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Reinterpretation of the two-dimensional seismic reflection of the Afaq structure region, central Iraq

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Abstract

This study investigates stratigraphic and structural interpretation of the Afaq structure area, central Iraq in Qadisiyah province, about 25 km north of Diwaniyah, using 2D seismic data. Synthetic traces are prepared using available data of the well (WK-1) using the Petral software program to define and choose the reflectors on the seismic section. Structure interpretation includes selecting a top of the Zubair Formation (Late Cretaceous), the Yamama Formation and Gotnia Formations are used in stratigraphic interpretation (Upper-Late Jurassic). Structure interpretation of the Zubair Formation shows that the area has several minors and a short extension of faults, where the fault system extends (NE-SW) direction. The structural interpretation of time and depth maps of the Zubair Formation shows that the Afaq structure is a monocline of NE-SW direction and plunges to the east. Several stratigraphic phenomena are presented in the study area, which helps understand the paleo-sedimentary environment. It could have significant hydrocarbon potentials, including carbonate buildup and stratigraphic trap. The indicators of carbonate building up are located in shallow areas where the sunlight reaches organisms and builds colonies. These carbonate buildups represent important oil and gas sources in many sedimentary basins. The stratigraphic trap in the Sulay-Yammama sequence was detected using the instantaneous phase attribute, which shows a difference in the acoustic impedance and the reflection's nature. The reflector peak's closure within the trough indicates a trap presence.

Keywords: 2D Seismic section, Afaq area, Zubair, seismic attributes

دراسة انعكاسية زلزالية ثنائية الأبعاد لمنطقة تركيب عفك(عفج) وسط العراق

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

الخلاصة

يمثل هذه البحث تفسيرات لدراسة زالزالية طباقية تركيبية لمنطقة تركيب عفك (عفج) وسط العراق في محافظة القادسية، على بعد حوالي 25 كم شمال الديوانية ، باستخدام البيانات الزالزلية ثنائية الأبعاد. تم اعداد الاثر المصنع باستخدام البيانات المتاحة للبئر (WK-1) باستخدام برنامج البترول لغرض تعريف و وتتبع العواكس على المقاطع الزلازلية. التفسير التركيبي تضمن انتقاء وتتبع اعلى تكوين الزبير(المترسب خلال اواخر العصر الطباشيري)، بينما التفسير الطباقي تضمن انتقاء وتتبع عاكسين يمامة وقطنية (المترسبين خلال اولى

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واواخر العصر الجوارسي). وضح التفسير التركيبي لتكوين الزبير أن المنطقة تتاثر بعدة من الفوالق الثانوية ذات امتدادت قصيرة ،يكون امتدادها (NE–SW). وضح التفسير التركيبي لـ خرائط الزمنية و العمق لتكوين الزبير أن تركيب عفك تركيب أحادي الميل له اتجاه شمال شرق–جنوب غربي وانحداره إلى الشرق. توجد العديد من الظواهر الطبقية في منطقة الدراسة ، والتي يمكن أن تساعدنا في فهم البيئة الرسوبية القديمة. يمكن أن يكون لها إمكانات هيدروكربونية كبيرة ، بما في ذلك Buildup، reef stratigraphic trap. Buidupيشير الى ان منطقة تقع في مناطق الضحلة التي يصل الضوء إليها. والمصيدة الستراتيغرافية في تتابع سلي –يمامة تم اشتكشافها باستخدام instantanrous phase attribute التي تظهر اختلافًا في الممانعة الصوتية وطبيعة الانعكاس ، وكذلك إنغلاق العاكس الpeak داخلة trough ، وكل ذلك يشير إلى وجود مصيدة في المقطع الزلزالي.

Introduction

The final stage of any seismic exploration project is seismic interpretation. Data acquisition and processing are the two initial processes that comprise generating reflected waves and processing them to produce the stacked seismic sections. These seismic data are combined with geological information to obtain structural and stratigraphic pictures of the subsurface geology [1].

Afaq District is an Iraqi city located in the Qadisiyah Governorate in southern Iraq, about 25 km north of Diwaniyah and about 170 km south of Baghdad (Figure 1). The significance of the study area comes from oil fields, including Al-Ahdab-1, Al-Nasiriyah-3, Kifl-3, and West Al-Kifl-1 (Figure 1).

It is a flat agricultural area with elevations ranging from 15 to 20 m above sea level [2]; it has alluvial flood and aeolian sediments covering north-eastern sections [3].

Tectonically, the study area is located in the Euphrates subzone, which belongs to the Mesopotamian zone within the Stable Shelf, situating between two major fault systems (Ramadi – Musaib fault at the East and Euphrates fault in the west). The Kut Dezful Transverse Fault, which is E-W oriented intersection, is located in the northern part of the study area, and several short and limited extension faults in the NE-SW direction (parallel to the transverse faults) are present (Fig. 2) [3].

The Gotnia Formation (Late Jurassic), which corresponds to the Late Toarcian early Tithonian tectonostratigraphic mega sequence Ap7 [3], is composed of the anhydrite with subordinate beds of brown calcareous shales, thin black bituminous shales, and recrystallised oolitic limestones [4].

The Yamama Formation (late Tithonian-Hauterivian) within the Upper Tithonian-Aptian Thamama Group corresponds to the Late Tithonian-Early Turonian tectonostratigraphic mega sequence Ap8 [3]. Bellen et al. in 1959 described a 257 m interval in Ratawi-1 as the Yamama -Sulaiy formations. The upper 203 m, now allocated to the Yamama Formation [5], consists of 12 m of specular and brown detritus limestone with thin shale beds overlain by 191 m of micritic limestone and Oolitic limestone. The thickness of the formation is up to 400m near Najaf city and up to 360m thick in the southeast of Iraq.

The Zubair Formation belongs to the Late Barremian - Aptian sequence within the Upper Tithonian-Aptian Thamama Group, corresponding to the Late Tithonian Early Turonian tectonostratigraphic mega sequence Ap8. It was introduced and amended in the Zubair oil field by Bellen et al. (1959) in [3]. The thickness of the Zubair Formation in NE of Iraq ranges from 380 to 400 m of alternating shale; siltstone and sandstone were reached up to 500m in southern Iraq[3]. The thickness of the Zubair Formation in the well of Afaq-1 reached more than 513 m, and it consists of sandstone and shale rocks, where the thickness of shale is about 12 m [7].

The current study is the first attempt to interpret the 2D seismic reflection survey of the Afaq area, aiming to identify the structural and stratigraphic pictures.

