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Lithofacies Analysis and Depositional Development of Zubair Formation in West Qurna Oil Field, Southern Iraq

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Abstract

This present study includes the petrography, lithofacies analysis and depositional development for the Zubair Formation in six boreholes (WQ-1, WQ-13, WQ-15, WQ-60, WQ-148 and WQ-356) within the West Qurna oil field. Zubair Formations was deposited within Mesopotamian Zone during the Barremain stage which belong to the Early Cretaceous epoch.

The major component of Zubair succession is sandstone which classify as quartz arenite (also known as orthoquartzite) has about 92% or more quartz grains. While a rock having >25% lithic fragments and subordinate feldspars are lithic arenites; those with clay content >25% and subordinate lithics is a gray wacke

Five major lithofacies within two groups of rock dominance are recognized in this succession as follow:- Quartz arenite well sorted-subrounded Lithofacies, Quartz arenite poorly sorted sub-angular Lithofacies and graywacke poorly sorted Lithofacies within the sand dominated rock; and Sandy claystone and Shale Lithofacies within clay dominated rocks. Three facies associations are distinguished in studied succession, they are: delta plain, delta front and back-shore. The microfacies analysis and reconstructed the paleoenvironments for the Barremain basin in the studied area has contributed to determine three stages matching with the observable units.

Main composed of the lower unit is shale with thin beds and lenses of sandstone to divided this unit into two parts, the upper most is sandstone and the lower part is consisting of shale in the south part of studied area. This sequence is interpreted to form in a delta plain deposits was common in the north and south part of the studied area (WQ-13, WQ-1 and WQ-356), while the middle part of this area (WQ-60 and WQ-15) was closed to shore face environment. The middle unit is the thickest and characterized by alternative of shale and sand beds as Three laterally heterogeneous cycles. These three-cycle appeared clearly in the southern part of studied area, while to the north became two cycle. In the central of studied area the middle part is represented by one cycle of quartz arenite well sorted-subrounded lithofacies as a delta front and shoreface association facies. The delta plain is common association in the WQ-13 and WQ-148 as a successive of lithofacies 3, 4 and 5, while this association is alternative with back shore association to the north direction (WQ-15, 1 and 356). Upper unit is composed of sandstone as quartz arenite well sorted-subrounded lithofacies. This refer to deposition in the delta front and shore face to mark the sea level rise in all studied well except WQ-60, which represent the delta plain association facies. This cycle was marked the end of Zubair deposition during the transgression stage.

Key Words:- Facies Architecture, Depositional development, Zubair Formation, West Qurna Oil Field

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Introduction

The Zubair clastic succession was deposited in the Mesopotamian basin during the Early Cretaceous epoch within the Barremain stage. This study is including the petrography and facies analysis of the Zubair sequence in six wells WQ-1, WQ-13, WQ-15, WQ-60,WQ-148 and WQ-356 in the West Qurna oil field. The studied area is situated in the south of Iraq within the zone of Mesopotamian. The West Qurna oil field is covering an area of 340km², the West Qurna oilfield lies 65km away from Basra in southern Iraq (Fig.1).

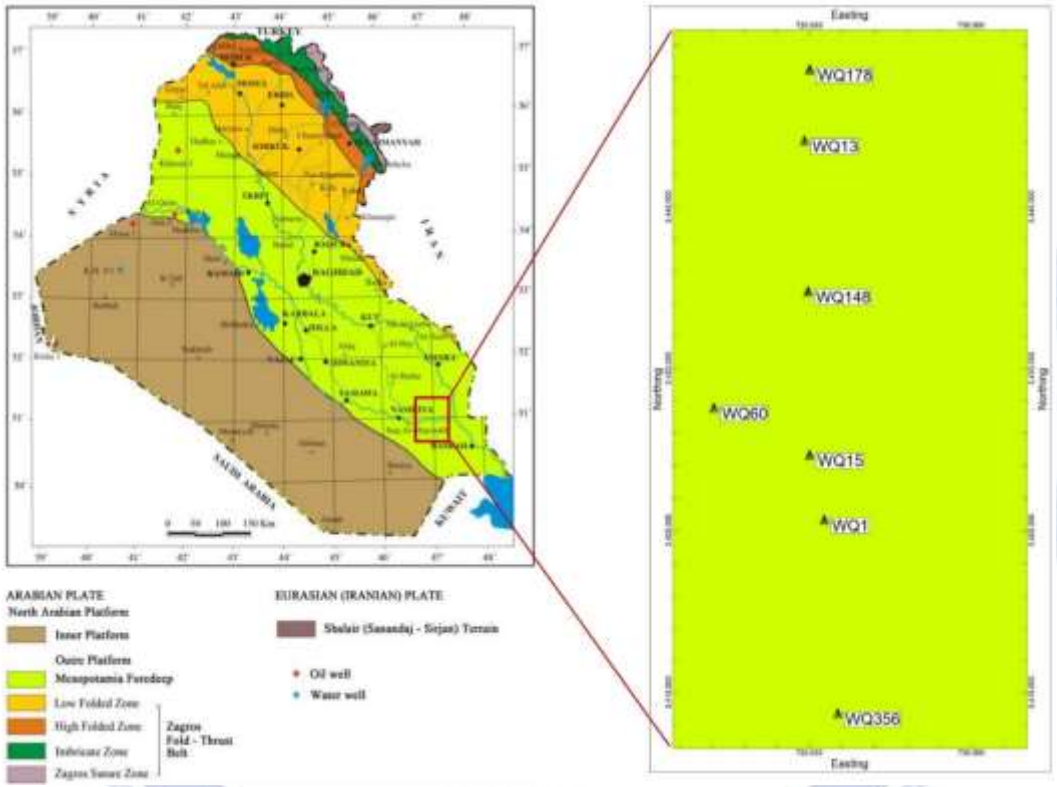

Figure (1) shows a map of studied boreholes with the tectonic setting of Iraq according to [1].

The Zubair succession represents a Barremain sequence which belong to the Late Tithonian-Early Turonian Megasequence. The formation was deposited in a large intra shelf basin contemporaneous with a new tectonic phase of sea floor spreading in the southern part of Neo-Tethys. The differential subsidence and the resultant thickness changes occurred across transverse faults. The axis of this basin was shifted towards the eastern Mesopotamian Zone

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into the Tigris Subzone from its previous position on the Salman Zone and western Mesopotamian Zone [2].

Al-Zaidy [3] studied the lithofacies analysis and stratigraphic development of the Zubair Formation in Majnoon and Suba oil fields. That suggests the Zubair Formation was deposited during three depositional stages of transgression system tracts, which was ended with appeared the shale lithofacies within the well-sorted quartz arenite lithofacies to mark the mfs in the Suba oil field. While, the Majnoon oil field the Zubair succession is characterized by three depositional cycles were represented by sequential of delta plain and delta front association with dominance of shale units. Addition to, study the lithofacies distribution and stratigraphic framework of this succession in Kifl oil field [4].

Zubair/Ratawi succession as a clastic shelf was covered by the shallow marine sediments of Shuaiba Formation following by prograding of the Zubair and Ratawi succession (Fig. 2). Jassim and Buday [2] were suggested that the Zubair basin depocenter was situated in the east of the Salman Zone [5], and the maximum values of thickness is appeared to the north of studied area (Fig. 3).

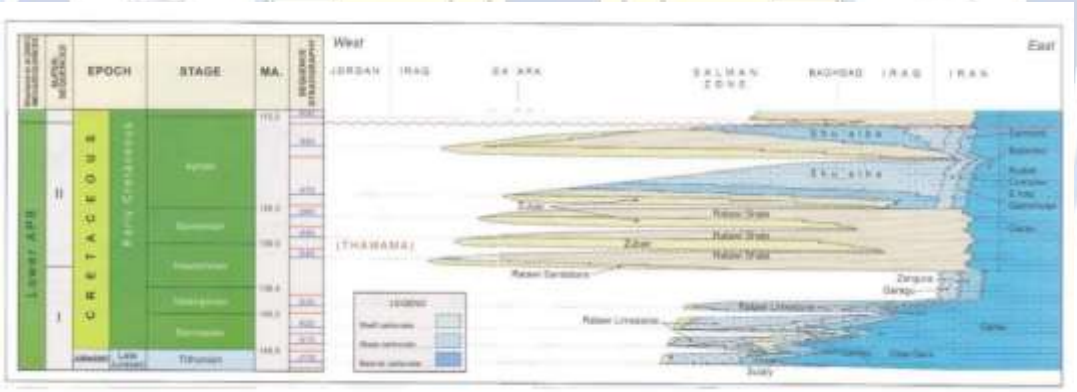

Figure (2) Chronostratigraphic cross section shows Early Cretaceous succession [5]

