Facies Analysis and Sequence Stratigraphy of the Barremian Succession in the Majnoon oil field, Southern Iraq.

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Abstract

The Barremian succession in the present study is represented by the Zubair Formation which the most significant sandstone reservoir in Iraq. The area of study is located in the Southern part of Iraq at the Majnoon oil fields, within the Mesopotamian basin.

The petrographic study showed that quartz mineral is the main component of the sandstone in Zubair Formation with minor percentage of feldspar and rare rock fragments to classified as quartz arenite. There are five lithologic changes (lithofacies) that have characterized the studied succession: - course to medium sandstone well sorted, fine sandstone well sorted, course to medium sand poorly sorted, clayey sandstone poorly sorted, and shale. These lithofacieses were deposited in the deltaic environments as three associated facies [delta plane, delta front and lacustrine(marsh)].

The different lithofacies contributed to division of the Zubair Formation into three distinct rock units, which had been used in interpreting and distributing the suggested environments. The lower unit is composed of shale with lenses of fine sand with high organic matter, and it was deposited in the flood-delta plain environment. The presence of the delta plain associated facies overlaying the unconformity surface (SB1) refer to the transgressive system tract (TST). This stage finished with appeared the channel fill deposit to mark a high-stand system tract (HST).

The middle unit is composed of sandstone with the shale inter layers with high amount of heavy minerals, which was deposited in the distributary-mouth-bar within the delta front environment. There are two sequences as TST in this part which end with the maximum sea level rise (mfs) to mark the upper part of the Zubair Formation.

While the upper part is composed of shale with high amount of pyrite and organic matters. This represents the lacustrine (marsh) associated facies within the delta plain environment which deposited during the high stand stage. The sea level rise was marked the end of this stage when deposition the upper part of Zubair Formation, and the beginning of deposition the Shuaiba Formation as shallow carbonate marine.

Key wards: - Facies Analysis, Sequence Stratigraphy, Barremian Succession, Zubair Formation, Majnoon oil field.

Introduction

The Zubair Formation was introduced by Glynn Jones in 1948 from the Zubair oil field and amended[1].

It is the most significant sandstone reservoir in Iraq, is composed of fluvio- deltaic, deltaic and marine sandstones. It covers wide areas of the Arabian Plate including northern Saudi Arabia, Kuwait and most of southern and part of Central Iraq. The formation correlates with the Biyadah (Riyadh) Formation in Saudi Arabia [2].

The study area is located in the Southern part of Iraq at the Mjnoon oil field, within the Mesopotamian basin at the stable shelf. The studied oil fields are located in Southern Iraq approximately 60 Km. Northwestern of Basra city, close to the Iranian border and extending North to Missan province (Fig.1).

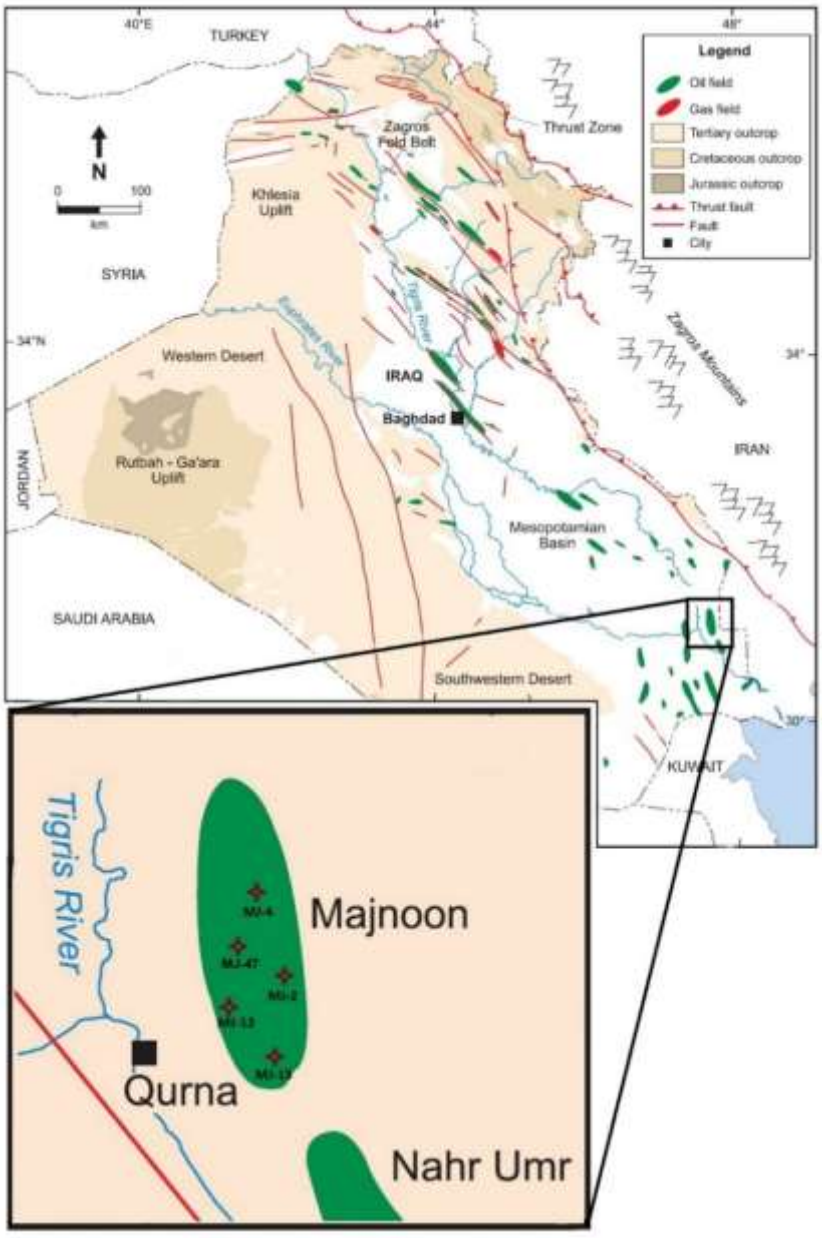


Figure (1): Location of the study area (Modified after [3]).

