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Facies Analysis and Stratigraphic Development of the Zubair Formation in the Mesopotamian Zone, Southern Iraq

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Abstract

The Barremain-Aptian succession represented by the Clasits deposits of Zubair Formation. This formation is the most significant sandstone reservoir in Iraq which deposited in fluvio- deltaic, deltaic and marine environments during the Barremain to Early Aptian age. The area of study is located in the Mesopotamian Zone at Southern part of Iraq which represented by five oil fields (Nasira, Luhais, Suba, Tuba and West Qurnah).

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. The formation consists of mainly interbedded sandstone, shale, siltstone and sometimes thin beds of carbonate. Shale thickness increase towards east and decrease the sandstone towards the east southern of Iraq.

Zubair characterized in the lower member by mud - dominated delta front 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 front associated facies overlaying the unconformity surface (SB1) refers to the transgressive system tract (TST). This stage was ended by the deposition the fluvial channel facies to mark a high-stand system tract (HST). The fluctuation point between the TST and HST is represented a maximum flooding surface.

The middle member of Zubair Formation is characterized by moderate to well sorted quartz arenite sandstone with appearance bands of the shale overlaying the sand body. This succession was deposited in the delta plain environment with steps of sea level rise during the transgressive stage. 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. 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.

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

Key words: Facies Analysis, Stratigraphic Development, Mesopotamian Zone, Southern Iraq

التحليل سحني و التطور الطباقى لتكوين الزبير في نطاق بين النهرين، جنوب العراق

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الخلاصة

ان تتابع الباريمين - ابتين المتمثلة بتكوين الزبير الفتاتي. هذا التكوين هو أهم خزان من الحجر الرملي في العراق والذي تم ترسيبه في البيئات النهرية - الدلتاوية ، والدلتاوية ، والبحرية ، خلال فترة من الباريمين إلى العصر الأيبي المبكر. تقع منطقة الدراسة في منطقة ما بين النهرين في الجزء الجنوبي من العراق والتي تمثلت بخمسة حقول نفطية (الناصرية ، لحيس ، صوبية ، طوبا وغرب القرنة).

أظهرت دراسة الصخور أن معدن الكوارتز هو المكون الرئيسي للحجر الرملي في تكوين الزبير مع نسبة مئوية صغيرة من الفلسبار و نسبة قليلة من المكسرات الصخرية المصنفة على أنها كوارتز ارنيت. يتكون التكوين من الحجر الرملي المتداخل بشكل رئيسي مع الصخر السجيلي و الحجر الغريني وأحياناً طبقة رقيقة من الكربونات. يزداد سمك الصخر السجيلي نحو الشرق و يقل الحجر الرملي من الشرق باتجاه جنوب العراق.

يتميز العضو الاسفل لتكوين الزبير بسحنة مقدمة الدلتاوات المحتوى الطيني الشائع. ويبدو أنها تفصل رأسياً بشكل نسبي بتعدد انماط الفرز وتغييرات جانبية متعددة لتداخلات رملية للقناة الدلتاوية ، مما ينتج عنه بنية مكامن مجزأة. ان وجود ترسبات مقدمة الدلتا التي تعلق سطح عدم التوافق (SB1) والتي تشير إلى حالة تقدم بحري . (TST) ان إنتهاء هذه المرحلة من خلال ترسيب القناة النهرية لتؤشر الترسيب خلال مرحلة ال (HST) تمثل نقطة التذبذب بين TST و HST سطح أقصى مستوى للبحر .

يتميز العضو الأوسط في تكوين الزبير بحجر رملي معتدل إلى عالي الفرز مع ظهور حزم من الصخر السجيلي يغطي طبقة الرمل. وقد ترسب هذا التعاقب في بيئة السهل الدلتاوي خلال مراحل ارتفاع مستوى سطح البحر. هناك متواليات اثنتين من TST في هذا الجزء والتي تنتهي مع الحد الأقصى لارتفاع مستوى البحر (MFS) لتحديد الجزء العلوي من تكوين الزبير. المرحلة التالية أظهرت تركيزات عالية من المواد العضوية ومعدن البيريت الذي يشير إلى أن البيئة الرسوبية قد تم اختزلها إلى بيئة الأهوار أثناء . أظهر الجزء العلوي من تكوين الزبير بيئة ضحلة مع مترافقة سحنية شائعة السجيل التي يهيمن عليها المواد العضوية العالية والبايريت. هذا يشير إلى وضع تنعم نحو الاعلى خلال مرحلة التوقف الاعلى عندما تغيرت بيئة الترسيب من قناة النهر النهرية العادية إلى فم الدلتا . يمثل ارتفاع مستوى سطح البحر نهاية هذه المرحلة عند ترسب الجزء العلوي من تكوين الزبير ، وبداية ترسب الكربونات البحرية الضحلة لتكوين الشعبية ككربونات بحرية ضحلة.

Introduction

The Barremian –Aptian it is a part of the late Tithonia-Early Turonian mega-sequence was deposits in a large-shelf basin contemporaneous with a new phase of ocean floor spreading in the southern Neo-Tethys resulting a differential subsidence and thickness changes and the axis of in basin with general direction to the eastern Mesopotamian zone and shifted to the Tigris Subzone from its previous position on the Salman zone and western Mesopotamian. [1]

The lower Cretaceous era's in the southern part of Mesopotamia is characterized by many of carbonate and clastic reservoir units [2]. The Shuaiba Formation represented a carbonate unit which shows low reservoir property but in the other hand the Zubair Formation is the most important lower Cretaceous reservoir of oil fields in the study area where hydrocarbons found the upper part member of Zubair. While the shale rocks in this formation is representing the impermeable bed represented a seal rocks [2].

The Barremian –Aptian sequence comprise many facies as following

1- In the south of Iraq

- Clastic inner shelf (Zubair)
- Carbonate ramp (Shuaiba)

2- In the north of Iraq

- Outer shelf basin facies (Sarmord and lower Balambo in high folded zone

- Balambo-Tanjer zones and the Kirkuk embayment of the foothill zone).

The Barremian sediments comprise the clastics of the Zubair and upper Ratawi for the stable shelf which represent a delta/pro delta facies (Figure-1).

The Aptian time transgression led to deposition on a broad carbonate shelf over the former Zubair delta, and in the foothill, high folded and Balambo-Tangero zones [3].

