

**University of Babylon  
College of Science  
Department of Applied Geology**



**High Resolution Sequence Stratigraphy of Nahr Umr  
Formation in Zubair, South Rumaila and North Rumaila  
oilfields, Southern Iraq**

**A Thesis**

Submitted to the College of Science

University of Babylon

In partial Fulfillment of the Requirements for the Degree

Of Master of Science in Geology

**By**

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B.Sc. Applied Geology, University of Babylon, 2013

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**1443 A.H**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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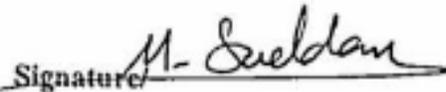
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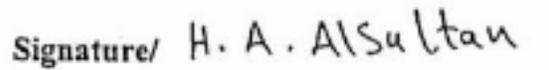
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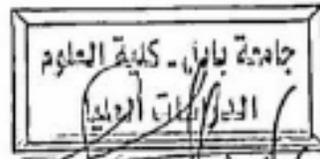
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## *Dedication*

*My God: Thank You for Your Mercy and Kindness That Always Lighten My Ways....*

*To The Big Heart and Candle of My Life .....*

*My father*

*To The Who Was Hand-in-Hand with Me, and Helped Me to Complete My Dream, By her Interest and Love ...*

*My Mother*

*To my wonderful brothers Ahmed and Mustafa for their love and support .....*

*To My Guidance and support in life .....*

*My Teachers & Friends*

*To the one who gave his time and attention to me...*

*(Thank you)*

*Israa*

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Israa Imad

## **Abstract**

The Nahr Umr Formation is one of the most important formations of the Cretaceous and one of the main important reservoirs in southern Iraq. as this formation represents the sandstone and shale deposition of the Albian in the country.

Five wells (R-555, Ru-403, Ru-463, ZB-190, and ZB-047) have been chosen throughout the fields to provide extensive information on the Nahr Umr Formation depending on existing data to determine facies characterization and sedimentary environment and diagenesis processes.

The monocrystalline quartz mineral is the major component of the sandstone, with small percentages of polycrystalline quartz, feldspar, and rock fragments, according to the petrographical analysis for 174 thin sections within the Nahr Umr Formation these rocks are of the type of quartz arenite. Mineral and textural maturity were present in the formation of rocks. Compaction, cementation, dissolution and dolomitization were the most important diagenesis processes that influenced the rock characteristics of Nahr Umr sandstone rocks . The lithological study showed that the Nahr Umr Formation consisted of six lithofacies, that were determined within Nahr Umr Formation, resulting in an intercalated sandstone and shale with a thin layer of siltstone. Based on the identified lithofacies and log responses within the Nahr Umr Formation, which show that the formation was deposited within both fluvial and deltaic environments in the lower part of the formation, the deltaic environment in the middle of the formation, the fluvial activity dominated on the end of Nahr Umr deposition.

The changes in the relative sea level play a major role in the distribution of sediments, as the vertical sequence of facies reflects the stratigraphic succession of

the rocks of the study area, which consists of stratigraphic sequences representing a five-order cycle. The stratigraphic surfaces were distinguished in the sequences of the Nahr Umr Formation represented by the sequence boundaries type one (SB1), which represents the beginning of the sedimentation of the Nahr Umr Formation, and sequence boundaries type two (SB2) that appeared in the upper part of the formation. The other surface was represented by the end of the deposition of the Nahr Umr Formation and the emergence of the transgressive ravinement surface (TRS) within the transgressive system tract (TST), and the maximum flooding surface (MFS) was distinguished in the middle of the formation, and each of these surfaces had a lateral extension along the five study sections.

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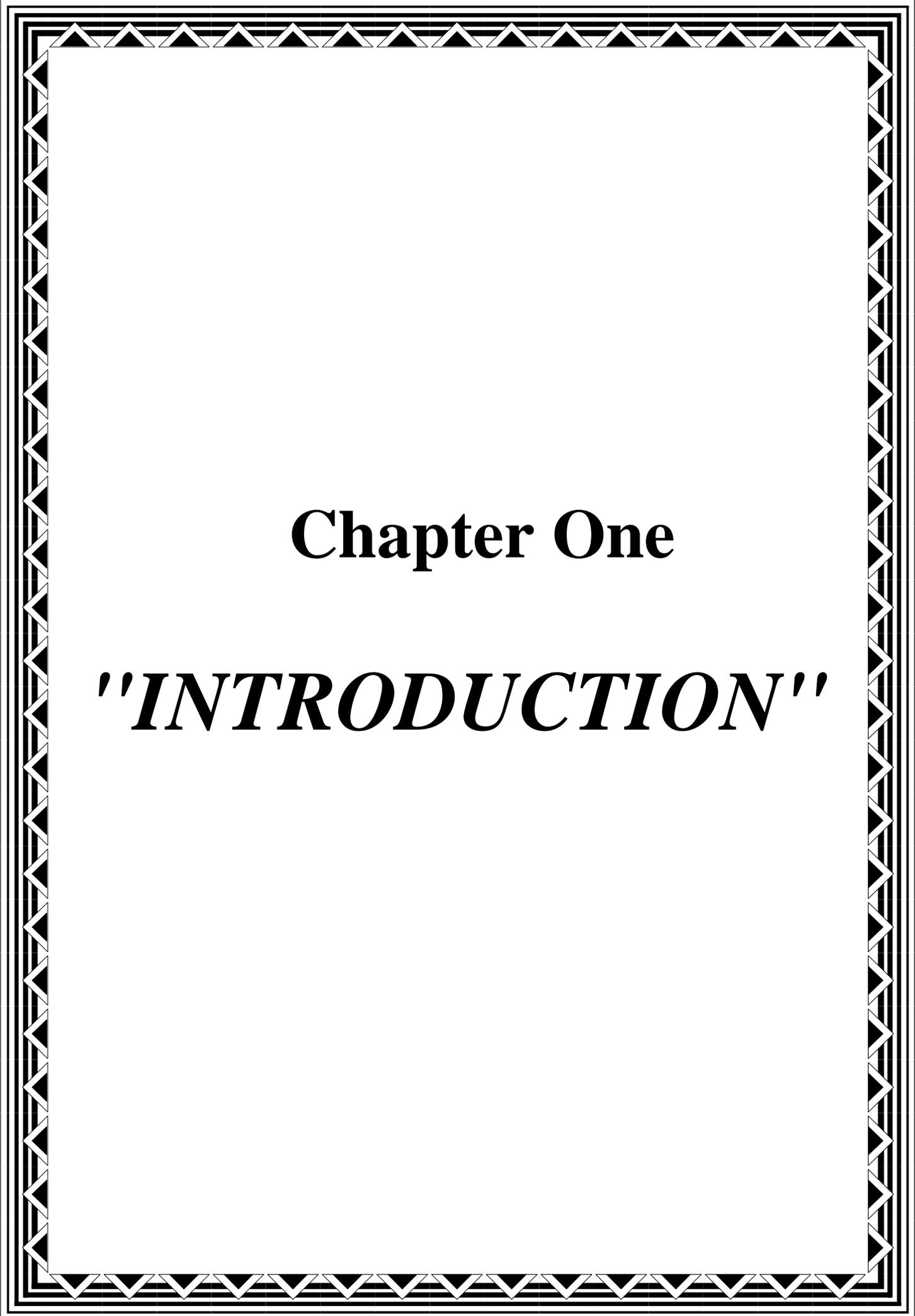
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**Chapter One**

***"INTRODUCTION"***

## **Chapter One**

### **INTRODUCTION**

#### **1.1 Preface**

Nahr Umr Formation (Albian) is one of the important formations in central and southern Iraq, as this formation represents the sandstone deposition of the Albian in the country. It is also considered one of the important reservoirs due to its petrophysical characteristics and oil accumulations (Anadarko, 2005).

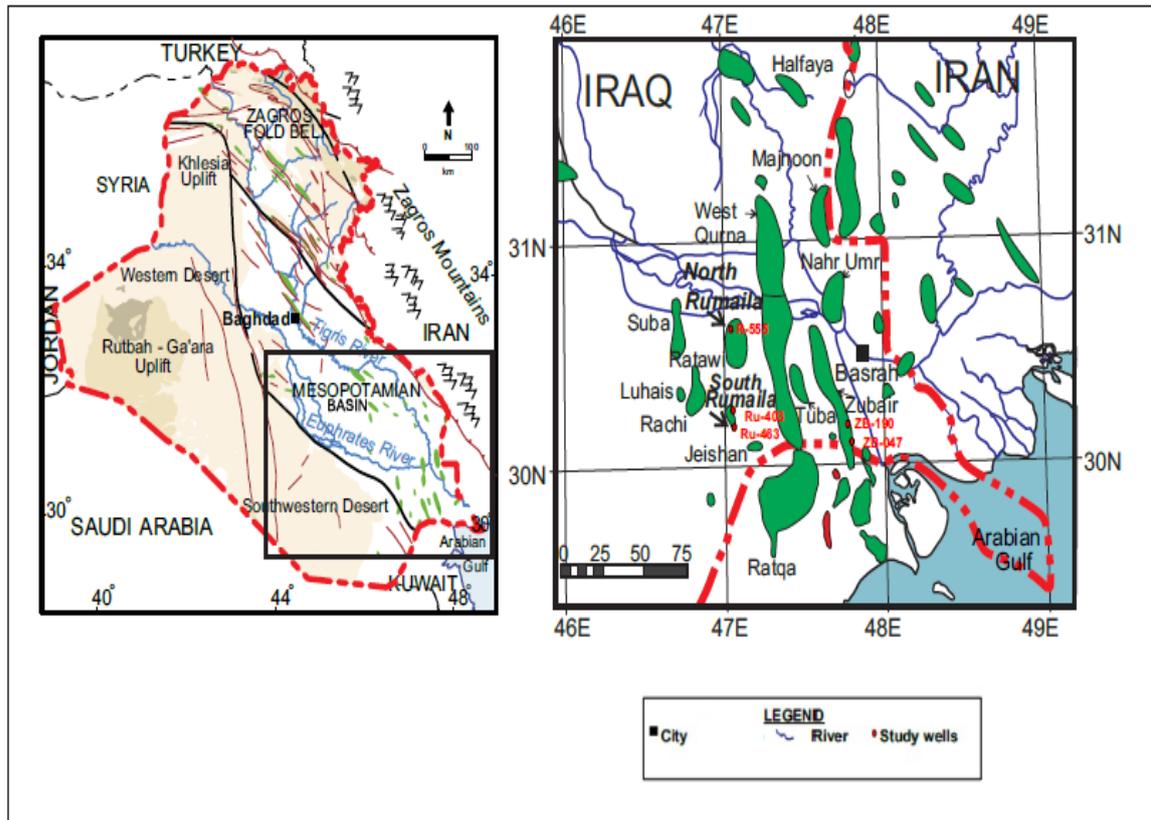
This study is based on the interpretation of core and wireline logs analysis from five wells distributed within the Zubair, North and South Rumaila oilfield.

#### **1.2 Aims of the Study**

- 1- Facies analysis and depositional environmental interpretation that aimed to a better understanding of the depositional setting.
- 2- Determination of the sedimentary cycles of the Nahr Umr Formation.
- 3- The diagenesis processes that affect the Nahr Umr Formation in studied oil wells.
- 4- Sequence stratigraphic analysis to clarify the effect of local tectonism and eustasy on the development of the succession.

#### **1.3. Location of the study area**

The study area is located in Zubair, South and North Rumaila oil fields, Southern Iraq. The studied region is located in the Mesopotamian Zone southernmost unit within the Zubair Subzone (fig. 1-1).



**Figure 1.1:** Location map of the study area, (modified from Al-Khafaji *et al.*, 2021).

### 1.3.1. South & North Rumaila Oilfield

The Rumaila oil field is a large oil field, which is located west of the city of Basrah about 50 km, west of Zubair oil field about 32 km in southern Iraq, and away from the northern borders of Kuwait about 32 km.

Rumaila oil field contains two anticline folds, which in turn are domes in the Northern and Southern Rumaila.

The Rumaila oil field consists of sandstone layers, it is considered to be an anticline fold with a slight dip, as its axis extends towards the northwest and extends to the Kuwaiti border for a distance of 100 km through the Hammar Marsh, passing through the land sites west of Qurna. The width of the structure in most areas of the field is about 18 km.

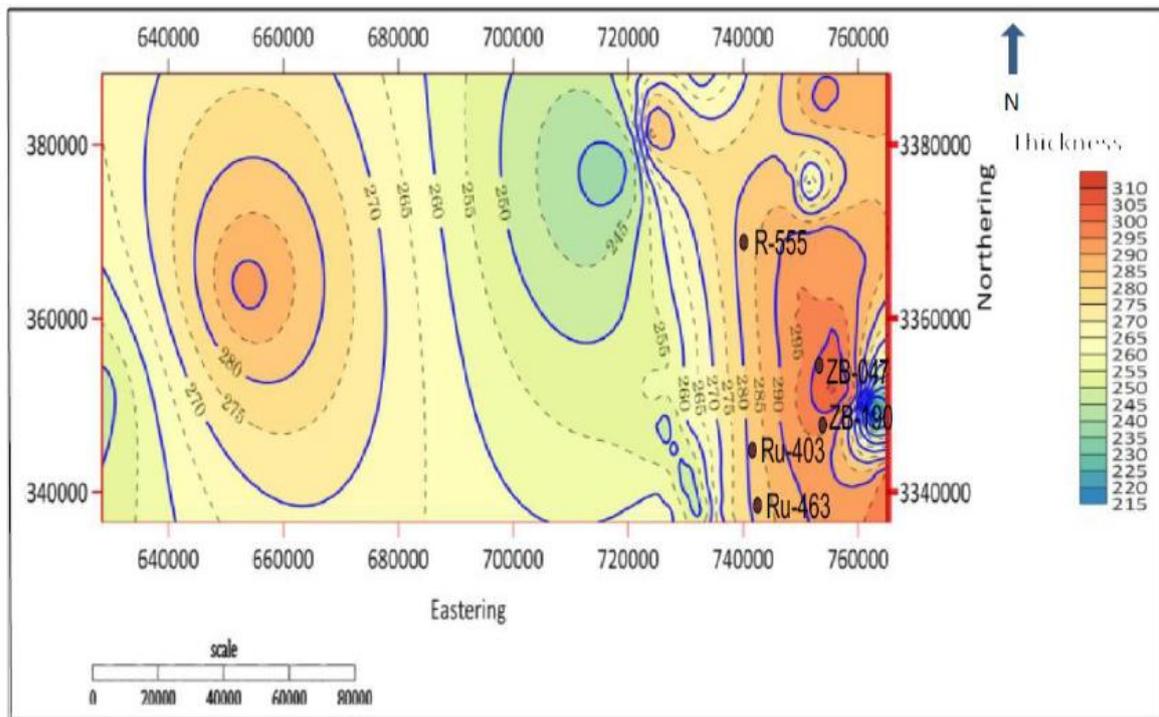
In the Southern Rumaila oil field, the structural form of its fold is a semi-symmetrical anticline fold, so its structural axis tends to the northwest-southeast. The eastern limb inclines at approximately 3.5°, while the inclination of the western limb is approximately 2.5°.

In the Northern Rumaila oil field, the structure tends towards the north gradually, forming a saddle with its secondary fold, where the width of the structure is 12 km, and the length of the structure is 41 km at the highest area in the Nahr Umr Formation (Razoyan, 2002).

As for the structural form of the Northern Rumaila fold, it is a longitudinal convex fold with two asymmetric limbs towards the south, and its axis extends towards (the north and northwest), as the Northern Rumaila fold lies between two folds from the south bounded by the Southern Rumaila fold and bounded from the north by the Western Qurna fold the width of the fold is approximately 11 km and its length is approximately 42 km (Ali, 1991).

### **1.3.2. Zubair oilfield**

The location of the Zubair oil field is about 20 km west of the city of Basrah and its axis is parallel with the axis of the Rumaila oil field with an extension starting from the Iraqi-Kuwaiti border and to the north of the marsh area (2 -3), it is considered an asymmetrical fold, as the slope of its western limb is more than the eastern limb, the length of the fold ranges about 60km, and its width is about 8 km when the dimensions are at a level 11,000 feet below sea level,(fig.1-2) shows the isopach map of the Nahr Umr Formation for selected oilfields.



**Figure (1-2):** Isopach map of the Nahr Umr Formation in Zubair, South and North Rumaila oilfields.

#### 1.4. Stratigraphic Setting

The Nahr Umr Formation is one of the formations of the Albian cycle within the main cycle within the Lower Cretaceous- Late Berrisian Albian cycle, which dates back to the Lower Cretaceous (Albian) (112-103.6 Ma).

Clynn Jones, 1948 is the first year in which the Nahr Umr Formation was known before (Owen and Naser, 1958) and (Buday, 1980) presented it as an independent stratigraphic unit.

The Nahr Umr Formation consists of black shale rocks overlapping with medium –fine-grained sandstone containing lignite, amber and pyrite (Bellen *et al.*, 1959: in Buday, 1980).

The formation consists of layers of black shale interbedding with medium – fine-grained sandstone and alluvial sediments with the appearance of thin layers of limestone that depended on the general division and definition (Jassim and Goff, 2006).

According to the general division and definition is given by, (Bellen *et al.*, 1959: in Buday, 1980) the lower boundary of the Nahr Umr Formation in the typical area is conformable and gradual, as the surface of the unconformity appears in the Dujaila area (Safar and Maclead, 1961).

It was accepted by Ditmar *et al.*, (1971 and 1972) that the upper contact is also conformable. The Mauddud Formation overlies the Nahr Umr Formation in a gradual conformable, as the base of the Mauddud Formation is topped by dolomitic limestone, while the base of the Mauddud Formation which is the top of the Nahr Umr Formation may consist of sandstone or layers of shale, the lower contact separating the Nahr Umr Formation from the Shua`aiba Formation is unconformity, which is represented by the presence of layers of dark, black, foliated shale as a base for the Nahr Umr Formation or at the top of the layers of yellow or pale gray dolomite of the Shua`aiba Formation (Qaradaghi *et al.*, 2008).

In the southern part of the Salman and Mesopotamia Zones, the thickness of the formation reaches more than 360 m and its largest thickness is in Iraq and Kuwait at 400 m, and it reaches 160m in southern Baghdad and northwestern Iraq (Jassim and Goff, 2006).

The Nahr Umr Formation is equivalent to the upper part of the Sarmord Formation in northern Iraq (Al-Naqib, 1959). In Kuwait, it is equivalent to the Burqan Formation and equivalent Khafji and Safaniya formations in the north of the Kingdom of Saudi Arabia (Power, 1968) (fig.1-3).

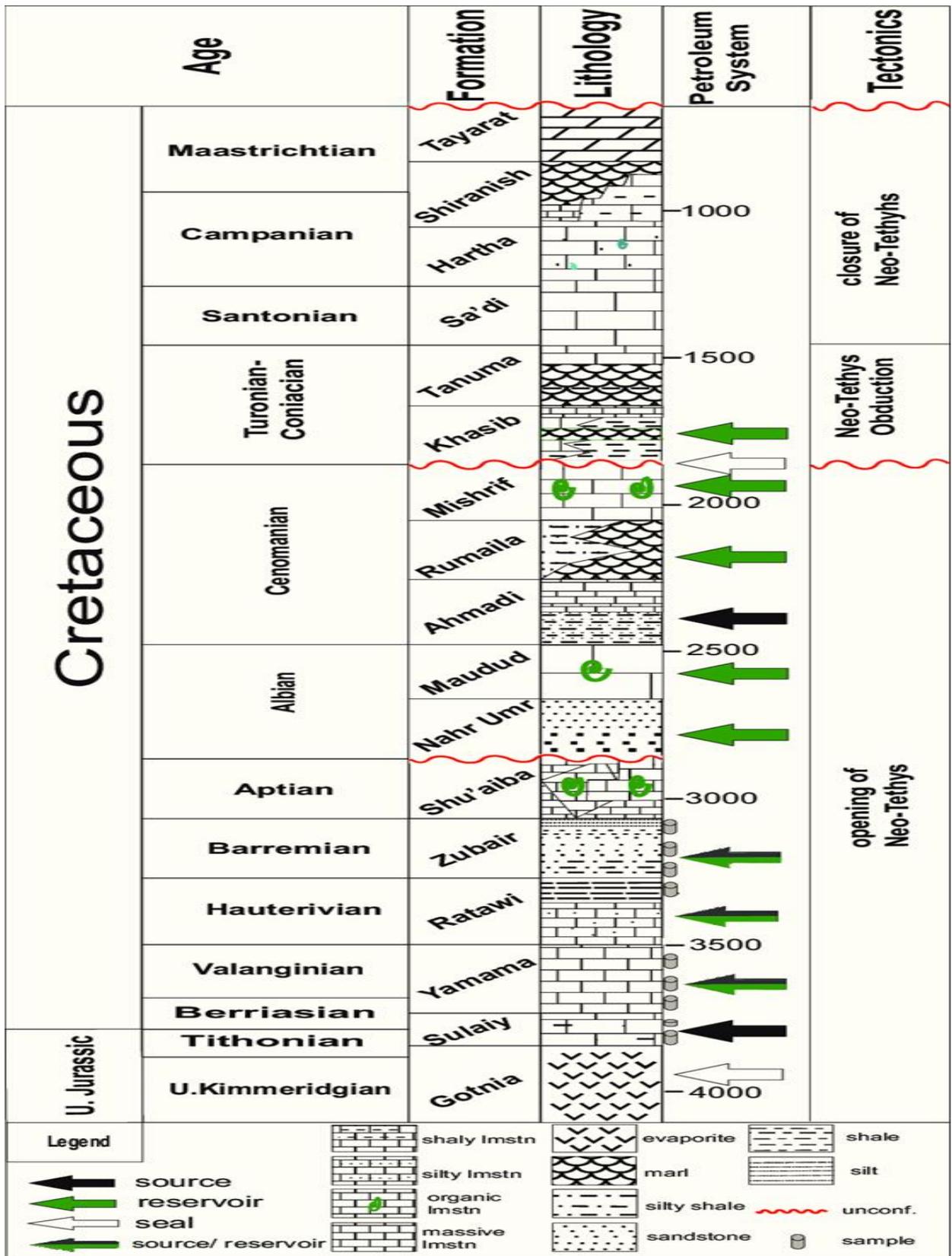


Figure (1-3): Stratigraphic Column of Nahr Umr Formation in Southern Iraq, modify (Al-Ameri *et al.*, 2009)

### 1.5. Tectonic Setting

The Middle East Region is located between two tectonic plates, the (Eurasian Plate) and the (Arabian Plate) (Hempton, 1987 in Numan, 2000).

Where Iraq is located in the northern and northeastern part of the Arabian Plate and is bounded by the Zagros and Taurus Zone from the north and north-east, and by the Levent Fault Zone and the depression of the Red Sea Rift from the west(Dewey *et al.*, 1973), the Gulf of Aden and the Owen Tissor Zone from the south(Buday and Jassim,1987) (fig.1-4).

On the other side, the location of Iraq is between two tectonic units represented by the western part of the African platform (Arab-Nubian) from its southern and southwestern sides, and between the unit represented by the Albian sedimentary basin from its northern and northeastern sides.

The tectonic location of the study area is within the Mesopotamian Zone, which is part of the unstable shelf as it includes the southeast part of Iraq (fig.1-5), where it was characterized by a large depression at the end of the Mesozoic when it reached its maximum end of the Cenozoic.

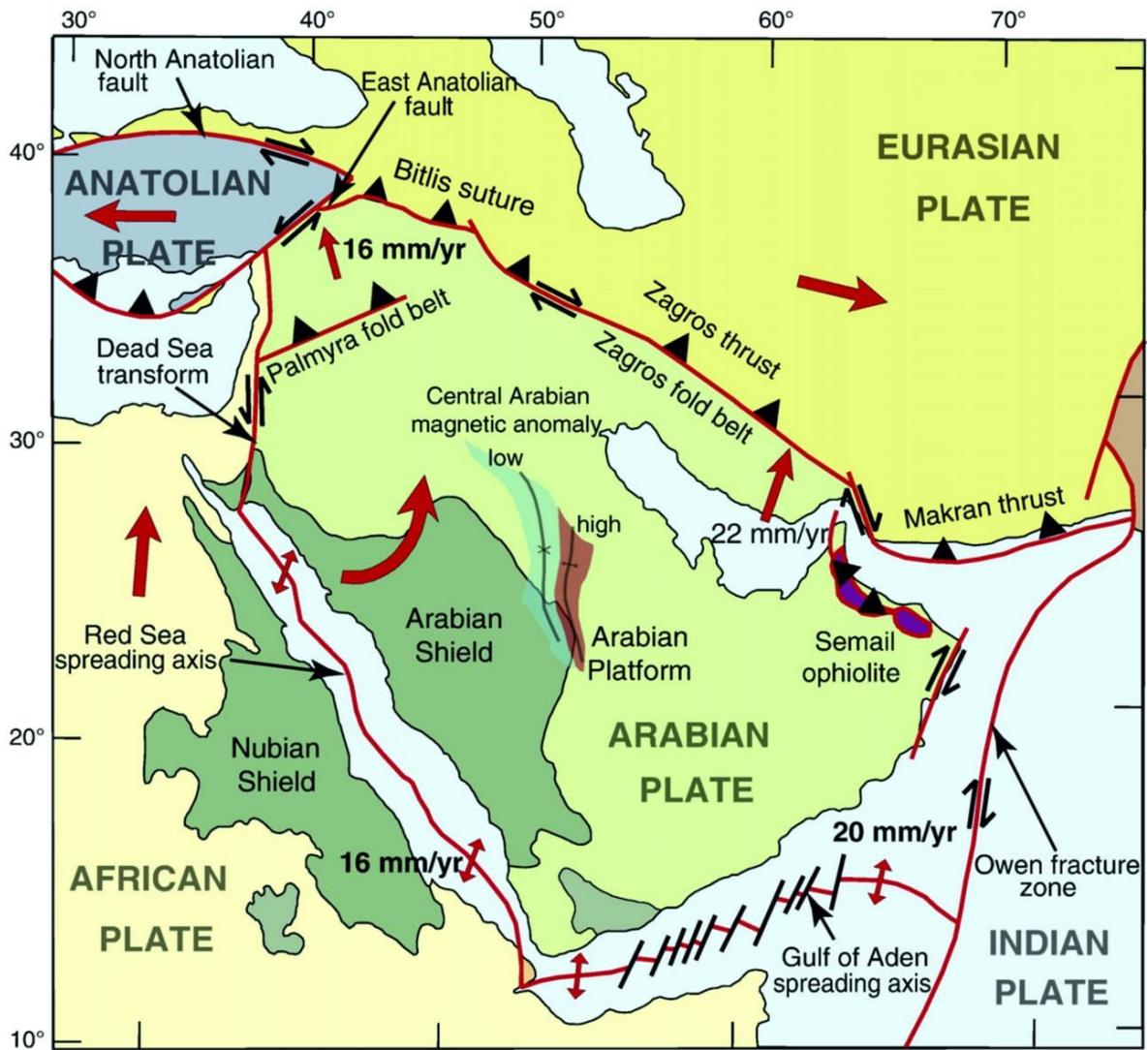


Figure (1-4): The Arabian plate for (Al-Khafaji, 2022).