During the Hauterivian to Early Aptian age the formation was deposition with 380-400 m of alternating shale, siltstone and sandstone [1]. The Zubair Formation is assumed to represent a prograding delta originating from the Arabian shield [4].

The upper contact of the formation with the Shuaiba Formation are mostly gradational and conformable (Fig.2). The lower boundary is, however unconformable with Ratawi Formation [4]. and this unconformity described by [5].

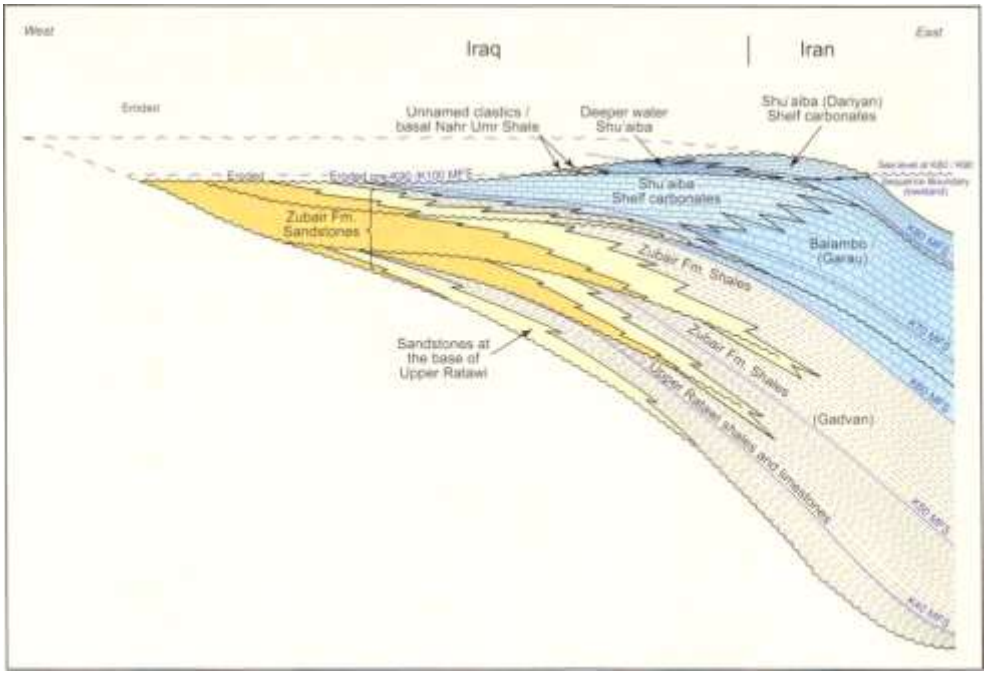


Figure (2) Schematic west-east profile across southern/ central Iraq illustrating stratigraphic position of Zubair Formation [2].

Methodology:

The present she study is divided into three stages:

1. **Collecting samples and data**:

   This stage is represented by going to the Southern Oil Company (SOC) in Basrah where the studied sections are described and collected. As well as the well logs, and the isopach map of Zubair Fn.

2. **Laboratory stage:**

   The petrographic study and microfacies analyses are based on the study of thin sections of cutting from the selected borehole of Majnoon oil field.

3. Studying of the available well logs of Zubair Fn. for MJ-2, MJ-4, MJ-12, MJ-15 and MJ-47 and relate the logs responses to facies and diagenetic changes.

The studied wells properties are shown in table (1).

Table (1): The studied wells of Zubair Fn. in Majnoon oil field.

Well no.	Formation	Top (m)	Bottom (m)	Longitude	Latitude
MJ-2	Zubair Fn.	3452	3665	E751906.1	N3436141.1
MJ-4	Zubair Fn.	3465	3650	E749948.3	N3444259.2
MJ-12	Zubair Fn.	3524.5	3725	E747940	N3436300
MJ-15	Zubair Fn.	3478	3690	E752574.3	N3432726.8
MJ-47	Zubair Fn.	3373	3615	E747650	N3449300

Lithofacies Analysis

The geological and reservoir properties 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 [6].

One of the first steps in the facies analysis of a clastic reservoir is the description and interpretation of available conventional core [8]. An important result of core description 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 the available of these parameters there are 8 lithofacies in the Zubair succession.

I. Course-moderate sandstone well sorted lithofacies

This facies consist of coarse sized quartz arenite sandstone, well sorted and well bedded about 10-20cm thick bed (Plt. 1-A).

II. Fine Sandstone well sorted lithofacies

This facies consist of fine grained quartz arenite sandstone, well sorted and laminated bed sedimentary structure (Plt. 1-B).

III. Course-moderate Sand poorly sorted lithofacies

Poorly sorted quartz arenite is characterized this lithofacies with graded bedded and wavy lamination (Plt. 1-C).