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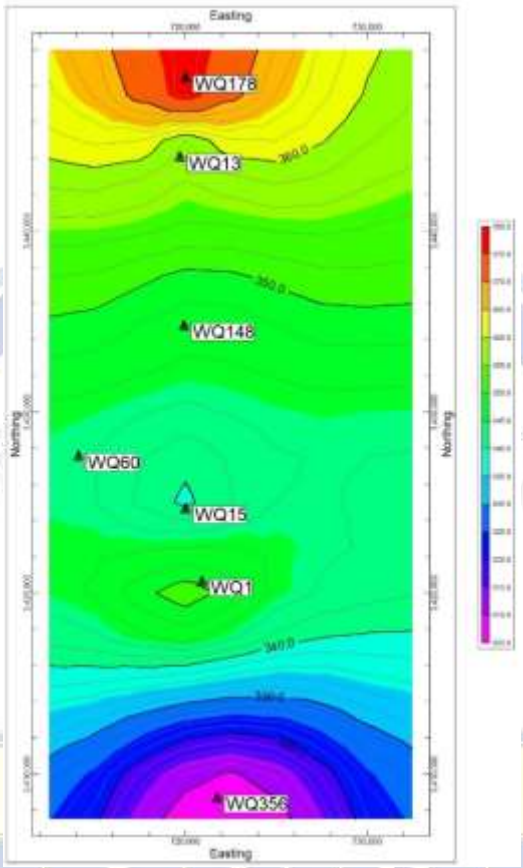

Figure (3) Isopach map of Zubair succession shows thickness distribution in studied wells.

The upper boundary of this formation with Albian succession (Shuaiba Formation) is mostly gradation surface and conformable, While the lower contact with Ratawi Formation is unconformable surface [6] and [7].

The purpose of this study is a petrography description and lithofacies distribution of Zubair succession in the West Qurna oil field to rebuilding the paleoenvironment.

Methodology:

- Sampling and recover the cores and cuttings samples for studied wells to prepare 150 thin sections.

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- Examine thin sections for studied wells to describe the petrography and lithofacies analysis.
- Point counting by used JMicroVision program has been developed specially to analyzing a high definition images of rock thin sections, but it can easily be used in other domains.
- Study the available full set of well logs (Obtained from SOC) and relate the log response to lithofacies changes and distribution (Table 1).

Table (1) thickness and coordinate sampling of the studied succession in West Qurna oil field.

Name	Top	Bottom	Thick	Longitude	Latitude
WQ-1 Zubair	3074.5	3425.9	351.4	34420680.42	720900.03
WQ-13 Zubair	3279	3637	358	3444122	719863
WQ-15 Zubair	3081	3420.5	339.5	3424700	720000
WQ-60 Zubair	3407	3571	344	3427600	714100
WQ-148 Zubair	3125	3472	347	3434800	719900
WQ-356 Zubair	3070	3380	310	3408734.91	721733.92

Petrography

The composition of sandstone can be controlled by many factors such as the minerals composition of provenance rocks, transportation distance of sediments before it reaches its final site of depositional basin, the residence time that detritus is held in environments other than its final site of deposition, the climate in the provenance area and diagenetic processes which effect following final depositional settings [8].

Texture is used when describing sedimentary rocks (sandstones) with a view to interpreting the depositional mechanism and environments. It is also a means of assessing the percentage of porosity and permeability which has proved to be a valuable tool in the analysis of potential hydrocarbon rich sand-bodies.

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Quartz

has the most abundant minerals ratio among main component grains which calculated by using JMicroVision (quartz, feldspar and lithic grains only) ranging from more than 90% in the well sorted, rounded quartz-arenite sandstone unit of Zubair Formation to the less of 25% in the shale dominated unit of the same formation. The ranges of Quartz grain size from medium to very fine according to Wentworth, 1932 [9]. Roundness of grains ranges from subangular to rounded based to visual chart of Powers [10]. The predominance of quartz grains can be result by reworking, long distance of transportation or predominance of tropical weathering [11].

This variation in size and roundness lead to form many types of quartz grains contact such as long edge, concave vs convex and Y-shape contact type, but in some case there are few of floating contacts and point contact which increase in sandstone studied rocks with high values of calcite crystals related to the growth of carbonate cement which leads to forceful wedging apart of the grains (Waldschmidt, 1941 [9]). Two types of quartz grains are recognized in Zubair Formation:

Monocrystalline Quartz (Plt.1A) as a dominant type. This type of quartz shows two types of extinction: sharp extinction and slightly undulating extinction. Monocrystalline quartz refers to granitic source rock [12].

Polycrystalline Quartz (Plt.1B) as a small percentage as a reason for that is the lack of stability during long-distance transport or lack of presence in the source [9].

Feldspar (Plt.1C) Like quartz, feldspar has low relief and low interference colors (white to gray first-order), and it can be easily misidentified as quartz grain where it lacks twins. But so many feldspar grains are recognized by complex twinning (plagioclase) while the orthoclase have occasionally a simple.

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Feldspar ratio less than (5%), due to the weak stability as it decomposes and eroded when transported to long-distance, Therefore the presence or absence of feldspar is referring to balance occurring between decompositional rate and rate of erosion [9].

Rock fragments are detritus particles made up of two or more mineral grains depending on the provenance rocks composition. It can provide the most direct lithologic changes [13].

Chert (Plt.1D) is microcrystalline quartz these grains occurs as a low relief and low first order interference color.

Lithic fragments (Plt.1E) are sedimentary rock fragments as poly and mono-grained. They are characterized by brown to black colors, with silt to sand sized of quartz grains and associated with opaque minerals such as hematite and magnetite (iron-oxide) or iron-sulfide as pyrite minerals. Because they are mechanical deposits, the shale fragments are dominance reworked and deformed during the compaction of rocks. They are confused with a matrix materials and sometimes are known as pseudo matrix.

Shale is a fine grained and laminated clastic sedimentary rocks, which composed of mud materials that is a mixed of clay minerals and very fine rock fragments as silt-sized particles of other minerals, especially quartz and calcite. Shale is characterized by breaks along thin laminated or parallel layers or bedding less than one centimeter in thickness, called sessility. It is the most common of sedimentary rock [14].

The shale beds continue as a thin laminated bed, weakly calcareous, pyritic, silty shale with abundant organic materials as is appeared and dominated in the lower and upper parts of Zubair Formation. This shale contains moderate to abundant bands quartz grains as sandstone, less of dolomite and calcite minerals, addition to bands with long calcite strands often with scattered of pyrite crystals. Pyrite mineral within the shale rocks occurs as microcrystals, framboidal aggregates, or as nodules that formed within the laminated shale beds. While, the middle part of this succession is characterized by lenses and flaser bands of shale within sandstone unit.

Matrix is the finer mineral material occurring between the grains which commonly consist of clay minerals, but may also contain very fine particles of quartz and feldspar. The matrix

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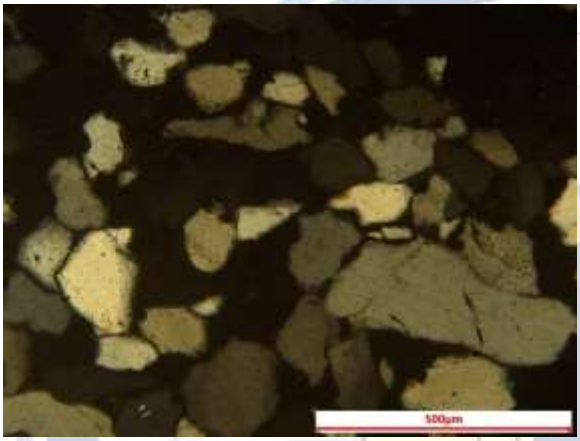
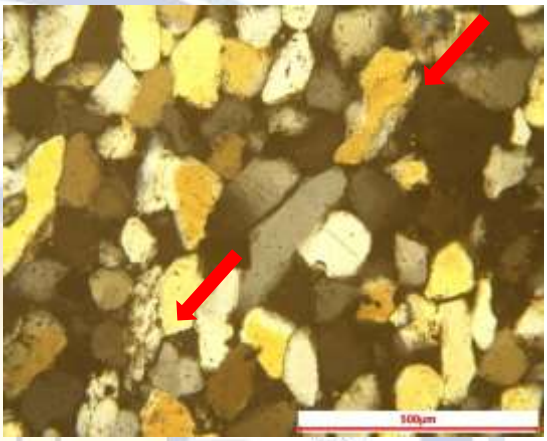
results from primary deposition; in addition, matrix may be infiltrated shortly after deposition [9]. The matrix of Zubair Formation consists mainly of silt, iron oxides and clay minerals.