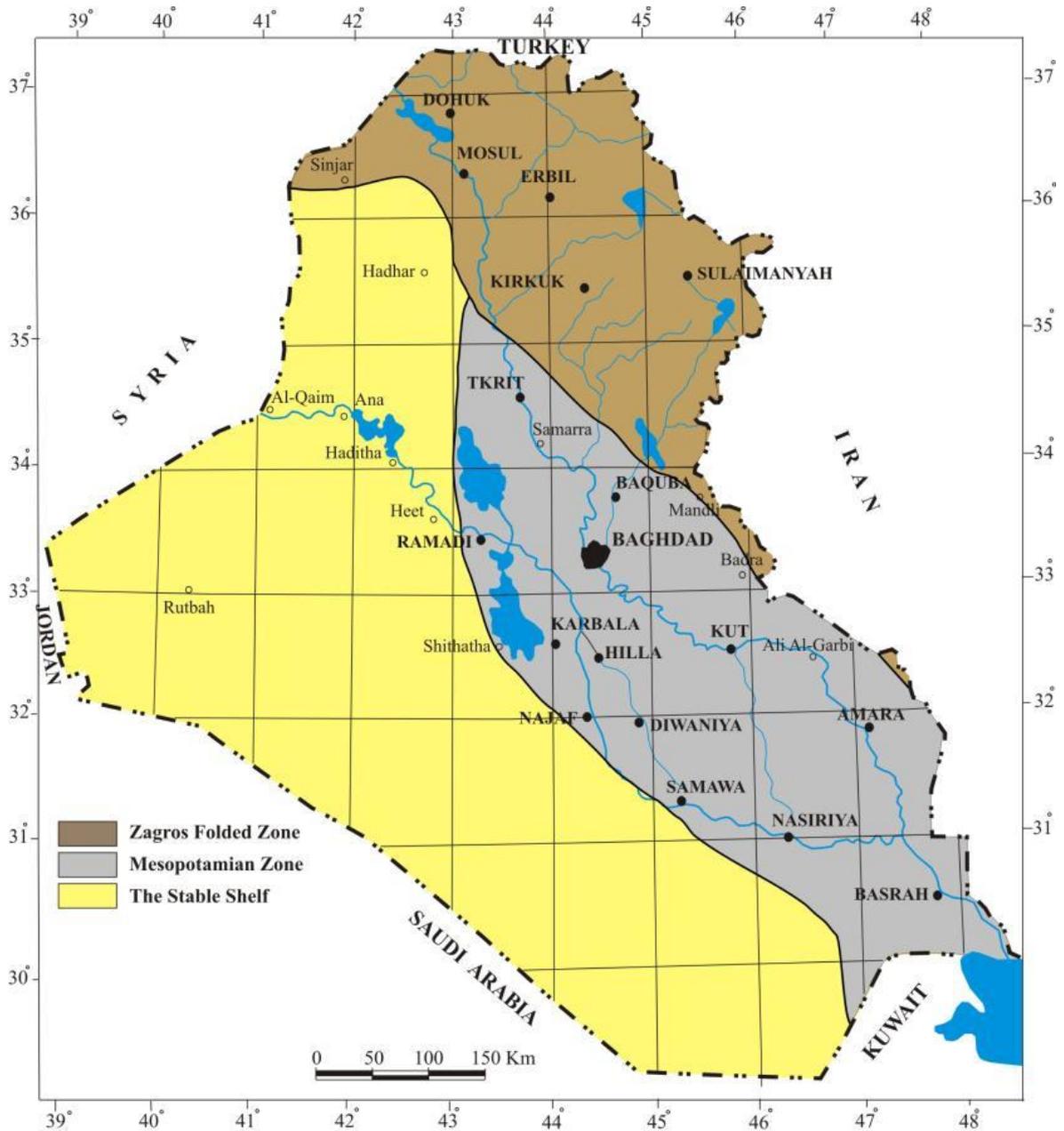


Figure (1-5): Tectonic Map of Iraq (Fouad,2012).

### 1.6. Paleogeography

The basins contained Mesozoic sediments along the passive margin of the Arabian Plate (Baydoon,1991 in Shawish, 2002).

(Sharland *et al.*, 2001) mentioned that the Arabian Plate went through phases extensive and compressive during the different geological ages where

the formation of the study was located within the Ap8, according to the tectonic divisions of the Middle East.

The last reference also mentioned that the Cretaceous witnessed in Iraq a geodynamic reversal for a tectonic system, from the elongation movement to the compression movement, as indicated by (Murriss, 1980) it was during the Cretaceous, specifically during the (Albian- Cenomanian) that a movement occurred active tectonics represented by the Austrian movement, followed by the Sub-Hercynian movement, which resulted in the continuation of the closure of the Neo-Tethys and the approach of the Arabian block to the Anatolian block.

The Lower Cretaceous was represented by two secondary cycles the intermediate Berriasian cycle - Aptian secondary cycle and the Albian secondary cycle (Buday, 1980), the sediments at the end of the Jurassic and the beginning of the Lower Cretaceous in southern Iraq were characterized by the sediments of the shallow open marine it was formed from sequences of evaporative and carbonate deposits, which were represented by the Gotnia, Sulaiy, Yamama, and Ratawi formations, during the Early Cretaceous, a humid tropical climate prevailed, leading to an increase in the process of weathering and erosion in the highlands represented by the western part of the Arabian Shield and the disappearance of evaporates and sea levels begin to subsidence, and the ramp model has replaced the shelf model(Murriss, 1980).

during the Early-Mid Valanginian, the construction of the carbonate platform expanded with time, representing the eastern side of the Neo-Tethys, on the south side the Gulf of Aden was revealed in the form of a wide arc, which remained in a state of non-deposition with exposure to erosion operations as for the crumbs their presence was confined to the southwestern corner of the Arabian Shield.

During the Period (Heterophene-Permen), the preparation of crumbs increased and continued during the Middle and Late Permian to occupy the western part of the basin pushing carbonite which led to the development of the limestone ramp forward towards the east.

The rise in sea level during the late Aptian was a characteristic feature of this Period and which affected ancient paleogeography in a less important way than the rise in sea level during the Late Jurassic, and during the Middle Aptian the clastic system spread over most parts of the platform except for narrow areas within the northern side the eastern, coastal and river sandstones of this Period are represented by the Burgan Formation in the northern Arabian Gulf, which is equivalent the Nahr Umr Formation in the study area (Murriss, 1980).

The uplift in the western part of the Arabian Plate gives a reasonable explanation for the spread of the Nahr Umr Formation within this Period as this was accompanied by the deposition of facies of the Mauddud Formation directly during the Late Albine - Early Cenomanian and continued to the Middle Cenocenian (Murriss, 1980).

(Numan,2000) mentioned the dispersal of some formations of the Lower Cretaceous for this cycle, in the western and southern desert region of Iraq the(Nahr Umr, Rutba and M'sad )formations were deposited, while in the semi-shelf area the deposition occurred in repeated successions of clastic and carbonate rocks, represented by(Nahr Umr, Jawan, Mauddud, Ahmadi, Rumaila and Mishrif ) formations were deposited, in the foreland basin region in the foreland fold belt the (Balambo, Qamchuqa, Girbier, Dokan and Gulneri) formations were deposited. Balambo Formation lime mudstone which represents the deepwater deposits on the continental slope, is

equivalent to the Nahr Umr Formations and contact between Balambo Formation and the formations on the carbonate platform is interbedded.

### 1.7. Methodology

The present study adopts the following strategy:

#### 1- collecting the samples

a- Choosing wells that contain the largest number of cores for the units included in the current study and are available in the laboratories of Basrah oil company. Five oil wells were selected in southern Iraq, as shown in table (1-1), and then described these cores and the available cutting and determined their characteristics such as color, texture and composition sedimentation, particle size, and inclusions of all study wells.

**Table(1-1):** The coordinates of the study wells with the top and bottom contacts of the formation, thin section, and thickness of core available for it.

Oil Field	Well no.	Coordinates(U.T.M.)		Top (m)	bottom (m)	Thickness (m)	Nahr Umr Core samples	Thin section
		Latitude	Longitude					
Zubair	Zb-047	743 200	3387 050	2650	2850	200	45	48
	Zb-190	753 529.3	3376 242.8	2440	2860	420	41	39
South Rumaila	Ru-463	730 439	3348 294	2670	2790	120	31	47
	Ru-403	732 436	3344 827	2620	2860	240	25	15
North Rumaila	R-555	721 447	3384 706	2400	2670	270	30	25

b- Sampling rocks samples from the available core from the Nahr Umr Formation and making thin sections (fig.1-6).



**Figure (1-6):** Smoothing the sample by Struers LaboPol device.

## **2-Laboratory work**

It included a description of the thin sections available for the Nahr Umr Formation, which were 174 slides, including 87 slides in wells (Ru-403), (Ru-463), and (R-555), 87 slides in wells (ZB-190) and (ZB-047) in the depths available to them for cores, as they were described petrographically and according to the classification (Pettijhon *et al.*, 1973) and using a polarized microscope (fig.1-7).

## **3- Office Work**

- a- The office work includes preparing thin sections and analysis of the well logs for the study by using (IP 2018) software, as they contain each of the Gamma-ray (GR) and the Spontaneous Potential (SP), logs.
- b- Drawing isopach map of the Nahr Umr Formation for selected oilfields.



**Figure (1-7):** Examine the slides under the polarizer Microscope to study the petrographic characteristic.

## 1.8. Previous Studies

**Glynn Johns,1948 in Van Bellen *et al.*,1959** was the first who referred to Nahr Umr Formation when he described the sandy and shaley strata between Shua`aiba Formation at the bottom and Mauddud Formation at the top.

**Owen and Nasr,1958** studied the Nahr Umr Formation in more detail and discovered that it is composed of black shale interbedded with fine to medium grain sands containing amber and pyrite.

**Chatton and Hart,1960 in Buday,1980**divided Nahr Umr Formation according to lithology into two units: Nahr Umr Shale and Nahr Umr Sands.

**AL-Naqib,1967** divided Nahr Umr Formation and its type section into three lithological units according to lithology and shale content.

**Castro,1978** referred to his sedimentological study in a Majnoon Nahr Umr area where Nahr Umr Formation was deposited in two major environments; the lower part represents a fluvial or tidal, while the upper part was deposited in the marine – deltaic environment.

**Mansour, 1982** referred to in his sedimentological study in southern Iraq, that the sandstone deposits were mixed, with coastal plain in the upper part and deltaic-fluvial in the middle and lower parts, with beach environment effects and the sedimentary environments are controlled by transgression – egression.

**Khurshed *et al.*,1982** studied the Nahr Umr Formation in Halfaya oilfield, south of Iraq and they referred that the clastic deposits of Nahr Umr Formation represent a small-scale sequence from coarsening upward, which is caused by a short regression phase, and these deposits are found mainly in the tidal marine part of the delta.

**AL-Joubory,1985** referred that the thickness of Nahr Umr Formation increases from west to east, and has a maximum thickness of 360m in well Abu-Khima-1; whereas the thickness reaches in East Baghdad oil field to less than 100 m.

**Ali *et al.*,1986** divided Nahr Umr Formation into two members in the Luhais oil field; claystone member and sandstone member and they divided each member into many units. They referred that the sandstone increased southward, and the upper and lower contact with Mauddud and Shua`aiba formations are gradient.

**Abd *et al.*,1988** pointed out that Nahr Umr Formation was deposited in deltaic and beach environments enriched by dunes, where Kaolinite is the widespread mineral in addition to Illite.

**Al-Rubaiy and AL-Joubory,1988** in the Luhais oil field studied the Nahr Umr Formation and divided it into three main parts according to shale content.

**Kendall *et al.*,1991** in their study of the Arabian Gulf and the Gulf of Mexico referred that the deposition of the Middle Cretaceous was affected by several sea level events; for instant, the Nahr Umr Formation represented the clastic response to a major eustatic drop in the Late Aptian time.

**Al-Hadithy,1994** divided the Nahr Umr Formation into two oil fields (Luhais and Subba) oil fields into eight lithological units and diagnosed eight lithofacies, and he referred that this formation was deposited in various environments including fluvial, pro-delta, and tidal flat.

**Al-Sharhan, 1994** due to the dominance of deltaic, coastal, and shallow-marine environments, the Nahr Umr Formation shows rapid changes of facies in both lateral and vertical directions, according to his sedimentological and petroleum–geological studies. In addition, the formation rests unconformably on the Aptian Shua`aiba limestone, which is gradually overlaid by conformable Mauddud limestone.

**Immenhauser *et al.*, 1999** in their study suggest the Aptian age to the base and late Albian to the top of Nahr Umr Formation in Jabal Akhdar, North of Oman. This study referred that this formation is organized into seven accommodation cycles.

**Anadarko, 2005** studied the reservoir quality and depositional environments of Nahr Umr Formation in Luhais oilfield and show that the depositional environments of the formation were Barriers isle system aggraded over a deltaic platform and generally the reservoir quality is excellent within the sands. Nevertheless; within the formation, the reservoir quality is controlled

by facies diversity where delta and barriers are reservoir facies in contrast to mudflat and tidal flat facies.

**Al-Dabbas *et al.*,2012** studied the sedimentological and depositional environments of the Nahr Umr Formation in central and southern Iraq and show that the formation is mainly composed of sandstone interlaminated with minor siltstone and shale, with the occurrence of thin limestone beds, and this formation was deposited in the shallow marine and fluvial deltaic environments and exhibit progradational succession of facies.

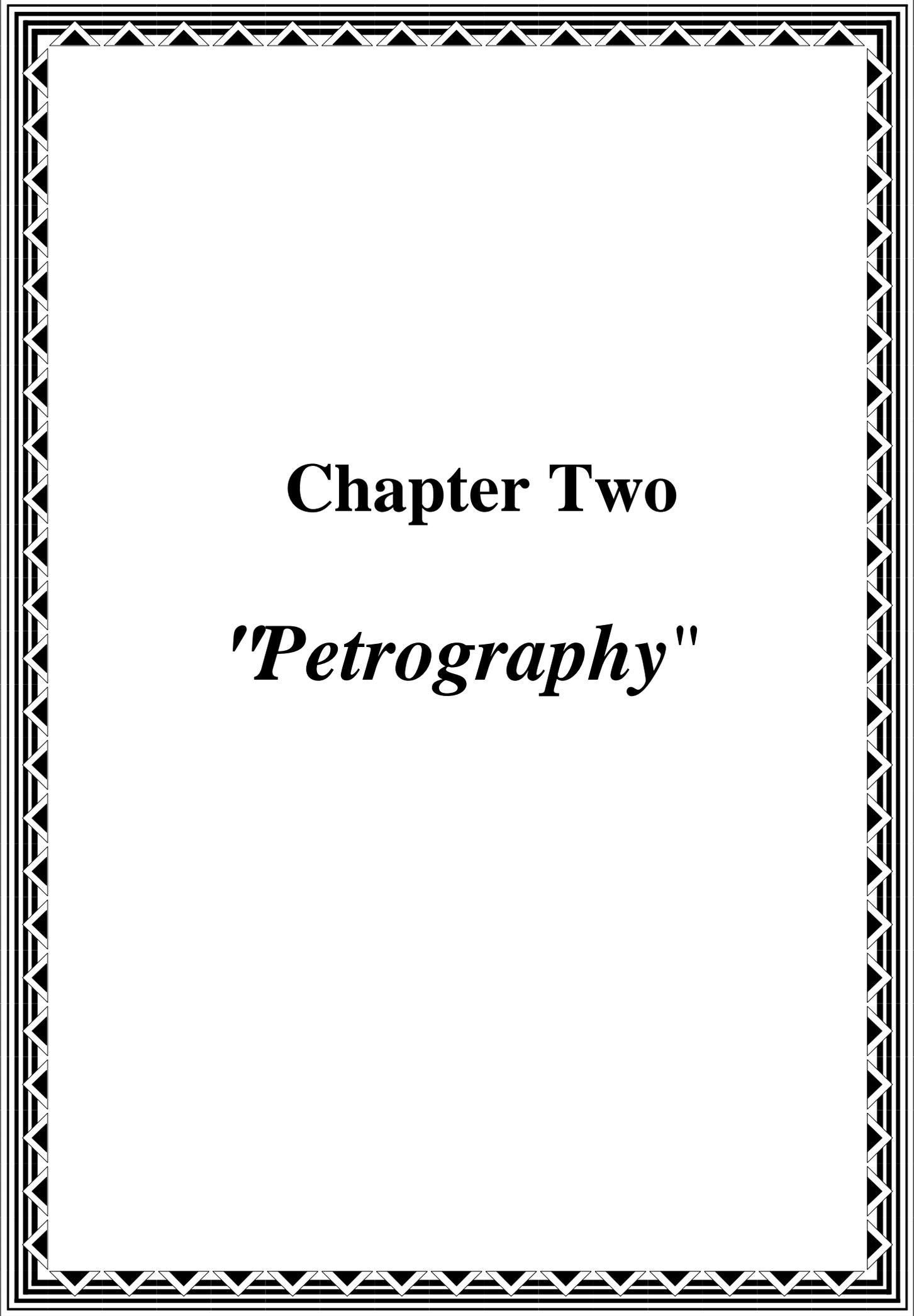
**Ebraheem, 2015** the petrophysical and reservoir properties of the Shuaiba and Nahr Umr formations were studied in the Arab Qurna field, where they showed that the Nahr Umr Formation sequence consists of five main facies and four main sedimentary environments and its impact on five diagenesis processes.

**Sahi *et al.*, 2017** A reservoir study for the Nahr Umr Formation in the Luhais oilfield. The formation was divided into three reservoir units (upper, middle, and lower) and each unit was divided into secondary units, where the upper and lower unit included one reservoir unit, while the middle unit included three reservoir units.

**Al-Zaidy, 2018** facies analysis and stratigraphic development of the Nahr Umr Formation in Luhais oil field, southern Iraq.

**Ali,2018** reservoir evaluation of Nahr Umr Formation in the luhais oilfield, Southern Iraq.

**Al-Nafie,2021** estimation of reservoir properties based on core plugs, lithofacies, microfacies, and well logs for Nahr Umr Formation in Noor oilfield, southern Iraq.



# Chapter Two

## *'Petrography'*

## **Chapter Two**

### **Petrography**

#### **2.1. Introduction**

Sandstone petrography and facies analysis can provide valuable information on the detailed composition and texture of sedimentary rocks.

In addition, it is useful in the determination of transportation mechanism, depositional environment of sandstone and their diagenetic history (Scholle, 1981).

In this study, examination of thin sections to detect mineral composition, depositional environment, and diagenesis (compaction, cementation, dissolution and dolomitization). Grain size and sorting are analyzed by studying thin sections.

#### **2.2. Petrography of sandstone**

The mineral composition of sandstone rocks can be controlled by many factors, including the mineral composition of the source rock, the distance of transporting debris before it reaches the final deposition sites, the climate in the source area, and the diagenetic effect after the completion of the deposition (Suttner and Dutta, 1986).

The sandstones of the Nahr Umr Formation are classified as quartz arenite (Pettijohn, 1975). Which formed after a long-distance transport from the source area.

Sedimentary rocks (sandstone) have been described to determine processes, depositional environments, and textures, as well as for determining

porosity and permeability, which is an important tool for the study of rich reservoirs with hydrocarbons.

### 2.2.1. Framework Grains

#### 2.2.1.1. Quartz

Quartz is the main mineral of sandstone in the study area, as it constitutes a very high percentage of about 95% in the Nahr Umr Formation (Pettijohn et.al.1973).

The main reason for this ratio is that quartz is caused by weathering tropical, long-distance transportation, and recycling, (Dickenson, 1988).

According to Wentworth, 1932 (in Pettijohn *et.al.*1973) quartz grains vary in size from medium to very fine. Fig.(2-1)shows the standard dimensions and sorting types used in the description of sedimentary particles.



**Figure (2-1):** Standard dimensions used in the description of sedimentary particle size, shape and sorting types (After Powers, 1953).

There are two types of quartz:

#### **2.2.1.1.1. Monocrystalline quartz**

Most of the quartz grains are monocrystalline (pl.-1a), as the monocrystalline quartz may be derived from a plutonic source or other types of source (Blatt, 1967; Folk, 1968). The size of the grains ranges from fine to medium, and the roundness of the granules ranges from subrounded (pl.3d) to round, and some are very round.

#### **2.2.1.1.2. Polycrystalline quartz**

Polycrystalline quartz is a group of quartz grains assemblage in different directions of light (Tucker, 1985) (pl.-1b).

The reason is due to the absence of polycrystalline quartz makes it unstable when transported over long distances, as well as its absence in the source rocks.

Increased temperature and pressure can cause polycrystalline quartz to transform into monocrystalline quartz, according to (Young,1976).

The characteristics of these quartz grains (the high percentage, fine grains, their roundness and good sorting)(pl.2a) indicate a relatively high degree of mineral and texture maturity, which indicates that these rocks are the final product of long-distance transport and severe weathering processes, which led to the desolation and destruction of less stable minerals, and then an increase in the proportion of quartz mineral that it is one of the minerals with high stability and the most resistant to weathering and erosion factors (Pettijohn, *et al.* 1973).

This result gives rise to two possibilities, either that the source area and the sedimentation basin are tectonically stable, or that the sand has gone

through several sedimentation cycles (Pettijohn,1957; Pettijohn, *et al.* 1973; Folk,1974), and these two possibilities are given in the case of sandstones to Nahr Umr Formation.

### **2.2.1.2. Feldspar**

Feldspar was found in less than 5% of the mineral components of the studied samples of the Nahr Umr Formation and the reason is less stable and sensitive to chemical reactions during weathering and long-distance transportation (Pettijohn *et al.*, 1973).

Feldspar is derived from coarse-grained plutonic rocks with less extension than the volcanic source (Pettijohn, 1975). In general, it includes orthoclase, plagioclase, and microcline (pl.-1c).

The types of feldspar that were found in the studied samples for the Nahr Umr Formation included alkali feldspar (orthoclase and microcline) and plagioclase.

The reason for the lack of plagioclase is the effect of the chemical weathering process of sediments in the source area.

### **2.2.1.3. Rock fragment**

They are pieces of rock that contain various mineral components that are present in little or not found during long-distance transportation (Pettijohn *et al.*, 1973).

The rock fragments in sediments are more essential because they provide detailed information on the nature of the source rocks (Blatt ,1982).

Two important points must be distinguished in the rock fragments: first, the sand content of the rock fragments is related to the particle size of the source rock. Second, the abundance of rock fragments depends on the size of

the grains (Selley, 2000). It includes chert and carbonate rock fragments and very few amounts of argillaceous rock fragments. These types refer to sedimentary source rocks (pl. 1-d, e, and f).

### **2.3. Petrography of Shale**

The shale continues as a thinly laminated, weakly calcareous, pyritic, silty shale with abundant organic matter as is represented thin beds of the Nahr Umr Formation.

This shale contains moderate to abundant bands of quartz grains, less calcite and dolomite. Pyrite within the shale occurs as microcrystals, framboidal aggregates, or nodules that formed within the laminated shale. While the middle part is characterized by lenses and false bands of shale within the sandstone unit (pl.2-e).

### **2.4. Matrix**

It is a fine mineral material found between grains, although it also contains very fine particles of quartz and feldspar (Berg, 1986). The matrix is the result of the first deposition; moreover, the matrix may be pierced immediately after deposition (Pettijohn, 1973). The Nahr Umr Formation consists of silt, iron oxides, and minerals matrix clay. Its percentage among sandstone components is less than 15%, and the percentage in some samples that contain fine sand is more than that.

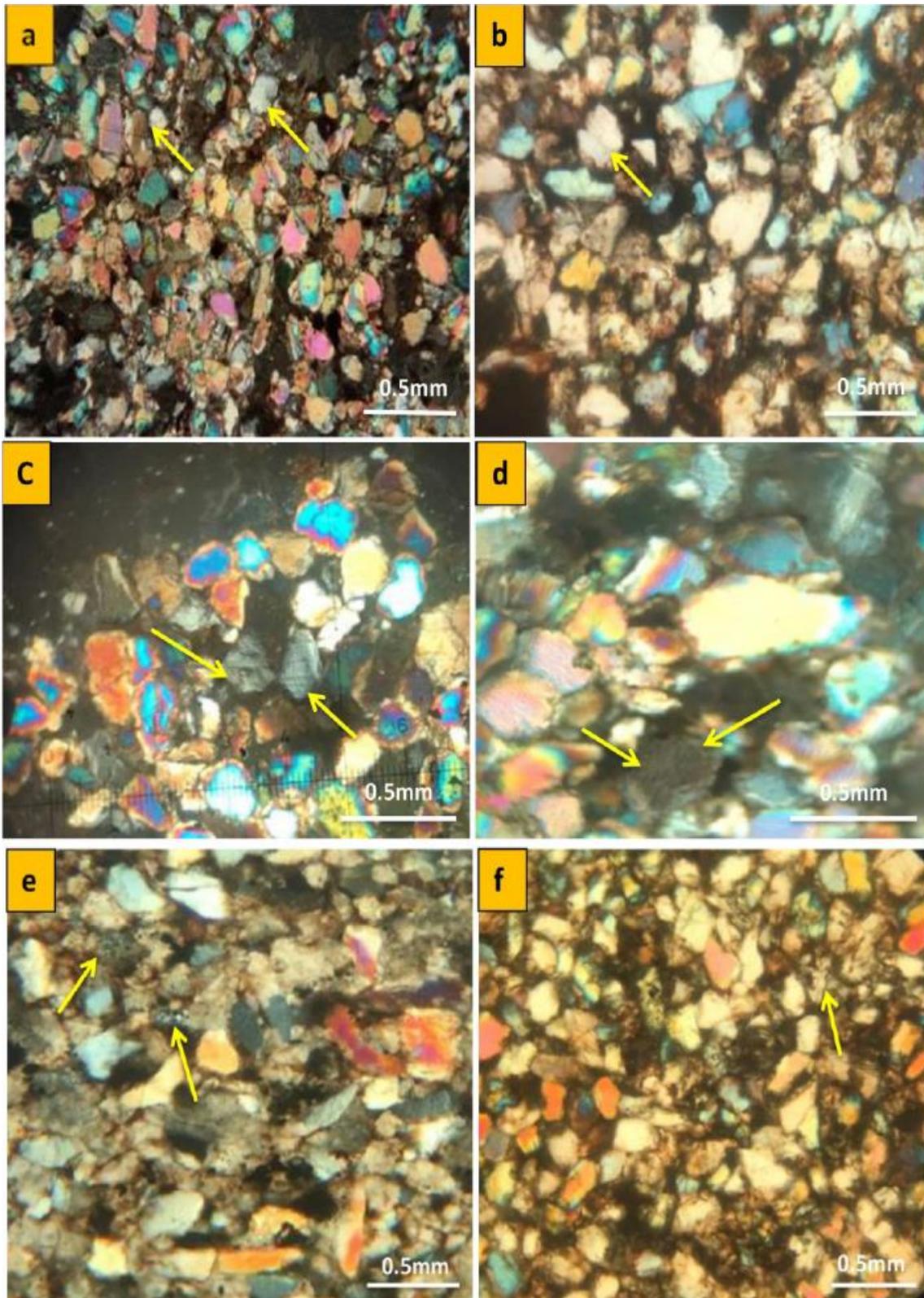
#### **Plate-1-**

- A.** Monocrystalline Quartz under the polarized (R- 555, 2500m).
- B.** Polycrystalline Quartz under the polarized (R- 555, 2670m).
- C.** Orthoclase under the polarized (ZB-047, 2715m).
- D.** Carbonate fragments under the polarized (Ru- 463, 2645m).