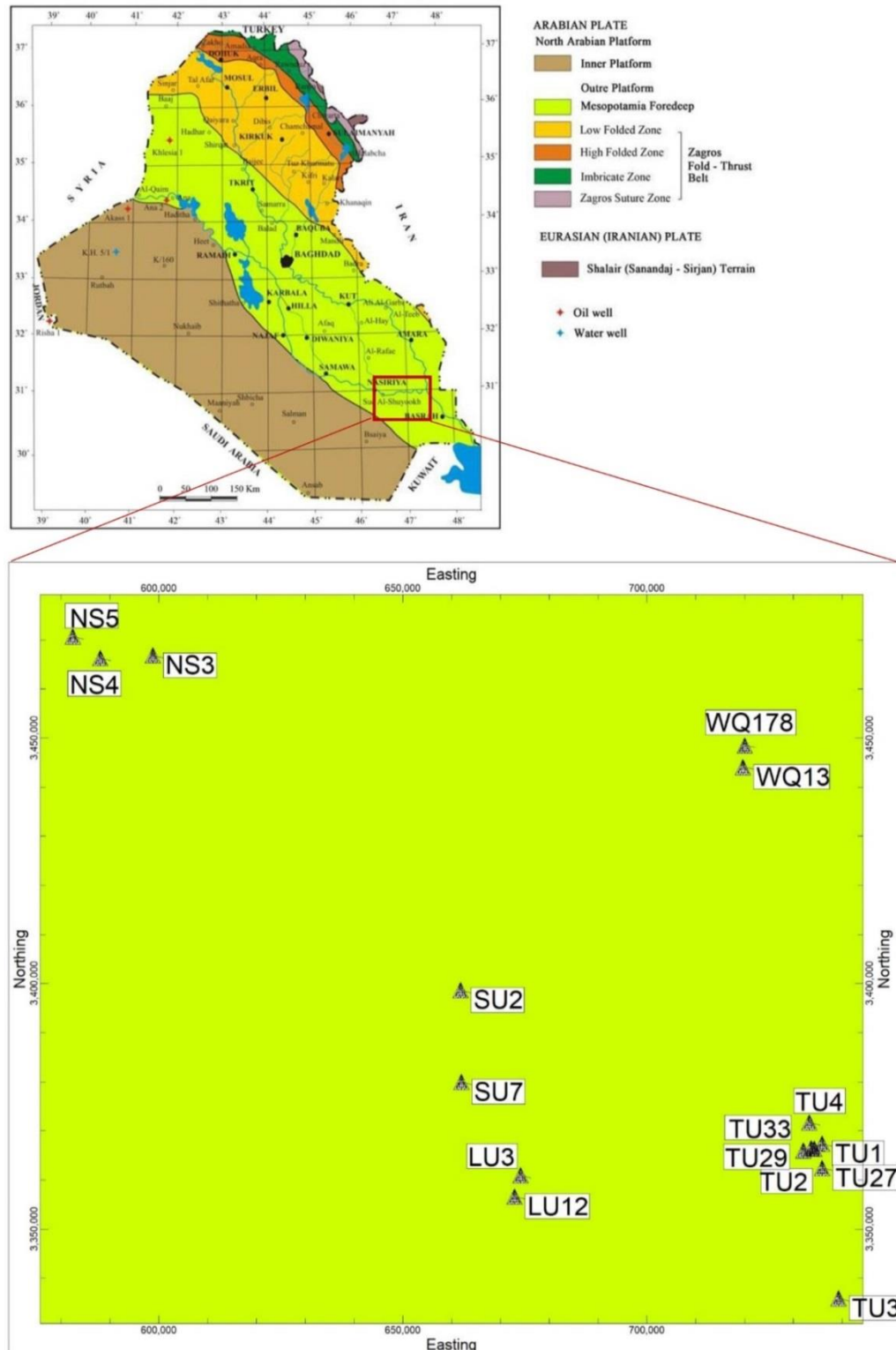


Figure 1 -Location and tectonic maps of studied area (according to Fouad, 2012)

Methodology

1. Sampling for the selected boreholes, as core and cutting.
2. Facies and Microfacies analysis.
3. Well logs analysis to determine the facies log and diagenetic features.

The present study is divided in to three stages:

1. Field observation and sampling stage :

This stage is represented by going to the Nasria, Suba, Luhais, Tuba and West Qurnah oil fields where core and cutting samples are collected. Additional to describe the selected cores and capture photos (Figure-2) and view the information and available final reports



Figure 2-shows the collected cores from studied oil fields

2. Laboratory stage :

- During this stage the samples were chosen for thin section preparation.
- The petrographic study and microfacies analysis are based on the study of more than 255 thin sections of cutting from the selected borehole (Lu-2), (Lu-3), (Lu-5), (Lu-8), (Lu-12), (Su-7-2-6), (Tu-2), (Tu-33), (Wq 148), (Ns-5) and (Ns-2). The cutting samples are provided by southern oil company and prepared by the author.

3. Study of the available well logs and relate the log response to facies and diagenetic changes.

Petrography of Sandstone

The composition of sandstone can be controlled by many factors such as the composition of source rocks, transportation distance of detritus before it reaches final site of deposition, their subsidence time that detritus held in environment then final site of deposition, the climate in the source area and diagenetic effect following final deposition [4].

The tools to determine their depositional mechanism and environment are the texture used when describing sedimentary rocks (sandstones). It is also meaning of evaluate the degree of porosity and / or permeability which has proved to be a valuable log in the analysis of potential hydrocarbon rich sand-bodies.

The recognized components in Zubair Formation sandstone are shown below:-

Quartz

The main component grains (quartz, feldspar and lithic grains only) range from more than 95% in the well sorted, rounded quartz-arenite sandstone unit of Zubair Formation to less than of 25% in the shale dominated unit of the same formation. The predominance of quartz can be resulted by recycling, long transportation distance or tropical weathering [5]. Quartz grain size ranges from medium to very fine according to Wentworth, 1932 [in 6]. Grains roundness ranges from subangular to round according to visual chart of [7] (Figure-3).

Adapted from BAKER HUGHES INTEQ - for use in field - © CPGS 2003	Very Coarse Sand: 2 to 1 millimetre				
	Coarse Sand: 1 to ½ millimetre				
	Medium Sand: ½ to ¼ millimetre				
	Fine Sand: ¼ to ⅛ millimetre				
	Very Fine Sand: ⅛ to 0.062 millimetre				
Very Poorly Sorted	Poorly Sorted	Moderately Sorted	Well Sorted	Very Well Sorted	
ANGULAR	SUB-ANGULAR	SUB-ROUNDED	ROUNDED	WELL ROUNDED	
					

Figure 3-Standard dimensions used in the description of sedimentary particle size [7]

This variation in size and roundness leads to form many types of contact between quartz grain such as long, concavo-convex and Y-contact type, but in some slides there are few floating contact sand point contact which increase in slides with high ratio of calcite cement related to the growth of carbonate cement which leads to forceful wedging part of the grains [8].

There are two types of quartz recognized in Zubair Formation they are: - the **First**, Monocrystalline Quartz (Plt.2-1A, B) 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 [9], and the **second**; Polycrystalline Quartz (Plt.2-1C, D) 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 [6]. The polycrystalline quartz can be develop from the monocrystalline quartz during metamorphism under the increasing of pressure and temperature .Non-undulatory monocrystalline quartz changes progressively to undulatory quartz, then to polygonised quartz (quartz that shows distinct zones of extinction with sharp boundaries), and finally to polycrystalline quartz [10].

Feldspar

Like quartz, feldspar has low relief and white and/or gray first-order interference colors, and it can be easily misidentified as quartz where it simple twins. But so many feldspar grains are recognized by complex twinning (plagioclase) (Plt.2-1E), while the orthoclase have occasionally a simple twin (Plt.2-1F).

Feldspar ratio is less than (1%), due to the weak stability as it decomposes and eroded when transported to long-distance, Therefore the limit presence of feldspar is a result of balance occurring between rate of decomposition and rate of erosion [7].

Rock Fragments

Rock fragments are detrital particles made up of two or more mineral grains depending upon the source-rock composition. It can provide the most direct lithologic evidence [11].

Chert is microcrystalline quartz and occurs as a mass of very fine crystals with first-order interference colors (gray and white) and low relief (Plt.2A).

Rock fragments are fine-grained sedimentary rock fragments. They are often brown, with silt-sized quartz grains and disseminated opaque iron-oxide and/or pyrite grains. Because they are mechanical eroded, shale fragments are commonly deformed during the compaction. They are thus often confused with matrix and sometimes known as pseudomatrix [12] (Plt.2B).