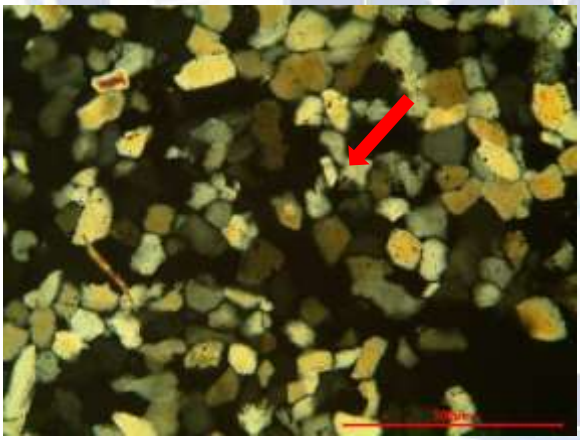
Plate-1



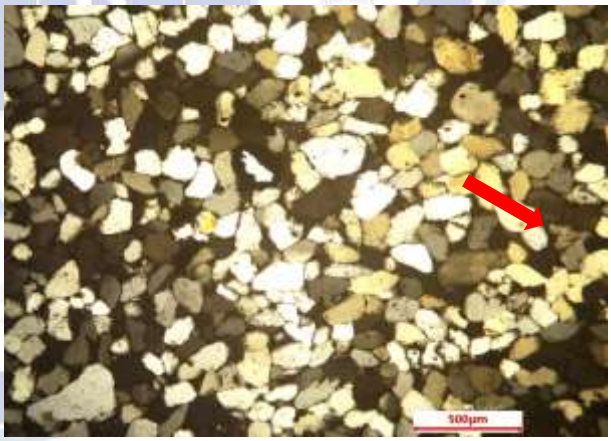
A. Monocrystalline Quartz
WQ-1(3213m)



B.Polycrystalline Quartz
WQ-1(3193m)



C. Feldspar
WQ-1(3241m)



D. Chert WQ-13
(3231.53-3232.53m)

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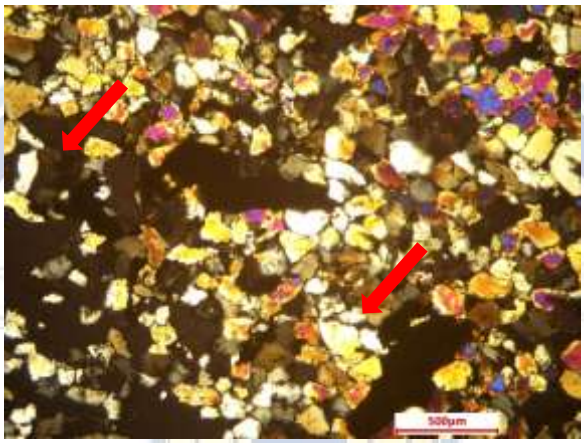

E. Rock fragments
Wq-13(3277.37-3278.37m)

Sandstone classification

In this study the sandstone units are classified and described according to the classification of Pettijohn and others [9] (Fig.4), which depends upon the texture and the mineralogical composition of sandstone. The major component of Zubair succession is sandstone which classify as quartz arenite sandstone and also known as orthoquartzite, has including about 92% or more of quartz mineral. While a rock having >25% lithic fragments and subordinate feldspars are lithic arenites; those with clay content >25% and subordinate lithics is a gray wacke

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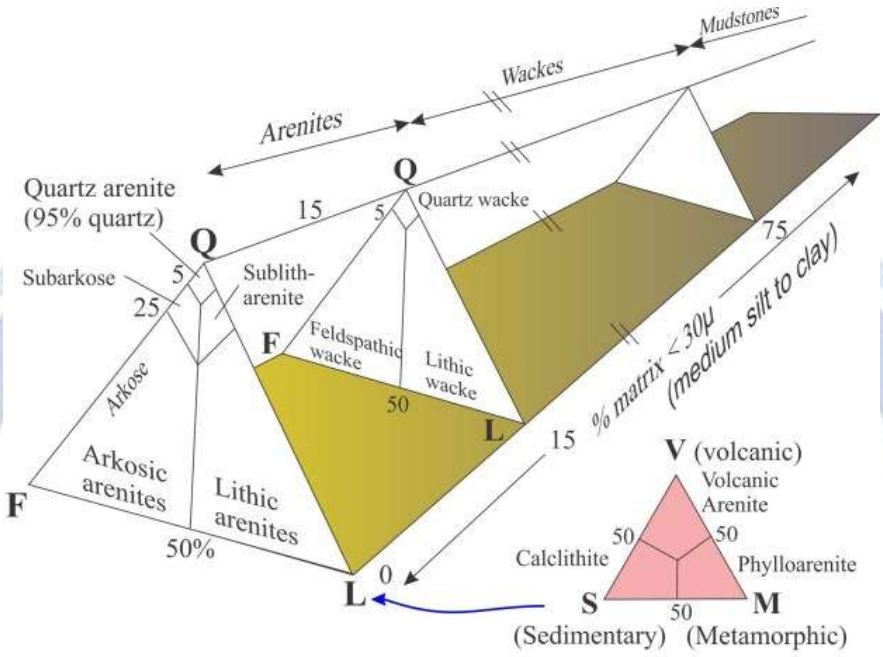

Figure (4): Classification of siliciclastic rocks modified after [9].

The provenance of Zubair sandstone

The mineral composition of sandstones is controlled by provenance area lithologic type and this in turn is also affected by tectonic effects [12]. In areas of high tectonic activity, provenance rock type determines the sediment composition more than the climate and relief effects [15]. Dickenson [11] mentioned that provenance rocks can provide accurate interpretations of the plate tectonic settings of source clastic area through analysis of the detrital modes of siliciclastic strata in diverse depositional basin.

Dickinson and co-workers were suggested a relationship between the compositions of detrital sandstone and major provenance of the rock types area such as stable cratonic setting, basement uplifting, magmatic island arcs and recycled of orogenic basin [11].

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Modal analysis of Zubair Formation has determined the ratio of quartz types, feldspar and lithoclasts in the sandstone of this Formation. These ratios are Plotted on the provenance diagram of Dickinson [11] (Fig.5).

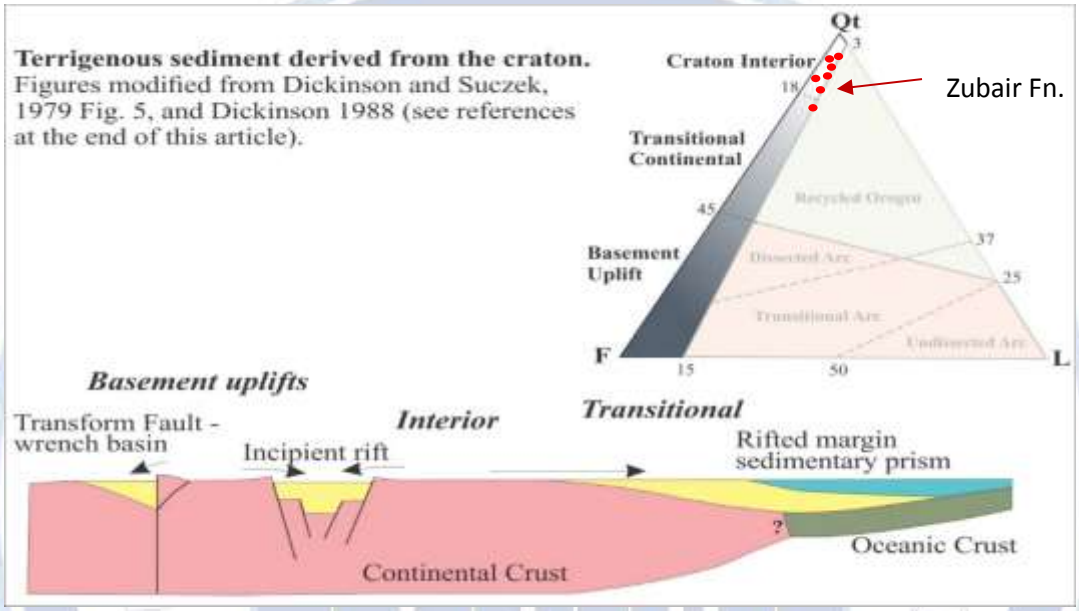

Figure (5): provenance diagram of Dickinson [11] for Zubair Formation Sandstone, (Q)=Total Quartz includes polycrystalline Quartz, (L)=Lithoclasts and (F)=Feldspar grain, (Qm)=monocrystalline grains and (Lt)= lithic grains and includes polycrystalline quartz grains.

The units of Zubair succession

Zubair Formation thickness values are ranging from about 310m to 358m in the West Qurna studied boreholes (Table 1).

Three major units are characterized the studied succession which divided by using well logging tools (GR, SP and DT) (Fig. 6). The lower member consists mainly of shale with less sandstone; the middle member is consisting of thin layers of sandstone with dominance of shale and the upper member is composed mostly of sand layers with thin shale beds: -

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- **Lower unit:**

The lower zone of this succession is characterized by shale dominated unit with high gamma ray log values with many cycles as finning upward (funnel shape) in the WQ-13, WQ-148, WQ-60 and WQ-15. While in WQ-1 and WQ-356 are appeared aggrading pattern with box car shape (cylinder). The lower unit is divided in to two cycles in the northern part of studied area and three cycles in the southern part (Fig.6). The thickness of this unit is ranging from 20m in WQ-60 to 60m in the others.