Subsurface Geology

In this study, three formations were studied, represented by the Zubair, Yamama and Gatina Formations. To identify the subsurface geology of the study area, and because the Afaq-1 well reaches the Zubair Formation, the area was defined from the stratigraphic column of the Afaq-1 well and the stratigraphic column of the well of a neighbouring province, which is the well of the West Kifl-1.

The Aq-1 was drilled in 1960 and reached the Zubair Formation at a depth of 3386 m. It was mainly drilled as a stratigraphic test and small positive closure indicated by gravity and seismic reconnaissance survey [6]

The West Kifl-1 oil well was drilled in 1985 and located on a structural dome, 10km long, part of a structure trending NW-SE, 40 km SW Karbala, and S of the Razaza lake. The main reservoir is Hartha limestone, the Nahr Umr, Zubair, and Yamama formations are secondary reservoirs, and the Najmah Formation contains Tar and bitumen [7].

The geological columns shown in Figures 3 and 4 show the age, name, thickness, and brief description of all the formations penetrated by the Afaq-1 and West Kifl-1 wells.

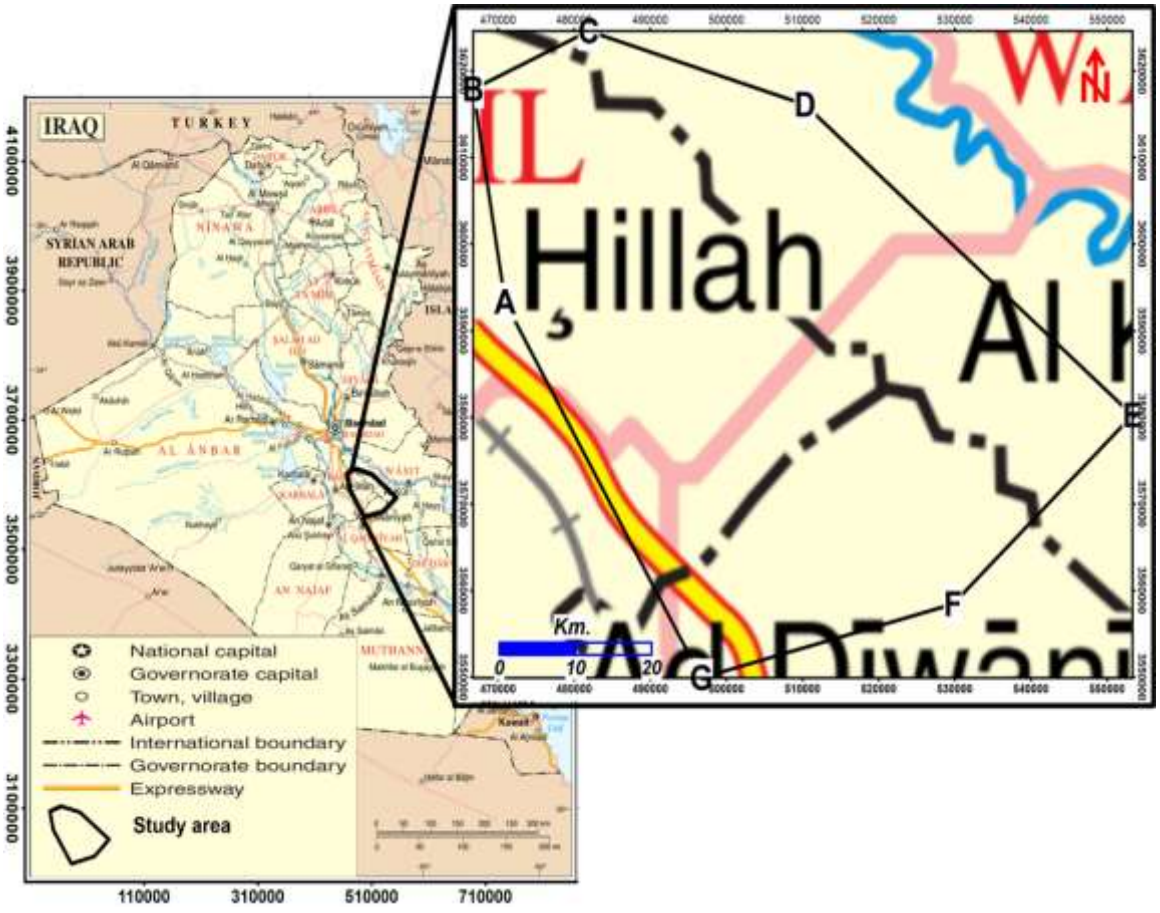

Figure 1- Location map of the study area

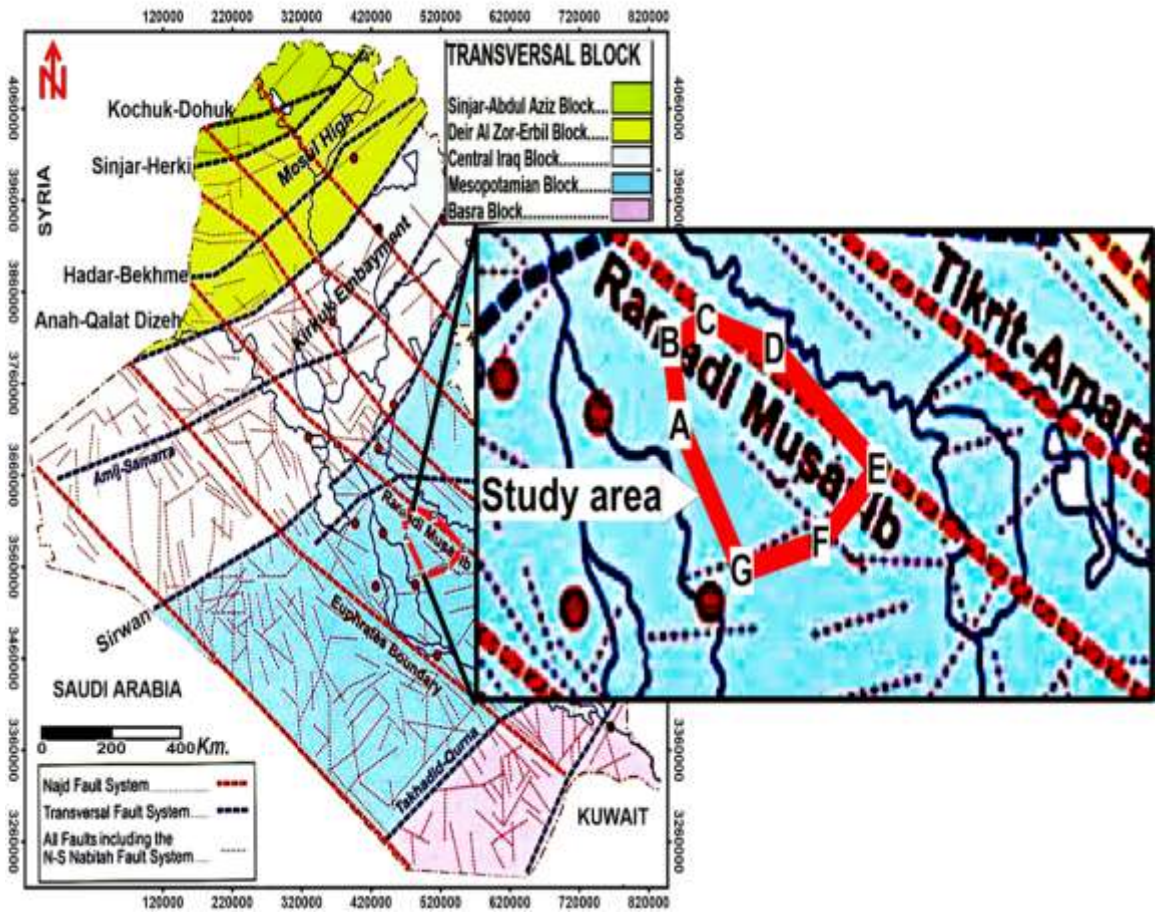

Figure 2- Tectonic map of the study area shows the longitudinal faults (Najd faults system) and transversal faults [3]

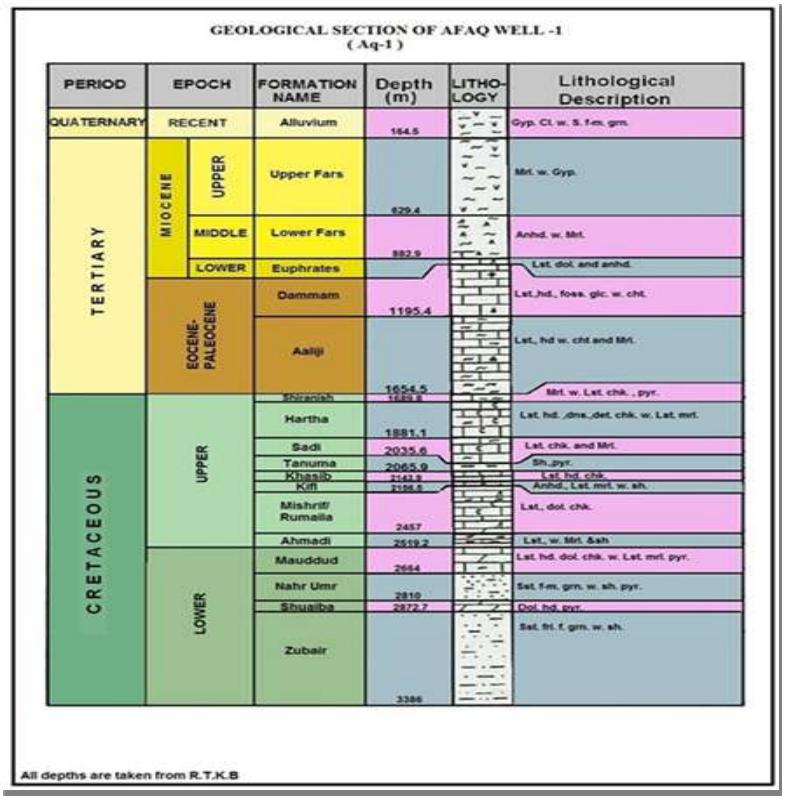

Figure 3- Stratigraphic column of well Afaq-1[6].

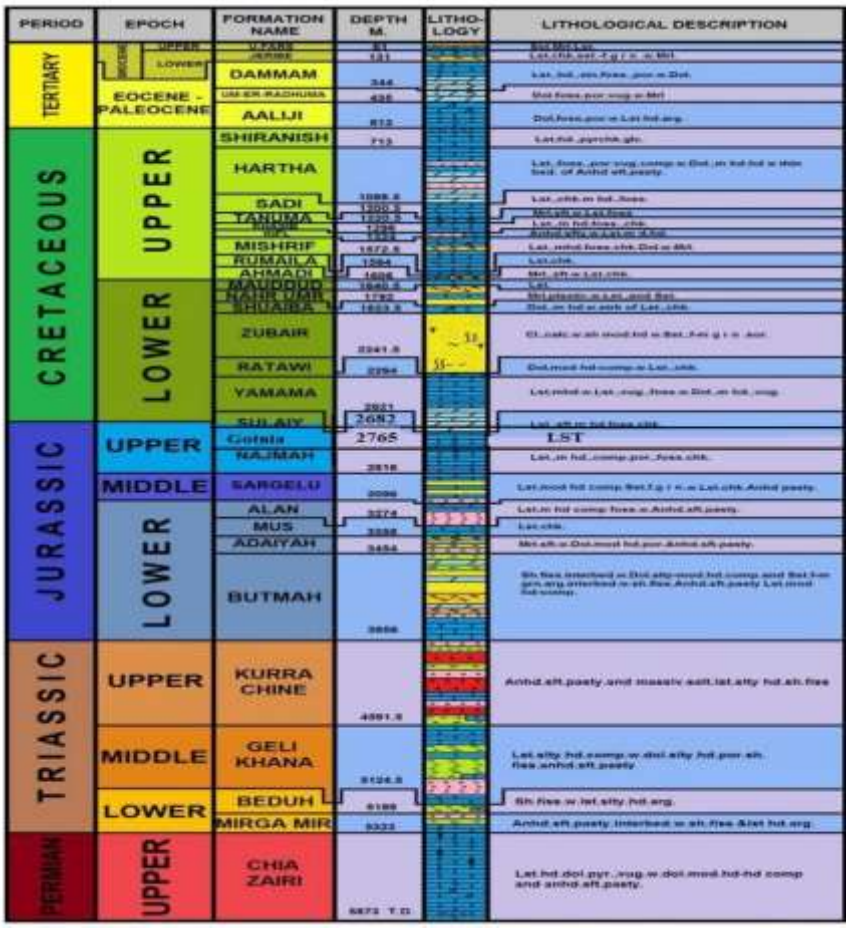

Figure 4- Stratigraphic section of Wk-1 well[8]

