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## 3D Seismic Reflection Study of Al-Akhadeir Area, Southwestern Iraq

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### Abstract

This study includes structural and stratigraphic interpretation of 3D seismic reflection data for Zubair Formation (L. Cretaceous) within Al-Akhadeir area, southwestern Iraq (Karbala Governorate). Depending on the 3D seismic reflection interpretation process, and based on the synthetic seismogram and well logs data, two horizons were identified and selected (top and base Zubair reflectors). These horizons were followed up over the entire area in order to obtain structural and stratigraphic settings. TWT, depth, and velocity maps for the base and top Zubair Formation were constructed. From the interpretation of these maps and based on the seismic section, the study concluded that there are some enclosures that represent anticline in the NW of the horizon and syncline in the NE, while the nose structure appears in the middle of the horizon and trends N-S. The horizon represents a progradational with sigmoid configuration.. Other seismic structural phenomena were recognized in this part of the area, such as flat spot, down lap, and top lap, which give indicators of potential hydrocarbon accumulations

**Keywords:** 3D Seismic; Reflection Al-Akhadeir Oilfield

### دراسة زلزالية انعكاسية لمنطقة الاخضر جنوب غرب العراق

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### الخلاصة :

تتضمن الدراسة تفسير تركيبى طباقى معلومات المسح الزلزالي ثلاثي الابعاد لتكوين الزبير (الطباشيري الاسفل) في منطقة الاخضر الواقعة جنوب غرب العراق (محافظة كربلاء) بالاعتماد على تفسيرالمعلومات الزلزالية ثلاثية الابعاد وباستخدام الاتار الزلزالية المصنعة ومعلومات مجسات الابار وتم تعريف عاكسين هما عاكسا اعلى واسفل تكوين الزبير وتم متابعتها على مستوى المنطقة لمعرفة الوضع التركيبى والطباقى للمنطقة . تم رسم خرائط زمنية، خرائط عمقية وخرائط سرعة لاعلى وأسفل تكوين الزبير. تفسير تلك الخرائط اعتمادا على تفسير المقطع الزلزالي وخلصت الدراسة الى وجود بعض الانغلاقات مثل طية محدبة في شمال غرب منطقة الدراسة و طية مقعرة شمال شرق المنطقة بينما خشم تركيبى وسط نطاق الزبير يتجه شمال-جنوب. وتبين ان نطاق الزبير يمثل سحنة تقدمية بشكل (sigmoid). كما تم تمييز بعض الظواهر الزلزالية الطباقية الاخرى مثل (flatspot) و (down lap) و (top lap) والتي تعطي شواهد على تجمعات نفطية محتملة في هذه الاماكن.

## Introduction

Seismic interpretation is the final stage of any seismic exploration project. The two preceding stages are data acquisition and processing, which includes generating reflected waves which are then processed to obtain the stacked seismic sections. These seismic data are integrated with the geological information in order to acquire structural and stratigraphic images of the subsurface geology [1].

This study involved the interpretation of 3D-seismic reflection survey which covered an area of 2024 Km<sup>2</sup> located in the west of Iraq within Karbala province (west of Euphrates River) (Figure-1). Al-Akhadeir area is located within the NE slope of the African-Arabian shelf which is located within the stable platform (within Salman zone), according to the tectonic map of Iraq (Figure-1) [2, 3]. AL-Akhadeir area is greatly influenced by the movement of the Arabian plate to N and NE directions during multiple geologic times, which separated the Arabian shelf from the dipped Mesopotamia sediment. Two parallel fault directions are identified; the first one is to the NW-SE direction (Abu-jir), whereas the second is to the NE-SW.