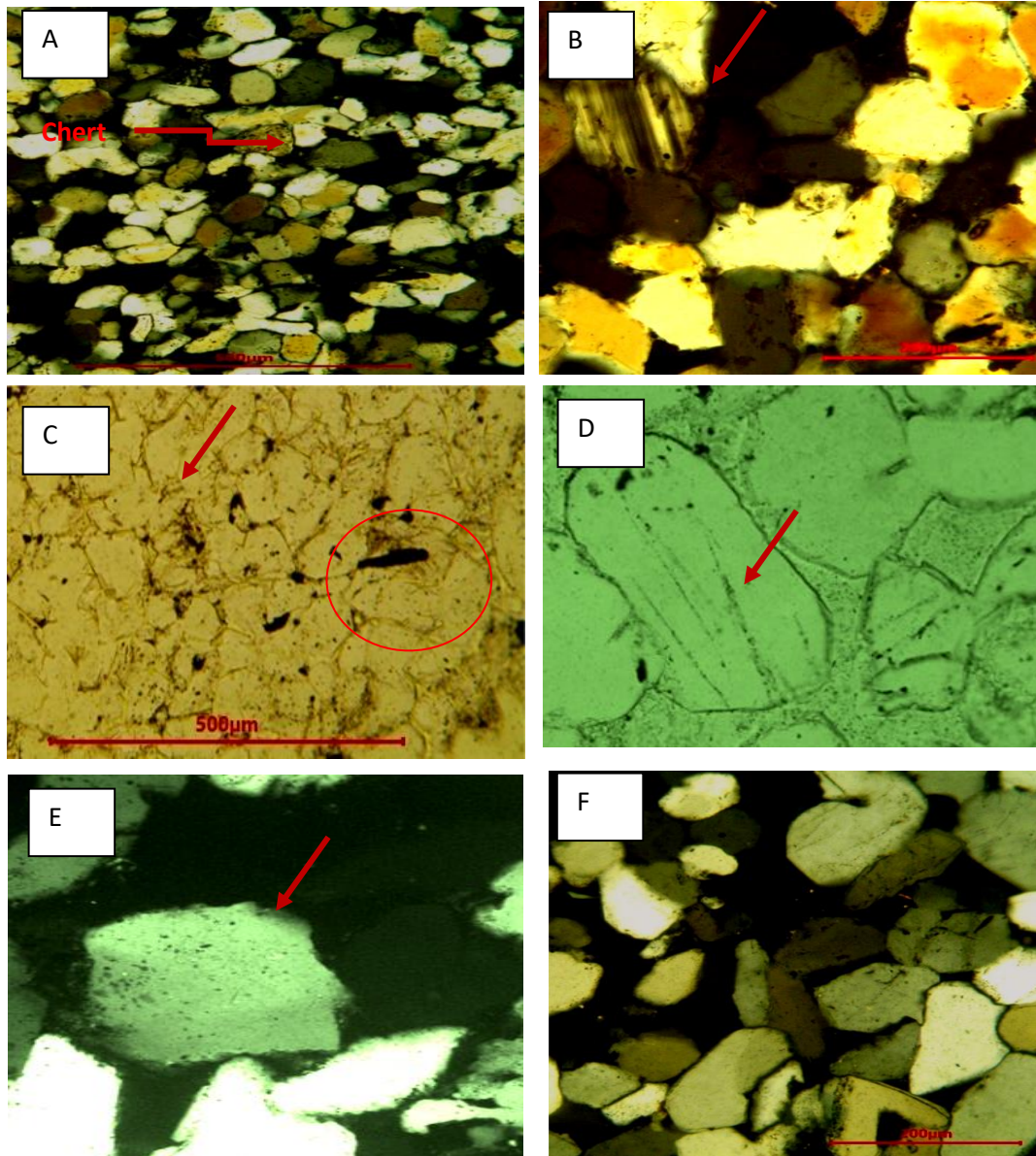
Composed of various components such as shale or flint and the proportion of their presence and a few are almost non-existent long distance transported [6].

Petrography of Shale

The shale continues as thinly laminated, weakly calcareous, pyritic, silty shale with abundant organics as is represented in the lower and upper parts of Zubair Formation. This shale contains bands of quartz grains (Plt.2C), with less of calcite and dolomite, as bands (plt.2D), often with scattered

pyrite crystals. Pyrite within the shale occurs as microcrystals, framboidal aggregates, or as nodules that formed within the laminated shale (Plt.2F). While, the middle part is characterized by lenses and flaser bands of shale within sandstone unit (Plt.2E).

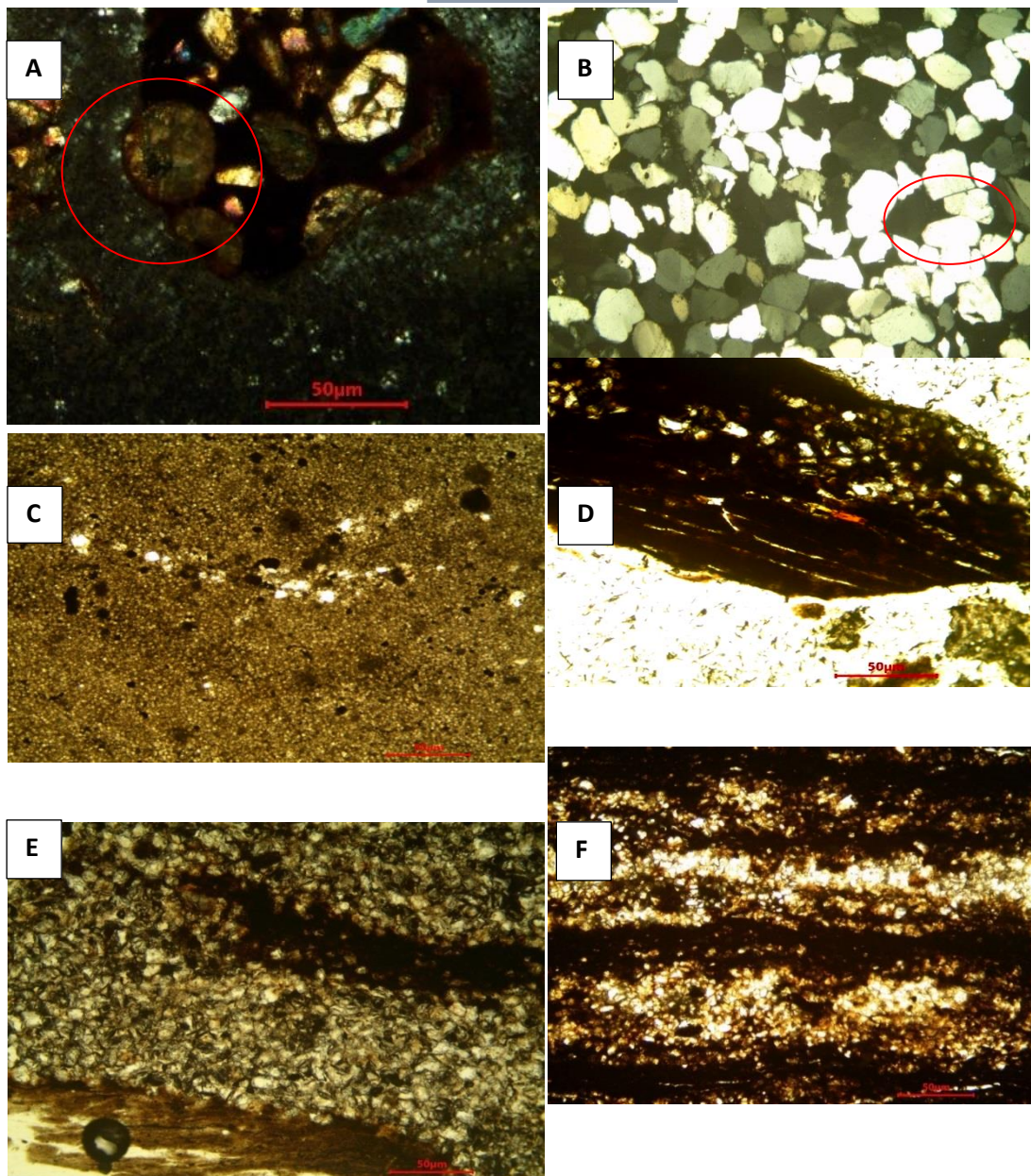
Plat (1)



Components of Sandstone of Zubair Formation in Lu-2 (Depth 2828.35-2829.35 m)

- A. Polycrystalline Quartz and chert under the polarized
- B. Plagioclase
- C. Polycrystalline Quartz
- D. Monocrystalline Quartz
- E. Monocrystalline Quartz under the polarized
- F. Orthoclase

Plate (2)



Components of sandstone of Zubair Formation in Lu-4 (2889- 2891 m)

- A. Rock fragments under the polarized
- B. Chert fragment under the polarized
- C. Pyrite mineral in shale rocks.
- D. Shale with sand lenses and calcite bands.
- E. Sandstone with shale flaser bands.
- F. Shale with sand bands

Maturity

The textural maturity determined by presence of matrix and the degree of rounding and sorting of framework grains. Textural maturity can range from immature (much clay, framework grain poorly sorted and poorly rounded) to super mature (little of no clay, framework grain well sorted and well rounded). That reflects the degree of sediment transport and reworking [12].