E. Chert fragment under the polarized (Ru- 403, 2630m).

F. Rock fragments under the polarized (ZB- 190, 2710m).

Plate-1

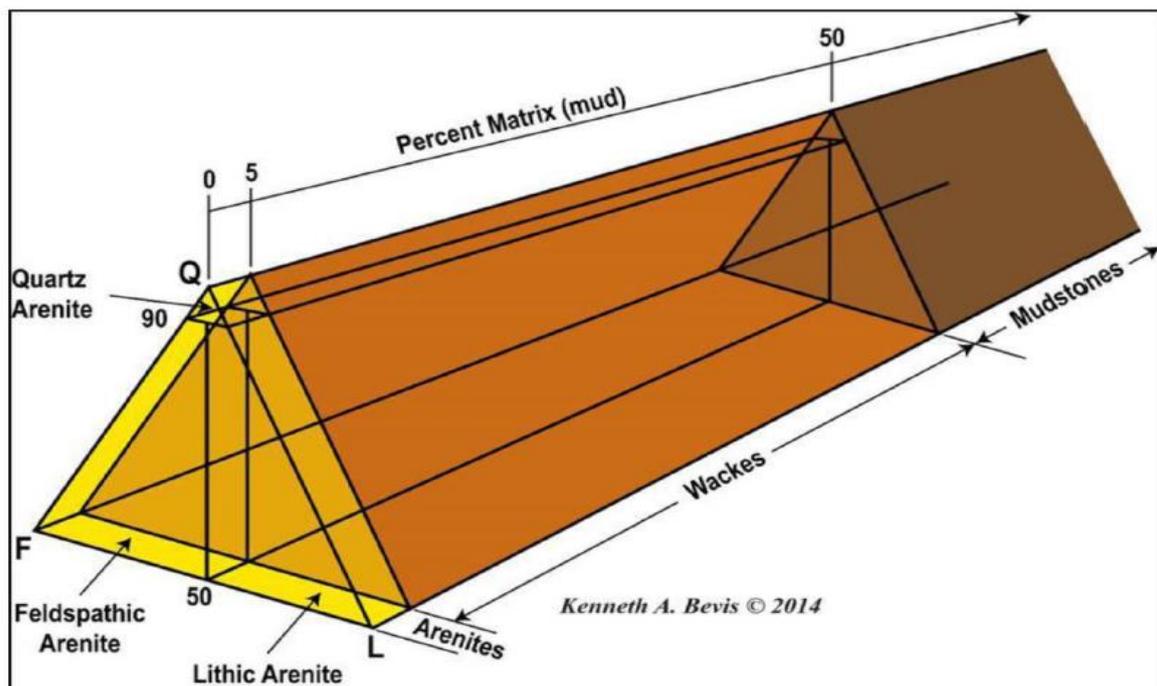


## 2.5.Sandstone classification

Any nomenclatural system has to have arbitrary bounding parameters that separate one rock type from another. These bounding parameters are most useful when based on some basic concepts of sand genesis (Pettijohn, 1975).

The basic problem of classifying sandstone is that they can be grouped according to their physical composition (grain size and matrix content) or according to their chemical composition (mineralogy). There are more textural and mineralogical components to be significant in sandstone nomenclature than can be conveniently represented in an end member triangle or tetrahedron (Selley, 2000).

In this study, the sandstone of the Nahr Umr Formation is classified according to the classification of (Pettijohn, *et al.*,1973) (fig.2-2) which depends on the texture and the mineralogical composition of the sandstone. All samples lie in the quartz arenite field because the quartz ratio among main component grains (quartz, feldspar, and rock fragment) is more than 95%, and the ratio of the matrix was less than 15%.



**Figure (2-2):** Classification of sandstone after (Pettijohn *et al.*,1975).

**2.6. Origin of Sandstone**

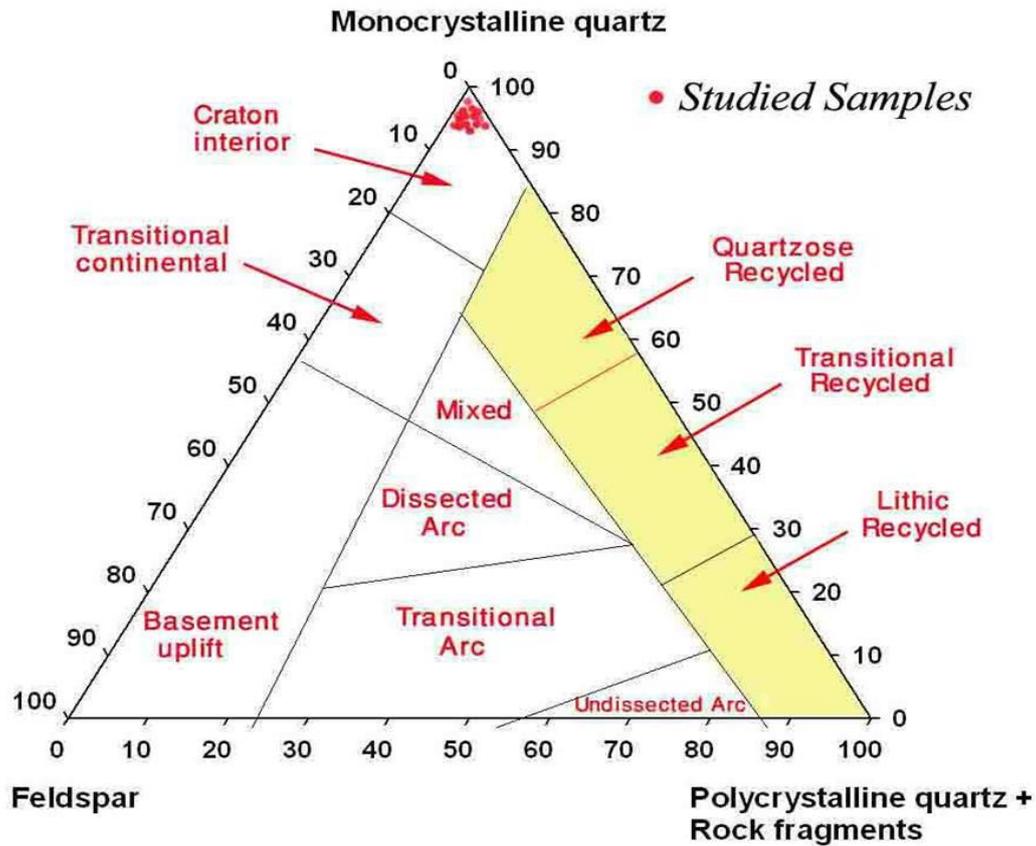
Dickinson, (1985) confirms the origin of the sandstones, and their tectonic history and sedimentation can be recognized by petrographic analyses of sedimentary rocks.

To infer the sandstone origin; the quantitative detrital modes can be used to calculate from point counts of thin sections.

Dickinson (1985) proposed a ternary diagram as a model analysis relating sand type to plate tectonic setting (fig.2-3).

It differentiates framework detrital grains proportions monocrystalline quartz, feldspar, and rock fragments, which included polycrystalline quartz, and rock fragments. Plots on this diagram provide useful information that can aid in understanding the geologic history of sediments.

The sandstone samples of the Nahr Umr Formation be located in the craton interior field, which is considered to indicate the sandstones are approximately derived from the continental source, mainly from craton as recycled sediment.



**Figure (2-3):** Tectonic discriminations fields show the Nahr Umr Formation sandstone modal data (27 samples) (after Dickinson, 1985).

**Table (2.1):** Components of studied samples of the main sandstone in Nahr Umr Formation at Well R-555.

Sample No.	Depth of samples (m)	Major Components				
		Monocrystal-line Quartz	Polycrystal-line Quartz	Feldspar	Rock fragments	Matrix
1	2500.3	89.2	5.8	1.0	1.0	3.0
2	2508.2	89.9	5.1	1.1	1.1	2.8
3	2460.1	88.8	6.2	1.8	1.1	2.1
4	2463.1	87.5	7.5	0.9	2.1	2.0
5	2466.2	88.9	6.1	2.0	1.0	2.0
6	2469.5	90.2	4.8	2.0	1.2	2.8
7	2472.5	89.4	5.6	1.0	0.9	3.1
8	2475.9	89.0	6.0	0.9	1.8	2.3
9	2479.2	90.4	4.6	1.2	2.4	1.4

**Table (2.2):** Components of studied samples of the main sandstone in Nahr Umr Formation at Well Ru-403.

Sample No.	Depth of samples (m)	Major Components				
		Monocrystal -line Quartz	Polycrystal -line Quartz	Feldspar	Rock fragments	Matrix
1	2656.3	92.2	2.8	1.8	1.2	2.0
2	2658.2	90.8	4.2	1.1	1.1	2.8
3	2660.1	88.9	6.1	1.1	1.8	2.1
4	2663.1	91.5	3.5	0.1	2.9	2.0
5	2666.2	89.6	5.4	2.0	0.9	2.1
6	2669.5	90.2	4.8	2.1	1.1	1.8
7	2672.5	93.4	1.6	1.9	0.0	3.1
8	2675.9	90.0	5.0	0.8	2.0	2.2
9	2679.2	91.7	3.3	1.0	2.1	1.9

**Table (2.3) :** Components of studied samples of the main sandstone in Nahr Umr Formation at Well ZB-190.

Sample No.	Depth of samples (m)	Major Components				
		Monocrystal -line Quartz	Polycrystall -ine Quartz	Feldspar	Rock fragments	Matrix
1	2756.3	88.8	6.2	1.5	1.4	2.1
2	2758.2	90.1	4.9	0.9	1.1	2.0
3	2760.1	89.6	5.4	0.9	1.1	3.0
4	2763.1	92.2	2.8	1.2	1.8	2.0
5	2766.2	88.5	6.5	0.6	2.1	2.3
6	2769.5	91.3	3.7	0.2	2.1	2.7
7	2772.5	89.8	5.2	1.0	1.0	3.4
8	2775.9	89.9	5.1	1.1	1.2	2.7
9	2779.2	90.0	5.0	1.4	1.3	2.3

## 2.7. Maturity

Textural maturity is defined as the degree to which sand is free of interstitial clay and is well sorted and well-rounded. Because the sediments result from the weathering of source rocks, and the unstable minerals are relatively destroying throughout weathering and transportation (such as feldspar which is a common example of an unstable mineral), whereas chemically stable minerals proportionally will increase (such as quartz which represents the most abundant stable mineral).

For that, an index of the chemical maturity of rock might therefore be the ratio of quartz to feldspar (Selley, 2000). Because Nahr Umr Formation consists of a very high ratio of quartz to feldspar, for that it can be considered chemically mature.

Textural maturity describes the textural changes that sediment undergoes from the time it is weathered until it is deposited. These changes involve both an increase in the degree of sorting, and roundness (Pettijohn, 1975) and a decrease in matrix content sediments (Selley, 2000).

The roundness and sphericity of sandstone grains are estimated by using a comparative visual chart of Powers (1953) (fig. 2-4). This chart shows that most sandstone grains are rounded (pl. 2-a) to sub-rounded (pl.3d) and they have low sphericity(pl. 2-b).

A comparative visual chart of Anstey and Chase (1974) (fig.2-5), was used to determine the degree of sorting this chart show that these samples are very well sorted, except in some places the fine grains are angular, and coarser ones are rounded to broken rounded.

This may be referring to a high-energy environment or long transportation distance, due to that, the well-sorted, coarse-grained sand

becomes not only completely rounded, but also break into fine-grained angular sand, and leads to a decrease the sediment roundness and sorting (Jafar Zadeh and Hosseini-Barzi, 2008). For that these samples are moderately sorted.

The rocks in the upper sand member are mature physically and chemically. This is indicated by the presence of the high percentage of quartz and by the medium to good sorting. And this supports the concept that the rock of the Nahr Umr Formation passes in many cyclic depositions and is transported to a far distance.

In Nahr Umr Formation there is high quartz content to other components and the well sorting and good roundness refer to a high degree of textural and mineralogical maturity. They are obviously the end product of long and severe weathering, sorting and abrasion. For that, there is sufficient time to achieve these results, and indicate that the source area and site of deposition are tectonically very stable or that the sand may have gone through several cycles of sedimentation (Pettijohn, 1975).

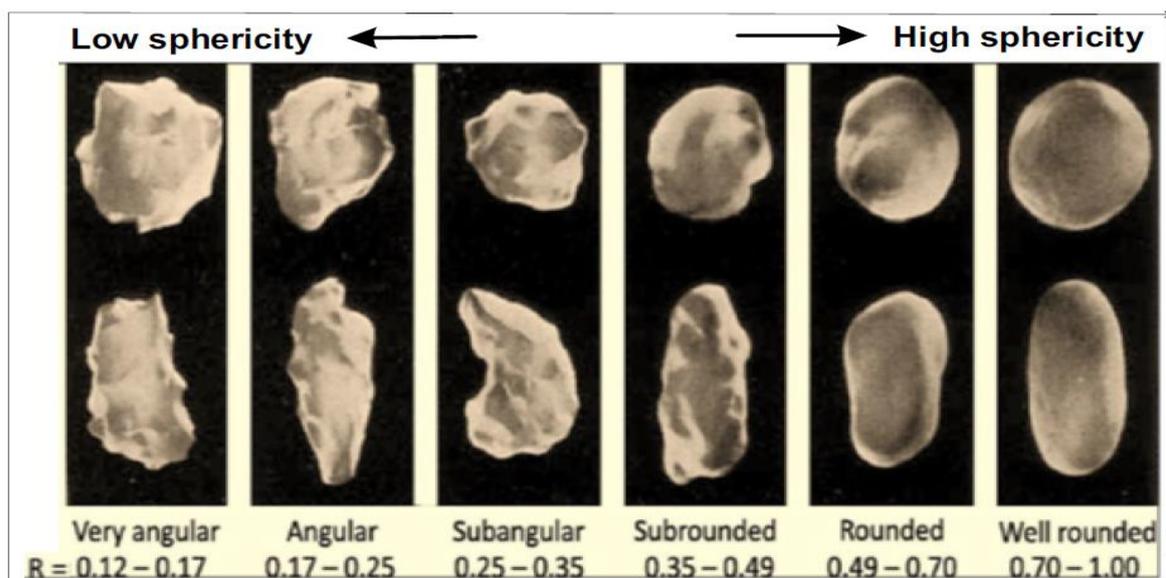
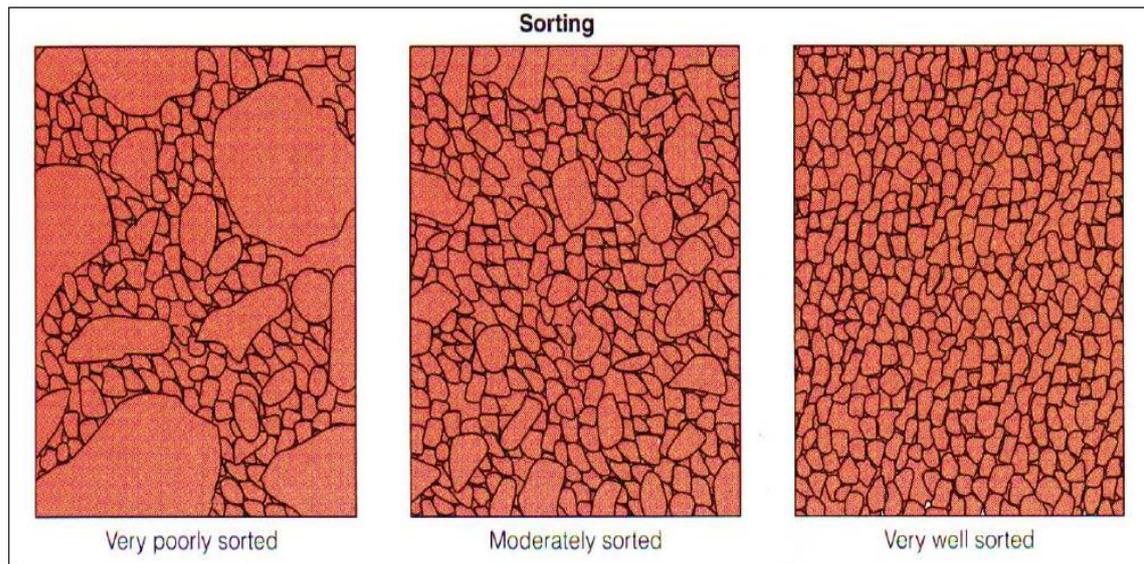


Figure (2-4): Grain shape for estimating the roundness of sedimentary particles (After Powers, 1953).



**Figure (2-5):** Grain sorting shape for Sediment with different degrees of sorting(After Anstey *et al.*, 1974).

## 2.8. Diagenesis processes

The term diagenesis refers to the processes that transform unconsolidated sediment into rock. Thus, diagenesis includes all changes (textural, physical, chemical, and biological) that occur in sediments or sedimentary rocks during and after deposition, but excludes processes involving high enough temperature and pressure to be called metamorphism. (Pettijohn, 1957). Diagenetic processes affect porosity and permeability.

The diagenesis processes can be divided into two types: the physical diagenesis processes which include (compaction), and chemical diagenesis processes which include ( cementation, dissolution and dolomitization,).

These divisions were adopted in the study of the diagenesis processes that occurred in the clastic sediments of the Nahr Umr Formation in the study wells.

**2.8.1. Physical diagenesis processes****2.8.1.1. Compaction**

Under the influence of the sedimentary cover, there are a set of processes that occur to reduce the primary porosity of the sediments and reduce the size of the rocks through the exit of fluids that are trapped between the grains of sandstone. The act of compaction was distinguished from the shattering, crushing, and expansion of the surface area of the grains (Pl. 2-c). It was found that the effect of compression is great in the Nahr Umr Formation, and the reason for this is the high content of clay.

The compaction increases by increasing the clay content and fine granules (Searl, 1989), and it decreases by increasing the structural components and the two named processes (early cementation and dolomitization) (Flugel, 1982).

The compaction process depends on several factors, including the mud content, the depth of burial, the rate of rock fragment, and grain sorting (Blatt, 1982).

And the effect of compaction in clay sediments is more than in sandy sediments because clay minerals are often lamellar in shape, and then their response is severe with the compaction process (Dapples, 1979), therefore, the compaction has a greater effect on the units formed from the sequence of shale with sandstone relative to the clean sand units (Dapples, 1979), and because the studied area consists of sandstone interspersed with units of shale, the effect of compaction was clear.

## 2.8.2. Chemical diagenesis processes

### 2.8.2.1 Cementation

The cementing process reduces the porosity that was present at the time of sedimentation because cement is formed around the edges of the grains and its growth outward in the pores leads to partially or filling the pores, which leads to a decrease in the porosity (Nichols, 2009). More than one type of cement was found in the Nahr Umr Formation rocks:

#### 2.8.2.1.1 Silica cement:

silica cement constitutes a greater proportion than other types of cement, which takes the shape of (Quartz overgrowth) (pl.2d) it is optically continuous with the quartz grain and appears partially or completely and it may be detected in many situations by spotting a ring. The original quartz grain is separated from the cement by iron oxides or clays and this is known as the dust line (Pettijhon *et al.*, 1973).

Silica cement may be formed from the processes of pressure solution, which leads to the dissolution of silica at the areas of contact with the grains, as with the increase in the burial process, the contact between the quartz grains increases, and the solubility of the silica increases in the areas of contact, and then it is re-deposition between the voids (Taylor and Soule, 1993; Pettijohn, *et al.*, 1973; Dapples, 1979).

#### 2.8.2.1.2. Calcite cement

Calcite cement was also found in smaller quantities than silica cement, which is either microcrystalline calcite or spary calcite cement also available in the shape of spots, also, some quartz grains appeared floating in the calcite cement, resulting in the (Poikililopic texture) (Boggs, 2009). It is known as

inconsistent cement because its chemical structure differs from the chemical structure of the granules that make up the rock.

It is believed that the most important sources of this type are the solutions saturated with calcium carbonate, resulting from the dissolution of granular and lime structures within the Nahr Umr Formation, as well as the dissolution of some lime layers located below and above the formation at the borders of contact with the Shuaiba and Mauddud formations, and then deposited in the form of cement in other sites within the Nahr Umr Formation.

### **2.8.2.1.3 Iron oxide cement**

It is distinguished in some samples of formation rocks by its color reddish brown or black and is found with silica and calcite cement and is in two forms, either filled the microfractures or between grains intergranular.

Iron cement is also incompatible cement (Dapples, 1972), and its presence is consistent with silicic or calcite cement, as it was not observed individually in the study samples. Iron cement may be a result of the partial dissolution of clay minerals of clastic origin (Dapples, 1972).

Which was observed as evidence of the change (alteration) occurring in some parts of the iron granules, or it may be the result of the dissolution of iron-rich minerals such as biotite, which is less stable in the diagenesis conditions and dissolution into clay minerals and iron oxides deposited in the form of cement.

Also, the leaching processes of the iron-rich sandy and shale layers have a role in the formation of this type of cement.

**2.8.2.1.4. Clay cement**

It is found in the form of pseudo-hexagonal sheets of the mineral kaolinite bound between quartz grains. This works to close the necks of the pores and then decrease the permeability, or in the form of a coating on the surfaces of the grains of the illite mineral, and the percentage of its presence was low in the studied samples, and it directly affects the permeability of the rocks (Burley, 2003).

The presence of these clays results from the partial dissolution of the granules and rock fragments and filling of the void with clay minerals, and in some cases, the original shape of the granule appears.

**2.8.2.2. Dissolution**

It is the diagenesis process through which solid sediments are dissolved by water pore solution, leaving voids or cavities within the sediment (Burley and Worden 2003). It is responsible for producing secondary porosity in sandstone by dissolving calcite cement or granular structures (Boggs, 2009).

More than one type of secondary porosity has been distinguished in formation rocks according to Schmidt and McDonald (1979) classification. Including the intergranular pore texture, the porosity resulting from dissolving a large area of calcite cement and leaving large craters is known as the oversize pore texture (pl.3c).

Secondary porosity was also diagnosed in some rock samples resulting from fractures forming continuous fracture from the porosity (pl.3a).

**2.8.2.3. Dolomitization**

It is a process whereby limestone or its precursor sediment is completely or partly converted to dolomite by the replacement of the original

CaCO<sub>3</sub>, with magnesium carbonate, through the action of Mg-bearing water, (Flugel, 2004).

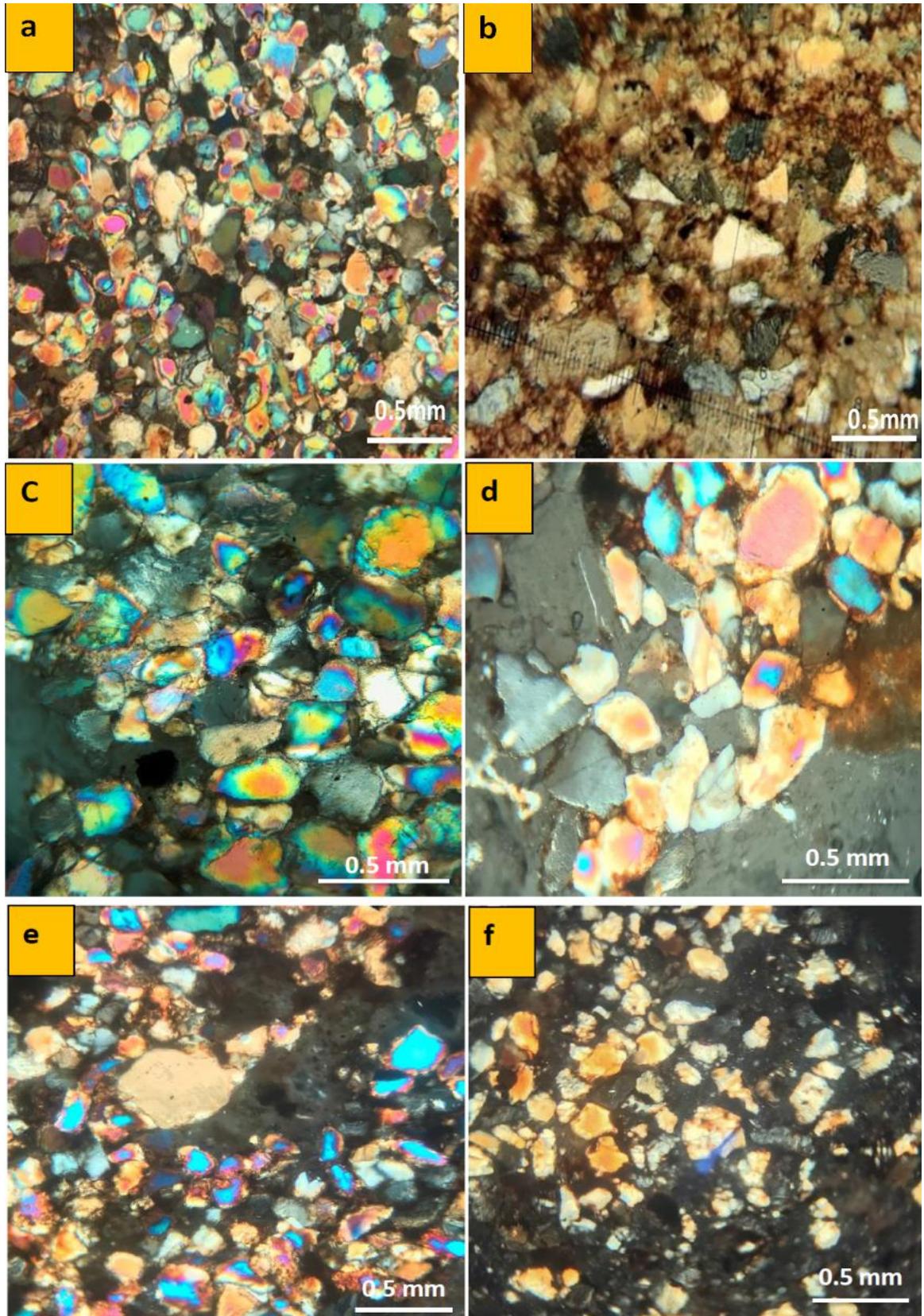
The size of crystals is (medium, coarse and very coarser) as well as most crystals have rhombohedral shapes where selective dolomitization attacks the limestone forming dolomitic limestone, where the original depositional texture may be preserved (Flugel, 2004).

In the studied succession, dolomite is occurred in some parts of the shale unit as a secondary pervasive zoned dolomite (cloudy rim) (pl.3b) and scattered fine crystal dolomite.