Materials and Methods

1. Database

Two types of data are required in the current study, including:

1. Well Data: including wellhead file which content (coordinates of well, Rotary Table Kelly Bushing (RTKB), total depths), well logs (sonic and density logs), well tops, and check-shot.
2. Seismic data: sets of two-dimensional seismic lines covering almost all the study areas according to the coordinates. These are:

a. (HA) The first seismic survey consists of 22 lines, which are HA36, HA44, HA50, HA18, HA25, HA27, HA29N, H31N, HA37P1, HA148, HA14b, HA15, HA16a, HA16B2, HA17, HA17N, HA160, HA166, HA186, HA188, HA250, Ha21.

b. (MZ) The third Survey consists of three lines, which are MZ-22P1, MZ-22P2, and MZ242.

c. (MD) The fourth Survey consists of one line (MD 8-Mig).

d. (C) Connection line survey is applied to connect well tops of Wk-1 to identify the reflector location in the study area, which are C1, C4, and C9 (Figure 7).

2. Interpretation Procedure

A structure interpretation of the top of the Zubair Formation includes the following:

1. Uploading Wk-1 well information, including well tops, check-shots, and well logs, including sonic and density logs, and loading 2D seismic lines.
2. Connecting seismic wells to the synthetic seismogram (Wk-1 well).
3. Identifying and selecting the reflectors of the top Zubair Formation.
4. Identifying and selecting the faults present within the Zubair Formation.

5. Preparing the TWT, Average Volocity, and depth maps to describe the structural condition of the Afaq area in the Zubair Formations.

The stratigraphy of stratigraphic phenomena has been explained by relying on seismic features as follows:

1. The first sequence (Zubair-Ratawi sequence) was determined as the top of this sequence is the top of the Zubair Formation, while the bottom is the top of the Yamama Formation.
2. The second sequence is determined as the top of the sequence is top of the Yamama Formation, and the sequence bottom is top of the Gotnia Formation

3. Base Map preparation

By using the Petrel software, the following information was loaded:

1. Well data includes wellhead files (well coordinates, RTKB, and total depths), well logs (sonic and density logs), well tops, and check-shot.
2. The 2D seismic lines (SEG-Y format), a collection of 2D seismic data, covered the whole study area according to the coordinates. After that, the map was drawn (Figure 5).

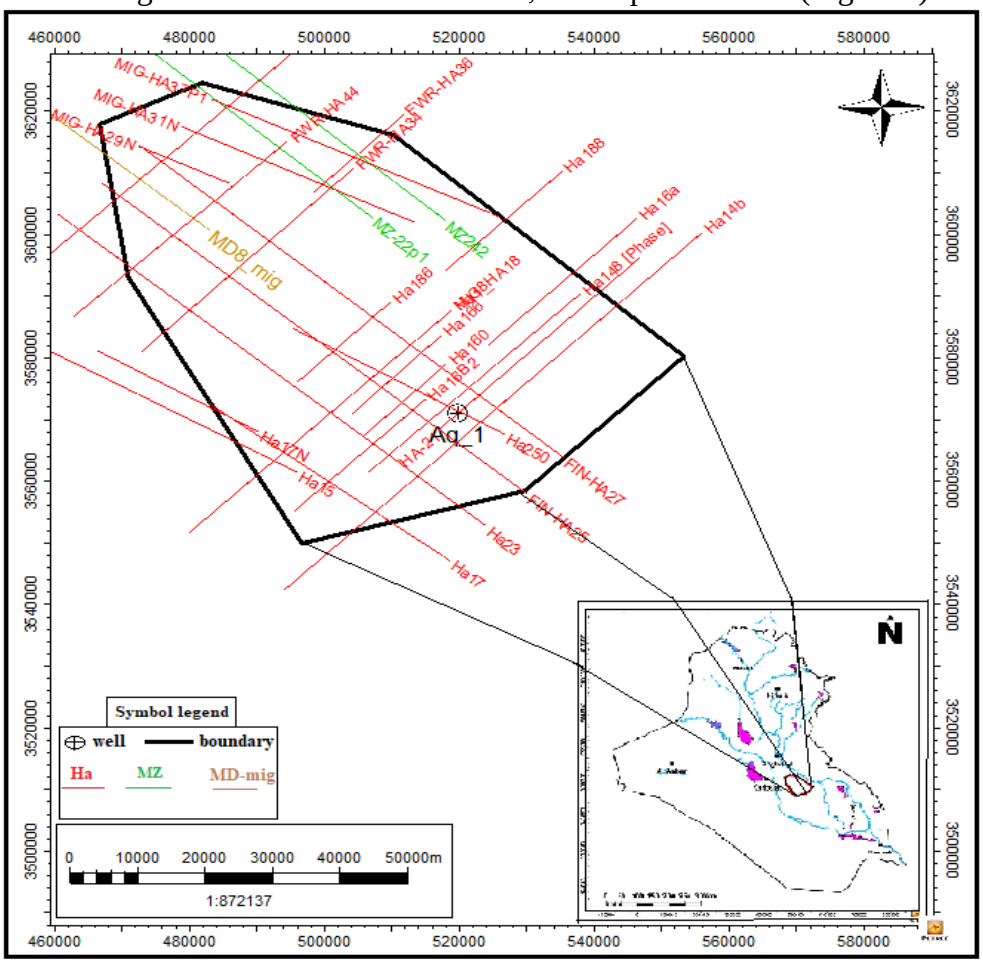

Figure 5- The base map of the study area.

4. Synthetic Generation of West Kifl -1 (wk-1) well

The initial step in this process is to calibrate the sonic log. The acoustic impedance (Z) and reflection coefficient (R.C) were determined using the calibrated sonic log multiplied by the density log as well as convoluting wavelet with reflection coefficient to construct or generate a synthetic seismogram in the second process[5]. In the Petrel program, several types of wavelets and extraction methods depend on the data type (Deterministic extended white wavelet was used). This type of wavelet is generated because it gives real values from the well where it generates Acoustic impedance and then performs the comparison with the well

and generates a real wave. Thus, a tie is made between the seismic traces and the synthetic seismogram of a process called well tie to determine and define the selected reflectors (Figure 6).