In this study, it represents a high percentage of quartz about 95% represented super maturities and according to classification of Pettijohn represented Quartz Arenite that composed of more than 90 percent siliceous grains that may include quartz (Plt.2-1E & F).

The rocks in the upper sand member are mature physically and chemically. This indicated by the presence of the high percentage of quartz and by the medium to good sorting. And this support the concept that sediments of Zubair Formation passes in many cyclic deposition and transport to a far distance.

Sedimentary structures

When describing layers of sedimentary rock it is useful to indicate how thick the beds are, and this can be done in common with many other fields of geology, there is some variation in the use of the terminology to describe bed forms.

Sedimentary structures are related to ancient depositional settings and parameters such as relative water energy, water depth, and current flow directions [13].

Parallel lamination

Many sandstones and shales display internal laminations that are essentially parallel to bedding surfaces. Individual laminae in these planar-stratified beds may range in thickness from a few grain diameters to as much as 1 cm. The laminae are observed on the basis of differences in grain size, clay and organic matter content, mineral composition, and in rare cases microfossil content of the sediment. The color changes may accentuate the formed of some laminae [12] (Figure-4).



Figure 4-Parallel Laminated in Zubair Formation (Lu- 5)

Flaser lamination

Is a special type of ripple cross-lamination as thin streaks of mud occur between sets of ripple laminae. The mud streaks tend to present in the ripple troughs but may partly or completely cover the crests. Flaser bedding shows to form under fluctuating depositional conditions affected by periods of current activity, when traction transport and rippling of fine sands takes place, alternating with periods of quiescence, when mud is deposited [13] (Figure-5).



Figure 5-Flaser lamination in Zubair Formation (Su- 6)

Lenticular lamination

This type of sedimentary structure is used instead of flaser bedding for interbedded mud and ripple cross-laminated sand in the ripples and/or sand lenses are discontinuous and isolated in both vertical and lateral directions [12] (Figure-6).



Figure 6-Lenticular lamination in Zubair Formation (Lu- 8)

Wavy lamination

It is represented upper boundary and lower undulating has a curved as result of sedimentation on the irregular surface [13] (Figure-7)



Figure 7-Wavy lamination in Zubair Formation (Su- 6)

Lithofacies

According the particle size and sorting as shown in Figure-3 with available sedimentary structures, 8 microfacies are recognized by core observation, thin section description and well logs (Gamma ray and sp logs)

A- Course well sorted sandstone

This facies consists of coarse quartz arenite sandstone good sorting and showing changes color from light gray to brown (Plt.3 C)

B- Course poor sorted sandstone

This facies consists of coarse quartz arenite sandstone poor sorting (Plt.3B)

C- Fine well sorted sandstone

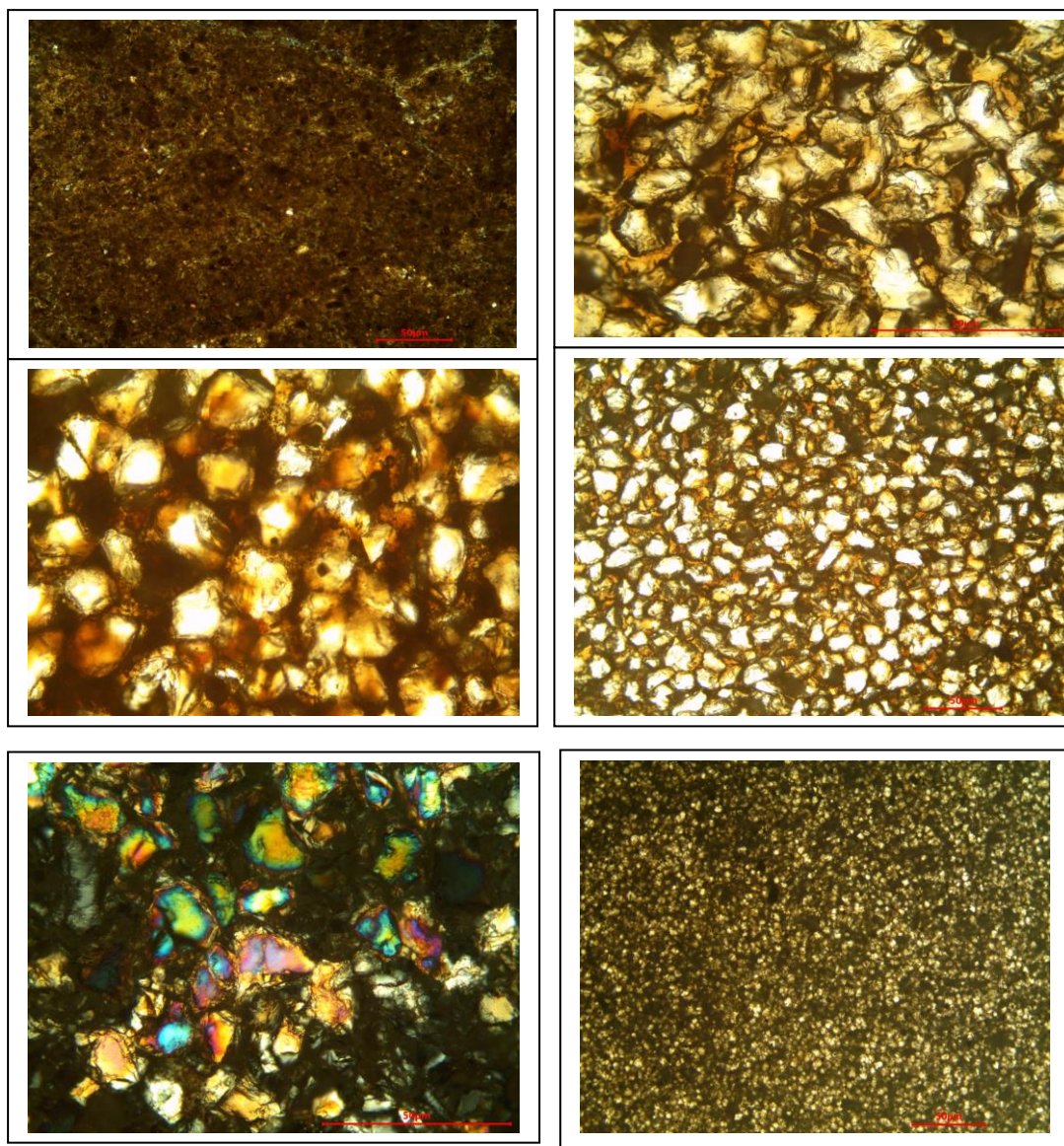
This facies consists of fine quartz arenite sandstone well sorting (Plt.3F)

D- Fine poor sorted sandstone

This facies consists of fine quartz arenite sandstone poor sorting (Plt.3D)

E- Shale (Plt.3 A)

Plate (3)



- A- shale (LU 3 3156 m)
- B- coarse poor sorting sandstone (LU 12 2855 m)
- C- coarsely well sorting sandstone (SU 2 2760 m)
- D- fine-medium good sorting sandstone (SU 7 2905 m)
- E- coarsely poor sorting sandstone (LU 3 2890 m)
- F- fine well sorting sandstone (LU 4 2820 m)

Paleoenvironments

The Depositional settings of The Barremian-Aptian succession represented by fluvial environment for Zubair Deltaic deposits from prodelta ,delta front to delta plain and carbonates Shuaiba deposits Carbonate ramps represented by reef-constructing organisms from shallow open marine, Reef to lagoon are basic principle for interpreting the associated depositional environments. Fine grain sediments deposits at deeper part and coarse sediments in shallower part of oceans as shown in Figure -8.