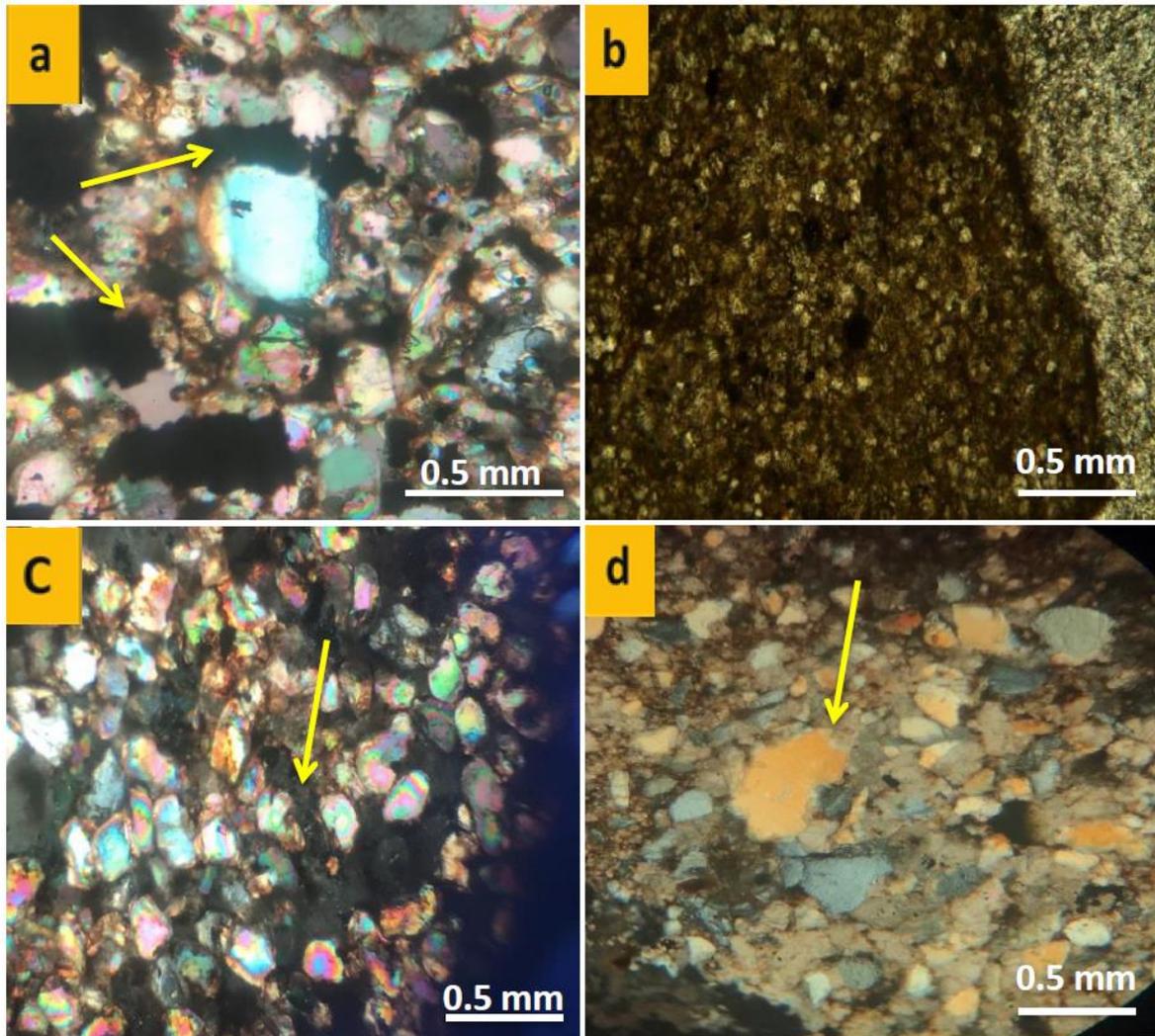
**Plate-2-**

- a. well-sorted quartz arenite sandstone under the polarized (Ru- 403, 2685m).
- b. Poorly sorted quartz arenite sandstone under the polarized (Zb-190, 2680m).
- c. Compaction to the grain of quartz contract relation between grains (Ru- 63, 2850m).
- d. Quartz overgrowths under the polarized (R- 555, 2700m).
- e. Shaly sandstone (ZB-047, 2840m).
- f. Claysandstone is poorly sorted(R- 555, 2470m).

Plate-2-



## Plate-3-



## Plate-3-

- a- porosity of sandstone under the polarized (Ru- 403, 2680m).
- b- Secondary pervasive zoned dolomite (cloudy rim) under the polarized (R- 555, 2570m).
- c- Dissolution under the polarized (ZB- 190, 2660m).
- d- Subrounded Quartz grains under the polarized (ZB- 047, 2854m).

# **Chapter Three**

*'Facies Analysis and  
Depositional Environmental'*

### **Chapter Three**

### **Facies analysis and depositional environmental**

#### **3.1. Introduction**

The facies analysis and depositional environment of sedimentary rocks depend upon an interplay of tectonics, sea level, sediment supply, physical and biological processes of sediment transport and deposition, and climate.

At the basin scale, these processes interact to produce the geometric arrangement of different depositional environments or systems tracts through time, known as the stratigraphic architecture of the basin (Maill, 1991).

One of the first steps in the facies analysis of a clastic reservoir is the description and interpretation of the available conventional core (Siemers, and Tillman, 1981). An important result of core description in this study is the subdivision of cores into lithofacies, defined as subdivisions of a sedimentary sequence based on lithology, grain size, physical and biogenic sedimentary structures, and stratification that bear a direct relationship to the depositional processes that produced them. Lithofacies and lithofacies associations (groups of related lithofacies) are the basic units for the interpretation of depositional environments.

According to the availability of these parameters, there are 6 lithofacies in the Nahr Umr succession.

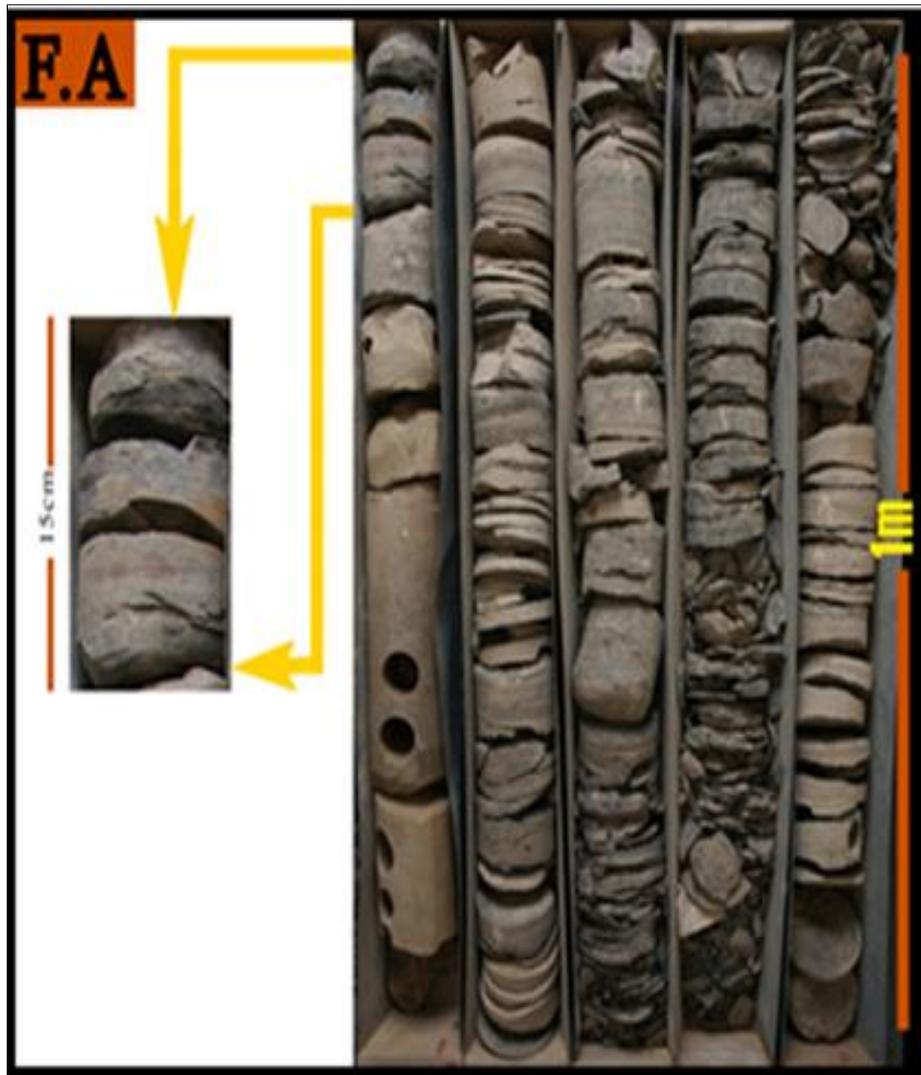
#### **3.2. Lithofacies of Nahr Umr Formation**

##### **3.2.1. Shale lithofacies (F.A)**

These are shale rocks with high organic content and a black or dark lead color (vegetation residues) (fig. 3-1). The main distinguishing feature of

## **Chapter Three Facies analysis and depositional environmental**

these facies is their high density. The Nahr Umr Formation lower section is dominated by shale, and these facies reflect that part.



**Figure(3-1):** Shale lithofacies , (R- 555/ 2460m-2461 m)

### **3.2.2. Lenticular bedded sandstone-mudstone lithofacies (F.B)**

These facies consists of soft sandy rocks in the form of lenticular sandstone that are interbedded with shale rocks of gray color, and non-foliation (fig.3-2).

This sandstone can develop into a sedimentary structure of the kind of wavy sand in one area due to energy fluctuations. This kind of rock was

## **Chapter Three Facies analysis and depositional environmental**

discovered towards the top and bottom of the Nahr Umr Formation, which is characterized by clay rocks.



**Figure(3-2) :**Lenticular bedded sandstone-mudstone lithofacies, (ZB-190/2445m-2446m) .

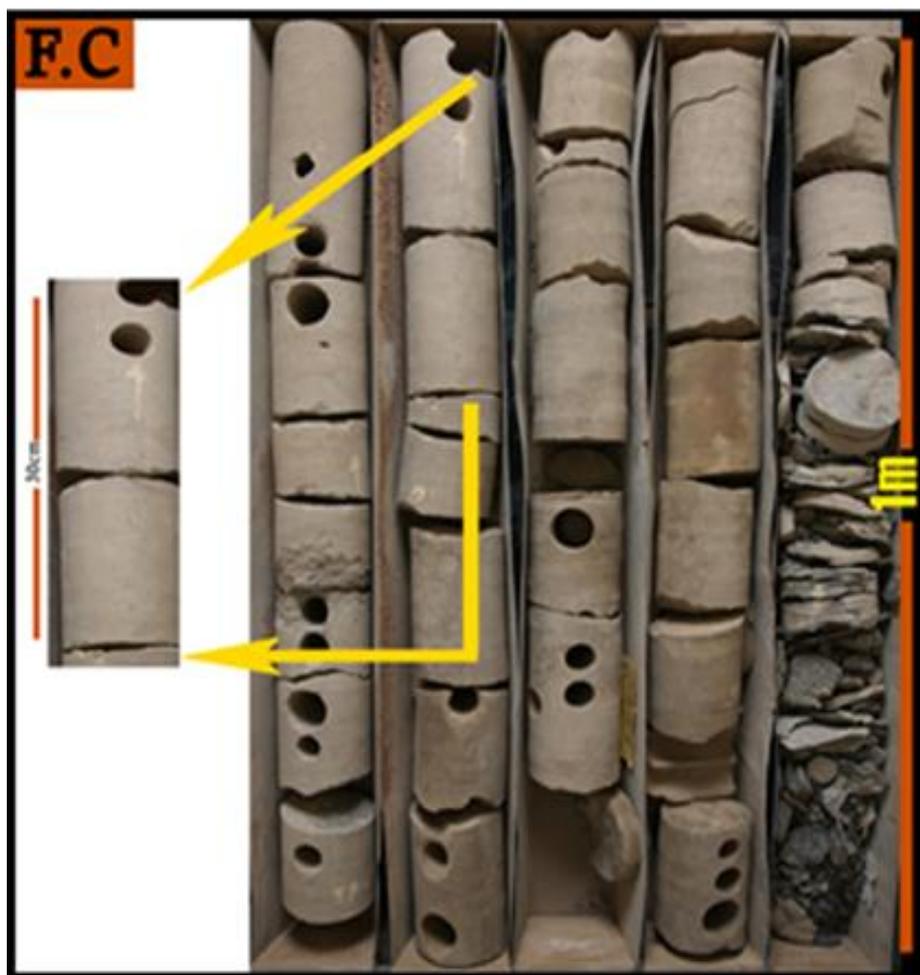
### **3.2.3. Falser bedded sandstone –mudstone lithofacies (F.C)**

These facies are composed of simple and falser layers with a thickness of less than one meter and a restricted distribution that may not be present in all, where it comprises falser bedding and fine-grained medium-size rocks of the investigated wells.

## Chapter Three Facies analysis and depositional environmental

When mud is caught between layers of sand that are not linked and separated, wave activity occurs because the mud was created as a result of alternating wave currents (fig. 3-3).

When sand is deposited in stagnant water when the sedimentation energy is low and the clay stays suspended, it is deposited on the peaks created in the early phases of the period when the sedimentation energy is low. When the strong currents return, they will deposit sand and wash away the mud that has accumulated on the tops of the ripples. As a result, the mud in the ripple depressions will remain stuck. As a result, these facies emerge in alternating energy settings (Alsultan *et al.*, 2021).

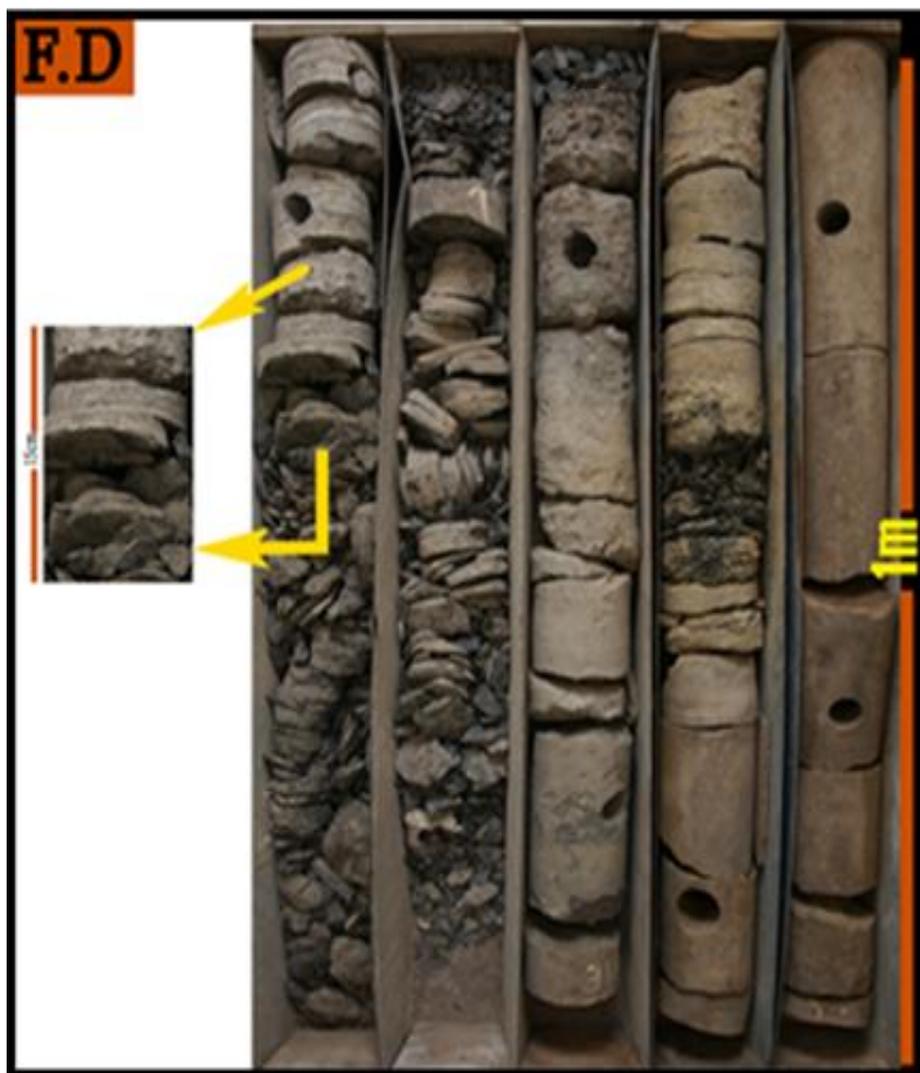


**Figure (3-3):** Falser bedded sandstone –mudstone lithofacies, (Ru- 463/ 2655m-2656m).

### 3.2.4. Siltstone–shale lithofacies (F.D)

This facies is composed of shale rocks containing silt and fine sand as well as plant fragments.

The quantity of shale here is smaller than the amount compared with the other shale lithofacies, resulting in rapid reductions in gamma-ray log values. This structure formed in the upper section of the Nahr Umr Formation which is dominated by shale (fig. 3-4).



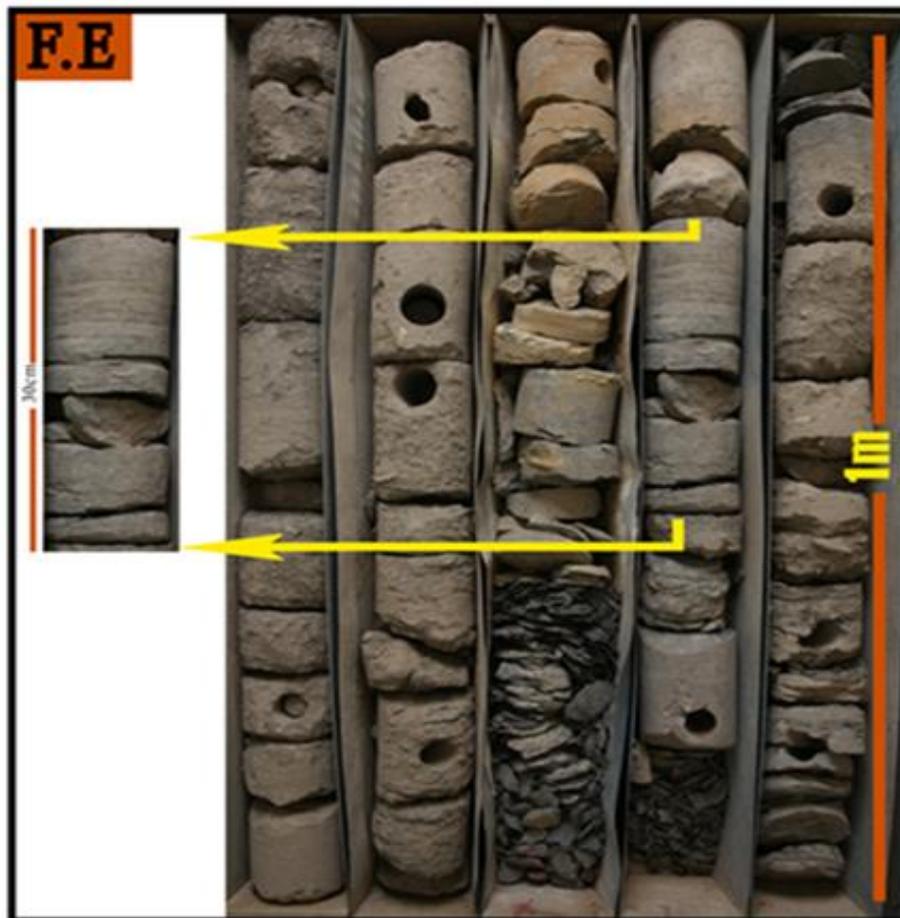
**Figure (3-4):** Siltstone–shale lithofacies(Ru- 403/ 2470m- 2471m) .

### 3.2.5. Cross-bedded sandstone lithofacies (F.E)

## Chapter Three Facies analysis and depositional environmental

These facies are composed of medium- coarse sandstone that is well-sorted and vary in color from pale to dark brown due to a rise in oil evidence. Two types of sedimentary structures have been observed: trough cross-bedding and planar cross-bedding (fig. 3-5). Minor layers of shale and silt were found parallel to the shale level and these facies may contain small layers of shale and silt.

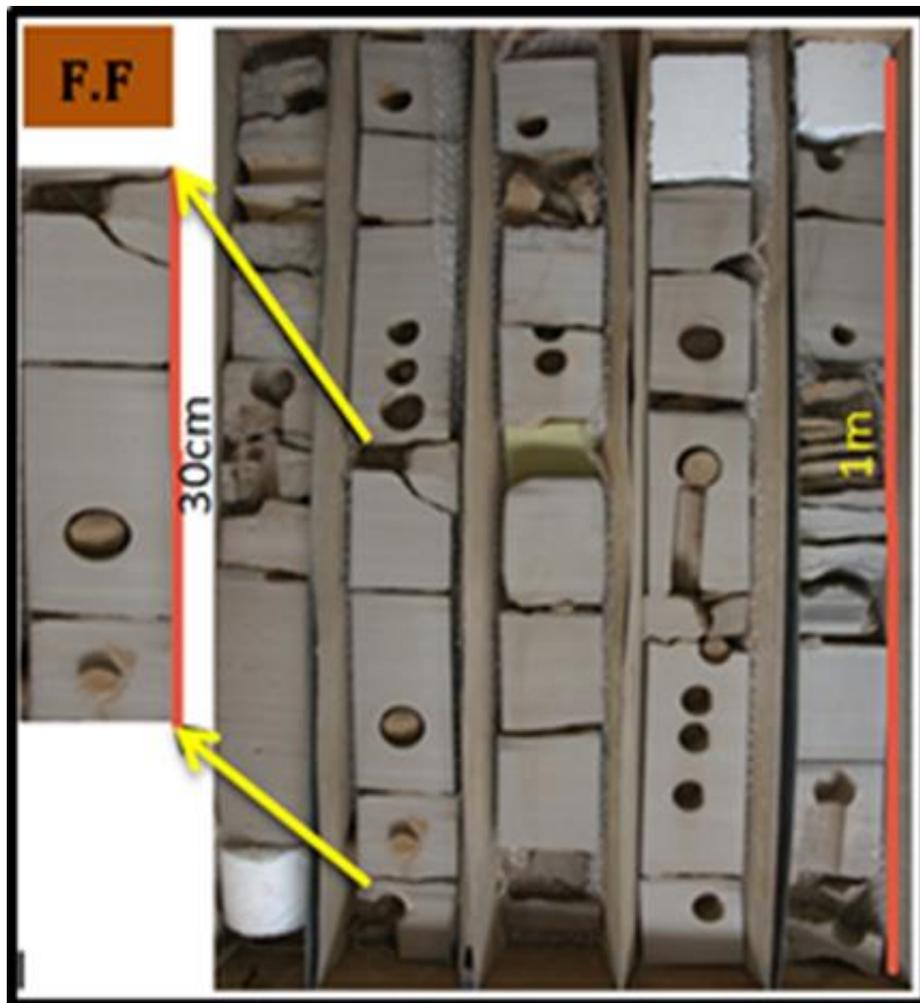
The red color on sandy rocks might occasionally indicate the influence of the oxidation process on the rocks. The facies of sandstone with parallel and cross-bedded are considered one of the most prevalent facies in the Nahr Umr Formation especially in the lower part of it, where these sands show two types of sequences, one of the fining to the upward and coarsening bottom sequences less and the first is less widespread than the second and may not appear different it is granular in size or difficult to distinguish.



**Figure(3-5):** cross-bedded sandstone lithofacies, (ZB-047/ 2820m- 2821m).

### 3.3.6. Parallel and Cross Lamination Sandstone lithofacies (F.F)

It is a facies that consists of fine to medium sand grains inclined at different angles from well-sorted sandstones. The cross lamination facies are mostly of the medium-sized type, with an inclination angle of 20°; in addition to a cross lamination of a lesser degree with an inclination angle between (5-10°) degrees. Calm tides, banks and dams (Qaradaghi *et al.* 2008). While the existence of the bioturbation as a mottled structure indicates an active deposition in river channels and prodelta (Qaradaghi *et al.* 2008) (fig.3-6).



**Figure (3-6):** Parallel and Cross Lamination Sandstone lithofacies,(Ru-403/(2584m-2585m).

### **3.3. Sedimentary environment**

Modern stratigraphic research tries to determine the sedimentary environments and attempts to construct a sedimentary model for the studied region using information gathered from sedimentary facies, electrofacies and microfacies.

The sedimentary environment is defined as a geographically defined part of the earth's surface where sediments accumulate and can be described from a geomorphological standpoint and it is characterized by complex physical, chemical and biological conditions that distinguish it from its surroundings (Selley, 1978).

The facies are one of the smallest units of the environment, Walther (1894) is the first to establish a link between the sedimentary facies and the sedimentary environment, which became known as Walther's Law.

This statement indicates that the vertical succession of sedimentary facies is produced by the lateral succession of environments. The facies association is defined by the vertical succession of facies, which is determined by the sedimentary environment.

It is thought to be a key to the environmental explanation and this succession is caused by a change in the sedimentary environment, which is caused by a change in sea level. It is clear from the preceding that it was possible to determine the sedimentary environment for the Nahr Umr Formation based on the availability and collection of sedimentary evidence, including the study of microfacies, sedimentary structures, sedimentary texture and rock components available in the facies and linking them with the logs study (electroscopic) and thus it was possible to determine the sedimentary environment for the Nahr Umr Formation:

## **Chapter Three Facies analysis and depositional environmental**

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### **3.3.1. Fluvial environment**

This environment has been characterized by fining upwards and the prevalence of high-energy sedimentary structures below these facies is represented by the cross-bedded and planer cross-bedded, respectively, which transform into the low energy structures, represented by the parallel and cross lamination at the top, which indicates the gradual low in the energy of sedimentation.

The study of modern rivers indicated that there are two types of sediments formed in the riverine environment, one of which represents coarse sediments at the bottom of the channel that moves as a bed load or as a (suspension load).

The suspension load in the stages of high or normal flow (Alsultan *et al.*,2021), while the second of them represents sediments above the banks represented by soft and transported sediments as a suspension load in the stages of floods, and thus the riverine environment can be divided into:

#### **3.3.1.1. Channel lag deposit**

This deposit consists of cross-bedded sandstone lithofacies (F.E), including coarse-grain sandstone, which is very rough sands resulting from very high energy flows transmitted as a bottom stratigraphic load. Erosion and transport occur in such an environment due to the high energy of the current, and when this energy of the current is reduced, this facies is deposited in the middle of the river channel, which is known as sediments. As a result (lateral accretion), which in turn leads to a decrease in the energy of the rivers responsible for the transport process, a decrease in the grain size occurs at the top, and its facies are (Parallel and Cross Lamination Sandstone lithofacies (F.F), respectively, forming sediments fining upwards.

## **Chapter Three Facies analysis and depositional environmental**

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### **3.4.1.2. Natural levee deposit**

These sub-environments sediments are deposited near river channels in the form of longitudinal bodies that reach over. The river's two sides are distinguished by a sharp slope towards the channel and a little inclination towards the flood plain. It is more noticeable on concave banks than on convex banks. It has cross-bedded sandstone lithofacies (F.E), sandstone–mudstone lithofacies (F.C), and siltstone–shale lithofacies (F.D).

The upper parts of these facies show a fine succession towards the top and that these facies (F.E) and (F.C) appear in succession, and finally, towards the top, the facies (F.D). As horizontal surf is formed in conditions of high run-off at the beginning of the flood stage, as the quantities of water carrying suspended matter and the confined interior increase, so does the energy of this water.

### **3.4.1.3. Flood plain deposit**

Floodplains represent wide and flat basins located along the two banks of the river, and sediments collect in them when water crosses into the floodplains. These facies are sometimes distinguished, especially the siltstone–shale lithofacies (F.D).

### **3.4.2. Deltaic environment**

This environment has been distinguished by the appearance of the coarsening sequences upward and the presence of organic materials, plant remains, and amber, which is found in the marshes and swamps environment within the deltaic environment, as well as the response of the spontaneous potential (SP) that shows the funnel shape, which indicates the cycles of coarsening upwards, and these deltas can be counted as the type dominated by the river, through the number of high sediments entering it and the large grain

## **Chapter Three Facies analysis and depositional environmental**

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size of sandy grains and the prevalence of sedimentary structures of high energy represented by intermittent stratification and the emergence of shale rocks and the spontaneous potential log tends to resemble the shape electrofacies of the deltaic environment controlled by the river according to (Pirson, 1970).