- **Middle unit:**

This unit is the largest unit in the studied succession, which characterized by sandstone - shale dominated with thickness ranges from 200 to 250m. The lateral distribution of this unit appeared three patterns of variation; the first pattern is showing in the northern part of studied area (WQ-13 and WQ-148) with two cycles of sandstone - shale successive as finning upward (funnel shape). The second pattern distinguished the middle unit in the WQ-60 only, which characterized by aggrading sandstone dominated succession with box car shape of log response (cylindrical). While the third pattern is appeared in the southern part of studied area (WQ-15, WQ-1 and WQ-356), which characterized by three cycle of shale dominated succession as box car shape separated with funnel shape of sandstone beds.

- **Upper unit:**

The upper unit is appeared low values of shale, which represents a sandstone dominated succession and the general trend of gamma ray log is almost forming a serrated shape, which refers to relatively decreasing upward in gamma ray values in all studied wells except the WQ-60. The WQ-60 is showing two cycle of shale dominated succession as funnel shape, with thickness about 40 m in all studied boreholes.

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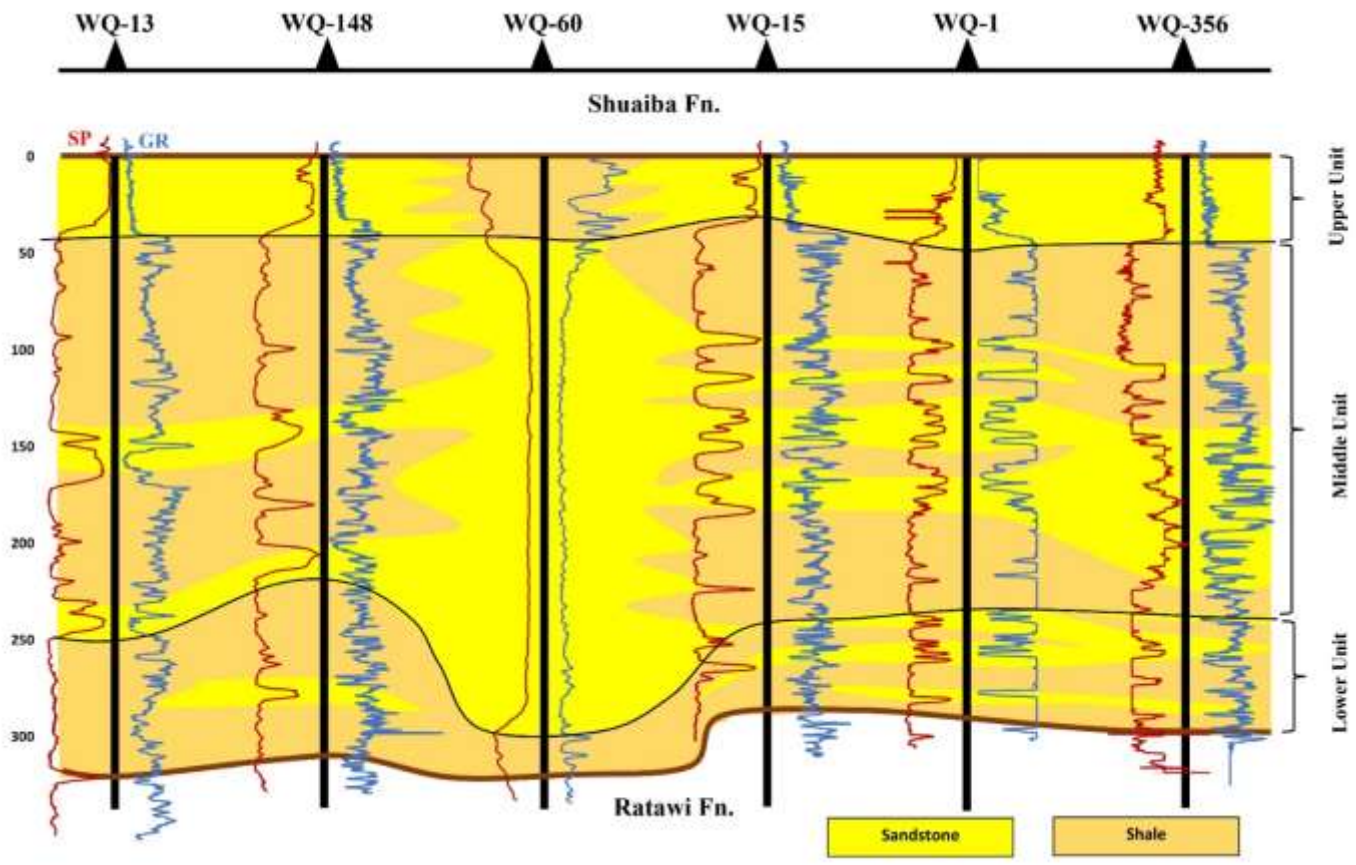

Figure (6): Cross section illustrate the main units of Zubair Formation in the studied area.

Facies Analysis of Zubair Formation

The sedimentology and reservoir properties of clastic sedimentary rocks depending on interplaying of tectonic development, sea level changes, rate of sediments suppling, physical

and biologic activity processes of sediments transportation and sedimentation, and climatic effects and changes. At the basin scale, these processes interaction to producing the geometric arrangement and distribution of different depositional environments or stratigraphic tracts through the time, known as the stratigraphic framework of the basin [16].

Therefore, there are 5 lithofacies in the Zubair succession for six boreholes (Figs. 7, 8, 9, 10, 11, and 12) which described according to the available of these parameters.

1. Lithofacies I (Lf.1) (Well sorted quartz arenite sandstone Lithofacies):- fine grained well sorting sandstone with subangular to subrounded grains shaped mode (Plt.1A) are characterized this lithofacies. The sandstone parts in this lithofacies is composing of more than 90% of quartz to classify as quartz arenite sandstone. This shows in the middle unit as very low gamma ray values and high values of resistivity with box shape mode of gamma ray log in addition to spontaneous potential logs.
2. Lithofacies II (Lf.2) (Poorly sorted Quartz arenite sandstone Lithofacies):- this facies is representing a wide range of sand grain size from medium to coarse sand size, and well rounded to subrounded grain shape mode, within the sandstone unit (Plt.1B). The sandstone in lithofacies II contains of approximate more than 90% of quartz to classify as quartz arenite which appeared in the upper unit of Zubair Formation. This lithofacies is appeared poorly sorting with very low values of gamma ray which represents as finning upward with bell shaped mode of gamma ray log and high values of resistivity log.
3. Lithofacies III (Lf.3) (Poorly sorted graywacke sandstone Lithofacies):- This lithofacies is described as muddy sandstone which composed of quartz grains dominance rocks. Its characterizing by poorly sorting mode of graywacke sandstone (Plt.1C), and appeared moderate values of gamma ray as funnel shaped mode. The Lf.3 is showed in the upper unit of Zubair succession, in additional to the lower unit as muddy rocks.
4. Lithofacies IV(Lf.4) (Sandy shale):-This lithofacies appeared in the sandstone members as shale lenses, which characterized by high V-shale values with funnel shape mode. The main components of this facies is mud dominated rocks with quartz mineral is characterized by angular shape of grains (Plt.1D).