The Zubair Formation was introduced by Glynn Tones in 1948 from Zubair oil field and amended by Nasr and Hudson in 1953 [4]. It is the most important formation of the Lower Cretaceous sequence in Iraq [5]. The thickness of the formation comprises 380-400 m of alternating shale; siltstone and sandstone reach their thickest depocenter at the boundary of Salman and Mesopotamian zones [3]. Whereas toward the west and northwest, the thickness is restricted roughly to 200 m. To the SW, the proportion of shale in the formation rapidly decreases. The Zubair Formation is assumed to represent a progradational delta originating from the Arabian Shield [6]. Bellen *et al.* [4] assigned a Hauterivian to Early Aptian age to the formation, while [3] suggested Barremian till Early Aptian, on the basis of both fossils and regional correlation [3]. On the west side of Mesopotamian zone and Salman zone, the Zubair Formation passes laterally into Ratawi and Yamama formations [7].

Towards the west, in Salman Zone, the lower boundary is unconformable and the Zubair Formation represents the lowermost unit of the Thamama Group. The upper boundary with the overlying Albian sequence in the Salman Zone is unconformable.

The exploration well of Al-Akhadeir-2 (EK-2) was drilled in 1979 in the studied area; the drilling reached 1859m depth. The drilling result showed oil in many geological formations, the most important of which was in Zubair Formation. A survey of this well in 1954-1975 showed no oil indication.

In 1980 - 1982, the American oil company, Mobil, studied the area and showed the presence of oil in Zubair Formation due to stratigraphic traps [8]. The seismic data were reinterpreted by the Iraqi Oil Exploration Company (OEC) [9] and the results indicated enclosures at Zubair Formation level.

During the last decade, many seismic studies were achieved to plot the stratigraphic and structural images of subsurface geology of different oilfields in Iraq. They concluded that the seismic reflection method provides a good evidence of oil accumulation and contributes to understanding the subsurface geology [10-16].

The current study is the first attempt to interpret the 3D seismic reflection survey of Al-Akhadeir area. The aim of the study is to identify the structural and stratigraphic pictures of Zubair Formation in Al-Akhadeir area.

