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Facies Analysis and Sequence Stratigraphy of the Zubair Formation in the Kifl oil field, Central of Iraq

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Abstract

The Zubair Formation is the most significant sandstone reservoir in Iraq which deposited during the Barremian. The study area is located in the central part of Iraq at the Kifl oil field, in the northern part of the Mesopotamian Zone.

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

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 part of Zubair Formation is characterized by wide spread mud - dominated delta plain associated facies. The presence of the delta plain facies overlaying the unconformity surface (SB1) refer to the transgressive system tract (TST). This stage ended with occurrence of the channel fill deposit to mark a high-stand system tract (HST). This stage has ended with the delta plain facies again to mark a high-stand system tract (HST). The fluctuation point between the TST and HST is represented by a maximum flooding surface.

The middle part of Zubair Formation is characterized by moderate to well sorted quartz arenite sandstone with bands of the shale overlaying the sand body. This succession was deposited in the delta front environment with steps of sea level stillstand during the high stand stage. The HST in this part ended with sea level rise (TST) to mark the upper part of the Zubair Formation with appeared the delta front facies.

While the upper part is represented by alternative of delta front and delta plain facies as four cycles. 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 marine carbonate.

Keywords: Facies Analysis, Sequence Stratigraphy, Zubair Formation, Kifl oil field.

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التحليل السحني و التتابعية الطباقية لتكوين الزبير في حقل الكفل النفطي، وسط العراق

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قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

إن تكوين الزبير هو أهم خزان نفطي من الحجر الرملي في العراق والذي ترسب خلال العصر الباريمي. تقع منطقة الدراسة في الجزء الأوسط من العراق في حقل نفط الكفل ، في الجزء الشمالي من نطاق ما بين النهرين.

أظهرت الدراسة الصخرية أن معدن الكوارتز هو المكون الرئيسي للحجر الرملي في تكوين الزبير مع نسبة منخفضة جداً من معادن الفلسبار والمكسرات الصخرية لتصنيفه كحجر رملي ارينايتي. هناك خمسة تغيرات صخرية (سحنات صخرية) ميزت التتابع المدروس: – حجر رملي من الكوارتز أرينايت ذو فرز جيد و حجر رملي من الكوارتز أرينايت مفروزة بشكل رديء وحجر رملي واكي رديء الفرز و حجر رملي سجيلي و الصخر السجيلي. ترسبت هذه السحنات الصخرية في البيئات الدلتا كثلاث من المترافقات السحنية لهذه البيئة [السهل الدلتاوي وواجهة الدلتا وقنوات التوزيع].

ساهمت الاختلافات في السحنات الصخرية في تقسيم تكوين الزبير إلى ثلاث وحدات صخرية مميزة ، والتي تم استخدامها في تفسير وتوزيع البيئات المقترحة. يتميز الجزء الأسفل من تكوين الزبير بسمات دلتا ذات انتشار واسع من الطين. يشير وجود مترافقة السهل الدلتاوي التي تعتلو سطح عدم التوافق (SB1) إلى نظام الترسيب التقدمي (TST) . انتهت هذه المرحلة مع ظهور ترسبات ملىء القنوات لتؤشر نظام الترسيب العالي (HST) . وقد انتهت هذه المرحلة مع ظهور سحنة السهل الدلتاوي مرة أخرى للتبين بداية نظام الترسيب العالي (HST) . ان مرحلة الانقلاب بين TST و HST تمثل سطع أقصى مستوى سطح البحر.

يتميز الجزء الأوسط من تكوين الزبير بحجر رملي ارينايتي متوسط إلى جيد الفرز مع ظهور حزم من السجيل الذي يغطي الحجر الرملي. هذا التتابع كان قد ترسب في بيئة مقدمة الدلتا مع مراحل توقف مستوى سطح البحر خلال مرحلة الترسيب العالي. انتهت مرحلة الترسيب العالي في هذا الجزء مع ارتفاع مستوى سطح البحر (TST) لتؤشر الجزء العلوي من تكوين الزبير مع ظهور سحنة مقدمة الدلتا.

في حين يتمثل الجزء العلوي من التكوين بتعاقب لتتابعات سحنية لبيئة مقدمة الدلتا و السهل الدلتاوي في أربع دورات ترسيبية. تم تمييز ارتفاع مستوى سطح البحر بنهاية هذه المرحلة عند ترسيب الجزء العلوي من تكوين الزبير ، وبداية ترسب تكوين الشعيبة في بيئة بحرية كربونايتة ضحلة.

Introduction

The Zubair Formation was described by Glynn Jones (1948) in the Zubair oil field and amended by Nasr and Hudson (1953) [1].

It is the most significant sandstone reservoir in Iraq, which deposited in the fluvio- deltaic, deltaic and marine environments. It is widespread in 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 the Saudi Arabia (Powers et al., 1966 in [2]).

The study area is located in south of Baghdad to the southwest of Hilla city about 35km, and lies within the Mesopotamian Zone between the Zagros fold to the north and the Stable Shelf to the west. This area lies between Najaf and Karbala governorates to the west of the Euphrates River (Figure-1), and limits from the east by Euphrates River and to the north Karbala city, while to the northwest by the Razaza lake.

