iraq. Depending on the studied sequence, there are two types of facies:-

a- Carbonate microfacies there are six types of carbonate microfacies, recognized in the Mauddud Formation:- ***Orbitolina*- Milliolids wackestone to packstone** is the main microfacies which reflect an open marine conditions; ***Orbitolina* wackestone to packstone**, this microfacies reflects open marine; **miliolids wackestone**, this microfacies reflects open marien environment; **Peloidal wackestone to packstone** reflects a very low energy environment; **Ooides to Peloids grainstone** represents the shoal environment; and **bioclastic wackestone-Packstone**, this microfacies reflects an open marine environment.

b- Clastic lithofacies there are six lithofacies distinguished in the Nahr Umr succession according to texture and particle sizes they are recognized by core observation, thin section description and well log interpretation.

Mudstone Lithofacies:-

This facies consists of shale rocks with black color high fissile and organic material (plant remains). The most important characteristic of this facies is the high density with a high volume of shale (High Gamma ray).

Siltstone-Claystone Lithofacies:-

This lithofacies consists of overlying shale rocks of dark gray color with silt and fine sand, and plant remains (sometimes are of red color). The volume of shale here is less than the first lithofacies and appeared in the gamma ray log as a rapid decreasing values.

Lenticular to Bedded Sandstone – Mudstone Lithofacies:-

This consists of alternation of sand and mud rocks with gray color, with laminated of soft sandy rocks as lenticular sand body. The volume of shale is showing increasing upward (fennel shape gamma ray).

Falser Bedded Mudstone – Sandstone Lithofacies

This facies consists of sandy rocks (greywackes) with soft granules medium-sized interspersed with shale rocks in the form of flaser bedding. The volume of shale is showing decreasing upward (bell shape gamma ray).

Parallel Lamination Sandstone – Siltstone lithofacies

This lithofacies consist mainly of quartz arenite sandstone with grain size ranging of medium-coarse, moderate sorted, rounded to sub-rounded grains. The gamma ray and sp logs showing random shape.

Cross - bedded sandstone lithofacies:-

This facies consist of coarse quartz arenite sandstone well-sorted and changes in color from light gray to brown. The gamma ray and SP logs showing random shape.

In the present study, there are **six**l lithofacies have been recognized within the Nahr Umr clastic succession, representing **three** types of environments: Active channel, channel fill and deltaic. And **six** microfacies within Mauddud carbonate succession which representing three depositional environments: open shallow marine, semi-restricted, and shoal.

The most common diagenetic features observed and distribution in the studied sections includes Micritization, Cementation, Leaching (dissolution), Dolomitization and Compaction fabrics. The most effective diagenetic processes were cementation, dissolution and dolomitization processes which have direct affect upon the study sections.

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