It was feasible to identify it from the south and north Rumaila oil fields and its gradient upwards to a deltaic environment dominated by tides, as evidenced by the spread of sedimentation of channels and tidal flats in the well (Ru-403 ) and the upper section of the well (Ru-463 ). This deltaic habitat was developed at the boundary of the seam between the development of Nahr Umr and Mauddud Formations, it was formed during the drop in sea level, generating a gradual delta.

### **3.4.2.1. Delta plain deposit**

The deposits consist of cross-bedded sandstone lithofacies (F.E) and false bedded sandstone–mudstone lithofacies (F.C). The sands of this environment show a consistent gradation in the grain size (uniform in grain size).

These facies can be counted within the sub-aerial part of the deltaic deposits. The subaerial part of the delta represents the sediments of the secondary deltaic channels.

### **3.4.2.2. Distributary mouth bar deposit**

The sediments of this sub-environment consist mainly of cross-bedded sandstone lithofacies (F.E). This shows coarse sequences towards the top due to the increase in sedimentation energy towards the top. These facies are deposited over the prodelta sediments. And such a sequence is explained by the fact that it was deposited in the environment of the developing Delta region (Prograding delta front). This may be observed through the behavior of

## **Chapter Three Facies analysis and depositional environmental**

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the spontaneous potential, which shows the funnel shape, and these represent the underwater part of the deltaic deposits. (subaqueous part of the delta) it represents the environment of the delta front affected by rivers (river-dominated delta front) (fig.3-7).

The effect of the riverine action is evident through the prevalence of discontinuous stratification structures and coarse granular size.

### **3.4.2.3. Distal bar deposit**

This deposit consists of false-bedded sandstone–mudstone lithofacies (F.C). With the presence of thin layers of siltstone–shale lithofacies (F.D) and shale lithofacies (F.A), the sands of these facies are of fine size.

The facies of this environment show coarse sequences towards the top, and this is consistent with the response of the spontaneous potential log, which shows the funnel shape and that the thickness of this environment increases in the middle of the study area. It represents a transitional environment between the prodelta environment from below and the environment of the river mouth barrier from the bottom.

The upper part of the Nahr Umr Formation represents the sloping edge towards the sea, and it is characterized by an increase in the sedimentation speed and the grain size towards the top. Fine grains are rich in organic matter (Canaanite, 2002).

### **3.4.2.4. Prodelta deposit**

This deposit is represented by the shale lithofacies (F.A) and the siltstone–shale lithofacies (F.D) .respectively, thus reflecting the phenomenon of coarseness towards the top.

## **Chapter Three Facies analysis and depositional environmental**

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This environment is characterized by its fine sediments, which result from the slow accumulation of sediments in a calm environment.

We infer from the types of rocks and sedimentary structures that these facies belong to the underwater part of the deltaic sediments located within the environment of the front of the delta (fig.3-7 ).

### **3.4.2.5. Tidal channel & Tidal flat**

The appearance of facies in this sub-environment confirms to us the transformation of the delta from a river-dominated delta. Several indications were observed in the core available in the wells of the study, especially in the wells (R-555),(ZB-190), and(ZB-047).

It gradually fines in the granular size towards the top, thus reflecting the phenomenon of fining towards the top as well as the gradation in the sedimentary structures towards the top, from the sedimentary structures characterized by high energy (planar and trough stratification) at the bottom to the distinctive low energy sedimentary structures (flaser and lenticular stratification) at the top.

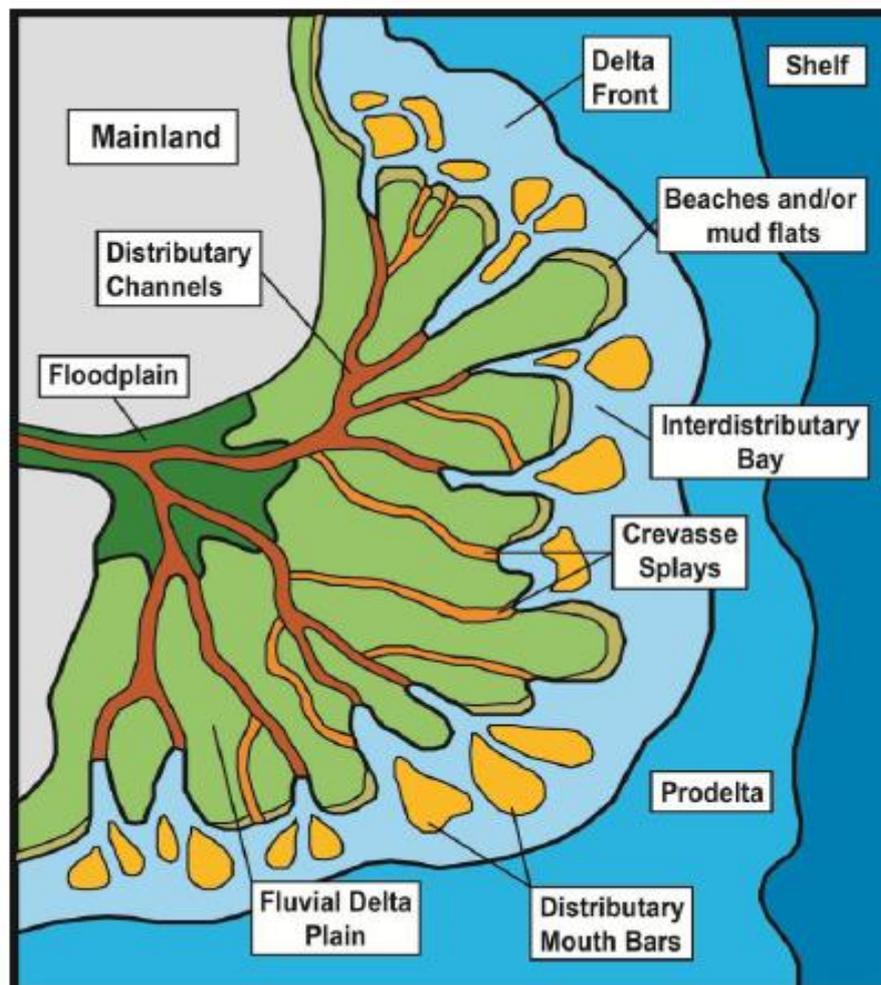
The presence of the latter is one of the important indications of the sedimentation of mixed intertidal flats, with the presence of mudstone and sandstone and bioturbation in the upper part of these sequences. The following describes each of these sedimentary structures.

This type of application results from the effect of displacement of sand waves or large ripples marks, due to the currents of the flood and island cities. Then, in Zabeel, it is topped by the basin stratification of the same previous facies (Klein, 1977).

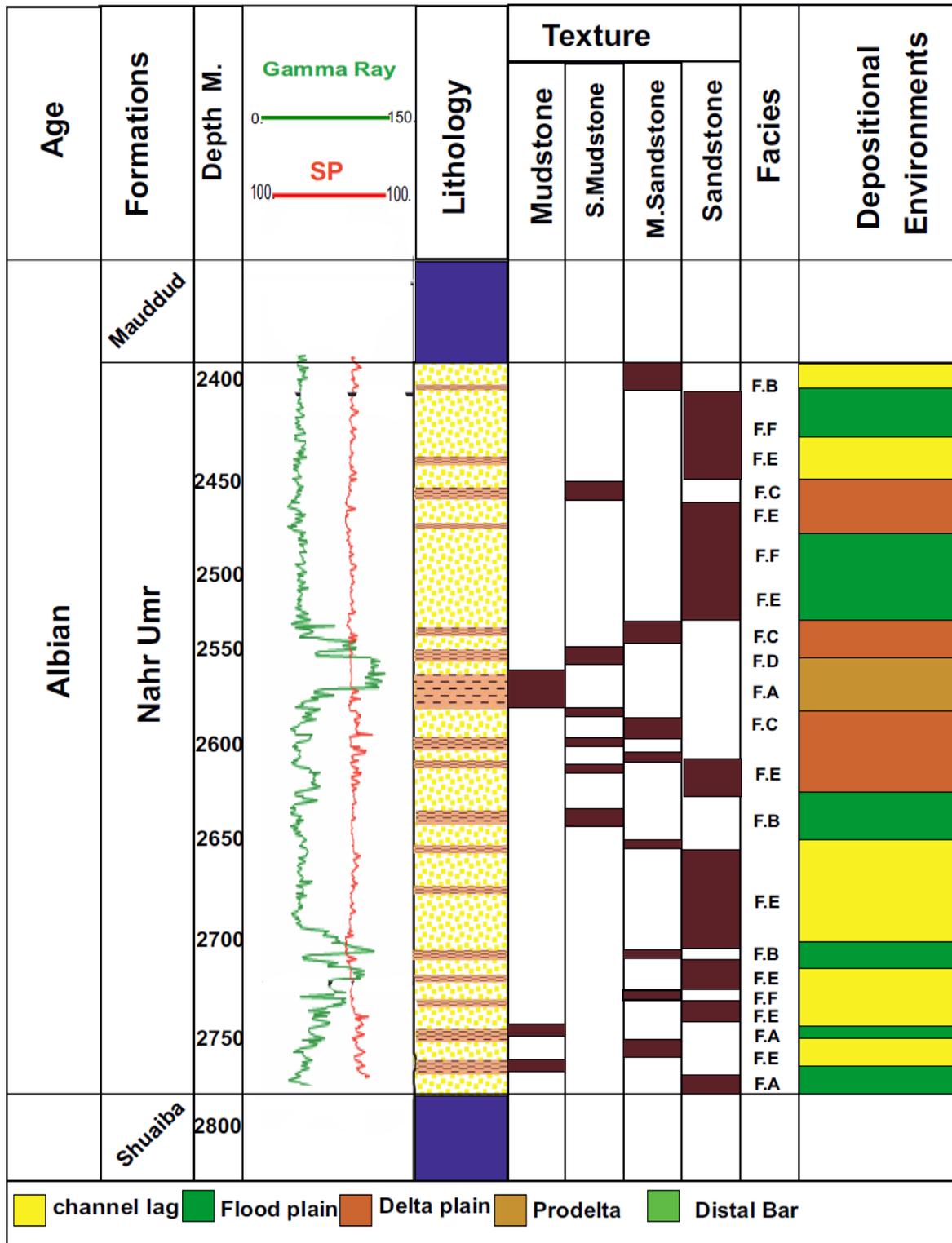
## Chapter Three Facies analysis and depositional environmental

This type of structure results from the displacement of the large ripples marks under the influence of tidal currents at the bottom of the tidal channels (subtidal sub environments).

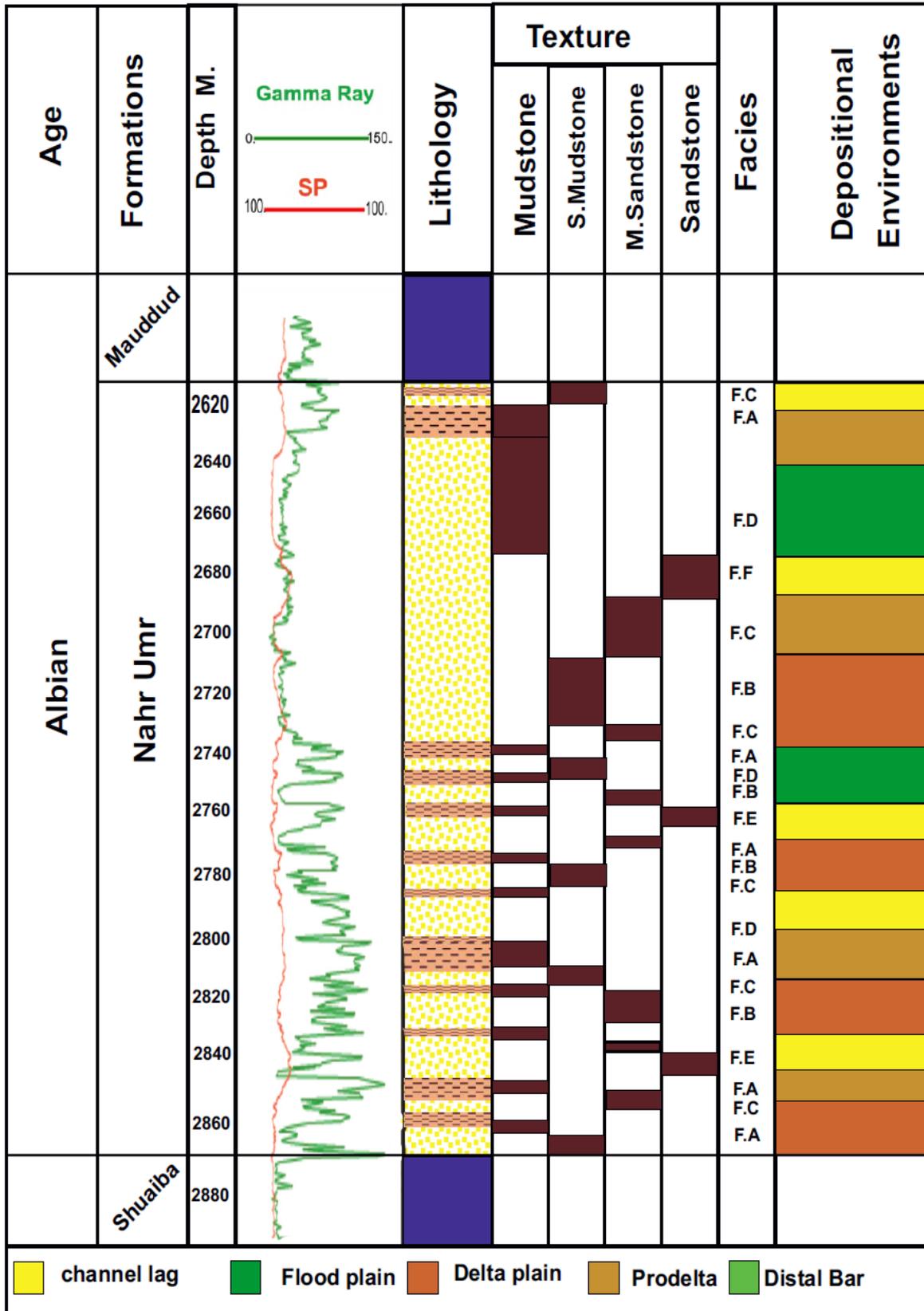
It is also called the lower tidal flat (Klein, 1972 Al-Karkaji, 1989 ) then it grades upwards, revealing the facies of the false bedded sandstone–mudstone lithofacies (F.C) and facies of the Lenticular bedded sandstone-mudstone(F.B). Widespread in this part and finally the facies of shale lithofacies (F.A) all these environments and facies appear in the lower member of the mixed unite, figures (3-8), (3-9), (3-10), (3-11) and (3-12).



**Figure (3-7):** Shows delta facies (Kenneth, 2013)

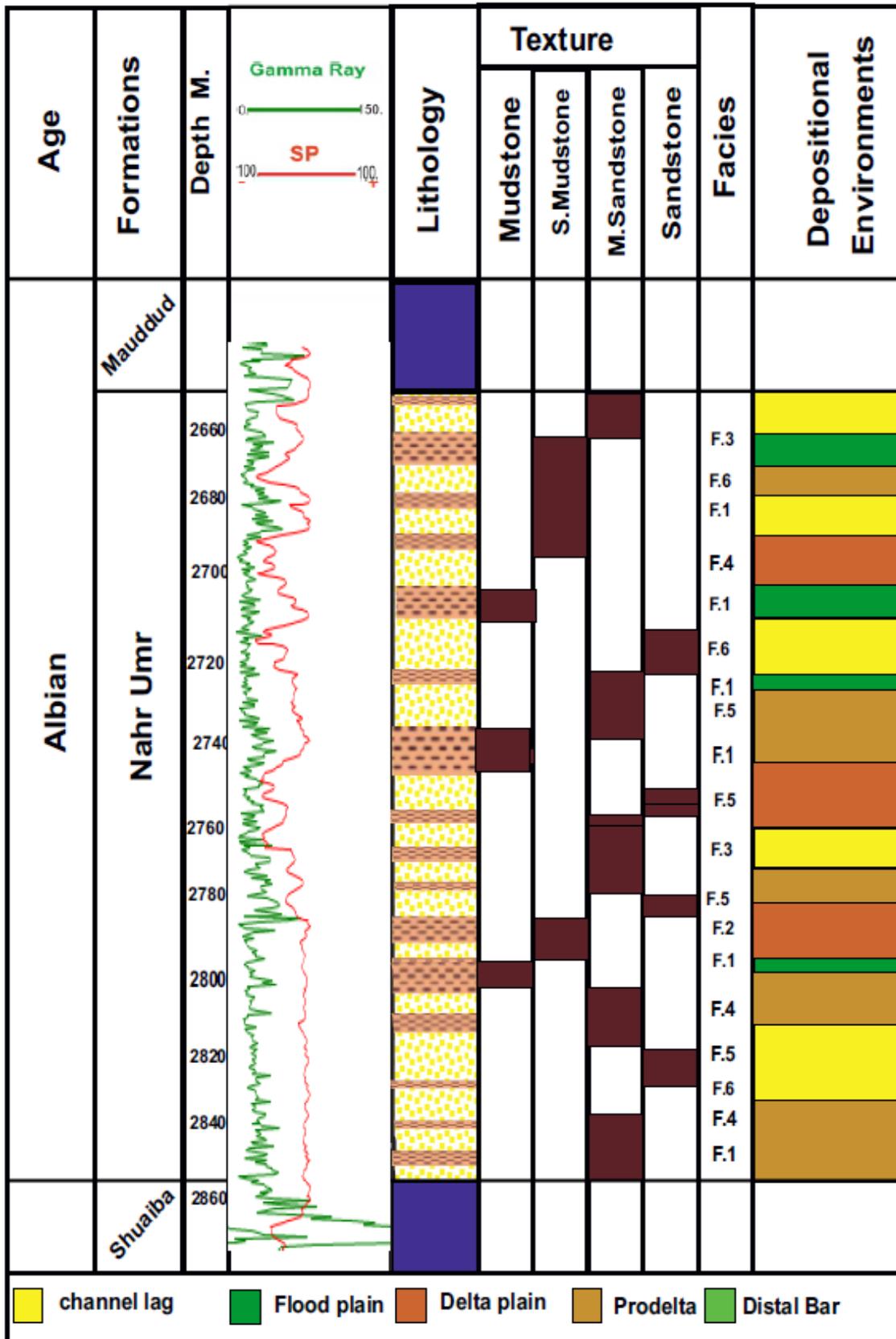


Figure(3-8): Microfacies and environments of Nahr Ume Formation at R-555.

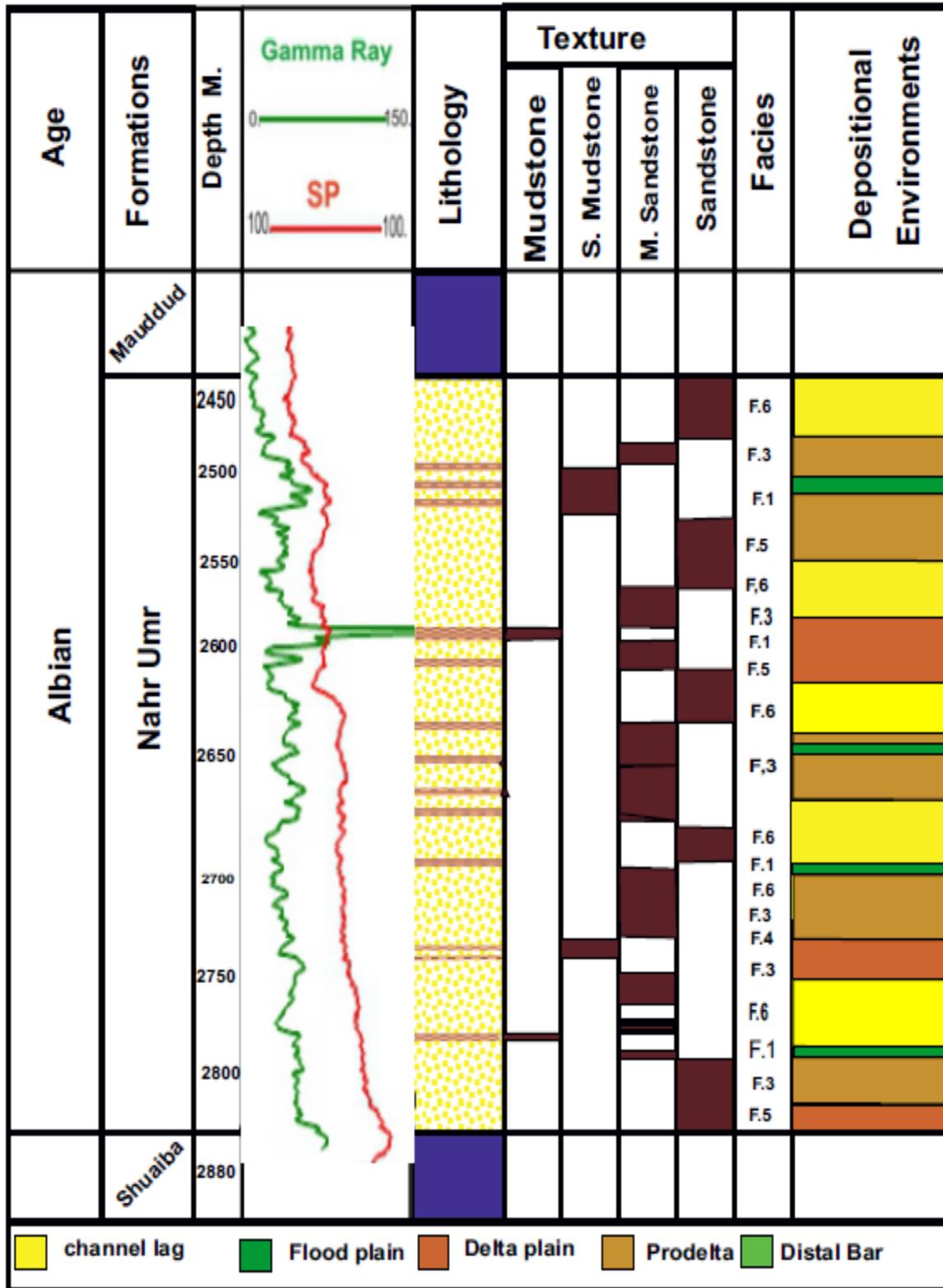


Figure(3-9): Microfacies and environments of Nahr Ume Formation at Ru-403.





Figure(3-11): Microfacies and Environments of Nahr Umr Formation at ZB-047.



Figure(3-12): Microfacies and Environments of Nahr Umr Formation at ZB-190.

# **Chapter Four**

## ***" Sequence Stratigraphy "***

## Chapter Four

### Sequence Stratigraphy

#### 4.1. Introduction

Stratigraphy is concerned with the study of stratigraphic sections, whether they are surface or subsurface detectors. The study may be in terms of rocky, fossil, geochemical, or geophysical, and each study gives certain results, ignoring the temporal dimension.

Therefore, it was necessary to have a science that gathers all this evidence, taking into account the temporal dimension. Therefore, this came based on the principle of convergence of evidence, where the concept of stratigraphy is the most organized and comprehensive concept of stratigraphy that is concerned with studying the geological history of stratified rocks, by dividing the rocky record and distributing rocks during time and space.

Study of rock relationships within a time-stratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition, or their correlative conformities (Posamentier *et al.*, 1988; Van Wagoner *et al.*, 1988).

It was (Vial *et al.*, 1977) had a significant impact on the development of sequential stratigraphy by establishing its bases through sedimentary structures and stratigraphic relationships deduced from seismic sections and related to global changes in sea level. Any change in the limits of marine and continental sedimentation is attributed to the intervention of three factors, namely the eustatic change of sea level and land sedimentation (subsidence) the percentage of sediment preparation for clastic rocks, and the rate of production and

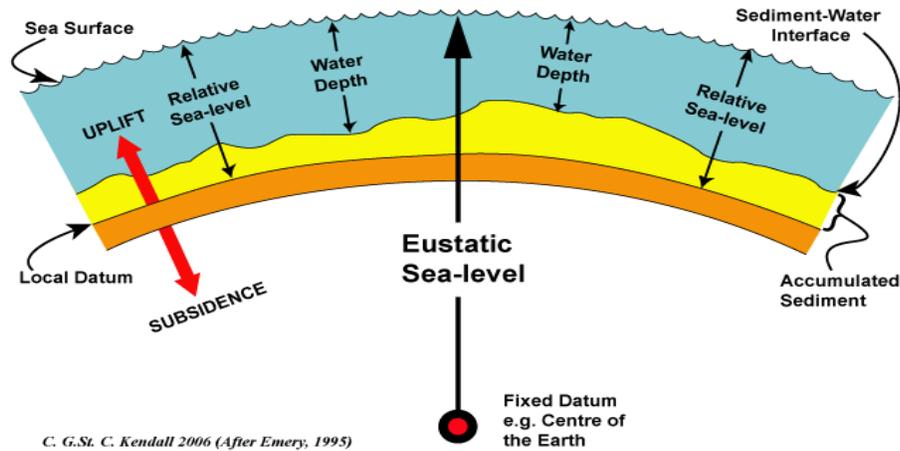
aggregation of sediments in limestone, which is determined by the climate factor (climate). And understanding the relationship between these changes helps predict future drilling locations. Finally, it should be noted that several branches of geological sciences support and pave the way for the concept of stratigraphy, which includes seismic stratigraphy, biostratigraphy, chronostratigraphy, and sedimentology.

#### **4.2. Relative sea level**

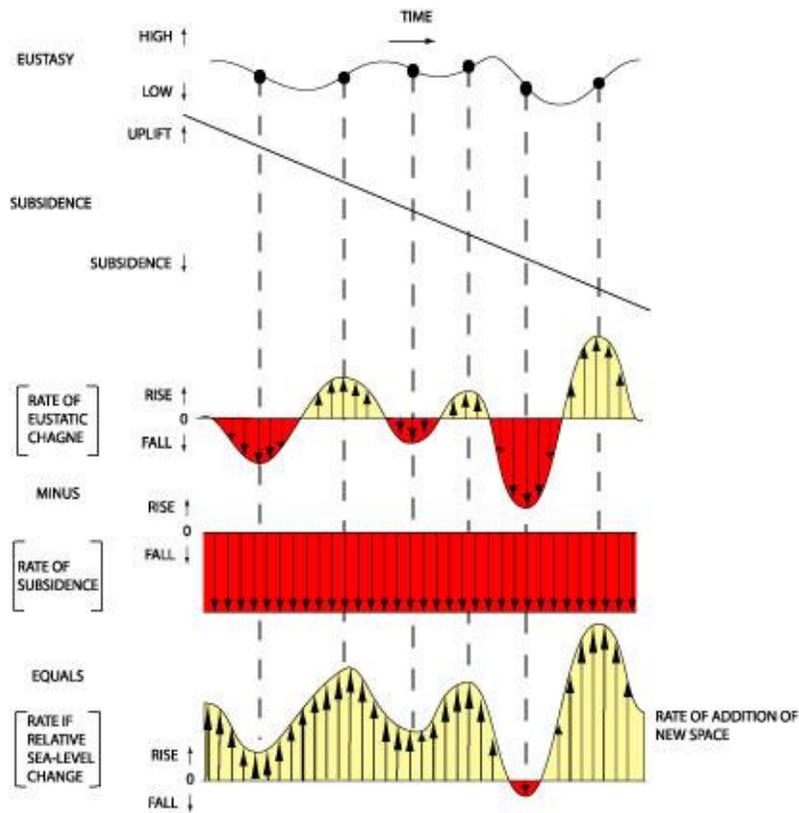
It is the sea surface's position about a fixed datum at the sea bottom, as determined by two factors: eustasy and seafloor movement (tectonism of sediment compaction) (Posamentier and Vail, 1988). The relationship between the eustatic sea level, which refers to the global sea level surface position concerning a fixed datum such as the center of the earth or a satellite in a fixed orbit around the earth, and the rate of subsidence determines whether the relative sea level rises or falls (fig.4-1),(Catuneanu, 2002).