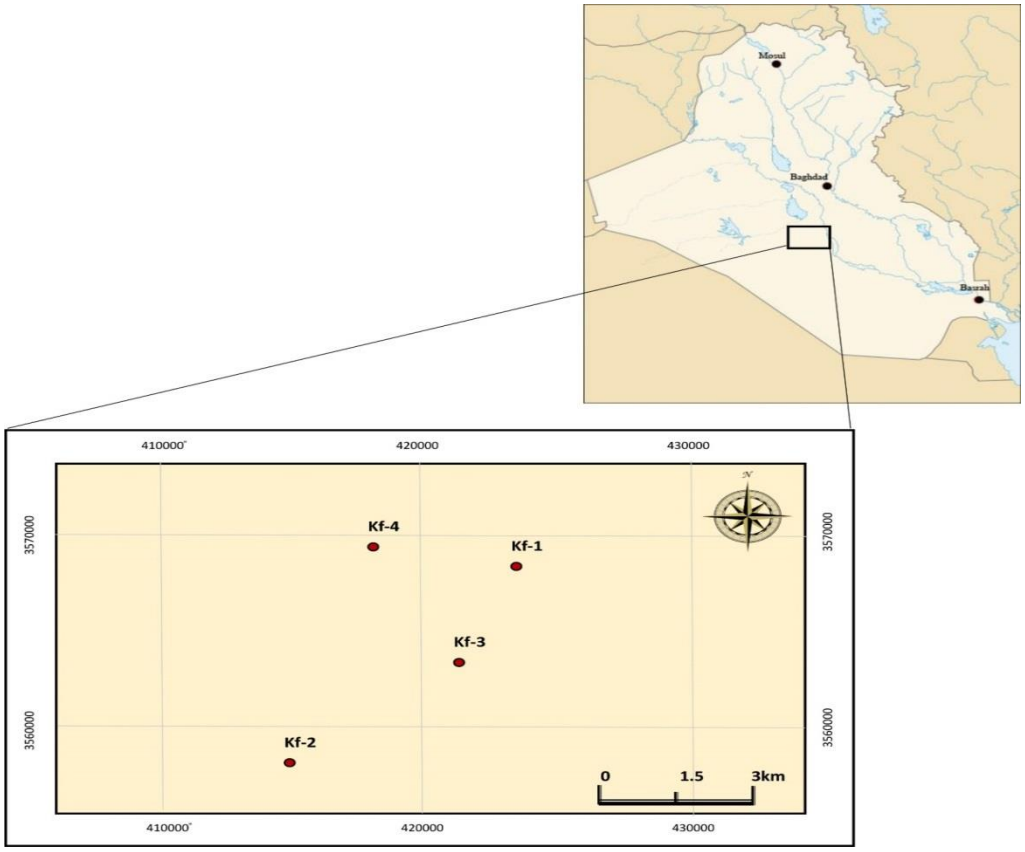


Figure 1-Map showing the study area.

During the Hauterivian to Early Aptian age the formation was deposited with 380-400 m of alternating shale, siltstone and sandstone [1]. The Zubair Formation is represents a prograding delta originating from the Arabian shield [3].

The upper contact of the Zubair Formation is mostly gradational and conformable with the Shuaiba Formation (Figure-2). While the lower boundary is, however unconformable with Ratawi Formation [4], and this unconformity was described by Douban and Al-Medhadi (1999)[5].

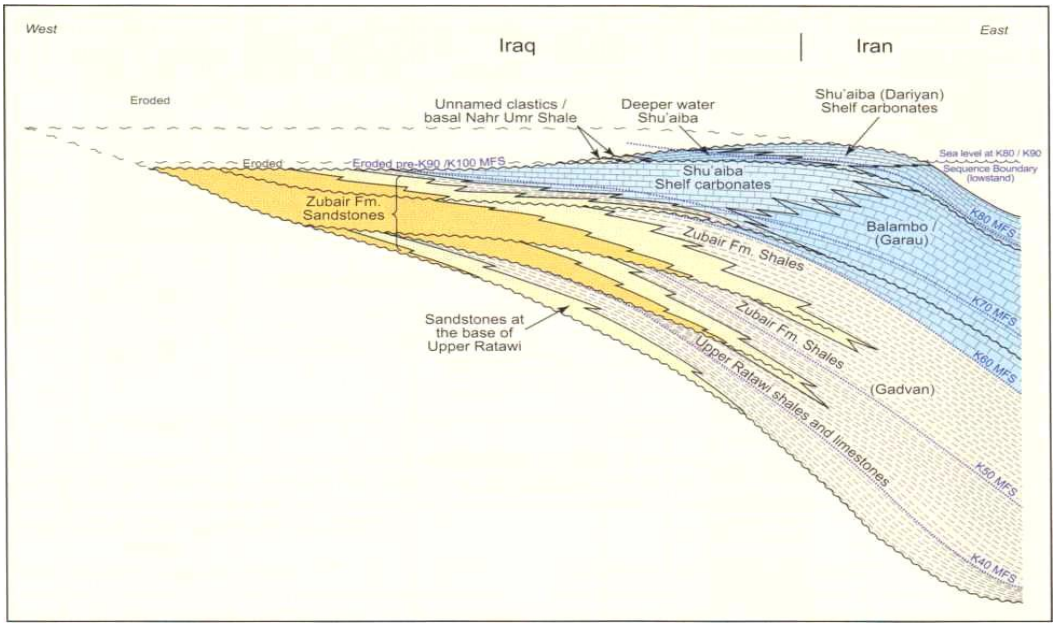


Figure 2-Schematic west-east profile across southern/ central Iraq illustrating stratigraphic position of Zubair Formation [2]

The present study involves facies analysis and depositional environment interpretation with stratigraphic development of the Zubair Formation in the Kifl oil field.