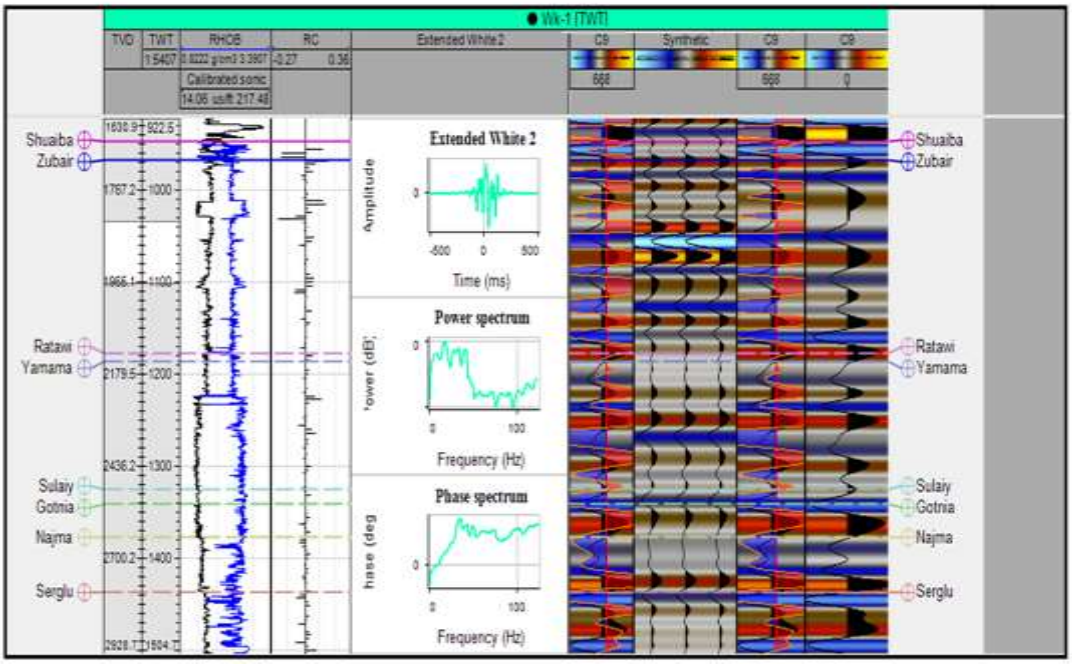

Figure 6-Synthetic seismogram of well Wk-1.

6. Composite Seismic line

Reliable two-way time maps are built by seismic sections, as seismic lines are connected according to the connection process called composite lines. Each reflector is then tracked with the composite illustrated in Figure 6.

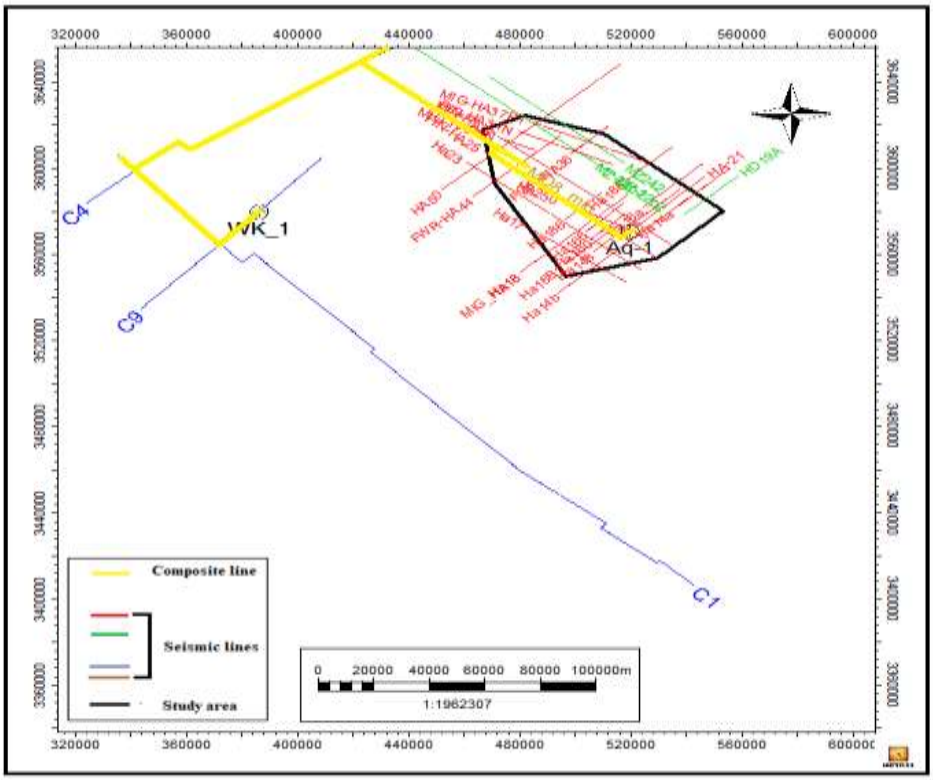

Figure 7-The Composite lines in the study area.

6. Description of the Picked Reflectors

In this study, three formations were selected, one for structure interpretation (Zubair Formation) and the other for stratarghrphic interpretation (Yamama and Gotnia Formation). The following is a brief explanation of each reflector used in this work. (Figure 8 displays the selected horizons and Afaq structure:

1. The wavelet's peak determined the top of Zubair in the seismic section with a time reaching 1700 msec; it is considered good reflector continuity in the study area.
2. The top of the Yamama Formation determined between troughs of the seismic wavelet with time reached to 2005msec has intermediate continuity.
3. The wavelet peak of time reaching 2250msec has determined the top of the Gotnia Formation as a good continuity.