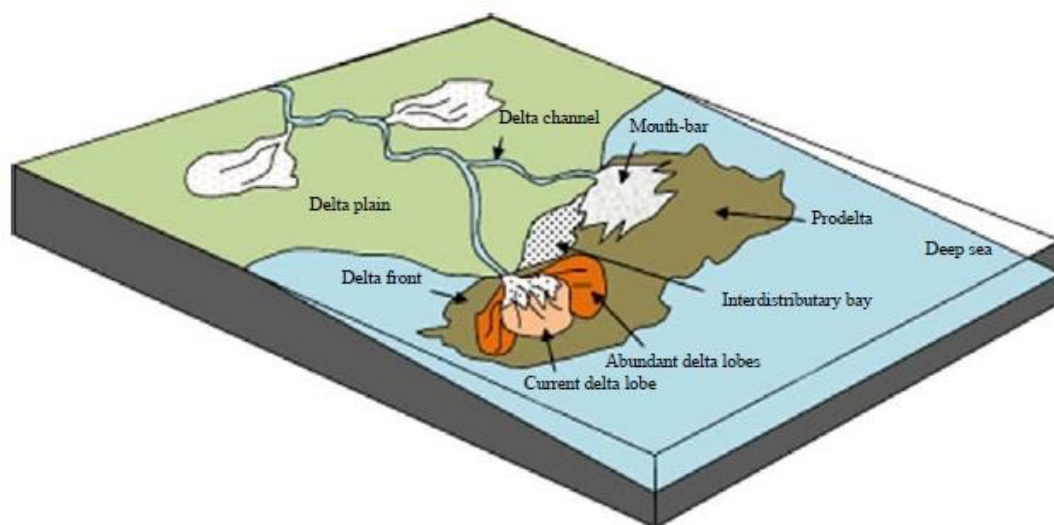


Figure 8-Delta environments divisions by Colman ,1981 represented depositional setting of Zubair Formation in southern Iraq [15]

Facies Analysis

By using the GR log shape relationships to the lithofacies changes (five observed lithofacies) and the available well logs, we will have discussed the depositional environment for this succession. Interpret depositional facies and the patterns of well-log curves recognized by [19] because the shape of log is directly related to the grain size of rock successions. [20] distinguished five different log curve shapes used to interpret the depositional setting and also considered the study of core with relation to logs as important tool of facies interpretation (as shown in Figure-(2-7)). This figure shows five prograding deltas and barrier bars deposit with coarsening up-ward grain size cycles. As grain size changes, log motif also changes and develops litho-logical pattern. Such grain size profiles in sand-shales sequences can be indicated by GR log.

[21] suggested that GR log response of shale contain which represents vertical profile of grain size (radioactivity/shalines content) in sandstone increases with decreases of grain size, Similarly, GR also shows deflection in trend as clay content decreases with increase of sand that good tool to interpreting the marine depositional environment is basic tool for fluvial –deltaic facies analysis (Fig. 10). Mostly GR is used as common log motif to distinguished the sedimentary facies of sand and shale.

Delta environment (Zubair Formation)

Zubair Formation in the study area is deposited in the delta environments, that deltaic depositional facies are by generated of interacting dynamics processes (wave energy, tidal regime, currents, climate, etc.), which modify and disperse of fluvial clastic deposits. In the broadest sense deltas can be defined as those depositional features, both subaerial and subaqueous, formed by fluvial sediments. The depositional features include distributary channels, river-mouth bars, interdistributary bays, tidal flats, tidal ridges, beaches, eolian dunes, swamps, marshes, and evaporate flats [15], [23].

Delta environments have a wide variety of individual depositional facies within the overall delta sequence. This complexity results from the following factors: (a) modern deltas exist in a wide range of geographic settings, ranging in climatic regimes from arctic to temperate to tropical to arid, with tectonic effects ranging from rather stable basins to extremely actively subsiding basins; (b) deltas form primarily in the zone of interaction between freshwater and marine processes, one of the most complex process settings in all coastal environments; (c) deltas carry large volumes of sediment, ranging in grain size from gravel to clay, and deposit these sediments both overbank and into the marine environment through distributary channels; (d) rapid rates of deposition often result in formation of extremely weak foundations, with a wide variety of mass-movement processes resulting in complex redistribution of the deltaic sediment. Thus sand bodies within deltas display a variety of geometries and vertical-sequence characteristics [25].

The complexity of depositional environments under the deltas exist results in a variety of vertical succession that can form within the delta facies changes. Delta types range from river dominated to tide dominated and wave-current dominated [15], [23]. From the stand point of petroleum accumulation, however, river- and tide-dominated deltas are probably the most important. In these two delta settings, reservoir-quality rocks are often deposited in close proximity to potential source beds, contemporaneous structure which forms major trapping potential is common, and most deltas exist in rapidly subsiding basins, allowing thick deltaic sequences to develop over a rather short time framework. The highly wave-reworked delta sequences are often devoid of major source rock deposits and often do not form in structure settings that result in major trapping characteristics of the deposits [25].

There are four main deltaic environments reflect the facies association in the Zubair Formation:-

1. Delta plain (fluvial channel) (Cylindrical Shape GR log)
2. Delta Front (daltic distributaries bay) (Bell Shape GR log)
3. Delta front (mouth bar sand) (Funnel Shape GR log)
4. Prodelta (shale deposits) (Serrated Blocky Shape GR log)

These different facies contributed to division of the Zubair Formation into three distinct rock units, which had been used in interpreting the suggested environments above Figure-(9 & 10).