Methodology

1- Field observation and sampling for the selected bore hole, as cores and cuttings for Kifl-1, Kifl-3 and Kifl-4.

2- Petrography and lithofacies analysis for studied wells by thin sections examination.

3- Study the available well logs and relate the log response to facies changes and stratigraphic settings.

Lithofacies Analysis

The geological and petrophysical properties of the sedimentary successions depend upon an interlaying of tectonic settings, sea level, sediment supply, physical and biological processes (transport and deposition), and the climate. At the sedimentary basin, these processes interact to produce the geometric arrangement of different depositional environments or systems tracts through the time, known as the stratigraphic architecture [6].

The first steps of the facies analysis for a clastic reservoir is the description and interpretation of available conventional core [7]. An important result of core description is the subdivision of the succession into lithofacies, defined as subdivisions of a sedimentary sequence based on lithology, grain size, physical and the 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 [7].

The Zubair Formation in Kifl oil field don't show a clear subdivision into three units as in the other oil fields studied in southern Iraq. Where described by Al-Zaidy and Mohammed (2017)[8] in Luhais and Rachi oil fields and Yousif and Al-Zaidy (2018)[9] in Majnoon oil field the Zubair Formation was subdivided into three units according the volume of shale in these areas.

In the present study the gamma ray (volume of shale) and SP logs don't show these subdivisions. However, by comparing the overall behavior of the acoustic and resistive logs with the gamma ray and SP logs, three modes of behavior of these probes were identified in the studied Zubair sequence.

1. The first is spacing the gamma ray log from the SP log on the one hand and spacing the acoustic log from the resistivity log on the other. This appeared in the upper part of the Zubair Formation with depth interval from 2000 to 2190m. The main components of this unit are sandstone with organic matters and interlaying of shale. This part is characterized by low gamma ray values with major trend of fining up-ward succession (Funnel shape) Figure-3.
2. The second part overlyies the gamma ray log with the SP log on the one hand and spacing the acoustic log from the resistivity log on the other. This appeared in the middle part of the studied succession with depth interval from 2190 to 2260m. The main lithology of this unit is sandstone and characterized by low gamma ray values with two cycles of fine up-ward (Bell shape) (Figure-4).
3. The third part reflects spacing the gamma ray log from the SP log on the one hand and overlying the acoustic log from the resistivity log on the other. This represents the lower part of the Zubair Formation with depth interval from 2260 to 2470m. This unit is unconformable with the Ratawi Formation according to Van Bellen and others [1], and its characterized by high gamma ray values with coarse up-ward trend (Funnel shape) (Figure-5).