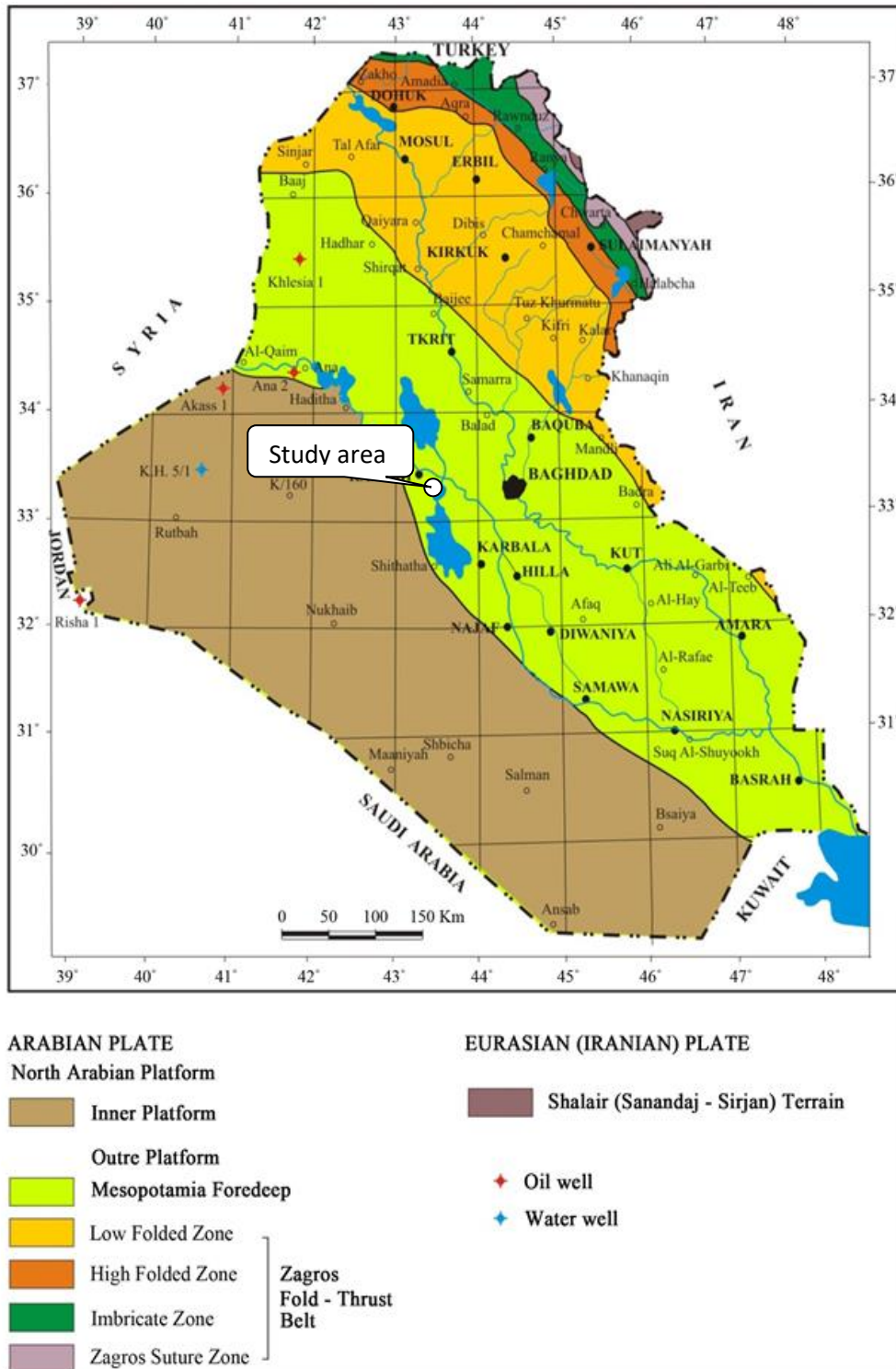


Figure 1- Tectonic map showing the study area is located within the stable platform [2].

**Acquisition and processing of data**

The 3D seismic reflection survey of Al-Akhadeir area used a specific design that ensures ease of execution with good quality of recorded data. Before the execution of the 3D survey, the pre-planning report of Al-Akhadeir area was prepared. A 3D symmetrical split spread with the vibrators source model Nomad 65 was achieved by the OEC in 2017 [17]. The survey in Al-Akhadeir area covered an area of 2042 Km<sup>2</sup>.

The data was processed by the OEC, the Iraqi Ministry of Oil, using OMEGA SPS version 2015.1 software. Noise attenuation process leads to a progress in the reflection continuity and an enhanced

ability to calculate seismic attributes. The main steps in processing include editing, deconvolution, pre-stack analysis, muting, and gain recovery.