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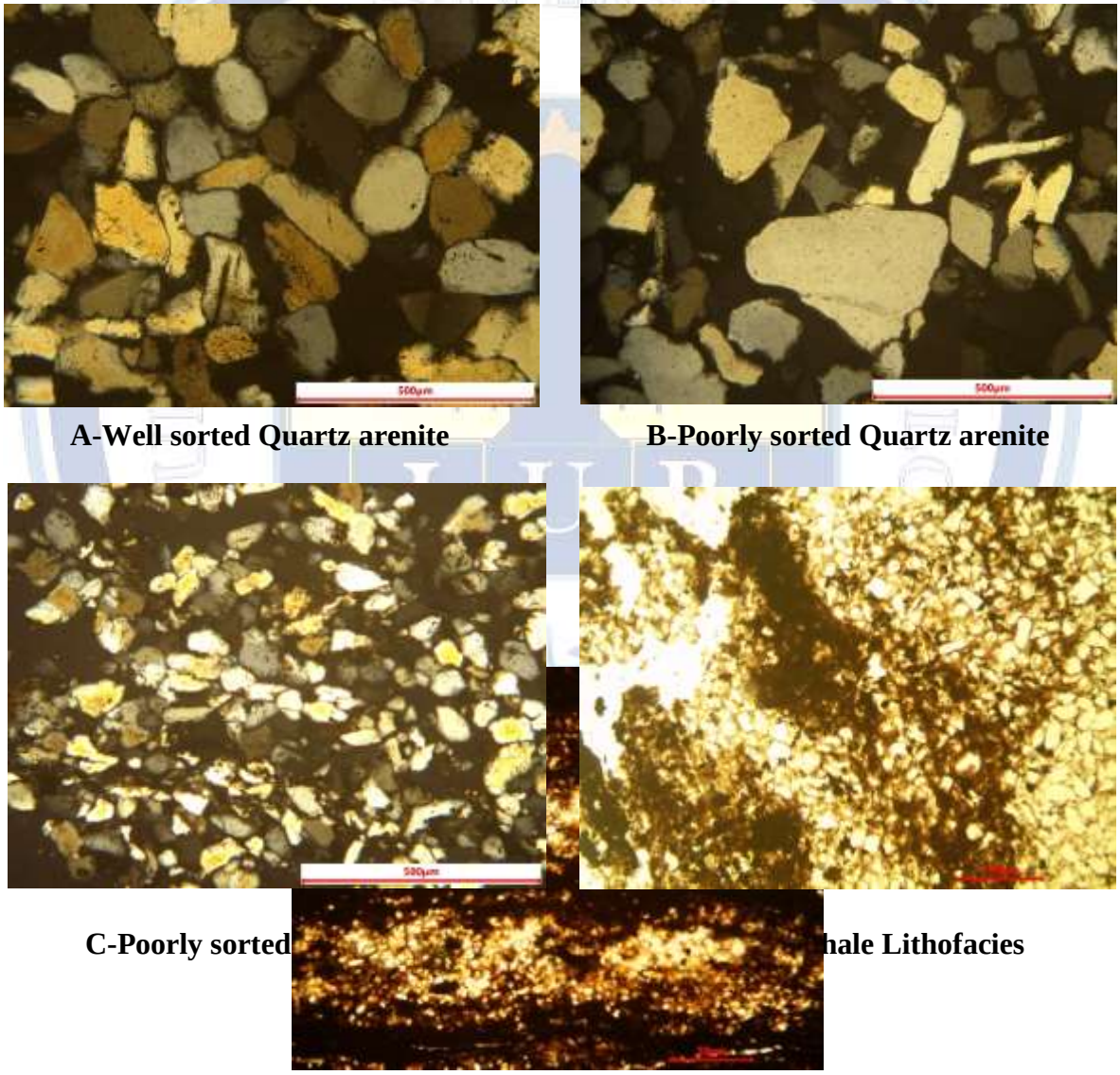
5. Lithfacies V (Lf.5) (Shale):- This lithofacies is appeared in all parts of Zubair succession. which composed of shale dominated rocks (Plt.1E), with high values of gamma ray as bell mode shaped.

Plate-2



A-Well sorted Quartz arenite **B-Poorly sorted Quartz arenite**

C-Poorly sorted **hale Lithofacies**

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E-Shale Lithofacies

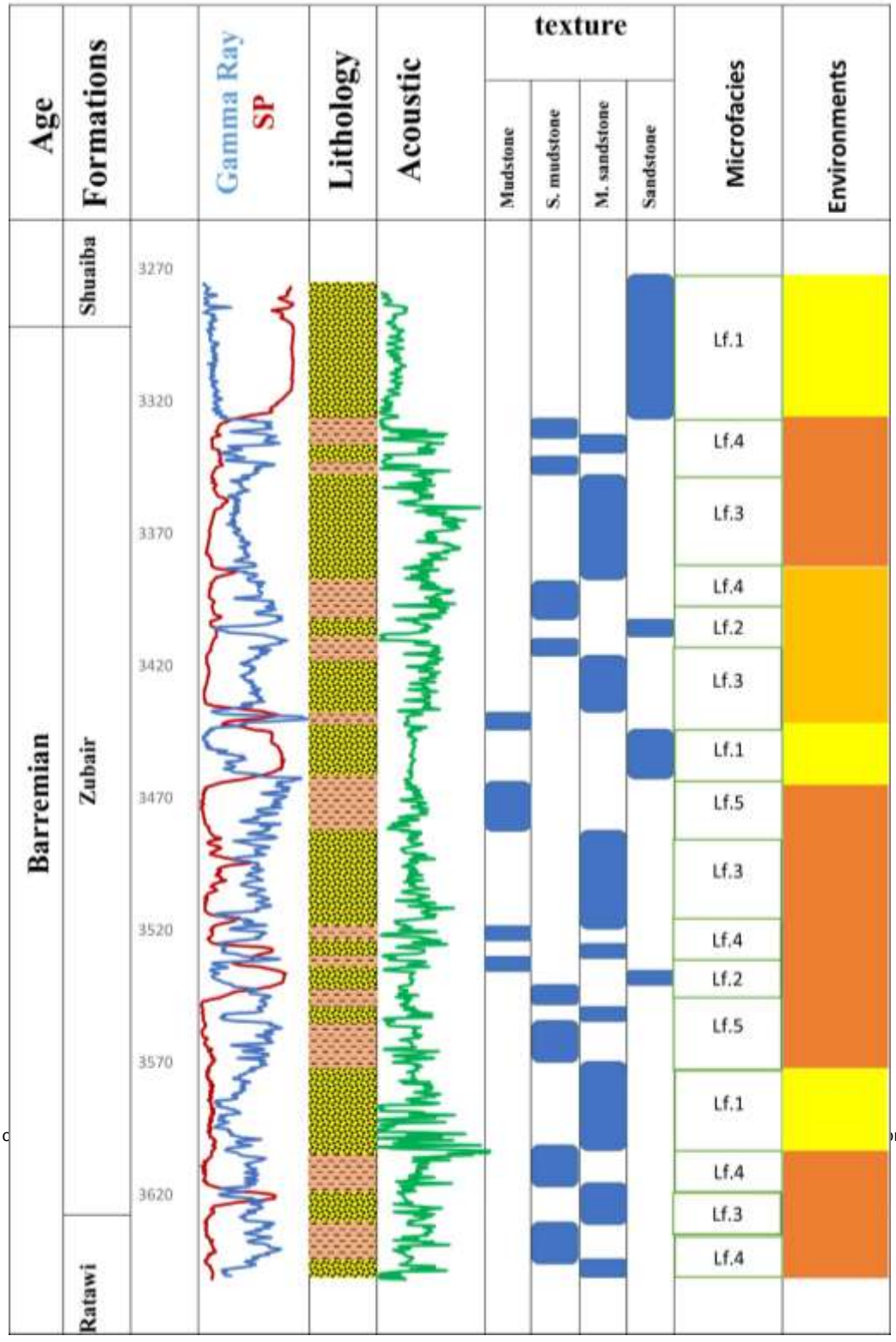

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Figure (7): Columnar section (WQ-13) shows the lithofacies distribution and major depositional environments.