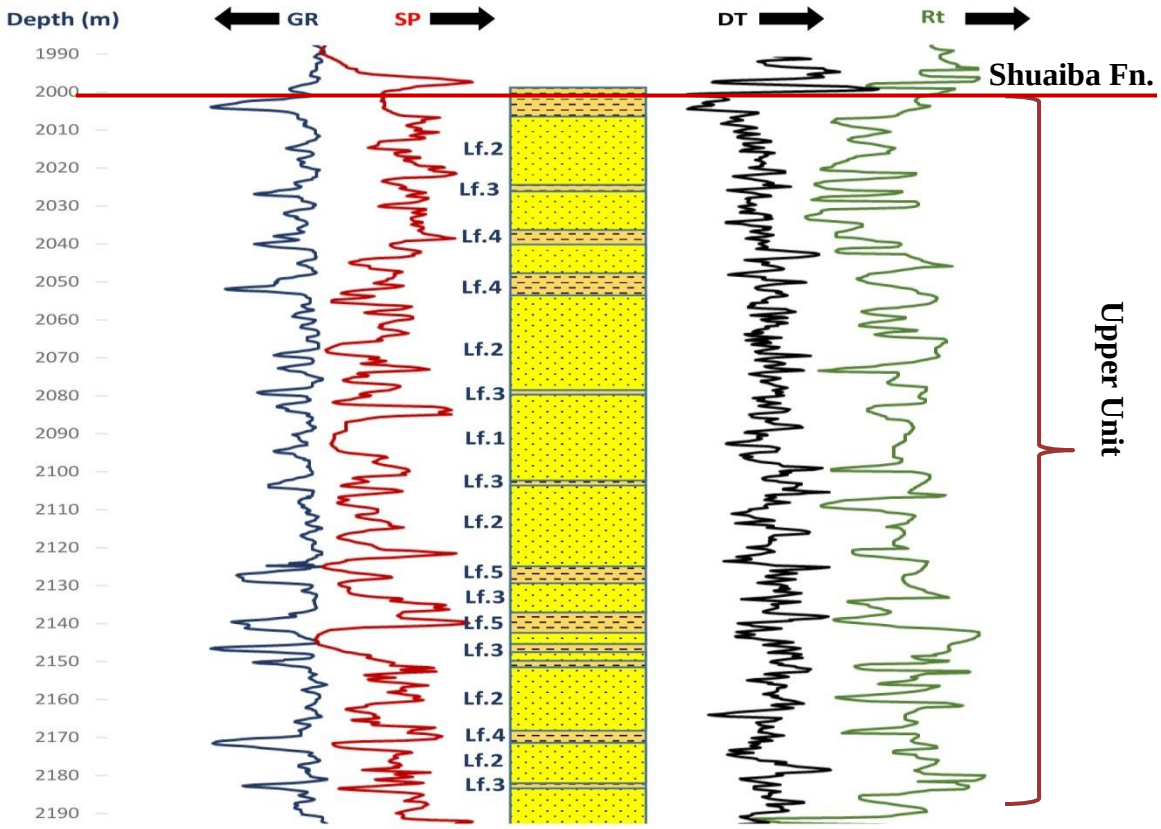


Figure 3-Variety of GR and SP log vs. DT and Rt log shapes with lithology for the upper unit of Zubair Formation (well Kf-1).

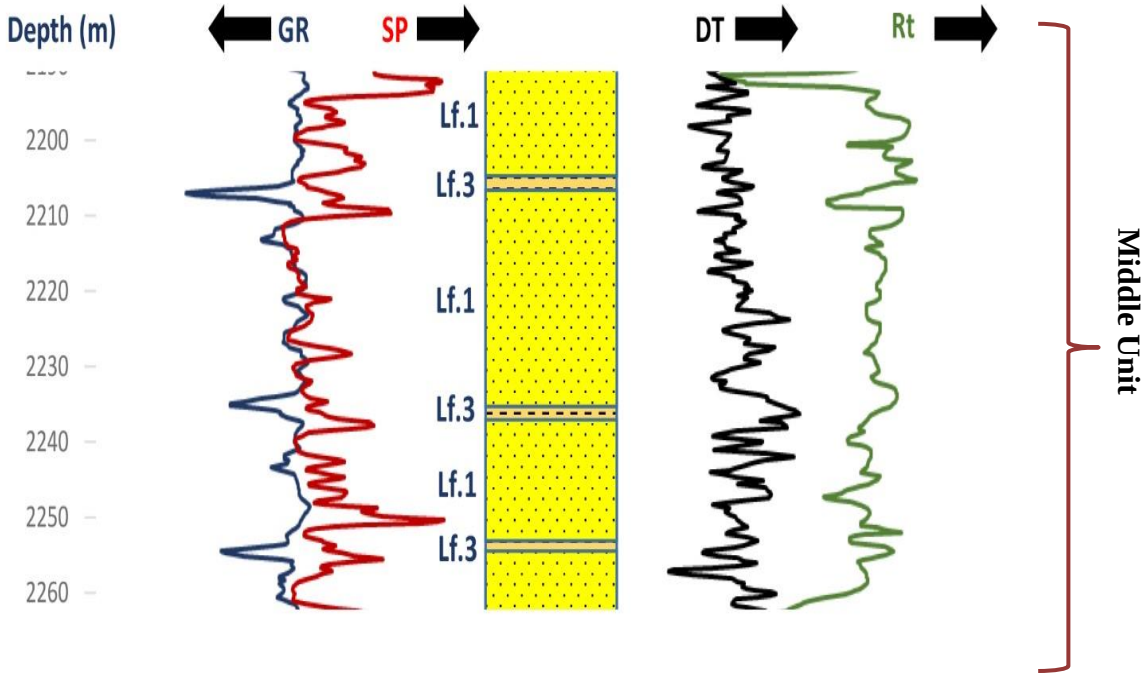


Figure 4-Variety of GR and SP log vs. DT and Rt log shapes with lithology for the middle unit of Zubair Formation (well Kf-1).