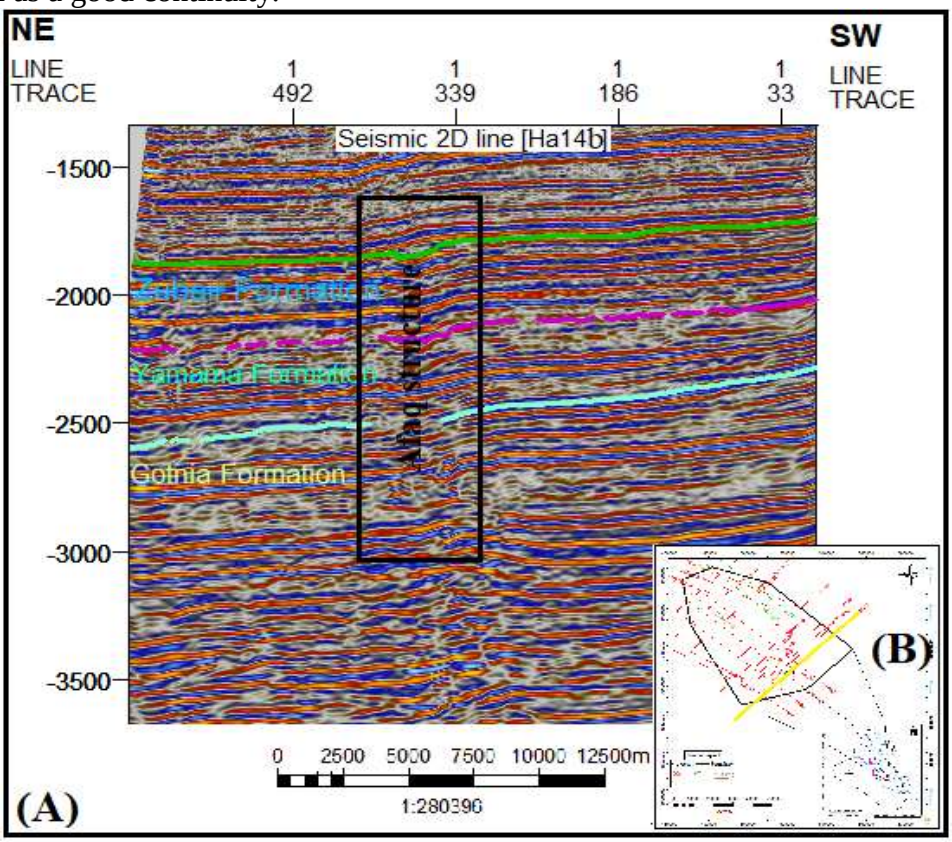

Figure 8-A- Part of the seismic line Ha14b showing formations top and Afaq structure B-base map shows the location of the line Ha14b marked by the yellow arrow.

Structural Mapping of the picked reflectors

1. Time Structural Maps (TWT).

The time structural maps of the top of Zubair show the lowest value of the time in the W and SW of the study area (Figure 7), while the highest value is in the E and NE. In TWT, the Afaq structure appears at the top Zubair map as a nose structure with an SW-NE direction with a length of about 30 km and a width of about 5 km. The study also revealed the presence of several secondary faults that affect a region within the Zubair formation, as shown in the TWT map in Figure 7. Faults in the studied sequences are affected by the reactivation of the striking faults mainly present in the base rocks. Their movement affected all the sedimentary sequences above them and formed inclined structures in the movement direction of these faults [9]. These fault types may be strike-slip faults that developed due to the reactivation of the transversal fault.

2. Average Velocity Maps

The average seismic velocity in the Zubair Formation increases toward the east and northeast direction and decreases toward the south and southwest direction (Figure 9).

3. Depth Structure maps

The depth map is calculated from a given reflector's time map with an average velocity map at the same reflector, as follows:

depth at any point = (velocity * one-way time) at this point [10].

The depth maps of the Zubair reflector demonstrate the deepest point is in the east and southeast direction, while the shallowest point is in the west and southwest direction (Figure 9). The Afaq structure appears like a nose structure with a small structural close of around 20 m on the top of the Zubair Formation's depth map, as it can be seen between -2750m and -3250m contour lines.