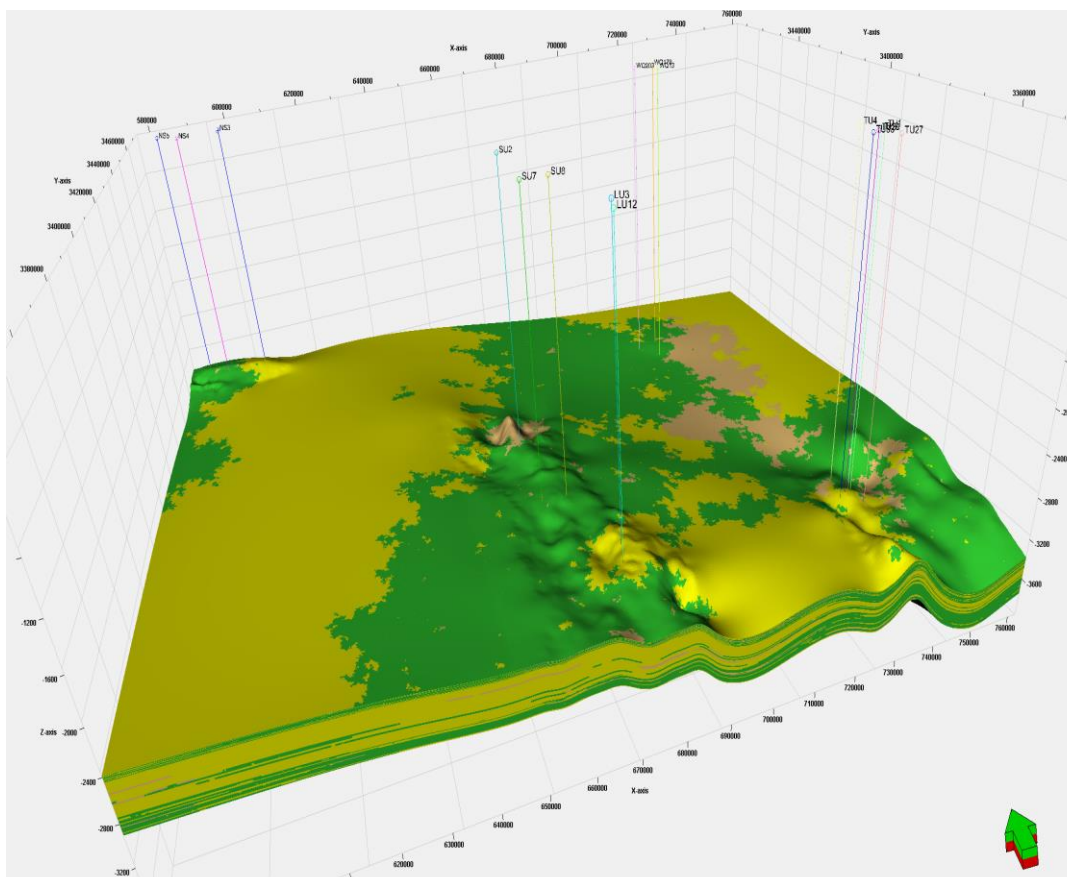


Figure 9-3D Facies distribution of Zubair Formation in the studied area.

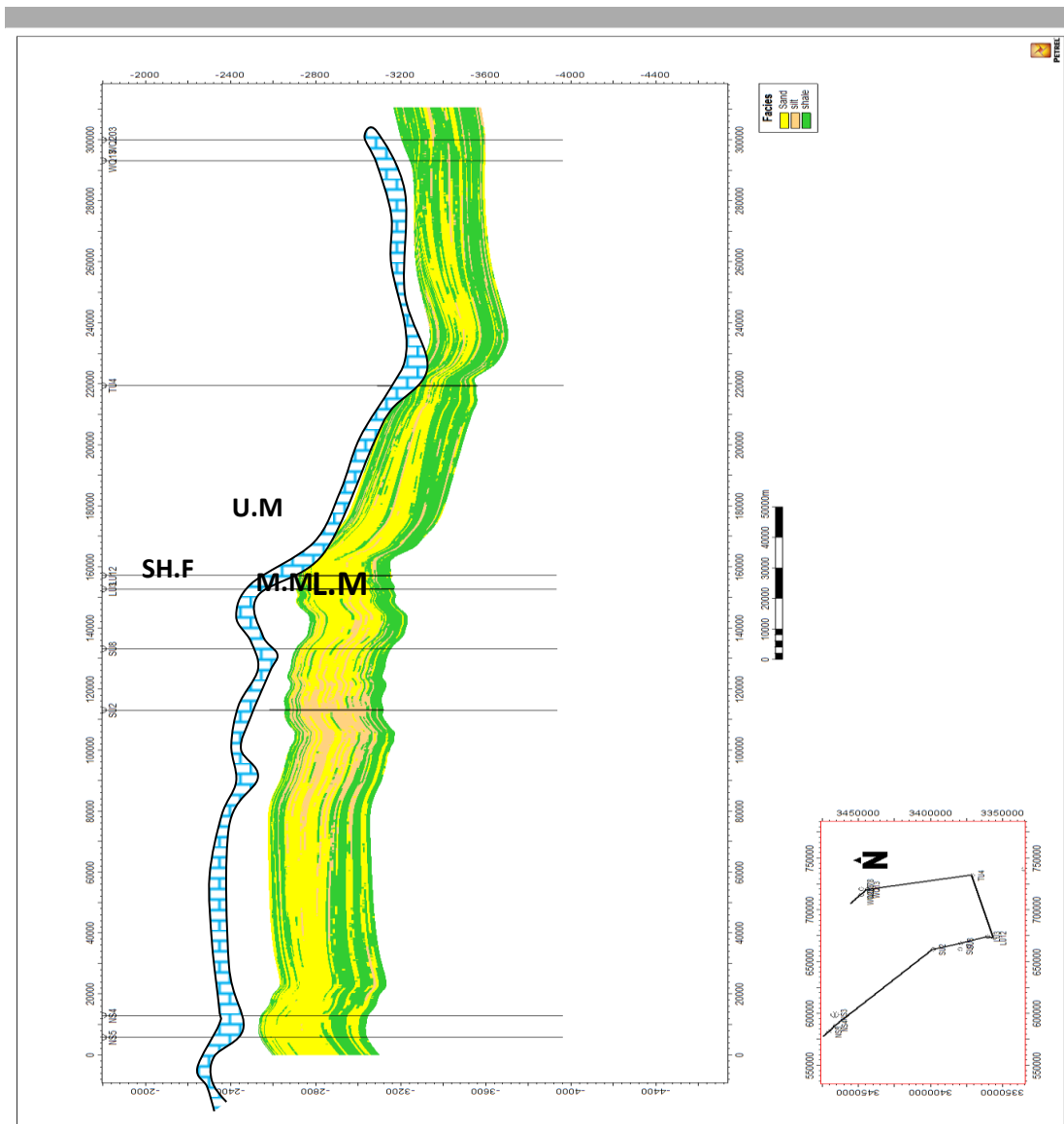


Figure 10-correlation faces across ne-sw for members of Barremain - Aptian succession in study area

Stratigraphic development

During the deposition of the Zubair Formation, the siliciclastic shelf followed a cyclical pattern of evolution from the prodelta depositional mode to throw delta plain ending with delta front mouth bar mode in the bottom. A sequence boundary type-I overlapping the basal shale of Ratawi Formation from the deltaic influenced lower Zubair Formation (Figures.2-11, 12, 13, 14)

Zubair characterized in the lower member by mud - dominated delta front associated facies. They seem to vertically separate relatively multi-storied mode and multi-lateral changes deltaic channel sand bodies resulting in compartmentalized reservoir architecture (Figures-(2-12,13,14),).

The presence of the delta front associated facies overlaying the unconformity surface (SB1) refers to the transgressive system tract (TST). This stage was ended by the deposition the fluvial channel facies to mark a high-stand system tract (HST). The fluctuation point between the TST and HST is represented a maximum flooding surface Figures-(2-11, 12, 13, 14).

The middle member of Zubair Formation is characterized by moderate to well sorted quartz arenite sandstone with appearance bands of the shale overlaying the sand body. This succession was deposited in the delta plain environment with steps of sea level rise during the transgressive stage. 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. 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.