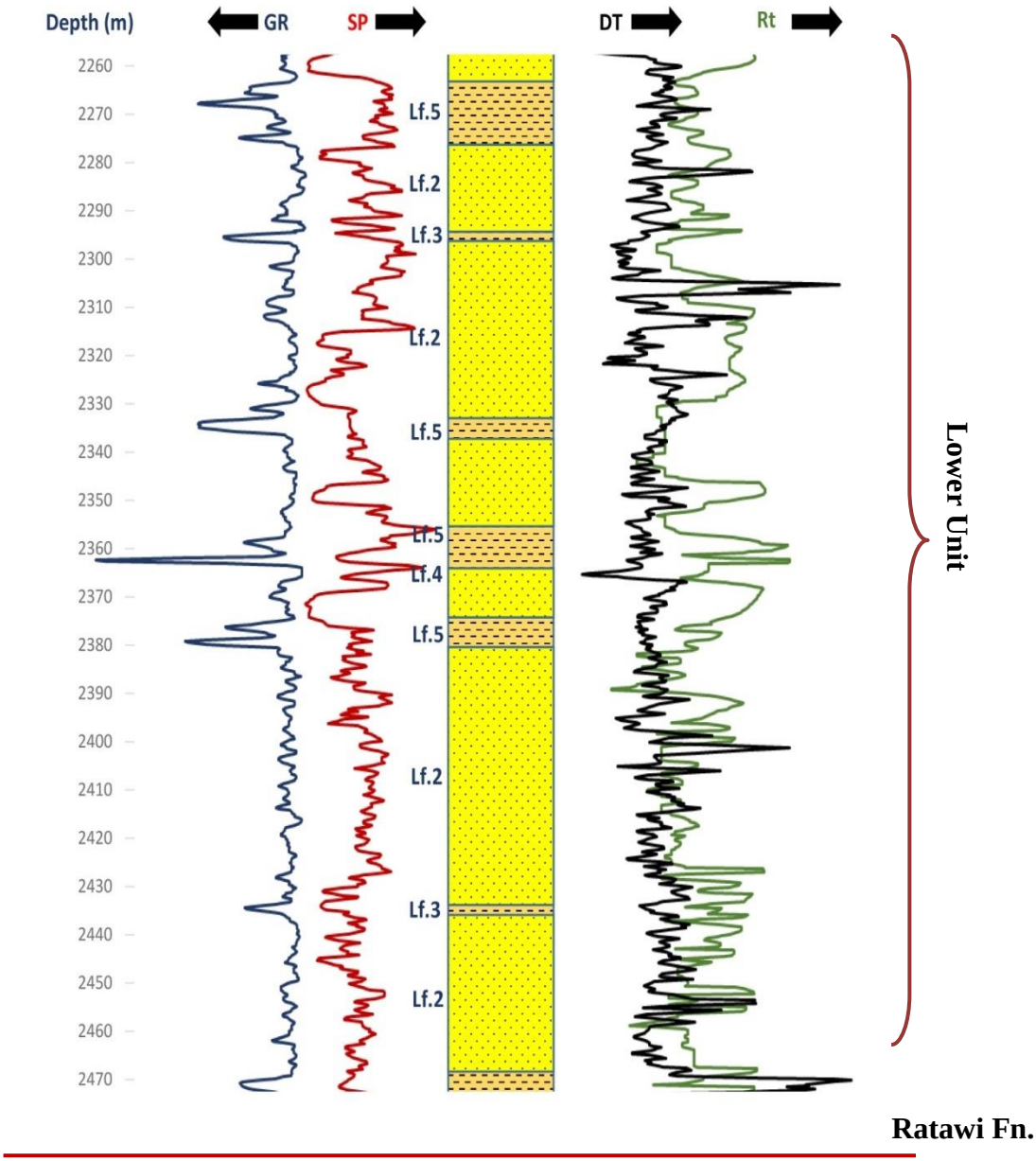


Figure 5-Variety of GR and SP log vs. DT and Rt log shapes with lithology for the lower unit of Zubair Formation (well Kf-1)

Associated Facies and Depositional environments

According to the available of these parameters there are 5 lithofacies in the Zubair succession.

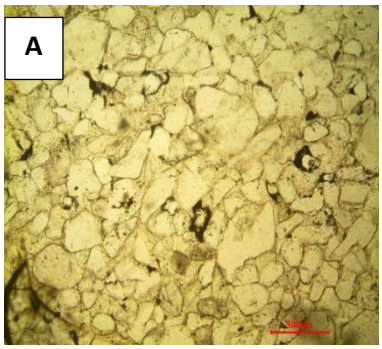
1. **Well sorted quartz arenite Lithofacies (Lf.1):-** fine grained well sorted sand dominated rocks with sub-angular to sub-rounded grains shape (Plt.1A) are characterized this facies. The sandstone in this facies is composed of more than 90% of quartz according to Folk classification [10] as quartz arenite sandstone. This appeared in the middle unit as very low gamma ray values and high values of resistivity with box shape of gamma ray and spontaneous potential logs ((Figures-3, and 4).
2. **Poorly sorted Quartz arenite Lithofacies (Lf.2):-** It represents wide range of grain size of sandstone (fine-coarse) and well-rounded to sub-rounded grain shape, within the sand dominated rocks (Plt.1B). The sandstone in this facies contains of more than 90% of quartz to classify as quartz arenite which appeared in the upper unit. This characterized by poorly sorted, very low gamma ray values which decreasing upward with bell shape of gamma ray log and high values of resistivity (Figure-5).
3. **Poorly sorted graywacke Lithofacies (Lf.3):-** This lithofacies represents the muddy sand dominated rocks which mainly composed of quartz. Its characterized by poorly sorted graywacke

sandstone (Plt.1C), with moderate values of gamma ray (funnel shape). This lithofacies is appeared in the upper unit of the Zubair Formation, in addition to muddy parts of the lower unit (Figure-5).

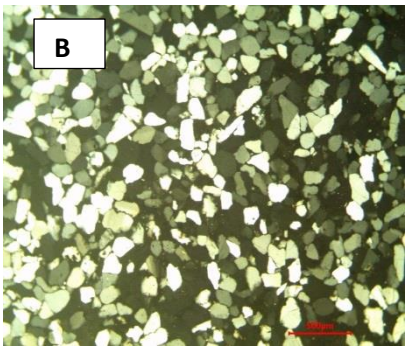
4. **Sandy shale Lithofacies (Lf.4):-**This facies appeared in the sand member as shale lenses, which characterized by high gamma ray values with funnel shape Figure-3. The main components of this facies is sand dominated rock with quartz grains characterized by angular shape(Plt.1D).