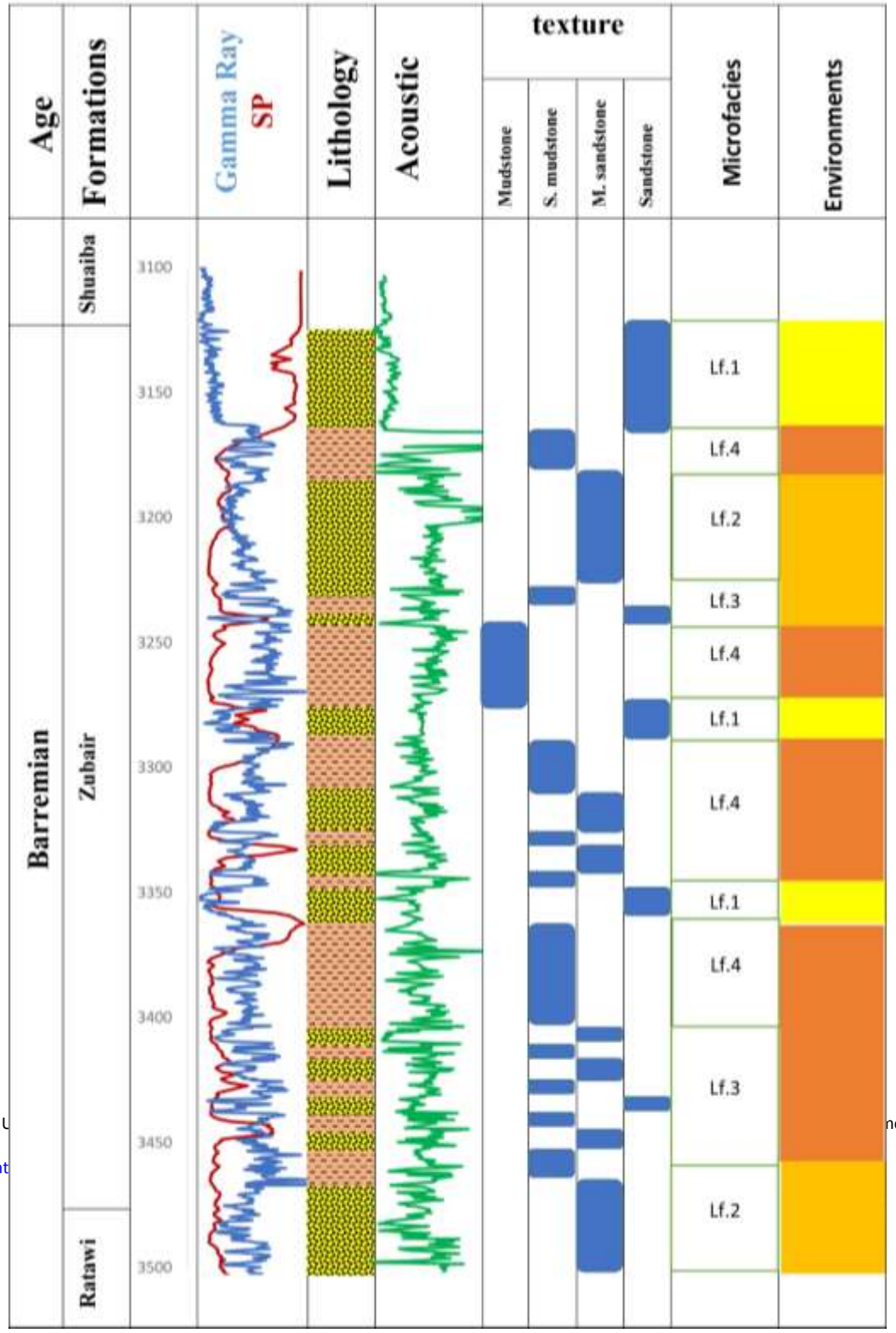

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Figure (8): Columnar section (WQ-148) shows the lithofacies distribution and major depositional environments

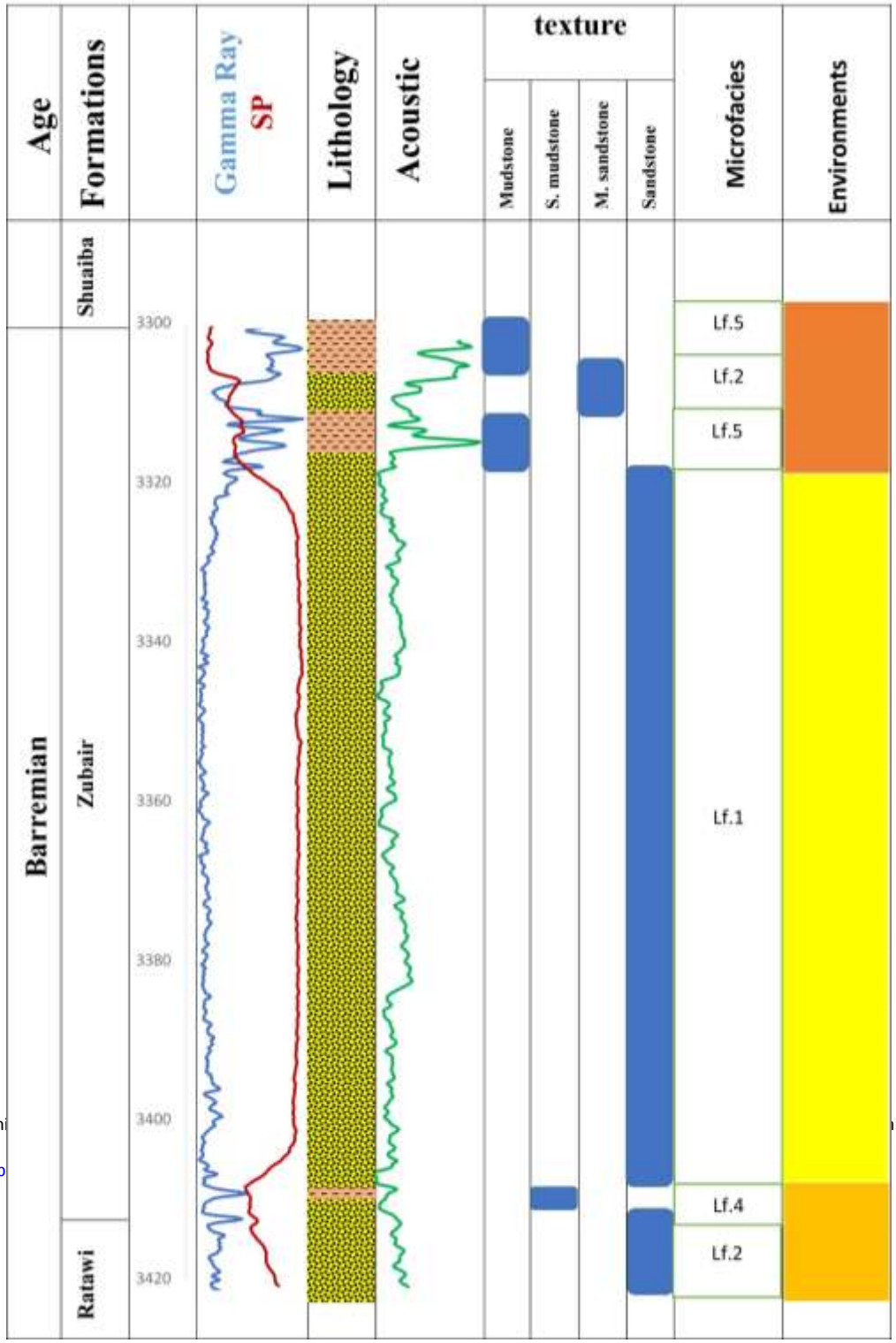

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Figure (9): Columnar section (WQ-60) shows the lithofacies distribution and major depositional environments

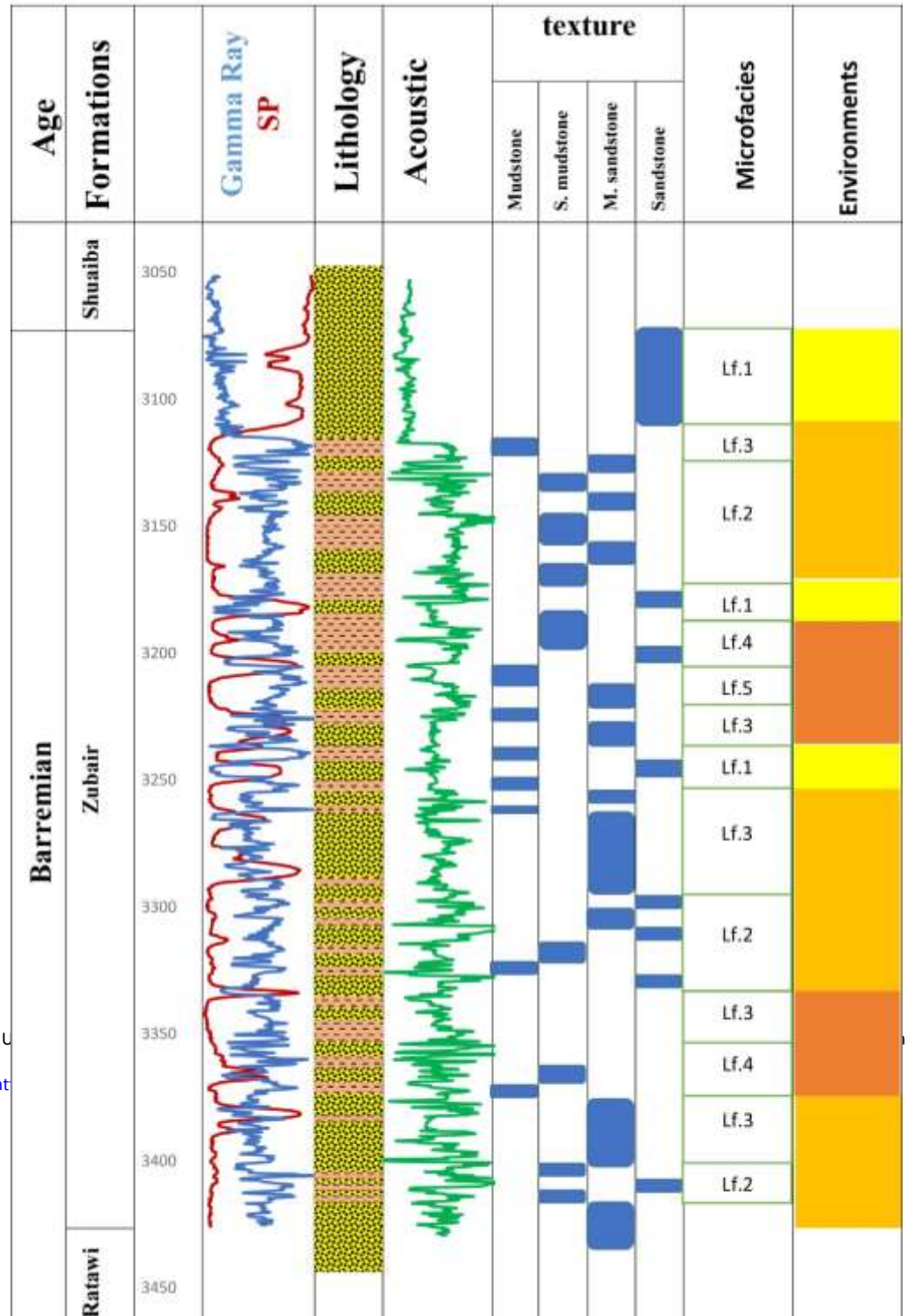

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Figure (10): Columnar section (WQ-15) shows the lithofacies distribution and major depositional environments