The upper part of the Zubair Formation showed a shallower environment with shale dominated rocks associated with high organic matters and pyrite. This indicates to the fining up-ward mode during highstand stage when the deposition environment changed from delta plain fluvial channel to delta front mouth bar. The sea level rise marked the end of this stage when deposition the upper part of Zubair Formation, and the beginning of deposition of shallow marine carbonate of the Shuaiba

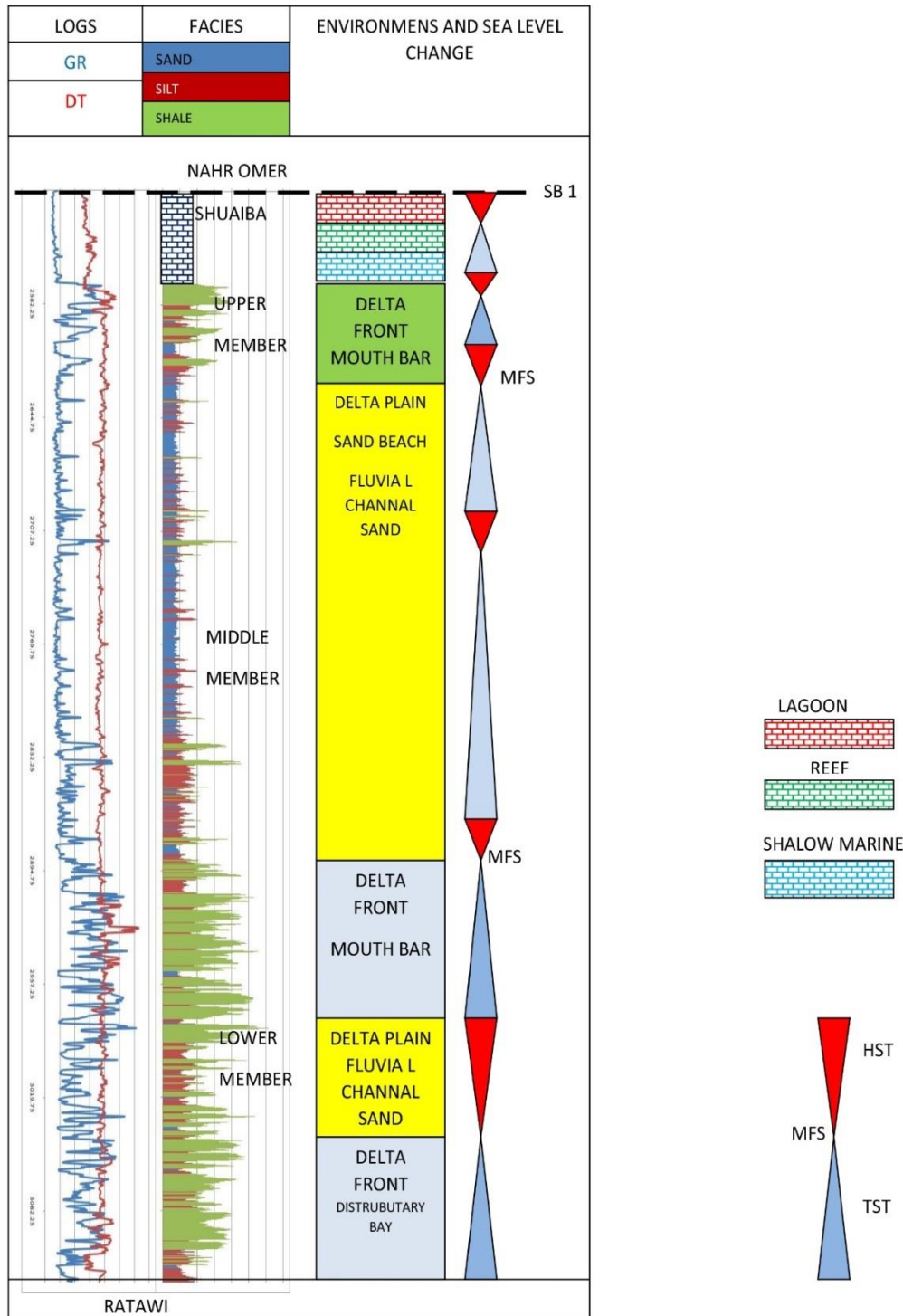


Figure 11-Facies changes and environments of Barrimian –Aptian succession in well Ns -2

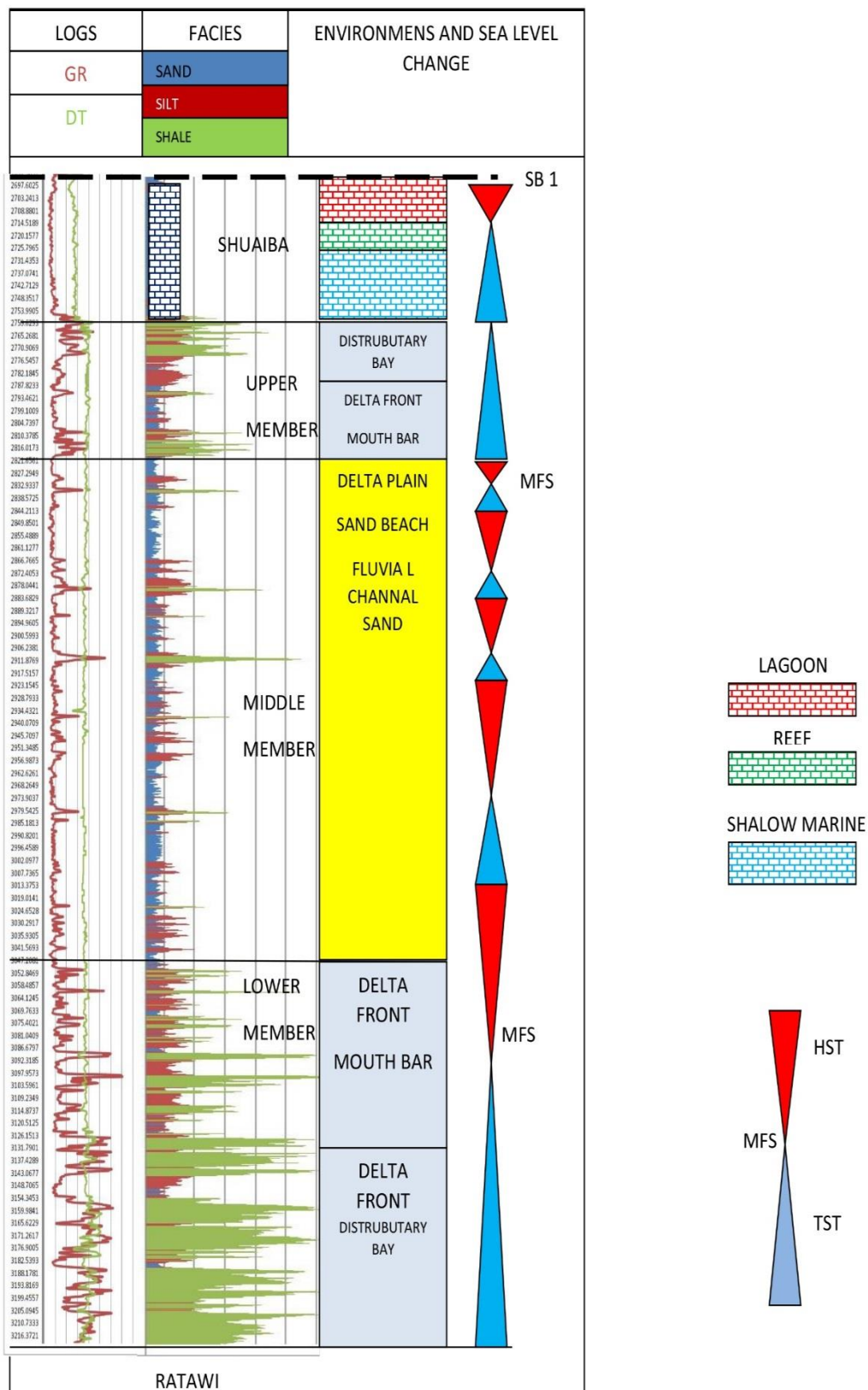


Figure 12-Facies changes and environments of Barrimian–Aptian succession in well Su -7