5. **Shale Lithfacies (Lf.5):-** This facies appeared in all parts of Zubair Formation. It is characterized mainly by shale (Plt.1E), with high gamma ray values with bell shape (Figure-5).

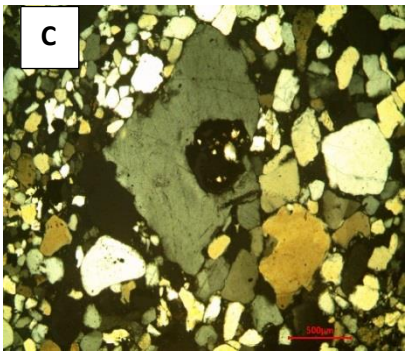
Plat (1)



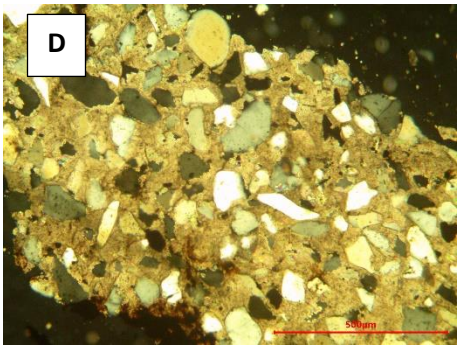
Coarse-moderate sandstone well sorting Kf-1(2200m)



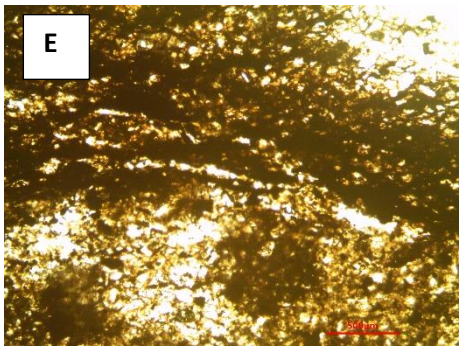
Fine Sandstone well sorting Kf-1(2020m)



Coarse-fine Sand poorly sorting Kf-1 (2295m)



Clayey Sandstone poorly sorting Kf-1(2050m)



Shale lithofacies Kf-1(2360m)

Stratigraphic Sequence

Sequence stratigraphy is the study of facies relationships within a chronostratigraphic sequence of repetitive genetically related strata bounded by the sequence boundary (surface of erosion or non-deposition), or their correlative conformities [11, 12]. The stratigraphic signatures and strata patterns in the sedimentary rock record are the result of the interaction of tectonics, eustasy, and climate changes. [13].

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 (Figures-(6, 7 and 8).

The lower part of Zubair Formation is characterized by mud -dominated delta plain facies. They seem to vertically separate relatively multi-storied mode and multi-lateral changes deltaic distributary 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(MFS).

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(Figures-(6, 7 and 8).

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 deposited 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 includes 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 Kifl-3 (Figure-7), where rock characteristics indicates 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 showed a shallower environment with shale dominated rocks associated with high organic matters and pyrite. This indicates to the finning up-ward mode during highstand stage when the deposition environment changed from delta front to marsh environment. The sea level rise 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.

Conclusions

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. Distributary channel

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

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.

The presence of the delta plain associated facies overlaying the unconformity surface (SB1) and underlaying the distributary channel facies refer to the transgressive system tract (TST). This stage has ended with appeared the delta plain facies again to mark a highstand system tract (HST). The fluctuation point between the TST and HST is represented a maximum flooding surface Figures-(6, 7, 8).

The middle part of Zubair Formation is characterized by moderate to well sorted quartz arenite sandstone with appearance of shale bands overlaying the sand body. This succession was deposited in the delta front environment with steps of sea level stilled during the high stand stage. The HST in this part which ended with the sea level rise (TST) and occurrence of delta front facies to mark the upper part of the Zubair Formation. While the upper is represented by alternative of delta front and delta plain facies as four cycles. The sea level rise 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.