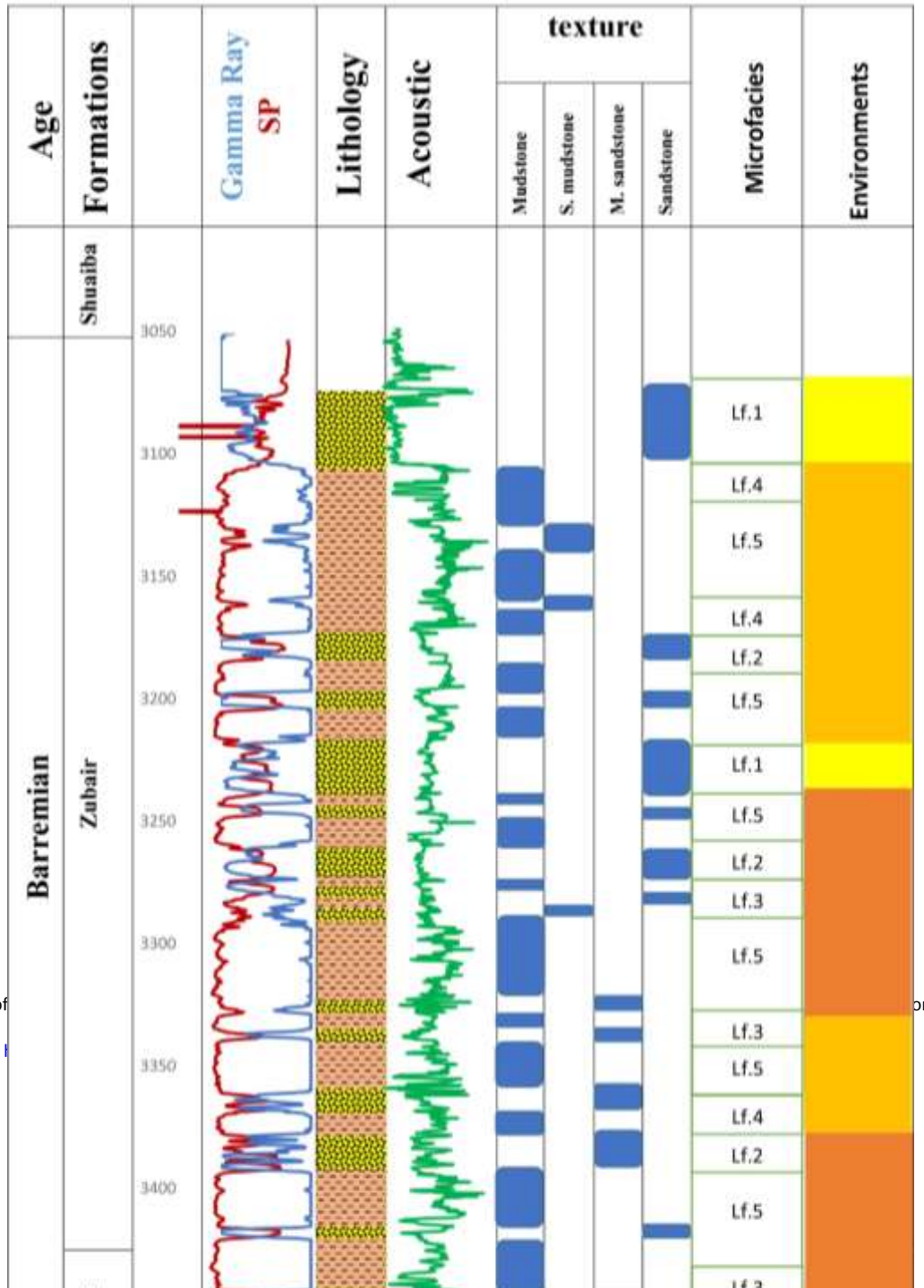

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Figure (11): Columnar section (WQ-1) shows the lithofacies distribution and major depositional environments

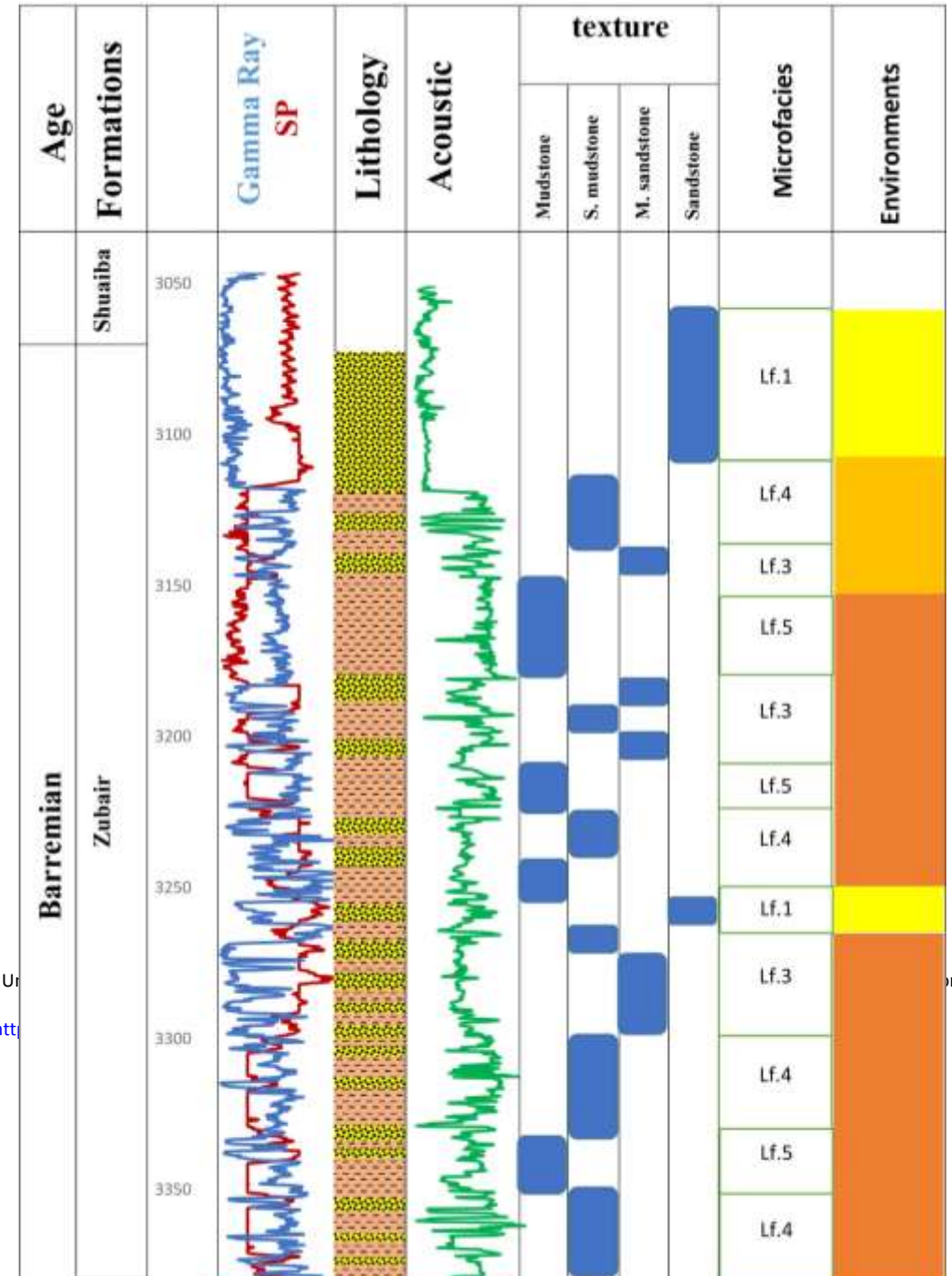

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Figure (12): Columnar section (WQ-356) shows the lithofacies distribution and major depositional environments

Depositional development

Three major association facies are distinguished in the Zubair succession, they are: delta plain, back shore and delta front depositional environments. These associations are suggested according to [17], [18] and [19]. Additional to use the well logging tools such as (GR, SP and DT logs) to determine the minor lithofacies changes and general trend of grain size sediments.