The space available for carbonates deposits will fluctuate depending on the combination of eustatic sea level and subsidence rates; this space was characterized by Jervey (1988) as "the space accessible for prospective sediment accumulation". It is the result of a combination of three elements (fig. 4-2):

- The sea surface (eustasy: global sea level measured from a datum such as the center of the earth).
- The ocean's surface (tectonics).
- Changes in sediment accumulation rates.

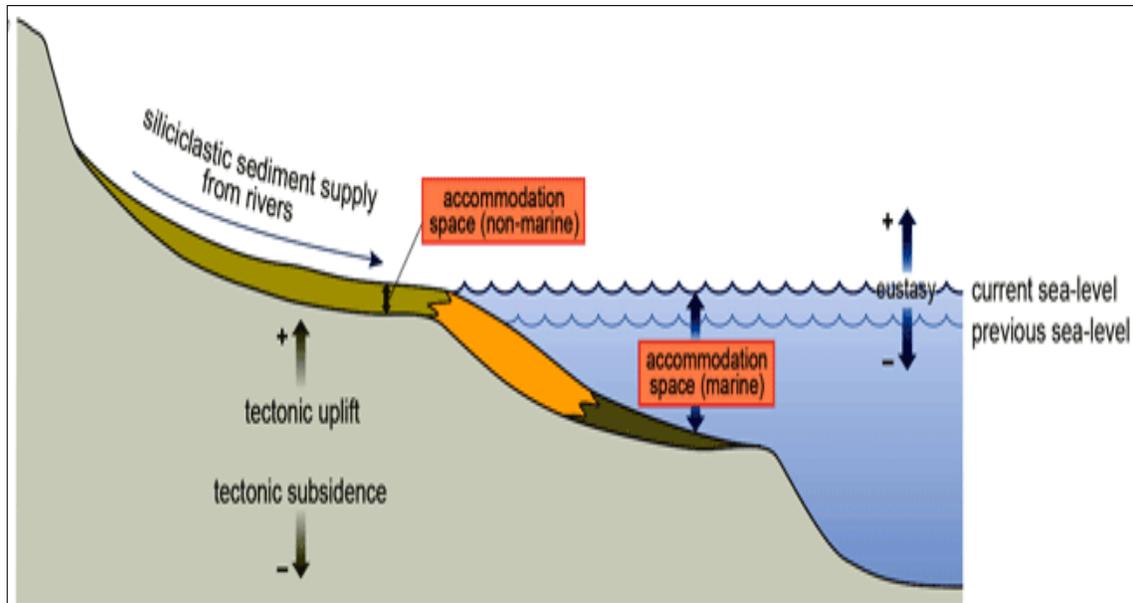


C. G. St. C. Kendall 2006 (After Emery, 1995)



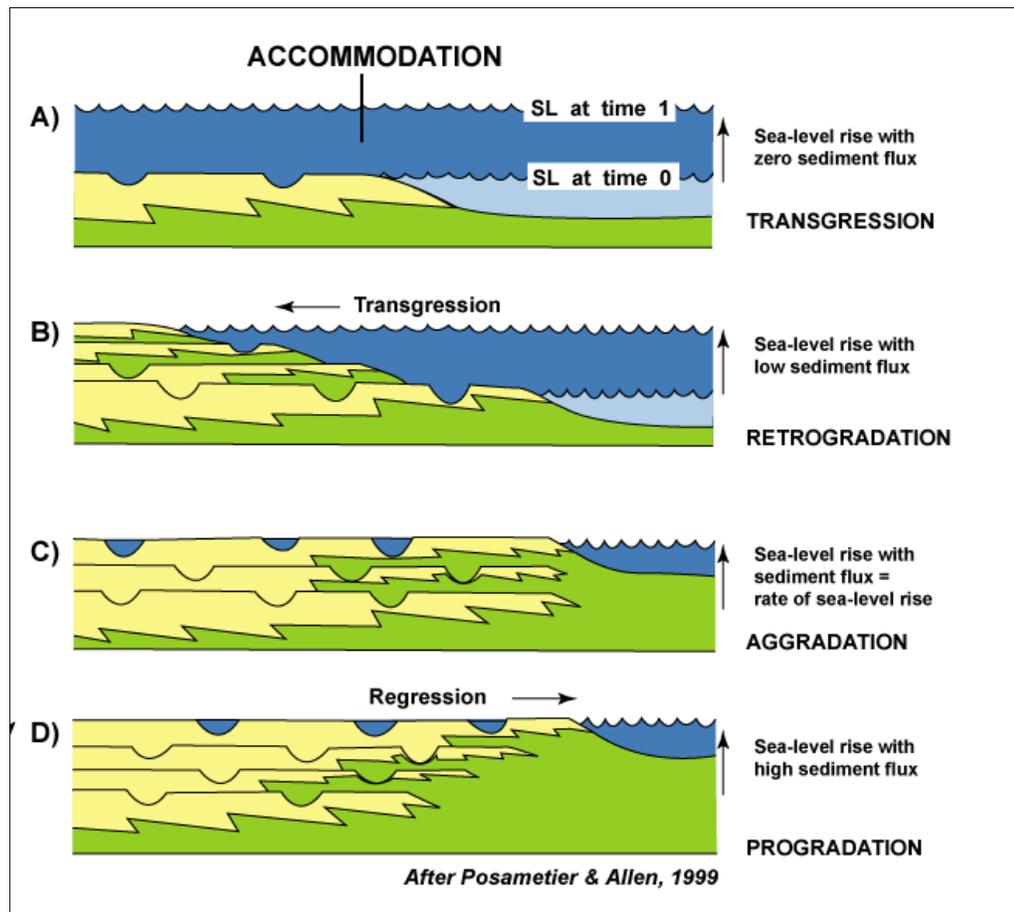
Relative Sea-level (from Posamentier & Jervey & Vail, 1988)

**Figure (4-1):** Relation between Relative Sea level changes and Eustatic and subsidence changes (after Van Wagoner, 1988; Catuneanu, 2002).



**Figure (4-2):** Accommodation space with sea level changes and tectonic subsidence (after Van Wagoner, 1988; Emery, 1996).

Changes in relative sea level, according to Jervey (1988), are the main constraints on accommodation (i.e. the combined product of eustasy and tectonic movement). According to Curray (1964), Posamentier and Allen (1999), Coe *et al.*, (2002) and Catuneanu (2002), sedimentation rates have the least influence on accommodation. Accommodation space results from variations in relative sea level balanced against rates of sediment buildup in response to transgressions and regressions (fig. 4-3).



**Figure (4-3):** The relation between the accommodation space and relative sea level (after Posamentier and Vail, 1988).

### 4.3. Sequence Stratigraphic Analysis of Nahr Umr Formation

The study section of (Nahr Umr Formation) is divided into one cycle with part of a second cycle of the (order"5) with a period ranging between (10,000 - 200,000)years, according to the divisions of ranks followed (Kerans and Tinker, 1997) and an integrated track with part of the second tract of the second cycle.

Each succession consists of regression and a marine facies transgression stacked during one sedimentation cycle defined from the bottom and top by unconformity surfaces comprising system tracts and sequence stratigraphy surfaces various data were determined based on well log data mainly due to the lack of core at great depth intervals, on the diagnosed facies, and relative sea-level change, the most important of which are:-

### **4.3.1. Sequences Stratigraphic Surface**

The stratigraphy study relied on some functional surfaces to identify and follow up the (sequence), and (parasequence) and the most important functional surfaces that were identified within the sequences of the Nahr Umr Formation are:

#### **4. 3. 1. 1. Sequence Boundaries Surface (SB)**

This surface represents the boundary with which it begins and ends at the sequence and the beginning of the sequence that follows it (Vail *et al.*, 1977), and this surface represents the subaerial unconformity surface represented by the surface of erosion or non-deposit that occurs during the decrease in the relative sea level, and extends gradually towards the basin during forced regression of the shoreline and reaches its maximum extension at the end of the forced regression (Helland - Hansen and Martinsen, 1996).

This surface also corresponds to the largest period of stratigraphic time loss in the sedimentary rock record, as it separates layers that are not genetically related, that is, that belong to different cycles of relative sea-level change, and it is evidence of sudden facies changes in the direction of the sedimentary basin (Catuneanu, 2006).

There are two types of succession boundaries distinguished within the stratigraphic succession of the Nahr Umr Formation in the study area, which are:

- **Sequence Boundary Type - 1 ( SB1)**

Occurs as a result of the significant decrease in the relative sea level resulting from the decrease in global sea level (eustatic sea level) at a rate greater than the rate of (basin subsidence) where the depression is below the slope fraction in the sedimentary section (shelf edge).

It creates a fluvial downcutting and the form of valley sediments, often above this succession boundary, is non-marine deposits (Catuneau, 2006).

This type of sequence boundary was identified at the beginning of the deposition of Nahr Umr Formation ,indicating the cleanliness of the rock units and their sudden shallowness towards the top (Cleaning/shallowing-upward trend), the abrupt transition of the facies tract and the vertical increase in the merging of sandy rocks, an increase in the average grain size, (Shanley and McCabe, 1994)(fig. 4-4).

- **Sequence Boundary Type-2 (SB2):**

The result of a small decrease in the relative sea level at the coastline results when the rate of decrease in global sea level (eustatic sea level) is slightly more than or equal to the basin subsidence rate (fig. 4-4).

It is a type of normal regression this type is characterized by the migration of facies towards the basin, but the effect of the riverine action and the form of river valleys do not appear because the drop does not exceed the slope fraction in the sedimentary section (shelf edge) this surface may appear compatible with the stratigraphic sequence separating of the highstand system

tract (HST) which is located below and the shelf margin system tract (SMST) which is located above it (Emery and Myers, 1996).

#### **4.3.1.2. Transgressive Surface (TS)**

It is a large marine flood surface that represents the stage of marine progress, most of its sequences are siliciclastic and some carbonate, indicating the beginning of the period in which the rate of generation of the accommodation space is greater than the rate of sediment supply, and this surface separates the lowstand system tract (LST) from below and the transgressive system tract (TST) from the above, (fig. 4-4).

This surface was distinguished in the formation sequences through the increase in the shale content, which is reflected by the increase in the reading of both the gamma-ray and the spontaneous potential logs, two transgressive surfaces have been identified, one in the center of the formation that separates the lowstand system tract (LST) from the transgressive system tract (TST) within the first and the last at the top of the formation peak in the second cycle.

#### **4.3.1.3. Transgressive Ravinement Surface (TRS)**

It represents a surface cut by waves or tides in the upper part of the coast face (shoreface) during the movement of the coastline towards land (Catuncanu, 2006) (fig. 4-4).

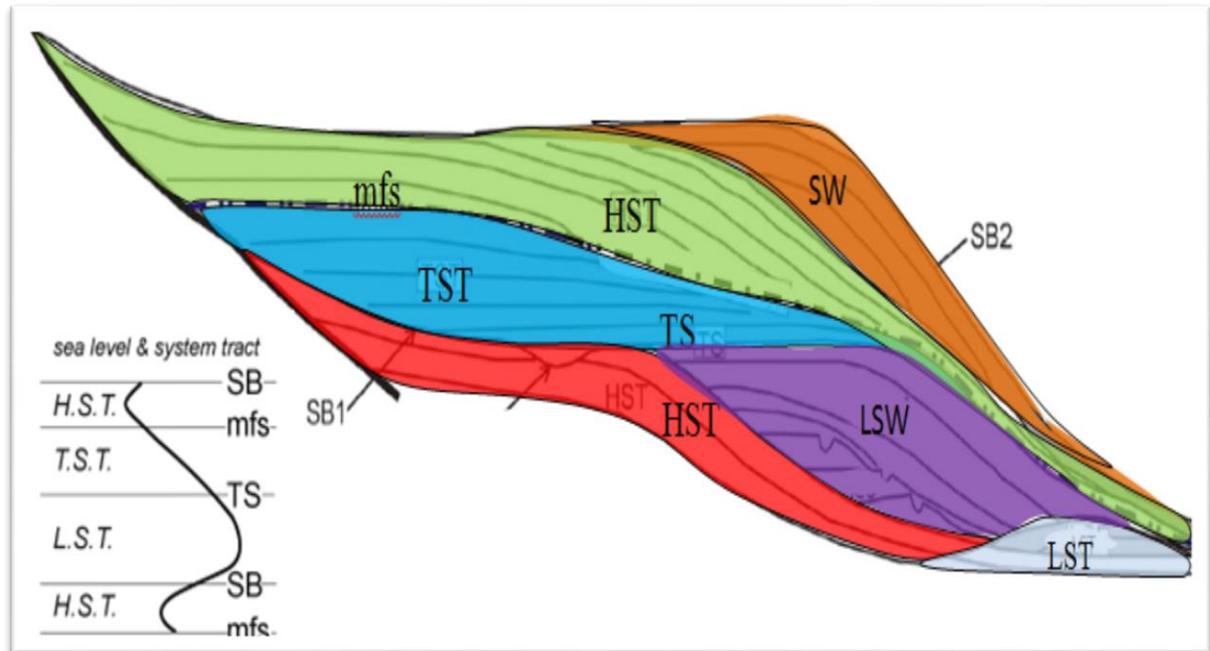
This erosion surface can remove more than (10-20 m) of the layers as a function of the effect of the wind system or related to the wave energy in each particular area (Demarest and Kraft, 1987). The facies below this surface are variable from riverine to coastal or shallow sea, while the facies above it are always shallow sea facies (Catuneanu, 2006).

This surface was distinguished in the sequences of the Nahr Umr Formation by the presence of a layer of iron oxides separating the tidal facies from the facies of the shallow marine environment within the transgressive system tract (TST).

#### **4.3.1.4. Maximum Flooding Surface (MFS)**

It is defined as the extreme or the last progressive surface (Helland-Hansen and Martinsen, 1996) (Nummedal *et al.*, 1993) it is an indicator of the end of the progress of the coastline (fig. 4-4), as it reflects the change from retrogradation to aggradational stacking patterns of the highstand system tract (HST) in the early part. This tract occurs in the absence of sediment supply along with a sudden increase in water depth (Galloway, 1989).

This surface was identified in the middle of the Nahr Umr Formation, as it separates the facies of the transgressive systems tract below it (TST) with retrogradation patterns from the facies of the highstand system tract above it (HST) with progradation patterns, the curves of the spontaneous potential and the gamma rays logs reflect the transition from deposits that (fining/deepening-upward) to (coarsening / shallowing-upward) where the maximum transgressive surface was determined at the highest reading of the gamma-ray log.



**Figure (4-4):** Systems tracts and sequence boundaries (after Handford and Loucks, 1993).

### 4.3.2. System Tracts

A systems tracts are linkages of contemporaneous depositional systems, where the depositional system is a four-dimensional assemblage of lithofacies genetically linked by active (modern) or inferred (ancient) process or environment (Galloway, 1989). sequences of the Nahr Umr Formation, are the lowstand system tract, transgressive system tract, highstand system track, and Falling stage system tract.

#### 4.3.2.1. Lowstand System Tract

The lowstand system tract (LST) represents the basal and oldest stratigraphic tract in the deposition during the period of decline in relative sea level at the principal fraction of a slope (shelf edge) (Emery and Myers, 1996) (fig. 4-4).

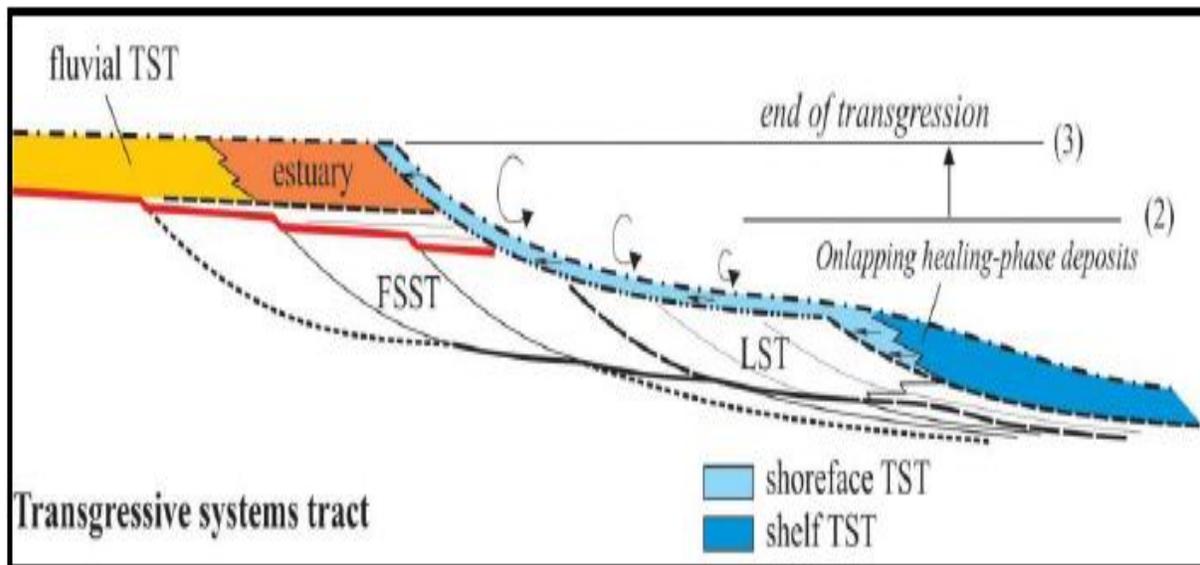
It is bounded from below by the sequence boundary type one (SB1) and from above by the transgressive surface (TS). Compensating for this tract in the sequence stratification type two of shelf margin system tract (SMST) this accompanies the slow eustatic fall less than the rate of subsidence at the shelf break, resulting in a sequence boundary type two (SB2) (Vail *et al.*, 1984).

lowstand system tract (LST) represents the lower part of Nahr Umr Formation and is determined from below by the sequence boundary type one (SB1). This tract includes deposits of the channel characterized by sandy bodies of high thickness, which form a vertical stacking pattern (aggradational), it records the low readings of the two gamma-ray (GR) and spontaneous potential (SP) logs. It also defines the shelf margin system tract (SMST) in the upper part of the Nahr Umr Formation represented by the facies of river channels, which was identified based on the behavior of gamma-ray (GR) and spontaneous potential (SP) logs this reflects the cylindrical shape it represents the first tract of the second sequence.

#### **4.3.2.2. Transgressive System Tract**

This tract (TST) is bounded by the transgressive surface (TS) from below and the maximum flooding surface (MFS) from the upper, where it lies between the lowstand system tract (LST) or shelf margin system tract (SMST) and the highstand system tract (HST). TST is deposited during a certain stage of the relative sea-level rise when the increase in the rate of generation of accommodation space is greater than the rate of sediment supply (Emery and Myers, 1996) causing the migration of facies or the advance of the coastline towards land (retrogradation) (fig. 4-4) and (fig.4-5).

This is clear in the middle part of the Nahr Umr Formation sequences located above the river environments, which indicates an increase in water depth, that is, an increase in the rate of accommodation space and a decrease in the rate of sediment supply, as it reflects the lowest percentage of sand presence from of the lowstand system tract (LST) represented by deltaic sediments and shoreface subenvironment an increase in the thickness of high-foliated shale rocks, rich in fossilized shells and the mineral gluconate, represented by the shallow marine shale environment, gamma ray (GR) and (SP) logs show bell shape, this reflects the cycles of (fining deepening /upward). The highest rate of relative sea-level rise is represented by the maximum flood surface falls within this tract, and this tract can be considered as reservoir cover rocks, and sometimes they represent source layers (Emery and Myers, 1996).



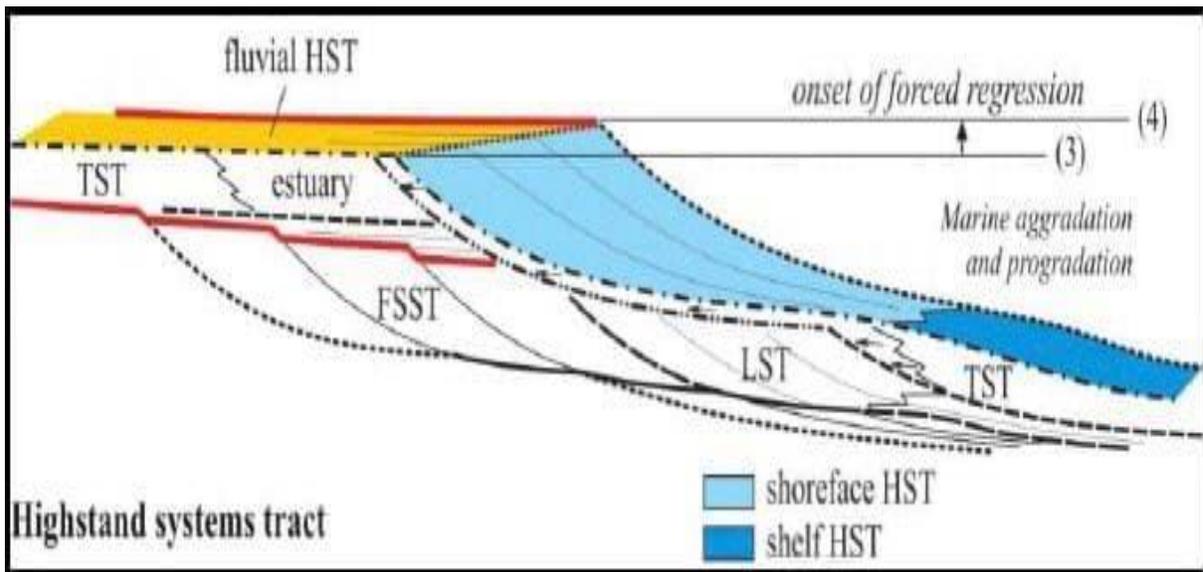
**Figure (4-5):** Transgressive systems tract (TST) (Catuneanu, 2006).

#### 4.3.2.3 Highstand System Tract

The newest tract in the sequence of types one and two (Emery and Myers, 1996), is formed in the later stages of sea-level rise and corresponds to

high sedimentation rates. The beginning of the sedimentation of these two tracts was characterized by staking patterns (aggradation) and then turned into progradation patterns (Catuneanu, 2006) (fig.4-4) and (fig.4-6).

The sedimentation of deltaic facies with progradation patterns including increased sandstone deposits and decreased shale layers, because the rate of rising in relative sea level is less than the rate of sediment supply.



**Figure (4-6):** Highstand systems tract (HST) (Catuneanu, 2006).

#### 4.3.2.4. Falling stage system tract

This succession includes all strata that were accumulated in the sedimentary basin during the forced regression of the shoreline stage. The FSST stage is bound at the top by a composite surface which includes the sub-aerial unconformity surface, it is correlative conformity (Hunt and Tucker, 1992), and the youngest part of the regressive surface (RS) of the marine erosion. The base is bounded by the correlative conformity surface (Posamentier and Allen, 1999), and the oldest part of the regressive surface (RS) of the marine erosional surface.

#### 4.4. A brief overview of high-frequency sequences

High-resolution sequence stratigraphy deals with small-scale sedimentary cycles that correspond to the 4th to 6th order of cyclicity of Vail *et al.* (1991), commonly referred to as parasequences (e.g., Van Wagoner *et al.*, 1988; Posamentier and Allen, 1999).

Following Zecchin and Catuneanu (2013) and Catuneanu and Zecchin (2013), we stress that sedimentary cycles associated with shoreline shifts are high-frequency sequences, irrespective of their allocyclic or autocyclic origin, whereas sedimentary cycles unrelated to shoreline shifts correspond to bed sets. Furthermore, the parasequence concept has become redundant and can be abandoned. An explanation for these conclusions is beyond the scope of this study and has been discussed by Catuneanu (2006), Zecchin (2010), Zecchin and Catuneanu (2013), and Catuneanu and Zecchin (2013).

High-frequency sequences are bounded by sequence stratigraphic surfaces and consist of systems tracts, following the general sequence definition of Catuneanu *et al.* (2009). In addition, outcrop and core studies showed that high-frequency sequences exhibit a high degree of complexity due to the presence of facies contacts and condensed shell beds that are recognizable only at this scale.

Zecchin and Catuneanu (2013) and references therein for a complete review of the physical and temporal characteristics of all these features, which are summarized below.

The same types of systems tracts that subdivide higher rank sequences are also recognized in high-frequency sequences and are bounded by sequence stratigraphic surfaces. They consist of the lowstand systems tract (LST), the

transgressive systems tract (TST), the highstand systems tract (HST), and the falling stage systems tract (FSST). It should be noted that the development of systems tracts can vary extremely depending on the amplitude and rate of eustatic change (e.g., Icehouse vs. Greenhouse cycles) and tectonics (Zecchin, 2007; Csato and Catuneanu, 2012; Catuneanu and Zecchin, 2013; Zecchin and Catuneanu, 2013; Csato *et al.*, 2014).

Among the features found in high-frequency sequences, onlap shell beds (OSB, Kidwell, 1991) are shell concentrations that mantle ravinement surfaces (RS), which develop within the shoreface during transgression and may rework former subaerial unconformities (SU) and maximum regressive surfaces (MRS) (fig.4-7).

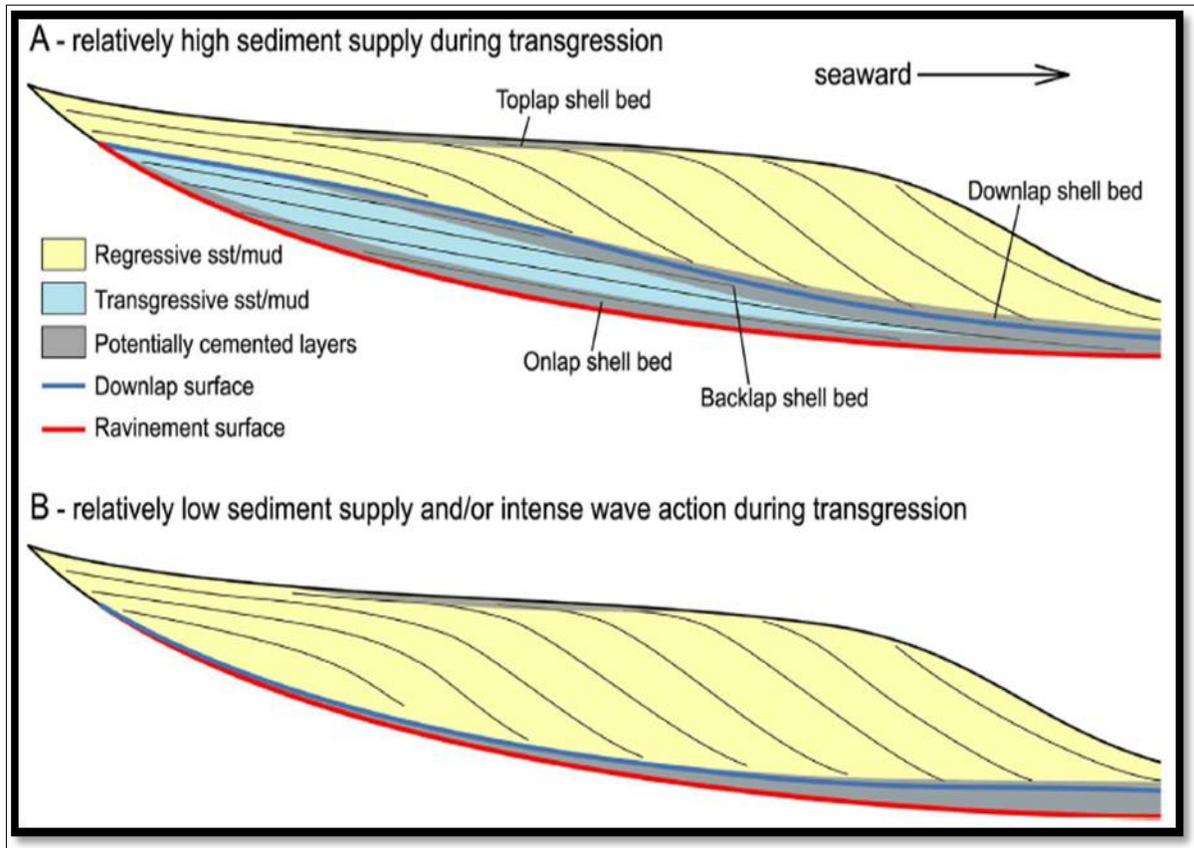
RSS is commonly paved also by transgressive lags. Condensed sections typically accumulate on the shelf during times of maximum shoreline transgression and clastic sediment starvation, although their development may encompass a more significant part of a cycle of relative sea-level change in distal settings (Zecchin and Catuneanu, 2013).