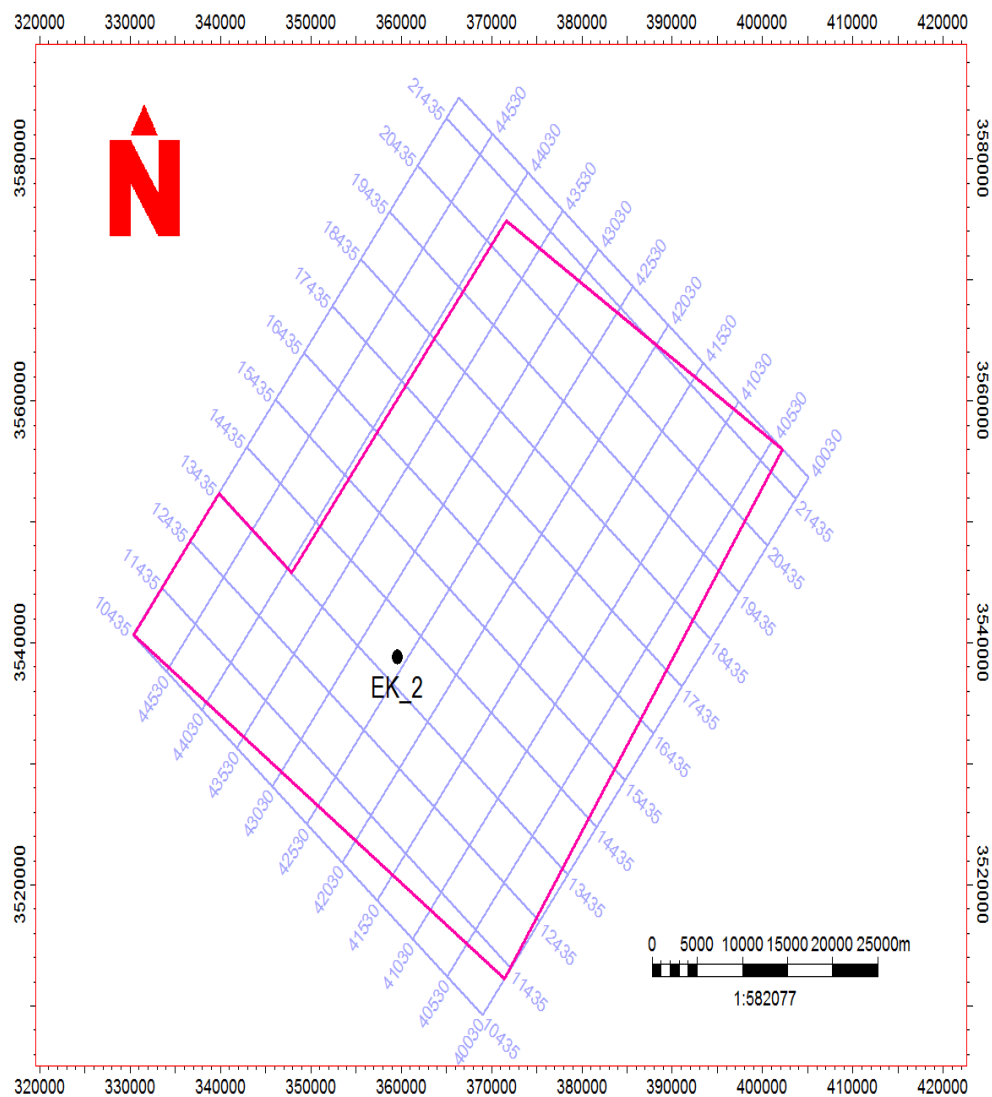
**Interpretation of data and discussion**

3D seismic surveys data of the EK-2, collected by the OEC, were interpreted by using the seismic program of petrel, through the following approaches:

- 1- Preparing time, velocity, and depth maps to explain the structural pattern elevation and identify the stratigraphic picture from Zubair Formation by using available 3D seismic data.
- 2- Applying seismic attributes (instantaneous phase, acoustic impedance, and alternative gain control (AGC) to investigate the hydrocarbon indicators within Zubair Formation.
- 3- Structural interpretation works.

**Base map preparation**

The base map of the study area was constructed by using seismic data which were loaded in an interactive workstation of interpretation in a SEG-Y format. Two types of perpendicular lines were assigned, termed as inline and cross line. Figure-2 shows the base map of the study area.



**Figure 2-** The base map of the study area showing seismic lines and location of well Akhadier-2 (EK.2).

**Generation of synthetic seismograms**

The main step of the generation of synthetic seismograms is computing the acoustic impedance, which was achieved based on the following equation:

$$z = \rho \times v$$

where  $v$  is seismic velocity and  $\rho$  is density measured from density log. The reflection coefficients of the incident wave are computed on the reflector separating two series of time intervals, (i) and (i+1), that have values of acoustic impedance denoted by  $(\rho_i, v_i)$  and  $(\rho_{i+1}, v_{i+1})$ , respectively. According to an earlier study [18], the reflection coefficients could be calculated as follows:

$$R = [(\rho_{i+1})(v_{i+1}) - \rho_i v_i] / [(\rho_{i+1})(v_{i+1}) + \rho_i v_i]$$

where  $(\rho_i, \rho_{i+1})$  is the density at the interval (i), (i+1), whereas  $(v_i, v_{i+1})$  is the velocity at the interval (i), (i+1), respectively. The convolution process between the reflection coefficients and the experimentally selected wavelet is made to obtain the synthetic seismogram.