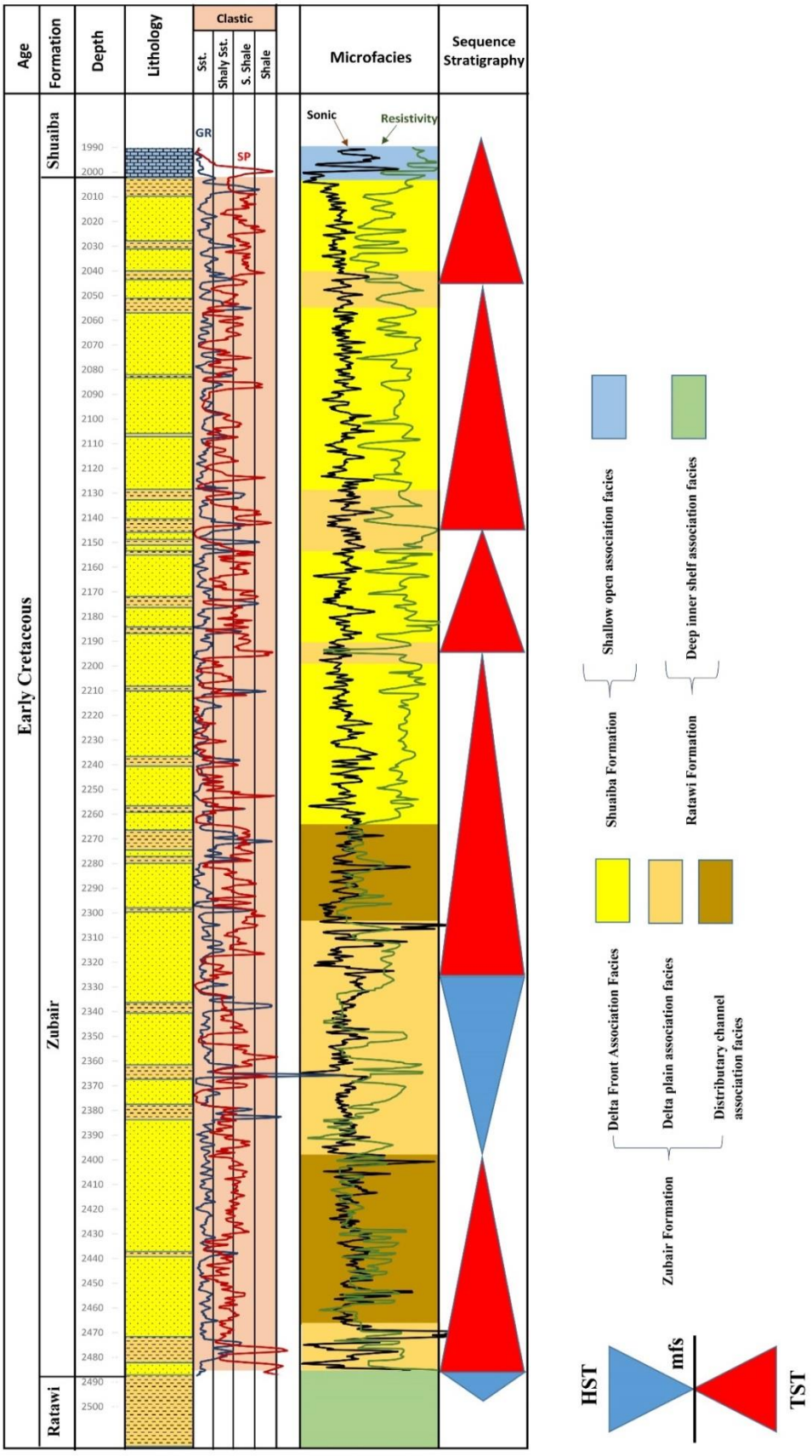


Figure 6-Stratigraphic columnar section for the Zubair Formation in the well Kf-1.