Condensed sections can be fine-grained, rich in authigenic minerals or organic matter, marked by hardgrounds, or mostly composed of skeletal accumulations, called backlap shell beds (BSB) (Kidwell, 1991) (figs. 4-7).BSBs may be bounded at the base by the local flooding surface (LFS), related to sediment starvation, and at the top by the downlap surface (DLS), which is a facies contact marking the base of the foreset portion of the highstand normal regressive clastic wedge (Abbott and Carter,1994; Zecchin and Catuneanu, 2013) (figs.4-7).

The DLS differs from other downlap surfaces that form during lowstand normal regression and forced regression at the base of LST and FSST forests, as the term is restricted to the surface that forms during highstand normal regression at the top of the condensed section (Zecchin and Catuneanu, 2013).

The maximum flooding surface (MFS) usually sits within the condensed section (Carter *et al.*, 1998). The aggrading to prograding highstand clastic wedge may include a downlap shell bed (DSB) at the base and toplap shell beds (TSB) toward the top (Kidwell, 1991; Kondo *et al.*, 1998) (fig.4-7). The basal surface of forced regression (BSFR), locally truncated by the regressive surface of marine erosion (RSME), marks the base of offlapping, downstepping forced regressive deposits forming the FSST.

In addition to the LFS and the DLS, facies contacts within high-frequency shelf sequences also include the within trend forced regressive surface (WTFRS), between the foreset and the bottomset of a forced regressive delta; the within-trend normal regressive surface (WTNRS), between the topset and the foreset of normal regressive deposits; the surf diastem (SD) at the base of upper shoreface prograding deposits; the turbidite shelf entrenchment surface (TSES) carved by turbidite currents during transgression; and bedset boundaries (see Zecchin and Catuneanu, 2013 and references therein).



**Figure (4-7):**The architectural variability of shelf sedimentary bodies along the depositional dip, in the case of (A) high sediment supply during transgression and (B) low sediment supply and/or intense wave action during transgression (modified from Zecchin, 2007). Condensed shell beds, which potentially produce cemented layers, develop near the lower and upper boundaries of transgressive and highstand deposits.

#### 4.5. Sequence Development of the Nahr Umr Formation:

The sequence analysis of the Nahr Umr Formation under study indicates that the formation includes an integrated sedimentary cycle with part of a second cycle, as the facies were distributed within the sedimentary systems according to two successive cycles of sea-level variations.

The sequence of the this cycle begins with a surface of erosion, which represents the boundary of the sequence of the type one (SB1) distinguished in all wells of the study.

As the result of the significant drop in the relative sea-level during the stage of the marine retreat (regressive), causing the erosion of the old sediments by the river drilling operations and controlling the amount of drilling in general, the presence of plant texture resistant to the river erosion processes (McCabe,1984), and this limit is the beginning of the deposition of the Nahr Umr Formation.

Then deposited on the surface of erosion sediments of river channels of the lowstand system tract (LST). These sediments are characterized by high thicknesses of sandy bodies with lateral and vertical extensions, forming vertical patterns of aggradation. Its thickness varies mainly depending on the depth of erosion within the valley (the size of the generated accommodation space) this was evident in the study wells.

The increase in the rate of relative sea-level rise and the lack of preparation contributes to the deposition of layers of shale, represented by the marine flooding surface within the sediments of this tract.

In the early stages of sea-level rise, the deposition of the sands of the deltaic channels begins, indicating the beginning of the deposition of the transgressive system tract (TST), which is separated from the lowstand system tract (LST) by a layer of shale rocks represented by the floodplain, which represents the transgressive surface (TS).

With the increase in the rate of rising the relative sea level, the size of the accommodation space increases, which contributes to finning the channels upwards, forming sediments from Gulfs with sedimentation continues within the

transgressive system tract (TST) as a result of the increase in the influence of tidal processes, the sediments of mixed tidal flats are deposited in a regressive staking pattern towards.

With the continuous rise in the relative sea level, there is an increase in the deposition of layers of lamination shale represented by the shallow sea shale with the deposition of coastal sands, ( transgressive ravinment surface) appearing within the course of the transgressive system tract (TST) separating the tidal deposits from the shallow sea shale with the continuation of the increase in sea level rise reflects an increase in the depth of water and an increase in the thickness of the shale deposits to reach its maximum height when sediments of the shallow.

The deposition of the sands of the marine shelf begins with a decrease in the sedimentation of the shale layers forming cumulative staking patterns (aggradational) within the highstand system tract (HST) and then continues decreasing at the relative sea level transforming into progradation patterns and this is reflected by the logs curves (GR, SP) which indicate (coarsening-shallowing upwards) and with continuous decreasing, a sequence boundary of type two (SB2) is formed at the end of this tract to end there the first sequence and the thickness of this tract increases in the north and south of the field.

The sequence boundary of type two (SB2) represents the decrease in sea level indicating the beginning of the second stratigraphic sequence, which shows the deposition of sands of the river channels as it reflects progressive staking patterns towards the basin represented by the shelf margin system tract (MFST) then the sediments begin to finning and the shale layer appears at the top of the Nahr Umr Formation, which reflects the regional marine progress and marked

the sedimentation of the Mauddud Formation that separates it from the Nahr Umr Formation on the regional transgressive surface (TS) and that supports and confirms the deposition of this surface at the top of the Nahr Umr Formation the presence of this surface at the top of the Burgan Formation in Kuwait is represented by the shale facies of dark black color with little biological influence (Strohmenger *et al.*, 2006), figures (4-10),(4-11),(4-12), (4-13)and (4-14).



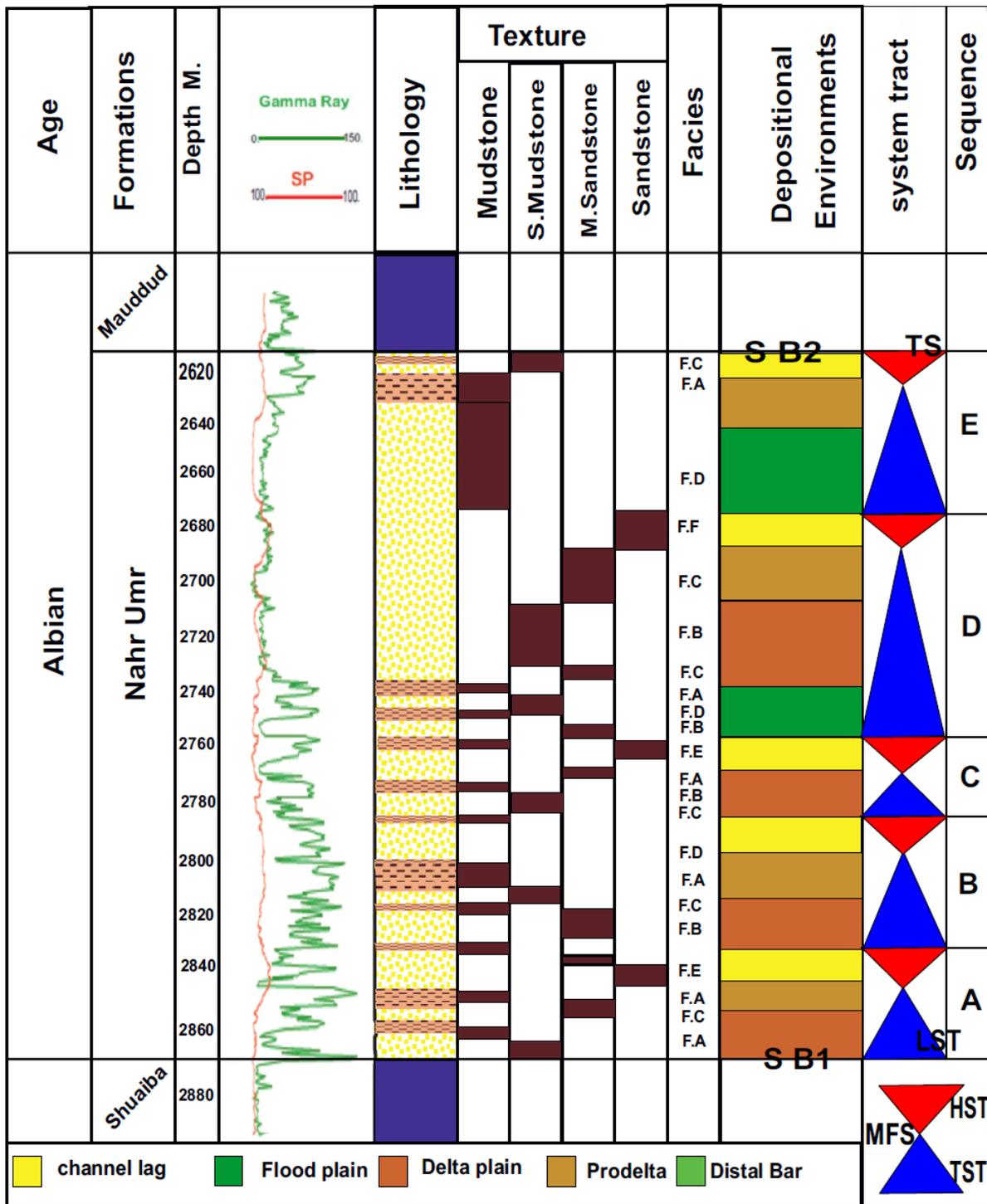


Figure (4-9): Sequence stratigraphy and depositional environment subdivision of Nahr Umr Formation at (Ru- 403).

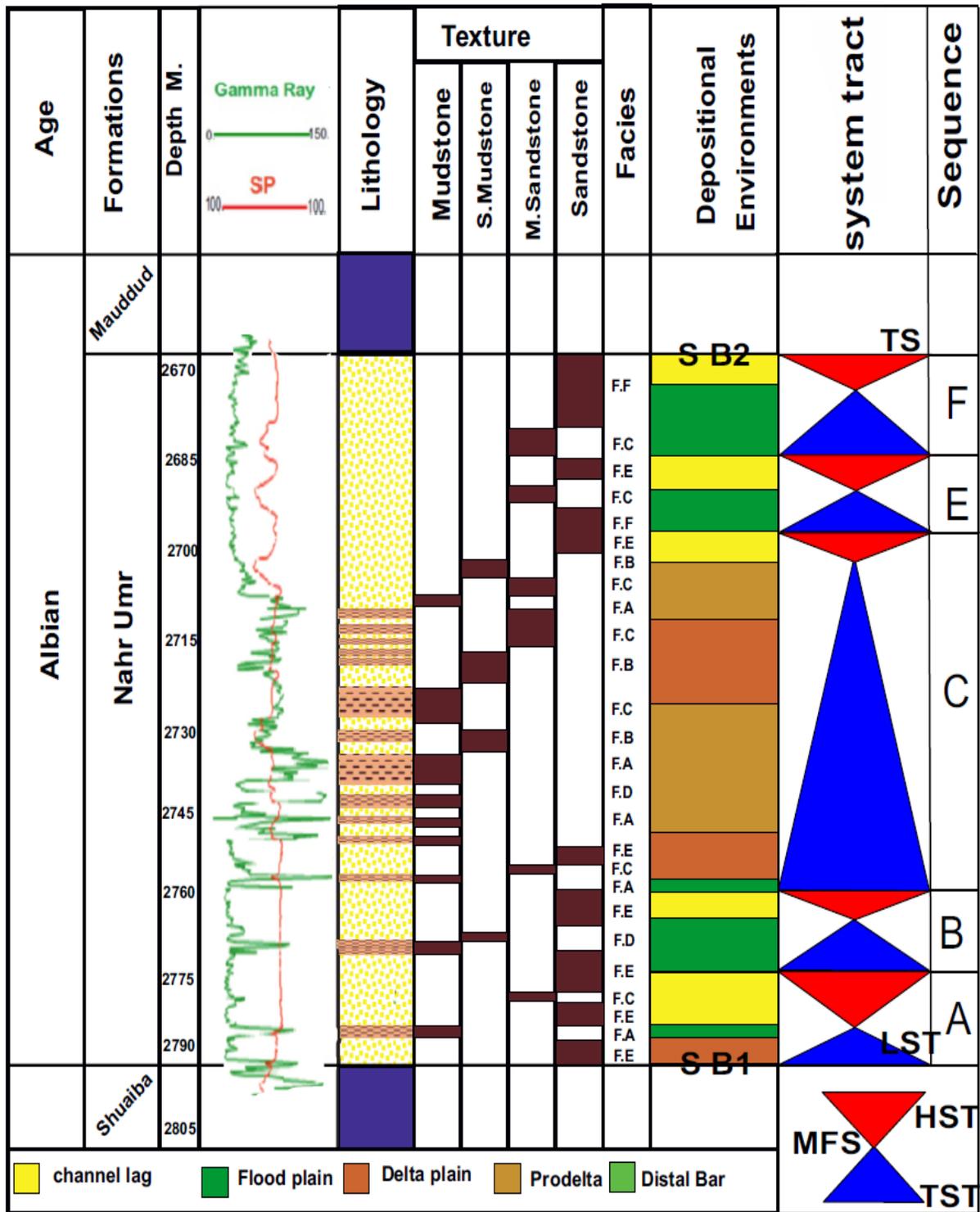


Figure (4-10): Sequence stratigraphy and depositional environment subdivision of Nahr Umr Formation at (Ru- 463).

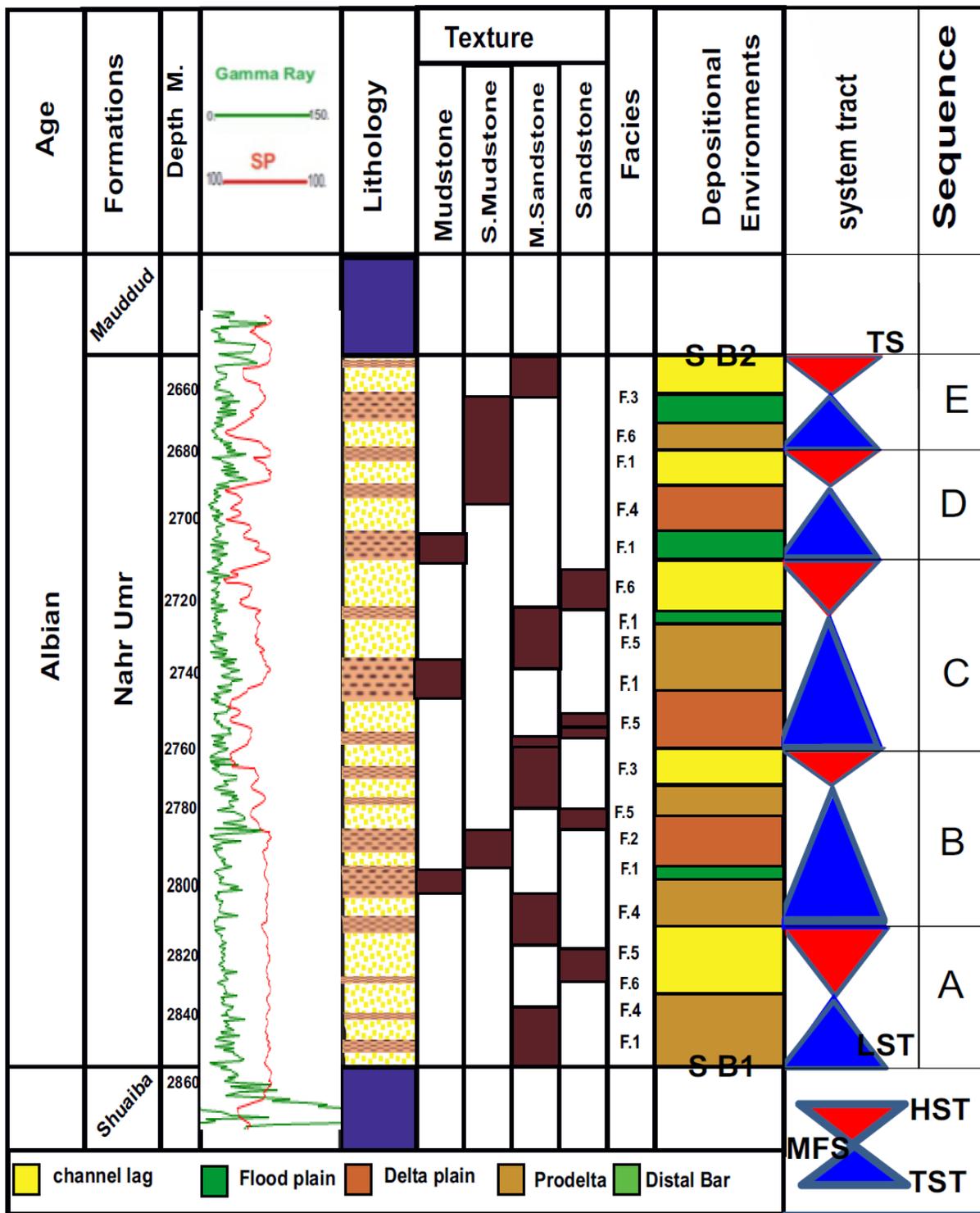
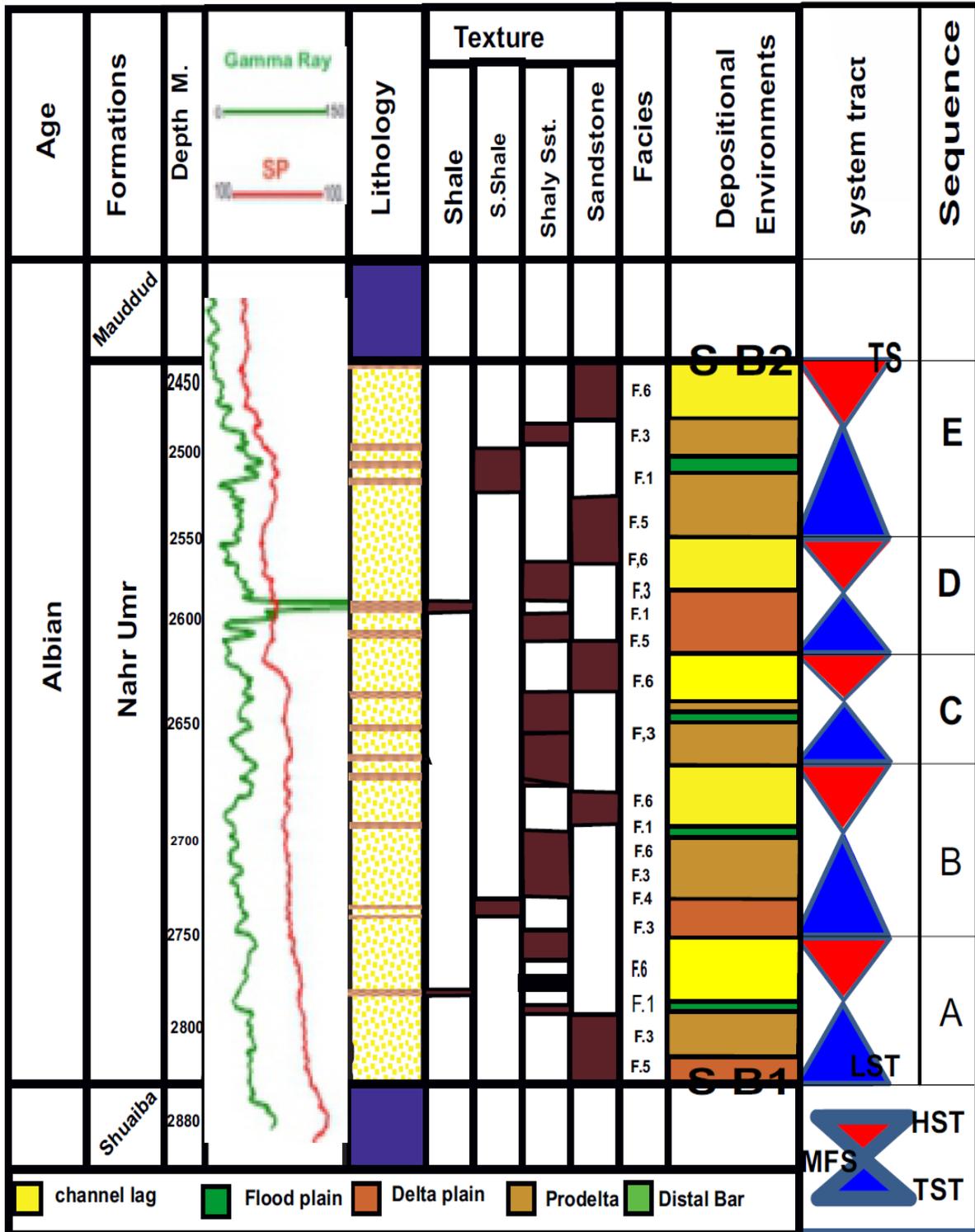
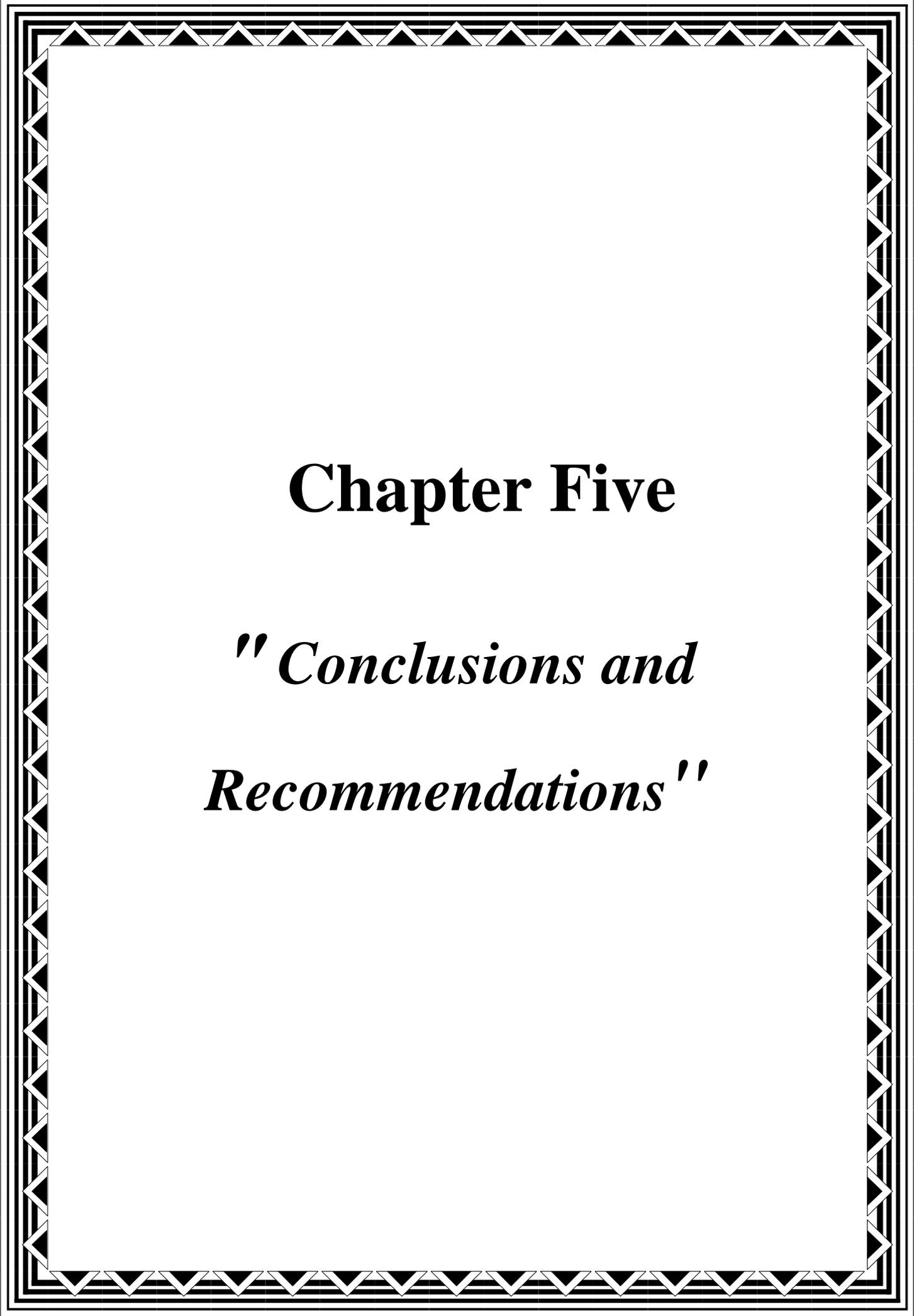


Figure (4-11): Sequence stratigraphy and depositional environment subdivision of Nahr Umr Formation at (ZB- 047).





# **Chapter Five**

## ***"Conclusions and Recommendations"***

**Chapter Five****Conclusions and Recommendations****5.1. Conclusions**

- 1- Nahr Umr Formation consists mainly of sandstone and shale, with few beds of siltstone. The sandstone in the Nahr Umr Formation is classified (Quartz arenite) at about 95% which is considered minerally and texturally mature in the studied wells, with a small percentage of rock fragment and feldspar minerals, the ratio of the matrix was less than 15%. This maturation refers to long-distance transportation, long period of weathering, and tectonically stability .This result gives rise to two possibilities, either that the source area and the sedimentation basin are tectonically stable, or that the sand has gone through several sedimentation and these two possibilities are given in the case of sandstones to Nahr Umr Formation. .
- 2- Nahr Umr Formation was affected by many diagenesis processes which are: compaction, cementation, dissolution, and dolomitization. These processes affected the porosity of sandstone of Nahr Umr Formations.
- 3- The lithological study showed that the Nahr Umr Formation consisted of six lithofacies, which are:  
  
shale lithofacies, lenticular bedded sandstone-mudstone lithofacies, false bedded sandstone –mudstone lithofacies, siltstone–shale lithofacies, cross-bedded sandstone lithofacies, parallel and cross lamination sandstone lithofacies.
- 4- The sedimentary environment for the Nahr Umr Formation was represented by the deltaic environment controlled by the river, in addition to the

appearance of some facies that reflect the influence of the riverine environments and these environments appear in the central and southwestern part of the study area.