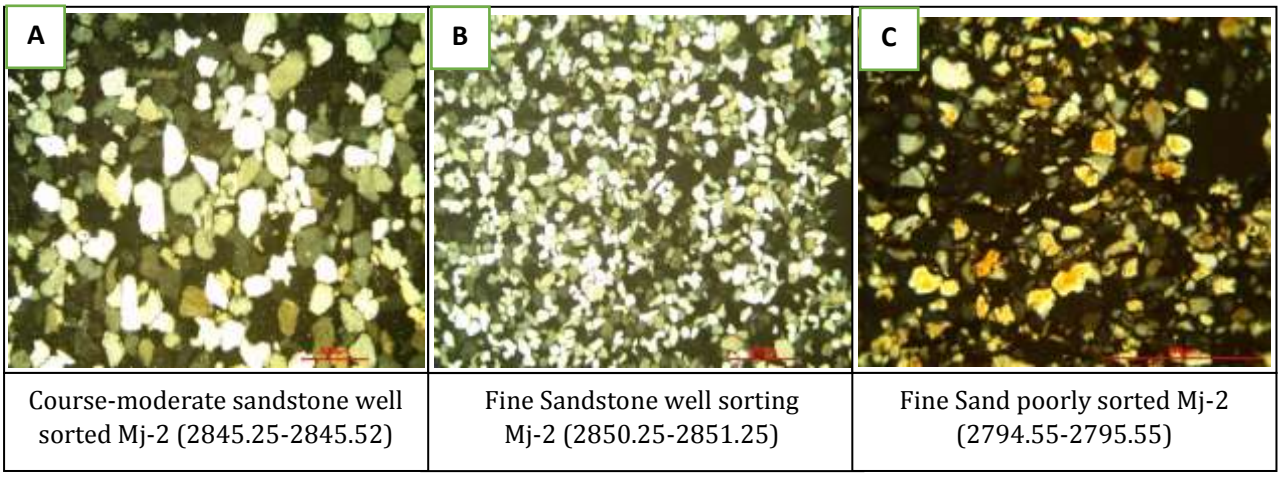
IV. Clayey Sandstone poorly sorted

The sandstone in this lithofacies is classified as wacke quartz arenite because it contains amounts of clay at rates exceeding 25% (Plt. 1-D). This lithofacies characterized by present of flaser lamination.

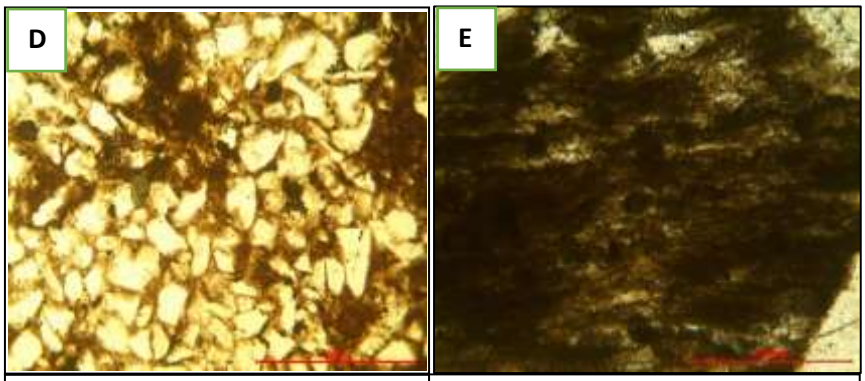
V. Shale lithofacies

Consisted mainly of mud (more than 50%) and less amounts of sand (quartz grains) with lenticular (Plt. 1-E).

Plat (1)



Course-moderate sandstone well sorted Mj-2 (2845.25-2845.52)	Fine Sandstone well sorting Mj-2 (2850.25-2851.25)	Fine Sand poorly sorted Mj-2 (2794.55-2795.55)



Clayey Sandstone poorly sorted Mj-2 (2790.35)	Shale lithofacies Mj-2 (2815)

Associated Facies and Depositional environments

There are three main associations of deltaic facies in the studied succession:

1. Delta plain (Upper delta plain- flood plain deposits)
2. Delta Front (Subaqueous delta plain)
3. Back shore (Upper delta plain- Lacustrine delta-fill)

These different facies contributed to division of the Zubair Formation into three distinct rock units, which we will use in interpreting the suggested environments above:

- ***Lower Part:***

The main composed of this unit is shale with the lenses of fine sand with high organic matter. The lower contact of this unit is unconformable with the Ratawi Formation according to [1].

This unit is characterized by high gamma ray values with abundant of coarsening up-ward (Funnel shape), with exception of the part near the lower contact which shown fin up-ward (Bell shape) (Fig. 3). The main lithofacies in this unit is shale lithofacies, and clayey sandstone that is poorly sorted. This represent the delta plain succession was deposited in the flood-delta plain environment.

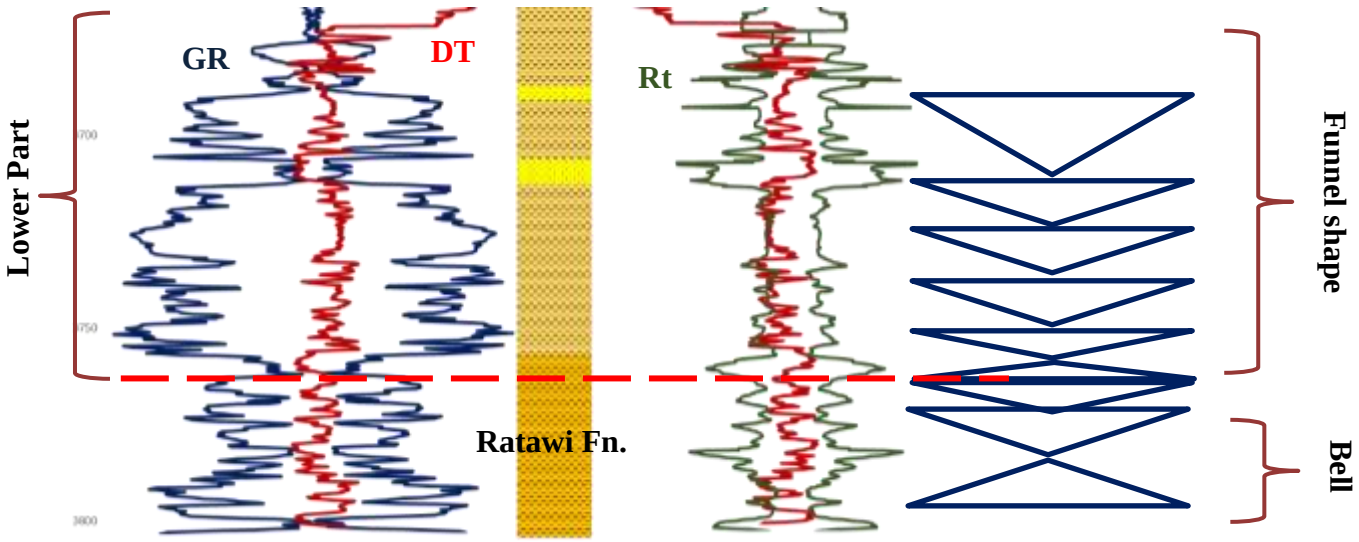


Figure (3): The direct correlation between facies and a variety of sonic and GR log shapes for the lower part of The Zubair Formation (Mj-1).