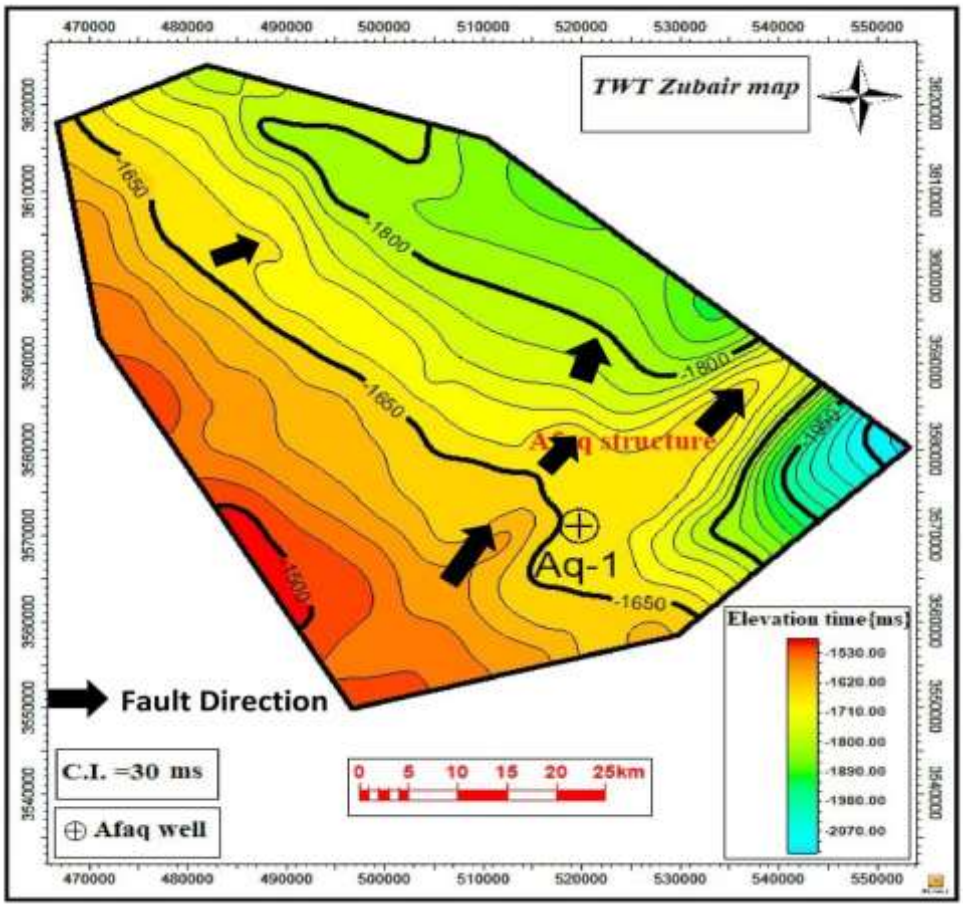

Figure 9-TWT map of the top of the Zubair Formation

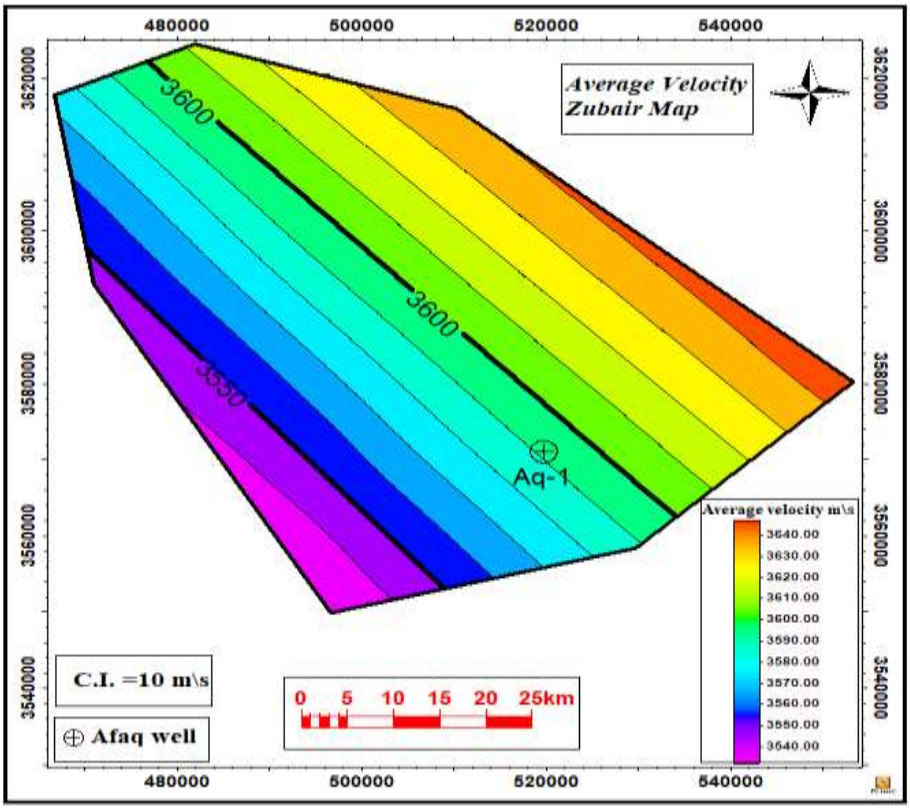

Figure 10-Average Velocity map of the Zubair Formation

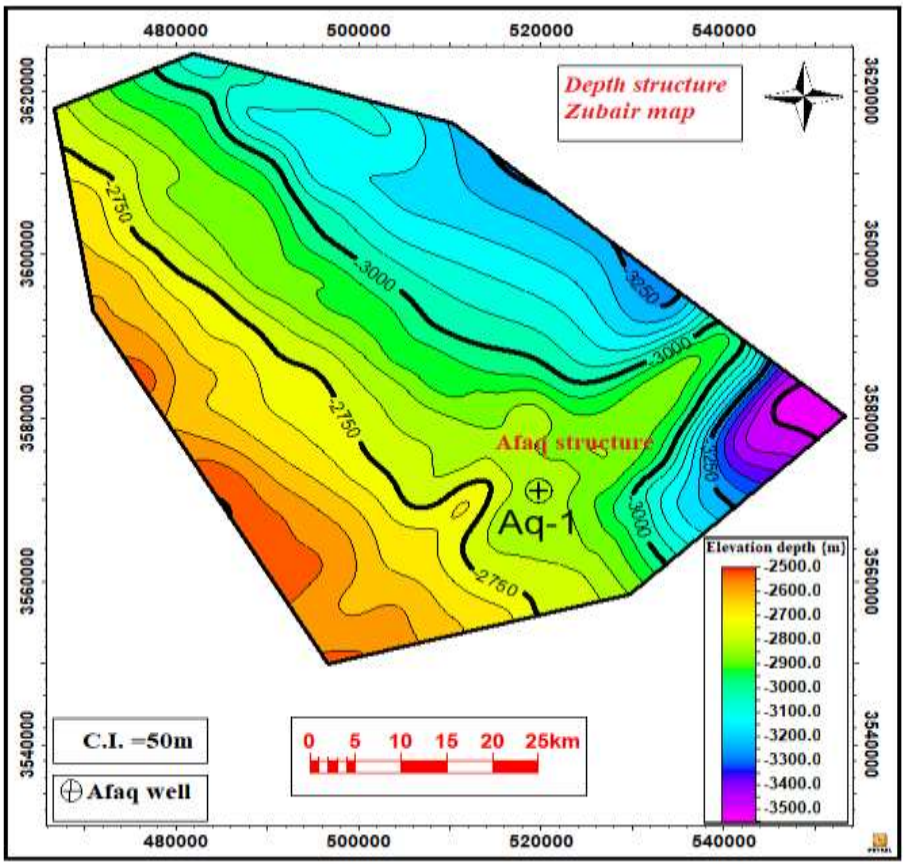

Figure 11- Depth map of the top of Zubair Formation

Stratigraphic phenomena

1. Build-up

A prominent topographic buildup is observed on the seismic reflection section of the Afaq structure area. Build-up can be defined as any carbonates composed mainly of fossil organisms, regardless of the rock body's shape or mode of origin [11].

The determination of buildups on a seismic section (Figure 12) identified using 11 a principal indication of buildup are the following:

The transition from a continuous-parallel reflection configuration to a discontinuous-reflection configuration of the seismic facies downdip the mounded configuration of the buildup and diffractions from the front of the buildup.

The buildup in the shelf margin needs many organisms in water, in calm places without strong currents, and in locations where the light and lower salt levels are reached. These conditions are ideal for organisms to form colonies, referred to as buildup. Figure 10 shows that Build up appears in Ratawi - Zubair and Sulaiy -Yamama sequences.