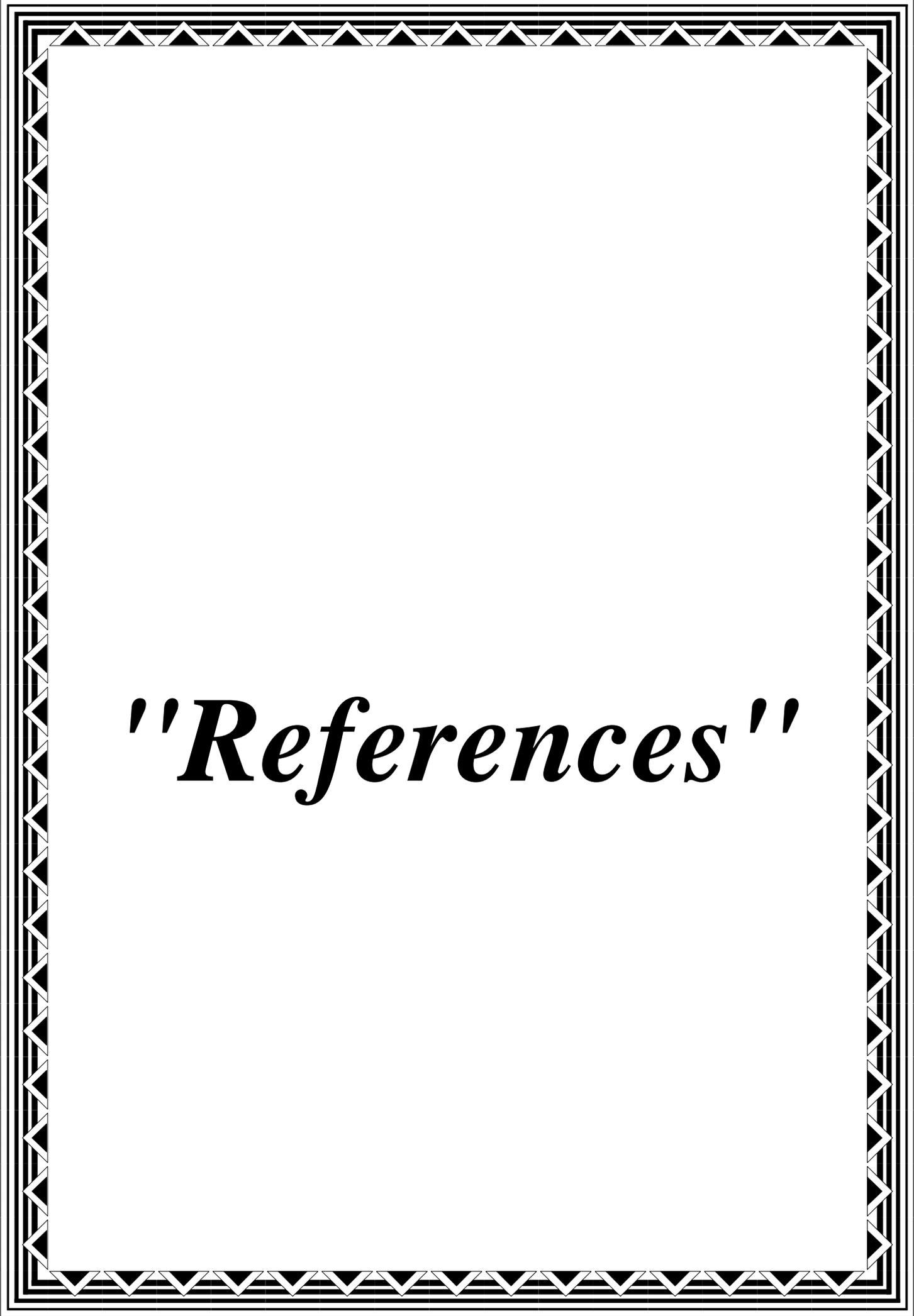
- 5- The variation in the amount of river and marine activities and the location of the well in the sedimentary basin caused variation and difference in the layers of sand and shale rocks, as the sandy bodies were distributed within the environments according to the sedimentary conditions.
- 6- The changes in the relative sea level play a major role in the distribution of sediments, as the vertical sequence of facies reflects the stratigraphic succession of the rocks of the study section, which consists of stratigraphic sequences representing a five-order cycle.
- 7- cycle reflects the tracts of different systems represented by the lowstand system tract (LST), which represents the lower part of the formation and includes the sediments of the riverine environment, and the tract of the transgressive system tract (TST), which includes the sediments of the deltaic environment and part of the sediments of the shallow sea environment and the highstand system tract (HST) and represents the part the top of the formation, which includes the secondary marine shelf environment, while the shelf margin system tract (SMST) appears at the top of the Nahr Umr Formation, and this tract includes the secondary river channel environment.
- 8- The stratigraphic surfaces were distinguished in sequences of the Nahr Umr Formation, represented by the sequence boundaries type one (SB1), which indicates the beginning of the sedimentation of the Nahr Umr Formation, and the sequence boundaries type two (SB2) that appeared in the upper part of the formation. The other surface was represented by the end of the deposition of the Nahr Umr Formation and the emergence of the transgressive ravinement surface (TRS) within the transgressive system tract (TST), and the maximum

flood surface (MFS) was distinguished in the middle of the formation, and each of these surfaces had a lateral extension along the five study sections.

## **5.2. Recommendations**

1-Adopting the stratigraphic surfaces that were diagnosed in the current study with seismic surfaces, misleading the verification of the rocky extension and the identification of the independent sandy bodies in their reservoir and separating them from each other.

2- Taking samples of core of the wells that will be drilled in the future at the top of formation and conducting tests for the analysis of the core because of the lack information available for the drilled wells.



*"References"*

## References

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### References

- Abid A.G.,Ishaq S.Y.,and Ferhan A.K., 1988. Clastic Sedimentology and clay mineralogy of Zubair Formation (Upper S.st. Member.) an Nahr Umr Formation in Luhais oil Field. South Oil Company- Basrah.
- Ali Jassam Habeeb, Salam I. Al-Dulaimi, "Reservoir Facies of Nahr Umr Formation in Luhais Oilfield, Southern Iraq", International Journal of Science and Research (IJSR), Volume 7 Issue 5, May 2018, pp. 31-36.
- Ahr,W.M.,1973,The Carbonate Ramp-an alternative to the Shelf Model,Gulf, Coast Assoc, Gelo. Soc. Trans. V.23, PP. 221-225.
- Al-Haddithy,A.H.,1994.Sedimentological studied of Nahr Umr Formation (Cretaceous) in Luhais & Subba Oil Fileds. Westren Basrah, Ph.D. Thesis, University of Baghdad. p.134.
- Al-Husseini, K.A., & Obaid, A.H, 2019. Analysis and risk management in software development using the logical-algebraic model. In CEUR Workshop Proceedings, 2475, 241–248.
- Al-Husseini, K.A.O., & Obaid, A.H., 2020. Interaction between project tasks and risk management tasks in software development. Periodicals of Engineering and Natural Sciences (PEN), 8(4), 2300-2308.
- Ali F.A., Abdul-wahab I., 1986. Geological Study of Nahr Umr Formation at Luhais oil Field. INOC, Southern Petroleum Organization, Basrah.
- Ali, A., Mannel, T., & Morozumi, T. (1991). Forward-backward asymmetry of dilepton angular distribution in the decay  $b \rightarrow s\ell^+ \ell^-$ . Physics Letters B, 273(4), 505-512
- Al-Jubory, T.S., 1981, Petrography, Porosity and Permeability of the Nahr Umr Formation in Wells in the Baghdad area. Unpublished M.Sc.

## References

---

- Al-Jubory, T.S., 1985, Petrography, Petrophysical and Environment factors influencing the reservoir properties of Cretaceous Nahr Umr Formation in Iraq. Unpub. Ph.D. thesis. Dundee University, 288P.
- Al-Khafaji, A.J., Hakimi, M.H., Mohialdeen, I., Idan, R.M., Afify, W.E., and Lashin, A.A., 2021. Geochemical characteristics of crude oils and basin modelling of the probable source rocks in the Southern Mesopotamian Basin, South Iraq. *Journal of Petroleum Science and Engineering*, 196, 107641.
- Al-Naqib, K. M., 1967. *Geology of the Arabian Peninsula-South Western Iraq*, Geo.Survey-special issue-Washington, P.54.
- Al-Naqib, K.M, 1959. *Geology of the southern area of Kirkuk Liwa, Iraq* :London, IIC pub., 50 P.
- AL-Rubaiy M., and AL-JouboryT., 1988. Sedimentological study of Nahr Umr Formation in Luhais oil field, southern Iraq. *OEC-library of*
- AL-Sharhan A.S., 1994. *Albian Clastic in the western Arabian Gulf Region: A Sedimentological and Petroleum Geological Interpretation* . *Jour. Of Petrol. Geol.* Vol.17, pp. (279-300).
- Al-Siddiki, A. A. (1978). *Subsurface geology of southeastern Iraq*. 10th Arab Petrol. Congr., Tripoli.
- Alsultan, A. A, and Awad, K. H., 2021. Sequence Stratigraphy of the Fatha Formation in Shaqlawa Area, Northern Iraq. *Iraqi Journal of Science*, 54 (2F), 13-21
- Alsultan, A. A, and Manhi, M. R., 2021. Stratigraphy and Depositional Environment of Mauddud Formation in Ratawi oil wells of Southern Iraq. *IOP Conf. Series: Earth and Environmental Science*, 877 ,1-10
- Alsultan, A.A., Awadh, S.M., Al-Owaidi, M.R., and Al-Khafaji, A.J., 2021. Sequence Stratigraphy and Depositional Environment of the Zubair

## References

---

- Formation in Rumaila Oilfields, Southern Iraq: Microfacies and Geochemistry. Iraqi Geological Journal, 54 (2B), 28-41
- Al-Zaidy, R. A., & Giles, C. L. (2018, April). Extracting semantic relations for scholarly knowledge base construction. In 2018 IEEE 12th international conference on semantic computing (ICSC) (pp. 56-63). IEEE.
- Anadarko Petroleum Company, 2005. Reservoir Study of Nahr Umr Formation, Luhais Field, Southern Iraq, P, 14. Architecture and permeability Structure of fluvial-deltaic Sandstone,
- Awad, K. H., and Alsultan, H. A., 2020. Stratigraphic Analysis of Gercus Formation in Dohuk area, Northern Iraq. Iraqi Journal of Science, 61(9), 2293-2302
- Bellen, R.C. van, H. V. Dunnington, R. Wetzel and D. M. Morton, 1959. Lexique Stratigraphique international. v.3, Asia, fasc. 10a, Iraq, 333p.
- Blatt, H., 1967. Provenance determinations and recycling of sediments. Journal of Sedimentary Petrology, 6, 779-792.
- Blatt, Harvey. Sedimentary petrology. 1982.
- Boggs JR, Sam; BOGGS, Sam. Petrology of sedimentary rocks. Cambridge university press, 2009.
- Buday, T. (1980). The regional geology of Iraq: stratigraphy and paleogeography (Vol. 1). State Organization for Minerals, Directorate General for Geological Survey and Mineral Investigations.
- Carter, R.M., Fulthorpe, C.S., Naish, T.R., 1998. Sequence concepts at seismic and outcrop scale: the distinction between physical and conceptual stratigraphic surfaces. Sediment. Geol. 122, 165-179.
- Castro, J.C.D.E., 1978, Clastic facies and reservoirs of lower Cretaceous, Nahr Umr and Zubair Formations, Majnoon, Nahr Umr area, Southern Iraq: research center, Braspetro, Petrobras International S.A.

## References

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- Catuneanu, O. (2002). Sequence stratigraphy of clastic systems: concepts, merits, and pitfalls. *Journal of African Earth Sciences*, 35(1), 1-43.
- Chatton, M., & Hart, E. (1960). Revision of Tithonian-Albian stratigraphy of Iraq. Manuscript report, GEOSURV, Baghdad, 177.
- Dapples, E. C. (1979). Diagenesis of sandstones. In *Developments in sedimentology* (Vol. 25, pp. 31-97). Elsevier.
- depositional environments studies, central and southern Iraq, 20January 2012 / Accepted: 31 October 2012 Saudi Society for Geosciences 2012.
- Dewey, J. F., PITMAN III, W. C., Ryan, W. B., & Bonnin, J. (1973). Plate tectonics and the evolution of the Alpine system. *Geological society of America bulletin*, 84(10), 3137-3180.
- Dickinson, W.R., 1985. Interpreting provenance relation from detrital modes of sandstones. In: Zuffa, G.G., *Provenance of Arenites*. Springer, Dordrecht, Holland, 333-361.
- Dickinson, W.R., 1988. Provenance and sediment dispersal in relation to plate tectonic and paleogeography of sedimentary basins. In: Klienspehn, K.L. and Paola, C. (Eds.), *New Perspectives in Basin Analysis*, Springer-Verlag, New York, 3-25.
- Dickinson, William ,R, Provenance and sediment dispersal in relation to paleotectonics and paleogeography of sedimentary basins. In: *New perspectives in basin analysis*. Springer, New York, NY, 1988. p. 3-25.
- Dunnington, H. V, 1958.Generation, accumulation, and dissipation of oil in Northern Iraq. In Weeks, L. G. (ed.)*Habitat of Oil*, AAPG, Tulsa, Oklahoma, USA, p. 1194-1251. East central utah,in: N. Tylor, J. Barton, and R.S.F. Fisher,eds.,
- ELF-Aquitaine, 1991, *Stratigraphic Sequentielle*, OEC Library, Unpub.Emery, D. and Myers, K., 1996. *Sequence Stratigraphy*. Blackwell. Sci.Publ.

## References

---

- London, 297 P.evidence (Nahr Umr Formation, Oman). Jour. Of Sediment. Res., Vol.69. No.2, Pp. (434-446).
- Folk, R.L., 1968. Petrology of Sedimentary Rocks. Hemphill, Austin, Texas, USA, 170 pp.
- Fouad, S.F.A. 2008. "Tectonic Map of Iraq, scale 1: 1000 000." Symposium on the 3rd edition of the Tectonic Map of Iraq, Erbil. Iraq Geological Survey (GEOSURV) Library, Baghdad. Iraq.
- Fuchtbauer, H., 1974. Sediments and Sedimentary Rocks. Schweizerbartsche Verlagsbuchhandlung, Stuttgart, 464 pp.
- Gardner, M.H., 1991, Sequence Stratigraphy of the ferroan Sandstone Ibrahim, M. W. (1983). Petroleum geology of southern Iraq. AAPG Bulletin, 67(1), 97-130. Geology Dept. Unpub. Rep.
- Good, M. \_\_, & Walker, W. D. (1960). Diffraction dissociation of beam particles. Physical Review, 120(5), 1857.
- Ibrahim, M.W., 1981, Lithostratigraphy and subsurface geology of the Albian Rocks South Iraq. Jour. Petrol. Geol. Vol. 4, PP. 147-162.
- Immenhauser W., Schlager S.J., Burns R.W., Scott T., Gael J., Lehmann S., Gaast V.D., and Bolder L.J.A., 1999. Late Aptian to Late Albian sea level fluctuations constrained by geochemical and biological
- Jafar zadeh, M., & Hosseini-Barzi, M. (2008). Petrography and geochemistry of Ahwaz Sandstone Member of Asmari Formation, Zagros, Iran: implications on provenance and tectonic setting. Revista mexicana de ciencias geológicas, 25(2), 247-260.
- Jalil, A. T., Al-Khafaji, A. H. D., Karevskiy, A., Dilfy, S. H., & Hanan, Z. K. (2021). Polymerase chain reaction technique for molecular detection of HPV16 infections among women with cervical cancer in Dhi-Qar Province. Materials Today: Proceedings

## References

---

- James, G.A. and Wynd, J.G., 1965. Stratigraphic nomenclature of Iranian Oil consortium agreement area. AAPG, Bulletin, Vol. 49, No. 12, PP.2182-2245.
- Jassim ,S, Goff ,J, (Eds.), 2006. Geology of Iraq. Dolin and Moravian Meseem, Prague, 341.
- Jassim, S.Z., and Goff, J.C., 2006. Geology of Iraq, Dolin, Prague and Moravian Museum, Brno, 337p.
- Khursheid A., Ishaq S.Y., 1982. Clastic Sedimentology of Nahr Umr Formation, Halfaya oil Field, Southern Iraq. INOC, Basrah, Geological Lab. 55p.
- Kenneth Lin, J. H., Aloulou, H., Mokhtari, M., Tiberghien, T., Biswas, J., Phua, C., & Yap, P. (2013). Deployment of assistive living technology in a nursing home environment: methods and lessons learned. BMC medical informatics and decision making, 13(1), 1-17.
- Kidwell, S.M., 1991. Condensed deposits in siliciclastic sequences: expected and observed features. In: Einsele, G., Ricken, W., Seilacher, A. (Eds.), Cycles and Events in Stratigraphy. Springer-Verlag, Berlin, pp. 682e695.
- Klein, S. A. Calculation of monthly average insolation on tilted surfaces. Solar energy, 1977. 19.4: 325-329.
- Kondo, Y., Abbott, S.T., Kitamura, A., Kamp, P.J.J., Naish, T.R., Kamataki, T., Saul, G.S., 1998. The relationship between shellbed type and sequence architecture: examples from Japan and New Zealand. Sediment. Geol. 122, 109e127.
- Maclead, J. H, 1961. Final well report on Afaq N0.1, Baghdad. Petroleum geology of Iraq. Scientific, Beaconsfield, 423P. Powers, R.W. and others Lexique stratigraphique international-Asia Fasc. 10 b, Arabie Saoudite, 1968.

## References

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- Mohammad mansour, A. M., 1982. Sedimentological study of Nahr Umr Formation (Southern-Iraq). M.Sc. Thesis, University of Baghdad, P.126.
- Mohammed H. Saqer, Muafaq F. AL-Shahwan and Abdullah A. AL-Yasiri, The standard model of oil characteristics of Zubair reservoir in Luhais field southern Iraq, *Biochem. Cell. Arch.* Vol. 19, No. 1, pp. 1849-1855, 2019
- Moutaz A. Al-Dabbas, Jassim A. Al-Jassim, Amanj I. Qaradaghi, 2012. Siliciclastic deposit of Nahr Umr Formation, sedimentological and Murriss, R. J. (1980). Middle East: stratigraphic evolution and oil habitat. *AAPG Bulletin*, 64(5), 597-618.
- Nichols, G, 2009. *Sedimentology and stratigraphy*, 2nd Ed. Wiley-Blackwell Science publication, 419p.
- Owen, R, Nasr ,S , 1958. The stratigraphy of Kuwait-Basra area. In: Weeks L (Ed.) *Habitat of Oil*, a symposium, AAPG Pub., p. 1252–1278.
- Pettijohn ,F, 1975. *Sedimentary rocks*, 3rd edn. Harper Row, New York, 628 p.
- Pettijohn, F.J., Potter, P.E., and Siever, R., 1973. *Sand and Sandstone*. Springer-Verlag, New York, 618 pp.
- Pirson, A, 1970. *Publik Inst Wiss Film*, Sekt Biol C 1042–43. IWF, Göttingen.
- Posamentier, H.W. and Vail, P.R., 1988. Eustatic Controls on Clastic Deposition II-Sequence and System Tract Models, in : Wilgus, C.K. et al., (Eds). *Sea Level changes. An intergrated approach*. *Sepm. Spec. Pub.* 42, PP. 125-154.
- Powers, M. C. (1953). A new roundness scale for sedimentary particles. *Journal of Sedimentary Research*, 23(2), 117-119. Publ. London, 297 P.
- Qaradaghi, A. I., Abdul-Kareem, B. M., & Al-Jassim, J. A. (2008). Petrography, diagenesis and depositional environment of Nahr Umr Formation, from selected wells in central Iraq. *Iraqi Bulletin of Geology and Mining*, 4(1), 67-94.

## References

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- Qaradaghi, Amanj I.; ABDUL-KAREEM, Beriwan M.; AL-JASSIM, Jassim A. Petrography, diagenesis and depositional environment of Nahr Umr Formation, from selected wells in central Iraq. *Iraqi Bulletin of Geology and Mining*, 2008. 4.1: 67–94-67–94.
- Safar, V. M. (1961). Final well report on Dujela N0.1.BPC Report, INOC Library, No.FWR 13,Baghdad.
- Scholle, P.A., 1981. A Color Illustrated Guide to Constituents,Textures, Cements, and Porosities of Sandstones and Associated Rocks, The American of Petroleum Geologists with the support of The American Association Petroleum Geologists Foundation, Tulsa, Oklahoma, U.S.A.
- Searl, Alison. Diagenesis of the Gully Oolite (Lower Carboniferous), South Wales. *Geological Journal*, 1989.24.4: 275-293.
- SelleY, R. C. Porosity gradients in North Sea oil-bearing sandstones. *Journal of the Geological Society*, 1978.135.1: 119-132.
- Selley, Richard C. *Applied sedimentology*. Elsevier, 2000.
- Sharland, P. R., Archer, P. R., Casey, D. M., Davies, R. B., Hall, S. ., Heward, A. P.,Horbury, A. D., and Simmons, M-DS., *Arabian plate sequence stratigraphy, an integrated approach*, Geo Arabian special publication 2 sponsors, 340 P.( 2001).
- Shubber, B.A., 1986. *Sedimentology of Muddud Formation in middle and southern Iraq*. Unpubl M.Sc. Thesis, University of Baghdad, 104 p.
- Suttner, L.J., and Dutta, P.K., 1986. Alluvial sandstone composition and paleoclimate. L. Framework mineralogy. *Journal of Sedimentary Petrology*, 56, 329-345.thesis, Dundee University, Scotland. 146 P.
- Tuker, M.E., 1985. Shallow-Marine Carbonate facies and models, in : P.J. Brenchley and B.J. Williams, eds, *Sedimentology, recent development and applied aspects*, Blackwell. Oxford, PP. 147-169.

## References

- Walther, Johannes. Einleitung in die Geologie als historische Wissenschaft: Beobachtungen über die Bildung der Gesteine und ihrer organischen Einschlüsse. G. Fischer, 1894.
- Wentworth, C. K., 1922. A Scale of Grade and Class Term for Clastic Sediments: Jour. Geology. V. 30, P. 377-392.
- Worden, R. H., & Burley, S. D. (2003). Sandstone diagenesis: the evolution of sand to stone. Sandstone diagenesis: Recent and ancient, 4, 3-44.
- Young, F. O.; ISAACSON, M. R. Soil Survey. Cambridge University Press. London, 1976.
- Zecchin, M., 2007. The architectural variability of small-scale cycles in shelf and ramp clastic systems: the controlling factors. Earth-Sci. Rev. 84, 21e55.
- Zecchin, M., Caffau, M., Civile, D., Roda, C., 2010.a. Anatomy of a late Pleistocene clinoformal sedimentary body (Le Castella, Calabria, southern Italy): a case of prograding spit system? Sediment. Geol. 223, 291e309.
- Zecchin, M., Catuneanu, O., 2013. High-resolution sequence stratigraphy of clastic shelves I: units and bounding surfaces. Mar. Pet. Geol. 39, 1e25.

المصادر العربية :\_\_\_\_\_

- البدري ، عباس ، واخرون ، 1983 ، دراسة رسوبية جيوكيميائية لتكوين نهر عمر في حقل شرق بغداد شركة الاستكشافات النفطية .بغداد 141 ص .
- عبد، اسحاق، واخرون، 1988، دراسة رسوبية ودراسة معادن الاطيان لتكوين الزبير (عضو الحجر الرملي الاعلى) وتكوين نهر عمر في حقل اللحيس .شركة نفط الجنوب البصرة.
- علي ،فصيل انور ، 1991، دراسة جيولوجية لتكوين نهر عمر في الجنوب جنوب العراق شركة نفط البصرة -العراق .
- منصور ،على منصور ،1982، دراسة رسوبية للحجر الرملي لتكوين نهر عمر في جنوب العراق ،اطروحة ماجستير غير منشورة ،كلية العلوم، جامعه بغداد ، 162ص .

## الخلاصة

يعتبر تكوين نهر عمر من اهم تكوينات العصر الطباشيري وأحد الخزانات الرئيسية المهمة في جنوب العراق . والذي تمثل بترسبات الحجر الرملي والسجيلي خلال دورة الالبان.

تم اختيار خمسة ابار للحقول المختارة وهي (R-555, Ru-403, Ru-463, ZB-190, and ZB-047) لعمل دراسة مستفيضه عن تكوين نهر عمر بالاعتماد على البيانات لتحديد الخصائص السحنيه، والبيئات الترسيبية ، اضافة الى العمليات التحويرية .

يعتبر معدن الكوارتز أحادي التبلور وهو المكون الرئيسي للحجر الرملي ، مع نسب صغيرة من الكوارتز متعدد التبلور والفلسبار والقطع الصخرية ، ووفقاً للتحليل البتروغرافي لـ 174 شريحة صخرية من تكوين نهر عمر ان الصخور الرملية له ناضحة معدنيّاً من نوع كوارتز ارينايت . ان اهم العمليات التحويرية المؤثرة على صخور تكوين نهر عمر هي عملية الانضغاط والسمنتة والذوبان والدلمته والتي اثرت على خصائص صخور الحجر الرملي لنهر عمر . وبالاعتماد على الصخرية تم تمييز ستة انواع من السحنات لتكوين نهر عمر مما ادى لوجود الحجر الرملي والسجيلي مع طبقة رقيقة من الغرين . وبالاعتماد على السحنات واستجابة المجسات داخل تكوين نهر عمر والتي توضح ان التكوين قد ترسب في كل من البيئات النهرية والدلتاوية في الجزء الاسفل من التكوين ، وبيئة الدلتا منتصف التكوين ، ساد النشاط النهري في نهاية ترسيب نهر عمر .

تلعب التغيرات في مستوى سطح البحر النسبي دوراً رئيسياً في توزيع الرسوبيات ، حيث ان التتابع العمودي للسحنات يعكس التتابع الطباقى لصخور مقطع الدراسة والذي يمثل دورة واحده من الرتبة الخامسة ، حيث ميزت في تتابعات تكوين نهر عمر أسطح طباقية تمثلت بحدود التتابع من النوع الأول (SB1) والذي يمثل بداية ترسيب تكوين نهر عمر وحد تتابع من النوع الثاني (SB2) ظهر في الجزء الأعلى من التكوين ، كما ميز سطحين اغماريين الأول ظهر في منتصف التكوين والسطح الآخر تمثل بنهاية ترسيب تكوين نهر عمر وظهور سطح الأنهيارتقدمي (TRS) ضمن المسار الأغماري (TST) و ميز اقصى سطح فيضان (MFS) في وسط التكوين، ولكل من هذه الأسطح امتداداً جانبياً على طول مقاطع الدراسة الخمسة .



وزارة التعليم العالي والبحث العلمي

جامعة بابل / كلية العلوم

قسم علم الارض التطبيقي

## تتابع طباقي عالي الدقة لتكوين نهر عمر في حقول النفط الزبير، الرميّة الشمالية و الرميّة الجنوبية ، جنوب العراق

رسالة مقدمة

إلى مجلس كلية العلوم جامعة بابل  
كجزء من متطلبات درجة ماجستير علوم  
في علم الأرض

من قبل

**اسراء عماد محمد هاشم المعموري**

بكالوريوس علم الأرض التطبيقي

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