- ***Middle Part:***

The main composed of this unit is sandstone with the shale inter layers with high amount of heavy minerals. This unit is characterized by low gamma ray values with two cycles of fine up-ward (Bell shape) in the lower zone of this part, and coarse up-ward (Funnel shape) in the upper zone divided the serrated shape into two cycle of pure sandstone (Fig. 4).

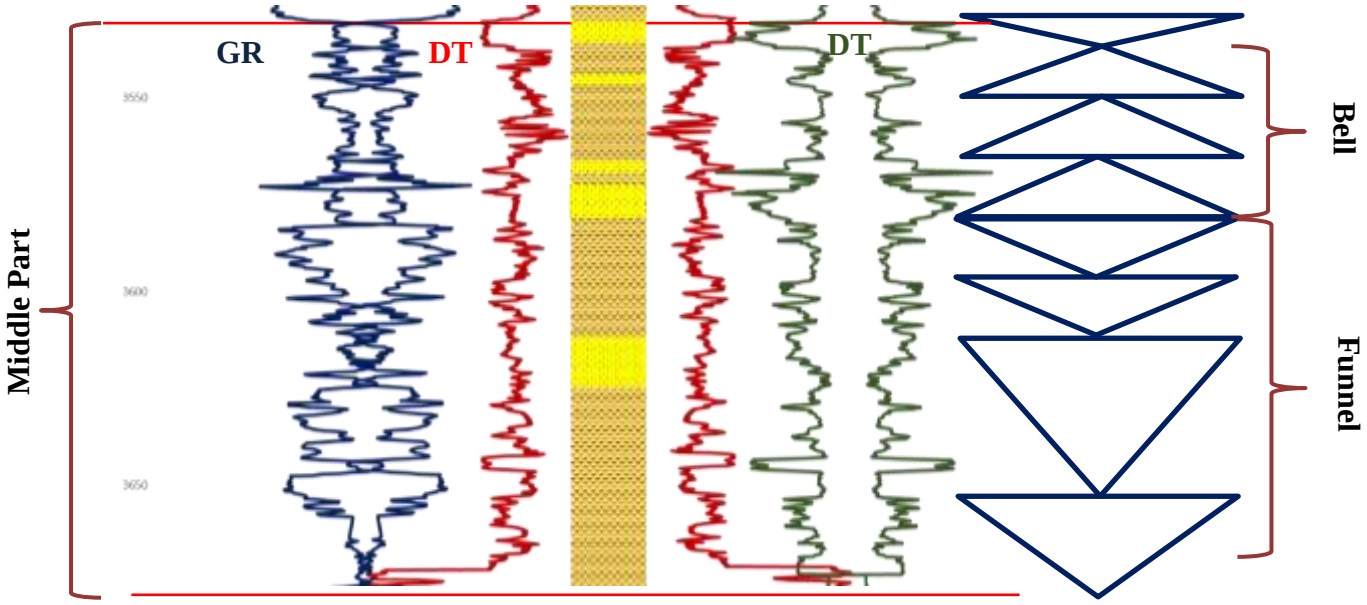


Figure (4): The direct correlation between facies and a variety of sonic and GR log shapes for the Middle part of The Zubair Formation (Mj-1).

The main lithofacies in this unit is Course-moderate sandstone well sorted lithofacies and fine Sandstone well sorted lithofacies, in addition to Clayey Sandstone poorly sorted.

This means that the delta plain succession was deposited in the distributary-mouth-bar within the delta front environment.

- ***Upper Part:***

The main composed of this unit is shale with high amount of pyrite and organic matters. This unit is interlaying with sandstone in the lower zone of the upper part.

The main lithofacies in this unit is shale lithofacies and Clayey Sandstone poorly sorted, while in the lower zone of this part the Course-moderate Sand poorly sorted lithofacies.

This part characterized by high gamma ray values with major trend of finning up-ward succession (bell shape) (Fig. 5). This represents the lacustrine associated facies within the delta plain environment.

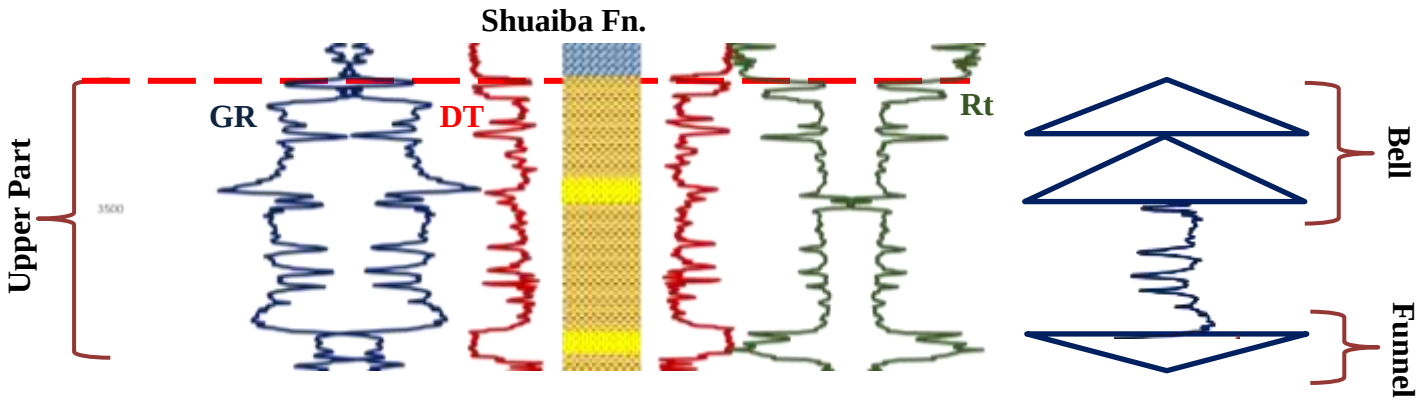


Figure (5): The direct correlation between facies and a variety of sonic and GR log shapes for the upper part of The Zubair Formation (Mj-1).