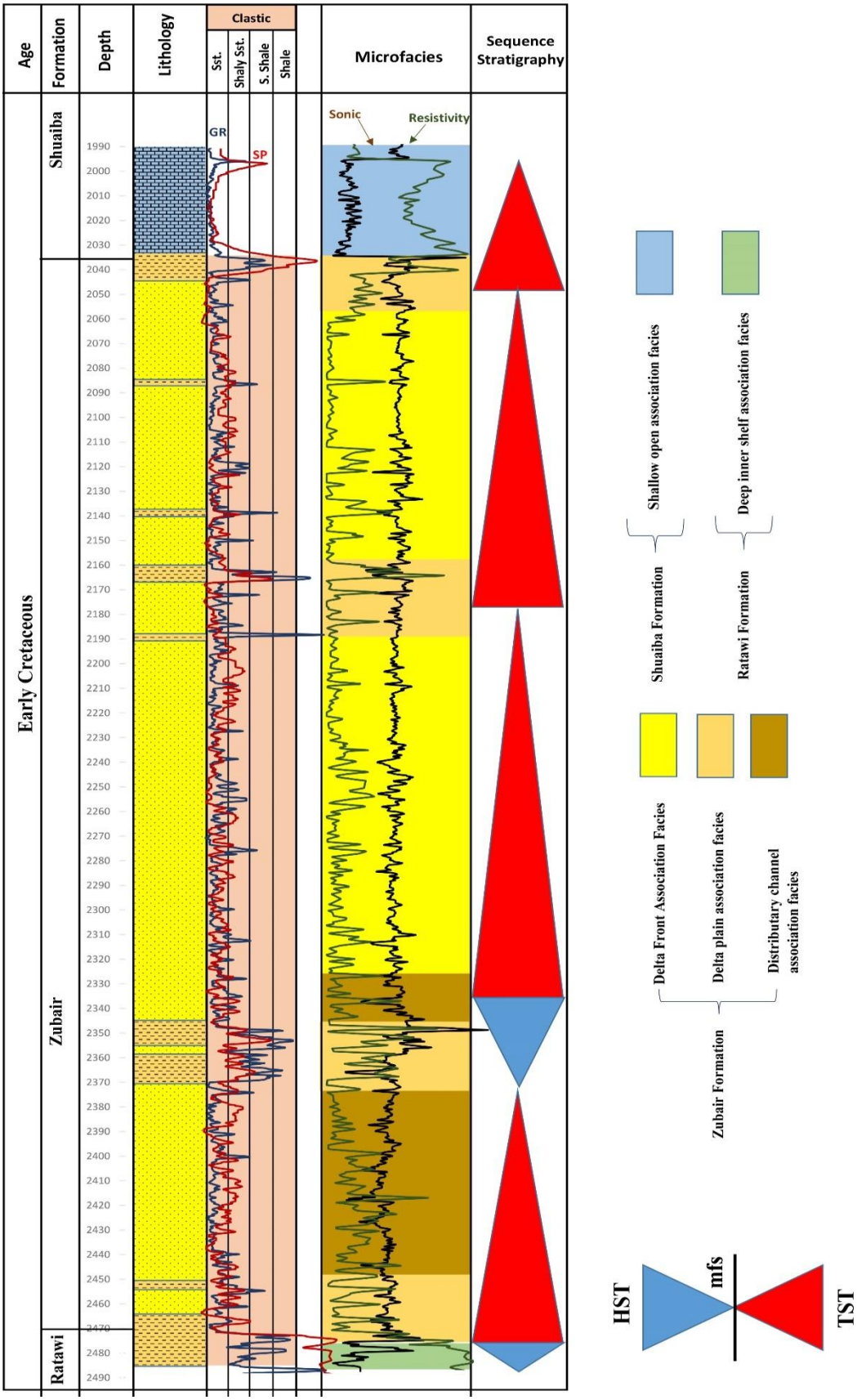


Figure 7-Stratigraphic columnar section for the Zubair Formation in the Kf-3.

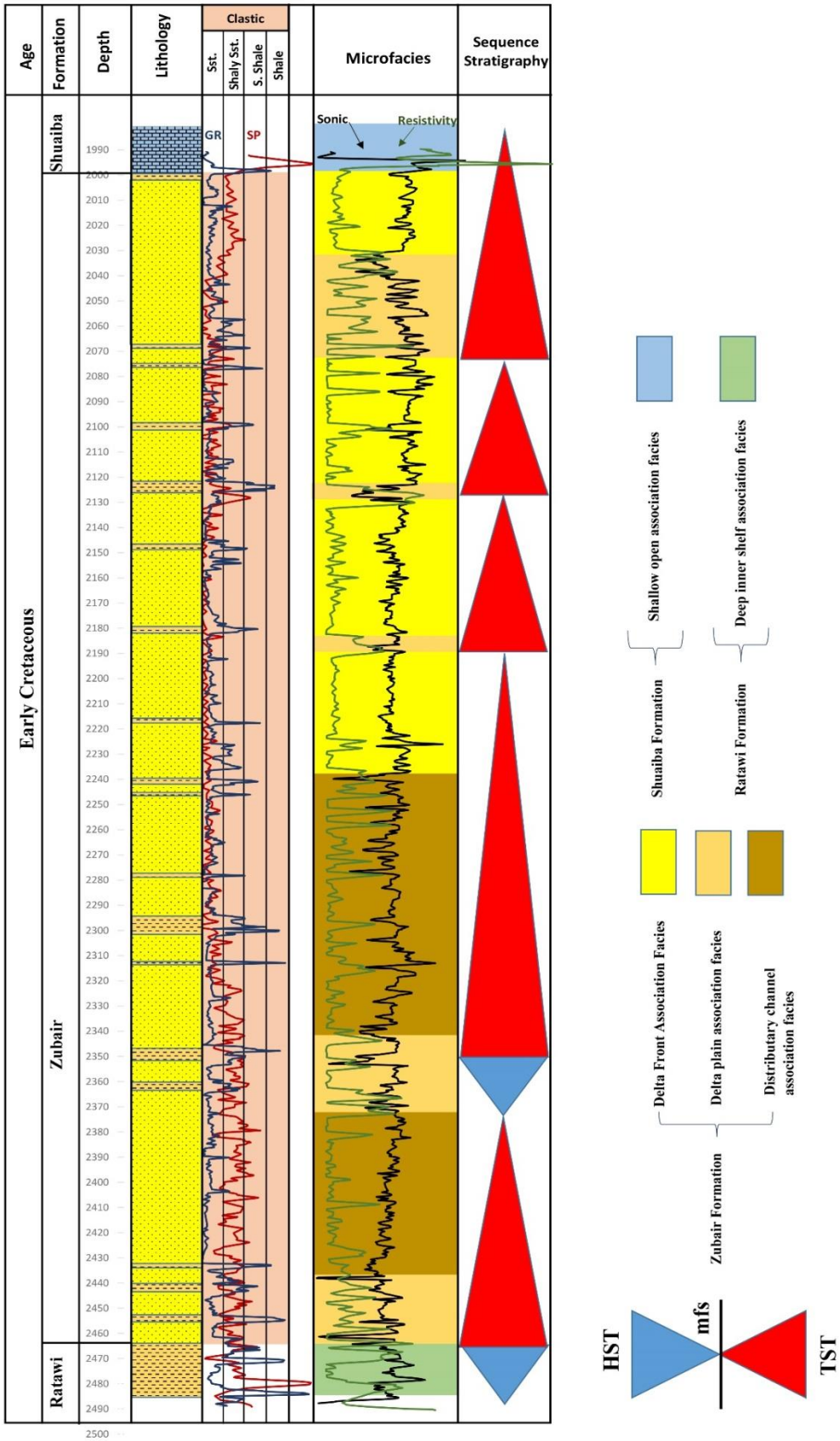


Figure 8-stratigraphic columnar section for the Zubair Formation in the Kf-4.

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