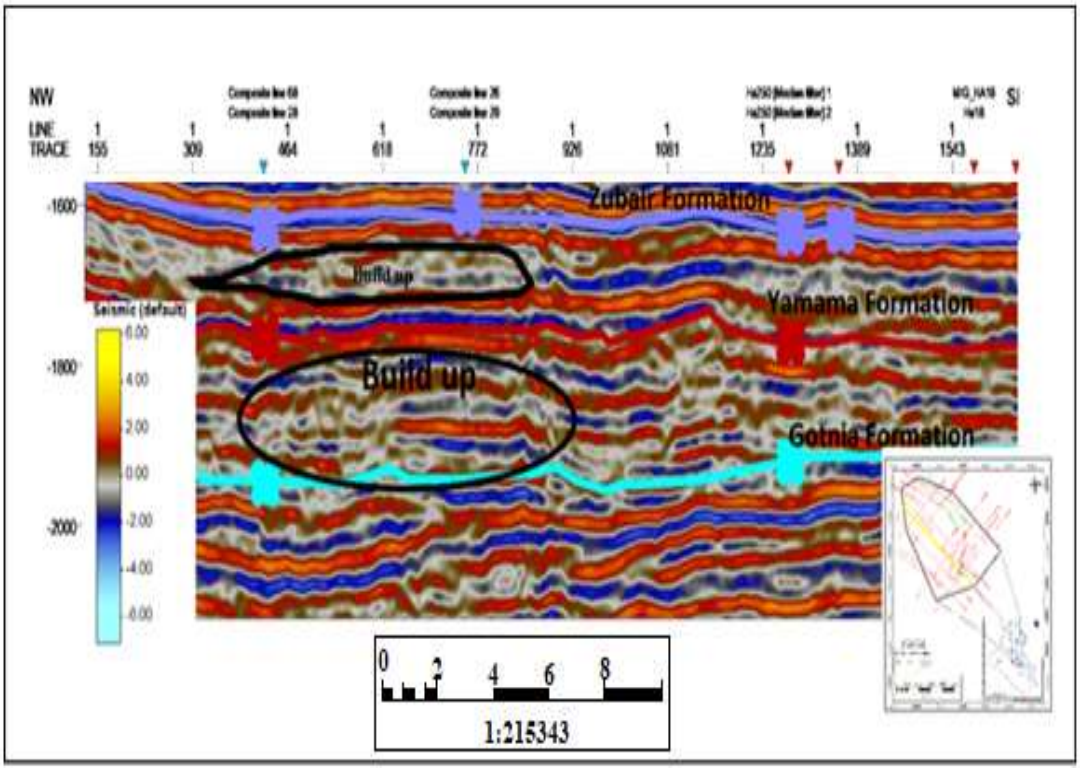

Figure 12-Stratigraphic features on the part of seismic line FIN HA25.

2. Stratigraphic Trap

Instantaneous phase attribute techniques on seismic line FIN Ha27 illustrate stratigraphy phonemes and observe a stratigraphic trap in the Sulaiy-Yamama sequence (Figure 13).

The presence of a difference in the Acoustic impedance and the nature of the reflection, and the closing of the peak reflector inside a trough all point to the presence of a trap in the seismic section. Because the location is inside the buildup, within the range that the light reaches and hence can develop coral colonies, this trap could be a Reef (stratigraphy reef trap). A stratigraphic trap is surrounded on one or more sides by zones of limited permeability and is associated with sediment deposition or erosion.

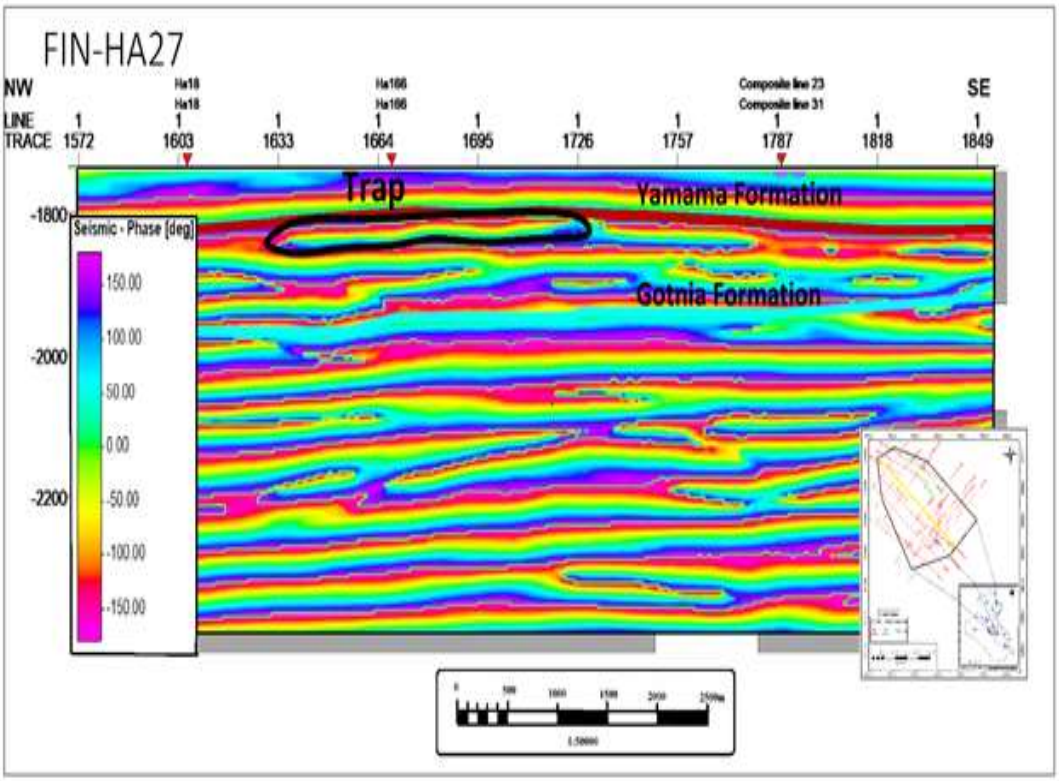

Figure 13-Instantaneous phase attribute of part seismic line FIN HA27.

Conclusions:

The study has concluded with these findings:

The structure interpretation of the Zubair Formation in the Afaq area was made by preparing three maps, TWT, average velocity and depth maps, and tracking pike the faults within the formation. From the above, the following points can be summarised:

a. The presence of numerous secondary faults with shorter and finite intervals, which are strike-slip faults, was formed as a result of the reactivation of the transversal fault system from the Late Jurassic onwards.

b. The TWT maps of the Zubair Formation demonstrated a higher value of TWT in the northeast and east, indicating that the reflector is slopping towards the area's northeast. The structure of the Afaq appears like a NE-SW nose structure in the Zubair Formation.

c. The Zubair Formation's depth maps show that the deepest region is in the E, suggesting that the Afaq structure is plunging to the E of the study area. The Afaq area is a monocline where the layer dips in one direction (one limb).

d. The average velocity of the Zubair Formation in the Afaq area increases in the NE and E.

e. Several stratigraphic phenomena in the study area helps understand the old sedimentary environment. It could have significant hydrocarbon potentials, including buildup and stratigraphic trap.

f. The buildup up in the Ratawi - Zubair and Sulaiy -Yamama sequences indicates a shallow environment in which the light easily reaches organisms that build colonies from carbonates which are an essential oil and gas sources in many sedimentary basins. Such sedimentary structures can be investigated as hydrocarbon reservoirs in the future.

a. Stratigraphic trap in Sulaiy -Yamama sequence indicator hydrocarbon accumulations.

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