Sequence development of Zubair Formation:

The sedimentary sequence of the Zubair Formation is composed of the products erosion of the Arabian Shield and the Stable Shelf Arabian Platform, which underwent uplift during Jurassic (Late Kimmerian) movement. These clastics were poured into the sea though deltas across the foreland of the Lower Cretaceous geosyncline. The Arabian Shield is assumed to have supplied the Biyadh Formation in Saudi Arabia under an alluvial environment [9].

The mouth bar facies is the dominant part of in the upper sandstone member of Zubair Formation, it results in topest and can notes the evolution of the sequence depositional, it began in topest deposits are mainly made up of marsh deposits also present are river channel deposits and natural levee deposits [10].

The deposits of upper sand member in Zubair formation are reflected another topest deposits for delta where move the channel facies to sea and the foreset deposits are made up of pro – delta silty clay and rather coarse sand, silt and clay deposits.

The deposition of the Zubair Formation sediments is concurrent with the early stage of the development of the Alpine geosycline basin and the progressive rising of the continent. Consequently, the palaeogeographic setting was characterized by an interaction of the movements in the geosyncline and those initiated by these movements on the Arabian Shield [5].

During the deposition of the Zubair Formation, the siliciclastic shelf followed a cyclical pattern of evolution from the delta depositional mode to lacustrine mode. A sequence boundary type-I separates the basinal shale of Ratawi Formation from the overlying deltaic influenced lower Zubair Formation (Figs. 6, 7, 8, 9 & 10).

The lower part of Zubair is characterized by wide spread mud -dominated delta plain associated facies. They seem to vertically separate relatively multi-storied mode and multi-lateral changes deltaic channel sand bodies resulting in compartmentalized reservoir architecture.

The presence of the delta plain associated with the facies that overlaying the unconformity surface (SB1) refer to the transgressive system tract (TST). This stage has ended with appeared the channel fill deposit to mark a high-stand system tract (HST). The fluctuation point between the TST and HST is represented a maximum flooding surface.

The transgressive system tract in Zubair Formation is prominent in the lower part of the formation and the depositional sequence which comprise a retrogradational parasequence units, separated from each other by deep water marine transgressive deposits, which mark a maximum flooding surface that separating the transgressive from highstand systems tract.

The middle part of Zubair Formation is characterized by moderate to well sorted quartz arenite sandstone with appeared bands of the shale overlaying the sand body. This succession was deposition in the delta front environment with steps of sea level rise during the transgressive stage. There are mostly three sequences of TST in this part which end with the maximum sea level rise (MFS) to mark the upper part of the Zubair Formation. The next stage was appeared high concentrations of organic matters and pyrite mineral which indicating that the sedimentary environment has been reduced to the marshes environment during the HST. This stage is not clear in the Majnoon oil field, where rock characteristics indicate that they belong to the middle part as a TST.

Highstand systems tract of the Zubair succession is recognized either by prograding fluvial facies over tidal flat facies, or prograding tidal flat facies over shallow marine facies, which are bounded below by maximum flooding surface.

The upper part of the Zubair Formation is showed a shallower environment with shale dominated rocks associated with high organic matters and pyrite. This indicate to the finning up-ward mode during highstand stage when the deposition environment changed from delta front to marsh environment. The sea level rise was marked the end of this stage when deposition the upper part of Zubair Formation, and the beginning of deposition the Shuaiba Formation as shallow carbonate marine.