Lower unit:-

The shale compound is the main composed of the lower unit with thin beds and lenses of sandstone to divided this unit into two parts, the upper most is consisting of sandstone and the lower part is shale beds in the south part of studied area. While to the north is showing one part with shale dominated (Fig.4). The poorly sorted graywacke lithofacies (Lf.3) is the main lithofacies in this unit and the sandy shale lithofacies (Lf.4) in the upper part. The lower part is characterized by shale lithofacies (Lf.5). This succession is interpreted to deposition in a delta plain environment was common in the north and south part of the studied area (WQ-13, WQ-1 and WQ-356), while the middle part of this area (WQ-60 and WQ-15) was closed to shore face environment (Fig.13).

Middle unit

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The middle unit is the thickest and characterized by alternative of shale and sand beds as Three laterally heterogeneous cycles. These three-cycle appeared clearly in the southern part of studied area, while to the north became two cycle. In the central of studied area the middle part is represented by one cycle of quartz arenite well sorted-subrounded lithofacies (Lf.1) as a delta front and shoreface association facies. This unique association facie is separated the two cycle in the north and three cycle of this succession to the south. The poorly sorted quartz arenite (Lf.2) is alternative with poorly sorted graywacke lithofacies (Lf.3) to south direction, while this sequence does not appear in the opposite direction. Therefore, the delta plain is common association in the WQ-13 and WQ-148 as a successive of lithofacies 3, 4 and 5, while this association is alternative with back shore association to the north direction (WQ-15, 1 and 356) (Fig.13).

Upper unit :-

The quartz arenite well sorted-subrounded lithofacies (Lf.1) is the main composed of this unit. This refer to deposition in the delta front and shore face to mark the sea level rise in all studied well except WQ-60, which represent the delta plain association facies as Lf.2 and Lf.5. This cycle was marked the end of Zubair deposition during the transgression stage.

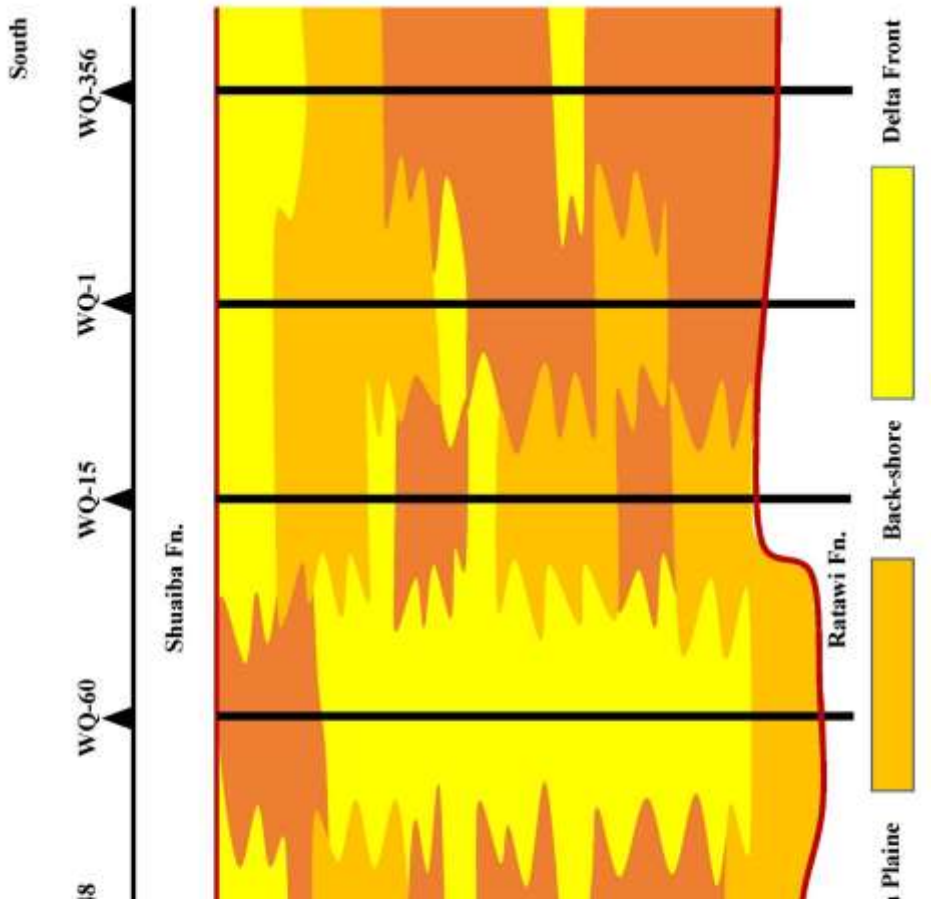

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Figure (13): Cross section shows associations facies distribution and major depo

Conflict of Interests.
There are non-conflicts of interest .

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الخلاصة

تتضمن هذه الدراسة دراسة الصخور ، وتحليل الصخور ، وتطوير الترسيب لتكوين الزبير في ستة آبار (WQ–1، WQ–13، WQ–15، WQ–60، WQ–148 و WQ–356) داخل حقل نفط غرب القرنة . ترسبت تكوينات الزبير داخل منطقة بلاد ما بين النهرين خلال مرحلة البارمين التي تنتمي إلى العصر الطباشيري المبكر.

المكون الرئيسي لخلافة الزبير هو الحجر الرملي الذي يصنف على أنه الكوارتز أرينيت (المعروف أيضًا باسم orthoquartzite) يحتوي على حوالي 92٪ أو أكثر من حبيبات الكوارتز. في حين أن الصخور التي تحتوي على أكثر من 25٪ شظايا حجرية وفلسبار ثانوي هي أرينيت حجرية ؛ تلك التي تحتوي على محتوى من الطين> 25 ٪ والليثيات الثانوية هي عبارة عن wacke رمادي

تم التعرف على خمس حواجز صخرية رئيسية ضمن مجموعتين من هيمنة الصخور في هذا التسلسل على النحو التالي: – كوارتز أرينيت جيد الفرز ، أحجار أرينيت كوارتز أرينيت سيئة الفرز تحت الزاوي وحصى رمادية سيئة الفرز داخل الصخور التي تهيمن عليها الرمال والحجر الطيني الرملي والحجر الصخري الصخري داخل الصخور التي يسيطر عليها الطين. تتميز ارتباطات ثلاث واجهات في التعاقب المدروس ، وهي: سهل دلتا ، واجهة دلتا أمامية وخلفية. ساهم تحليل الأحياء الدقيقة وإعادة بناء البيئات القديمة لحوض بارمين في منطقة الدراسة في تحديد ثلاث مراحل مطابقة مع الوحدات التي يمكن ملاحظتها.

يتكون الأساس من الوحدة السفلية من الصخر الزيتي مع طبقات رقيقة وعدسات من الحجر الرملي لتقسيم هذه الوحدة إلى جزأين ، الجزء العلوي هو الحجر الرملي والجزء السفلي من الصخر الزيتي في الجزء الجنوبي من منطقة الدراسة يتم تفسير هذا التسلسل على أنه يتشكل في رواسب سهل دلتا كانت شائعة في الجزء الشمالي والجنوبي من المنطقة المدروسة (WQ–13 و WQ–1 و WQ–356) ، بينما الجزء الأوسط من هذه المنطقة (WQ–60 و WQ –15) مغلق لبيئة واجهة الشاطئ. الوحدة الوسطى هي الأكثر سمكًا وتتميز ببدائل من طبقات الصخر الزيتي والرمل بثلاث دورات غير متجانسة أفقيًا. ظهرت هذه الدورات الثلاث بوضوح في الجزء الجنوبي من منطقة الدراسة، بينما في الشمال أصبحت دائرتين. في وسط المنطقة المدروسة، يتم تمثيل الجزء الأوسط بدورة واحدة من صخور الكوارتز الأرينيت المفروزة جيدًا كواجهة دلتا ووجهات رابطة سطحية. سهل الدلتا هو ارتباط شائع في WQ–13 و WQ–148 باعتباره سلسلة متتالية من الصخور 3 و 4 و 5، في حين أن هذا الارتباط بديل مع ارتباط الشاطئ الخلفي بالاتجاه الشمالي (WQ–15 و 1 و 356). تتكون الوحدة العلوية من الحجر الرملي مثل الكوارتز الأرينيت الذي تم فرزه جيدًا وسطحه الصخري. يشير هذا إلى الترسب في واجهة الدلتا والشاطئ للإشارة إلى ارتفاع مستوى سطح البحر في جميع الدراسات المدروسة جيدًا باستثناء WQ–60، والتي تمثل واجهات ارتباط دلتا البسيطة. كانت هذه الدورة إيذانا بنهاية ترسيب الزبير خلال مرحلة التعدي.