The traverse seismic sections passing through the well location and synthetic traces of reflectors are displayed in Figure-3.

The picked reflectors' wavelets appeared as peaks and troughs on the synthetic trace (peak in the top and trough in the base of Zubair Formation).

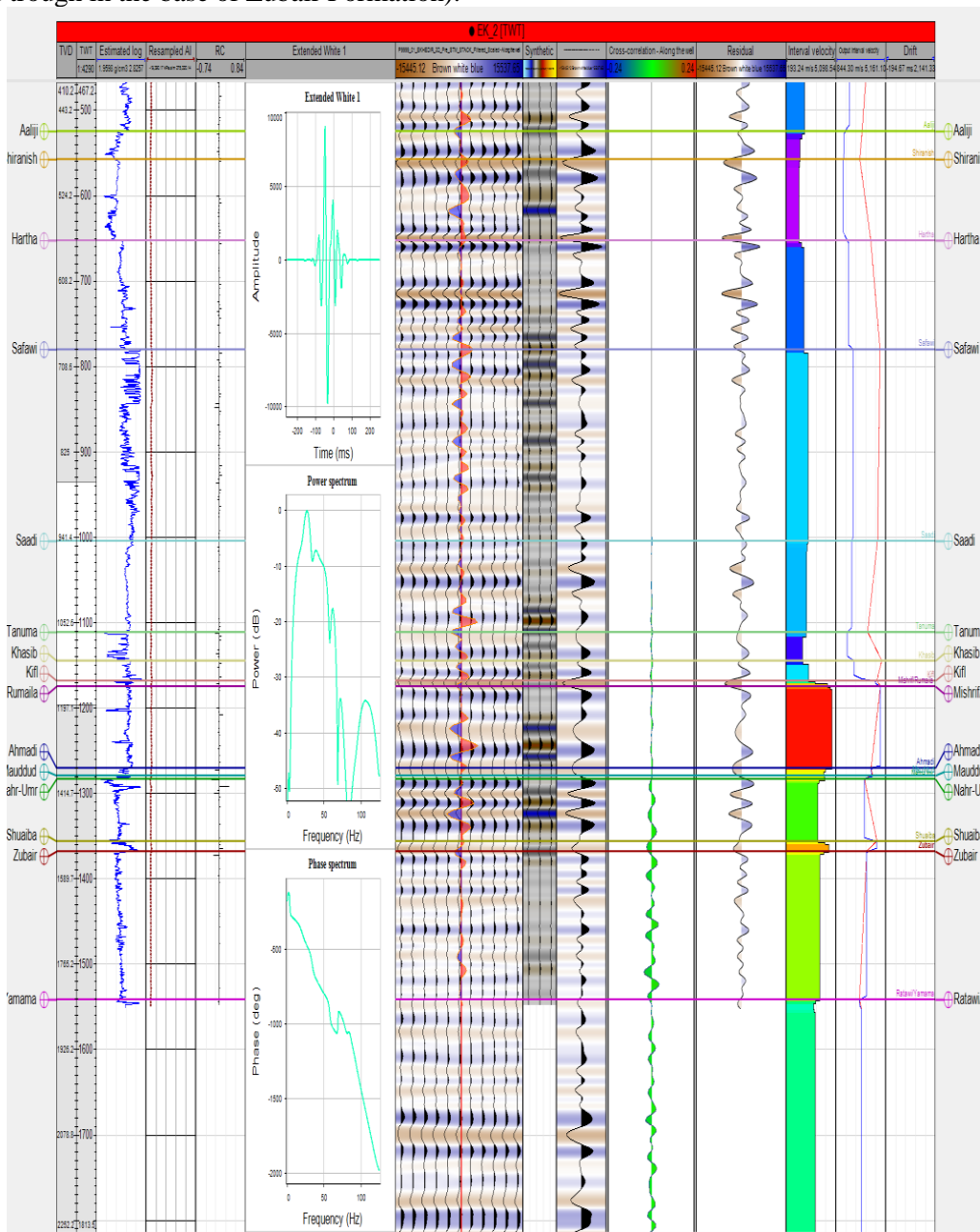


Figure 3- The synthetic seismogram of EK\_2.