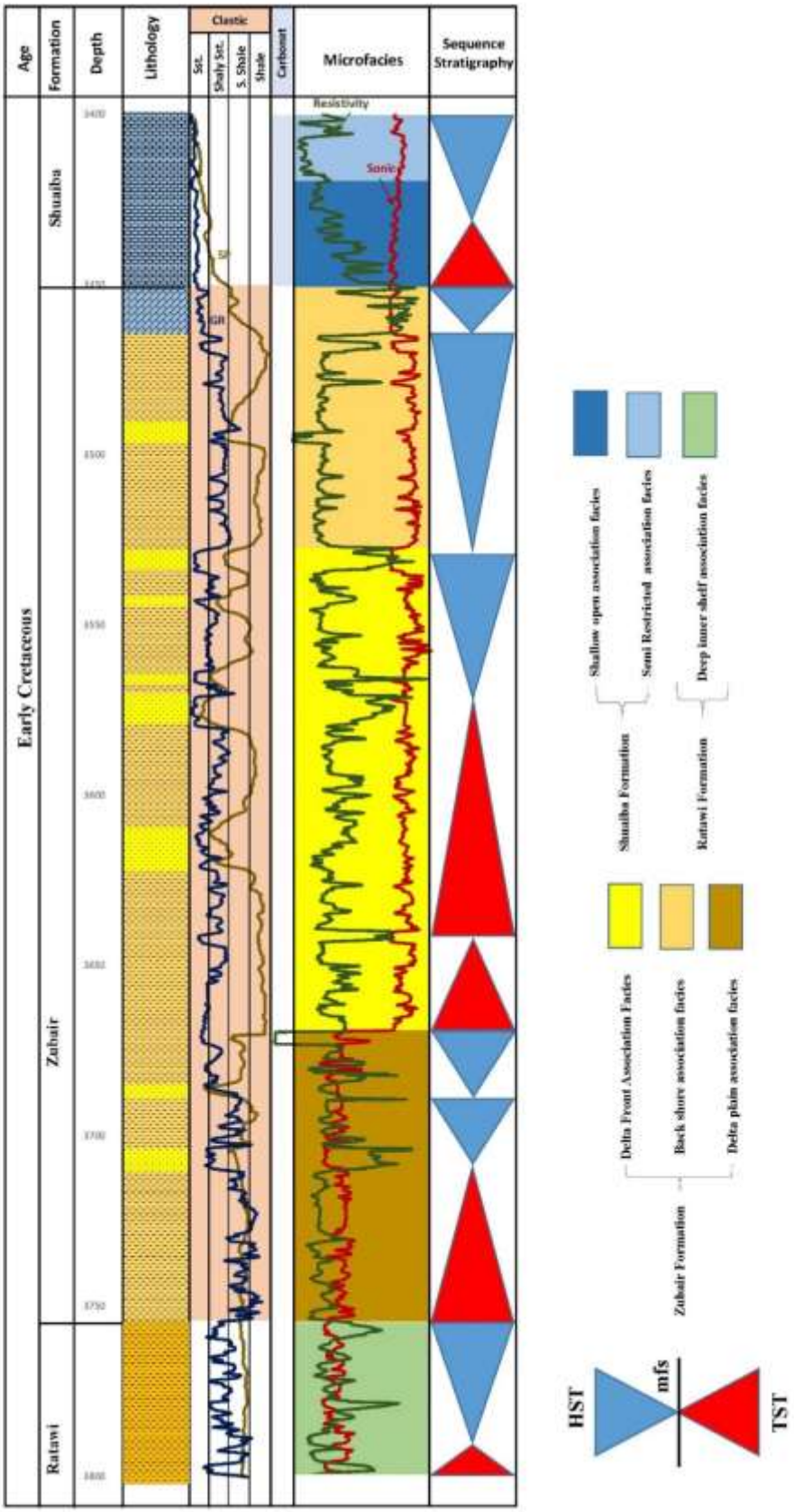


Figure (6): Sequence stratigraphy subdivision at MJ-2.

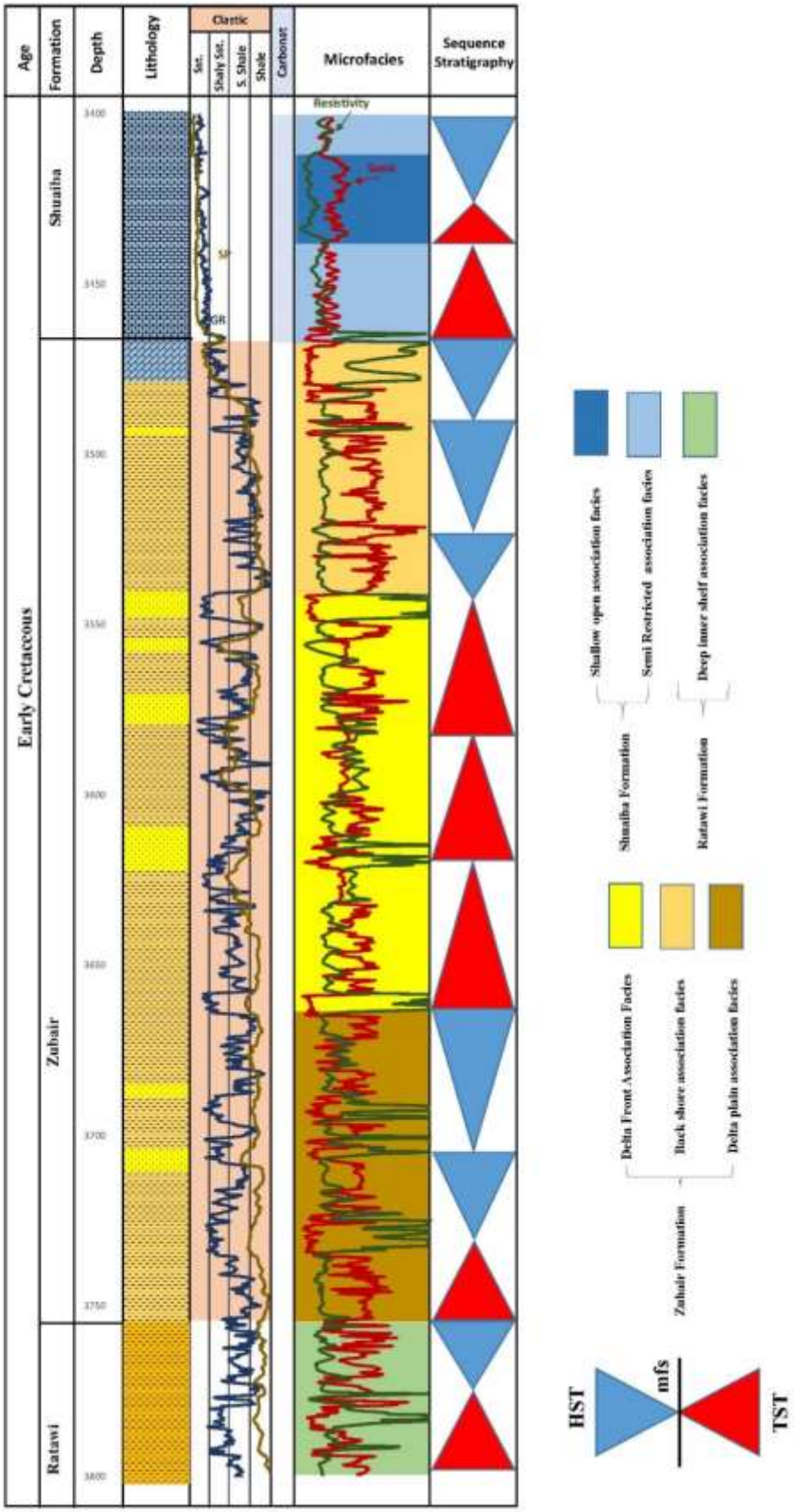


Figure (7): Sequence stratigraphy subdivision at MJ-4.