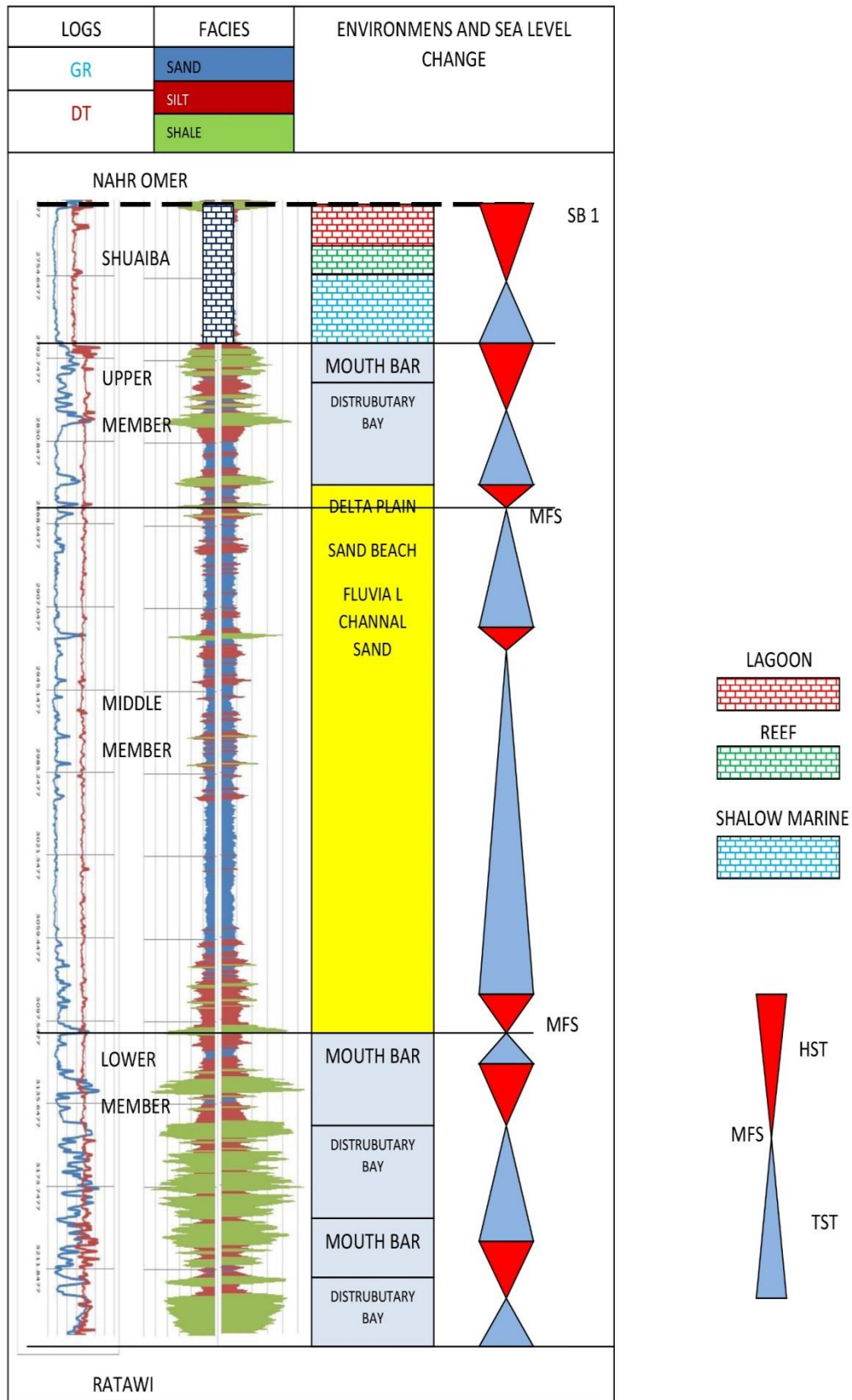


Figure 13-Facies changes and environments of Barrimian –Aptian succession in well Tu -4

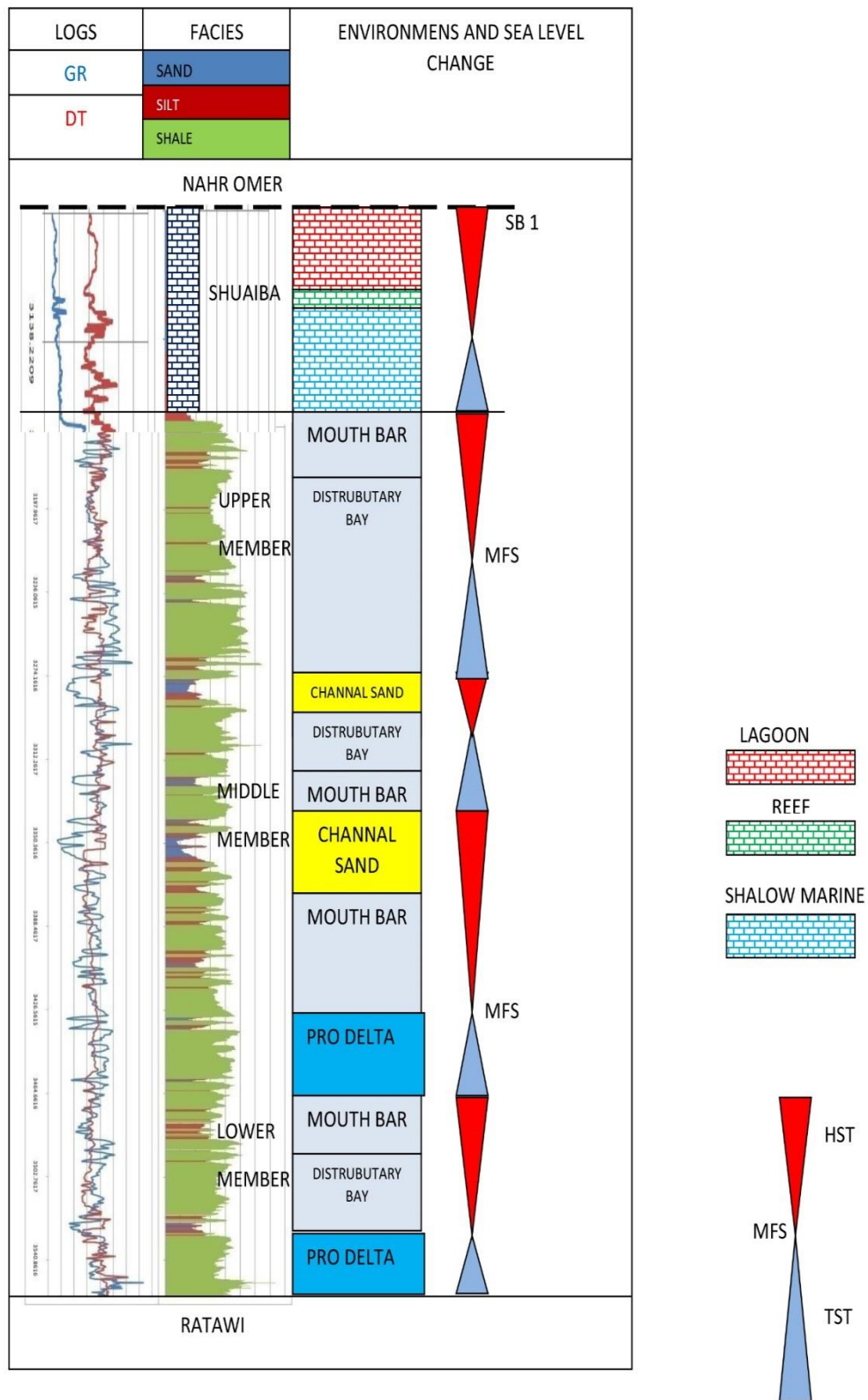


Figure 14-Facies changes and environments of Barrimian –Aptian succession in well Lu-12

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