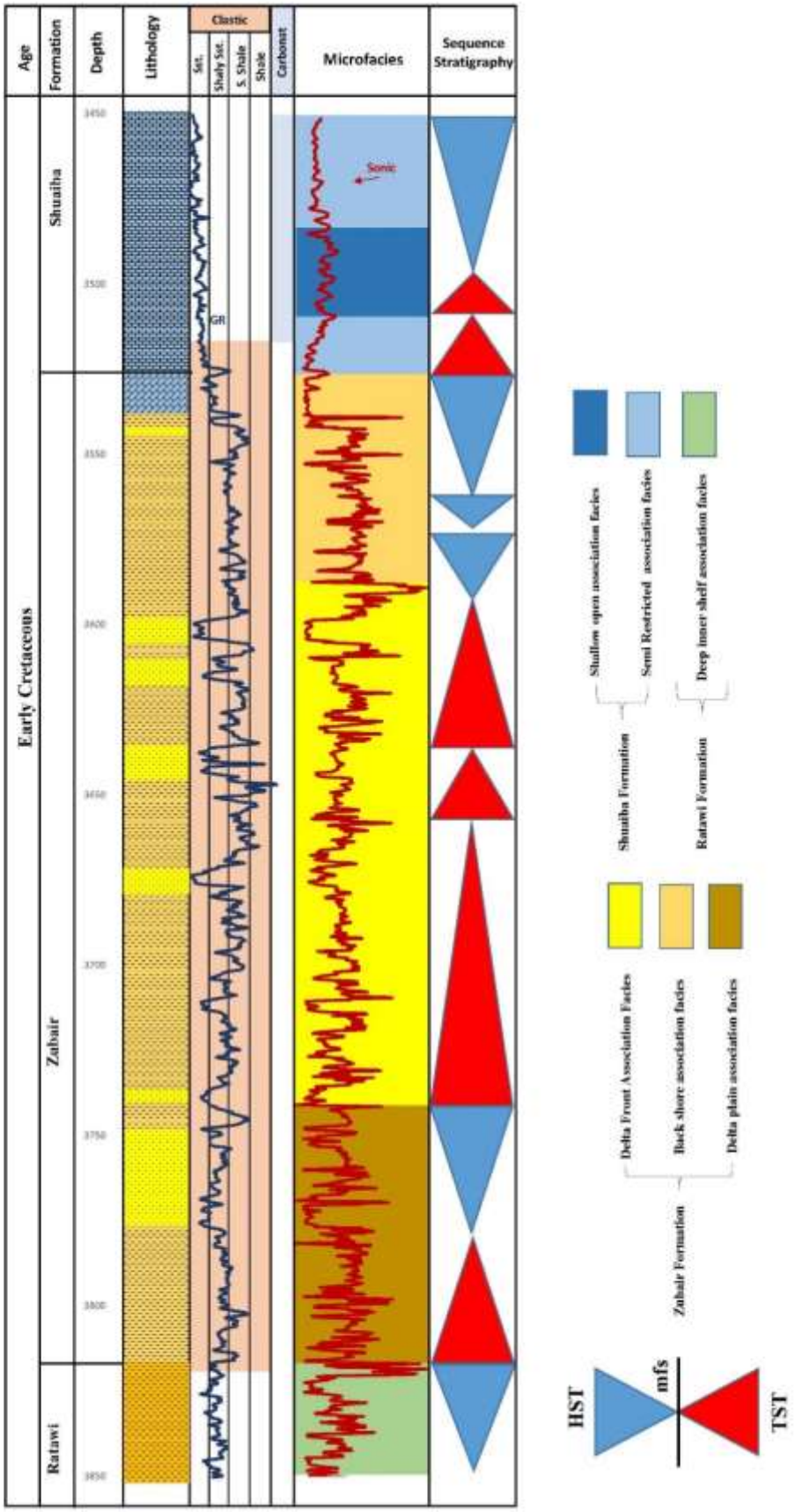


Figure (8): Sequence stratigraphy subdivision at MJ-12.

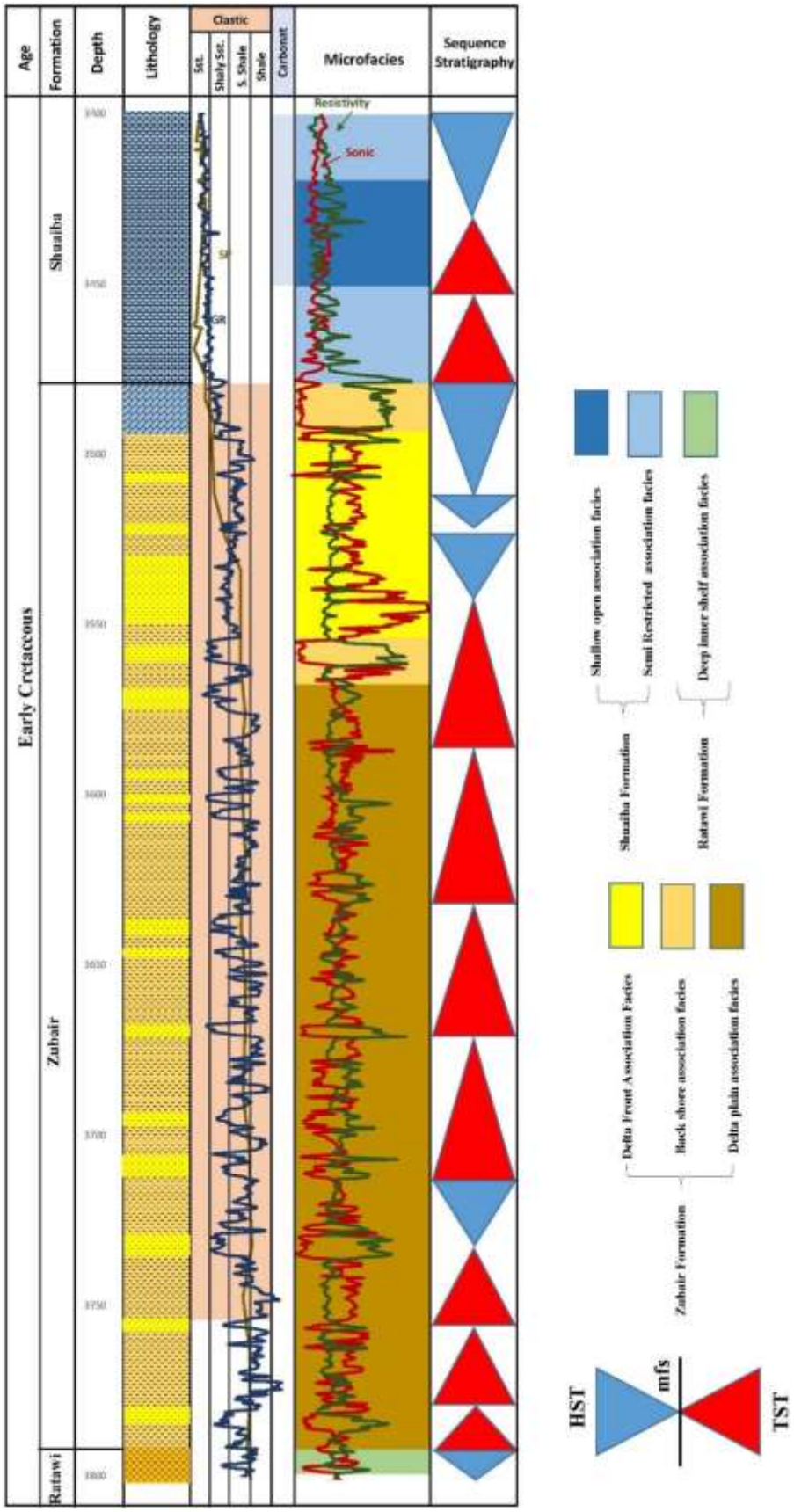


Figure (9): Sequence stratigraphy subdivision at MJ-15.

CONFLICT OF INTERESTS.

There are non-conflicts of interest.

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الخلاصة

ان تتابع الباريميان في الدراسة الحالية يتمثل بتكوين الزبير والذي يعتبر من اهم مكامن النفط الرملية في العراق. تقع منطقة الدراسة في الجزء الجنوبي من العراق في حقل مجنون النفطي، ضمن حوض بلاد الرافدين التكتوني. اظهرت الدراسة البتروغرافية ان الكوارتز هو المكون الرئيسي للحجر الرملي في تكوين الزبير مع نسبة ضئيلة من الفلسبار ومكسرات الصخور لتصنف على أنها أرينيت الكوارتز. هناك خمسة تغيرات صخرية (سحنات صخرية) ميزت التتابع المدروس وهي سحنة الحجر الرملي الخشن–المتوسط جيد الفرز و الحجر الرملي الناعم جيد الفرز و الحجر الرملي الخشن–المتوسط رديء الفرز و سحنة الحجر الرملي الحامل للطين الرديء الفرز و سحنة الحجر الطفلي. وقد ترسبت هذه السحنات الصخرية في بيئة دلتاوية كثلاث متتابعات سحنية (السهل الدلتاوي و مقدمة الدلتا و البيئة البحيرية–المستنقعات)

وقد ساهمت مختلف أنواع االسحنات الصخرية في تقسيم تشكيل الزبير إلى ثلاث وحدات صخرية متميزة، والتي أُستخدمت في تفسير وتوزيع البيئات المقترحة وهي الوحدات السفلى و المتوسطة و العليا. تتكون الوحدة السفلى من الصخر الطفلي مع عدسات الرمل الناعم و المواد العضوية العالية التركيز، حيث ترسبت في بيئة سهل الدلتا الفيضي. ويشير اعتلاء مترافقة بيئة السهل الدلتا لسطح عدم التوافق (SB1) إلى الترسيب خلال فترة التقدم البحري .(TST) وقد انتهت هذه المرحلة مع ظهور مترافقة قنوات الماليء النهري لتؤشر مرحلة ترسيب خلال توقف مستوى سطح البحر الاعلى.(HST).

بينما تتكون الوحدة الوسطية من الحجر الرملي المتداخلة مع طبقات الطفل وتركز كمية عالية من المعادن الثقيلة، والتي ترسبت في شريط التوزيع في مقدمة الدلتا. في هذا الجزء هناك اثنان من التتابعات التي ترسبت خلال فترة التقدم البحري (TST)والتي تنتهي باقصى ارتفاع لمستوى سطح البحر (mfs) لتؤشر بداية الوحدة العليا لتكوين الزبير.

في حين يتكون الجزء العلوي من الصخر الطفلي مع كمية عالية من معدن البيريت والمواد العضوية. ويمثل هذا التتابع مترافقة البحيرية (الأهوار–المستنقعات) لبيئة سهل الدلتا المترسب ضمن مرحلة توقف سطح البحر الاعلى .(HST) ان ارتفاع مستوى سطح البحر بعد ترسيب الجزء الاعلى اشر نهاية هذه المرحلة وبداية ترسب تكوين الشعيبة في بيئة بحرية جيرية ضحلة.

الكلمات الدالة:– التحليل سحني ، التتابعية الطباقية، تتابع الباريمي، تكوين الزبير، حقل مجنون النفطي