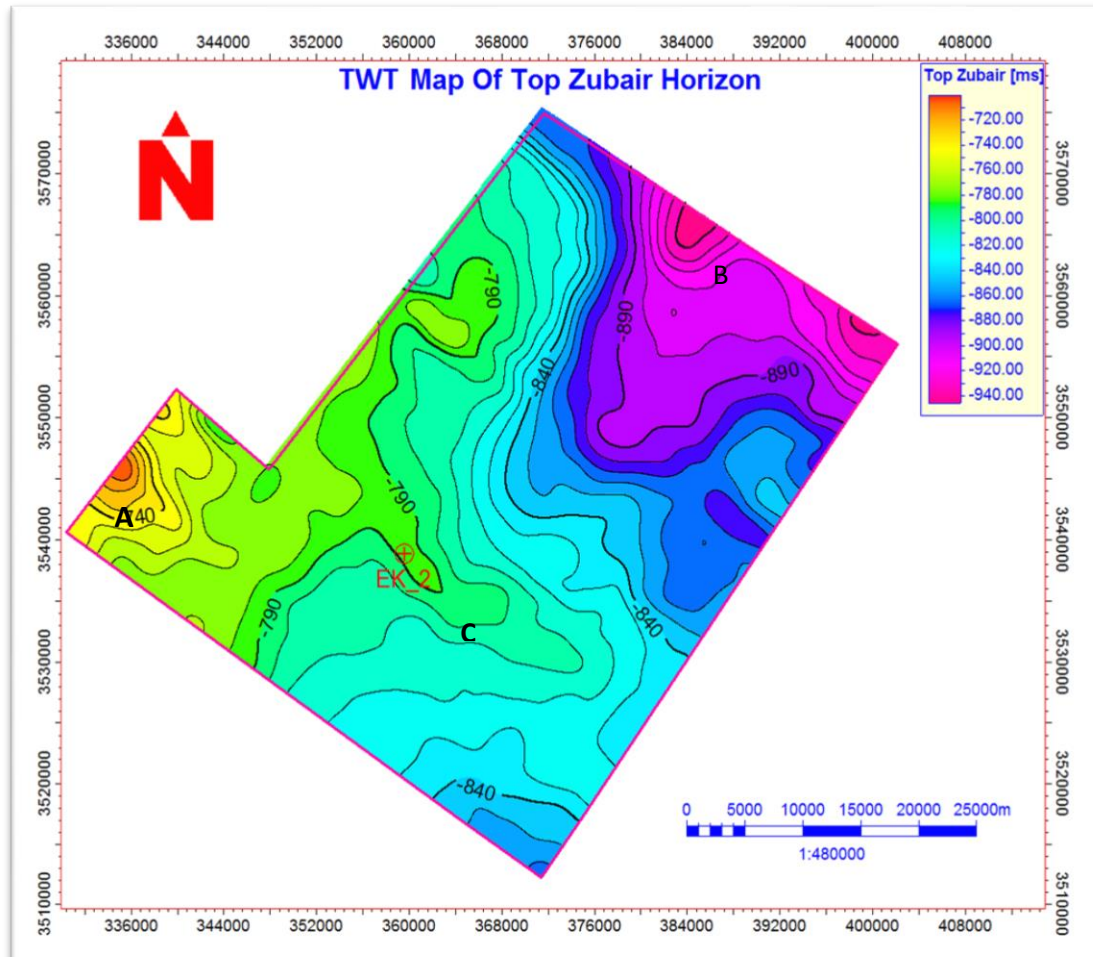


## Structural images of the picked horizons

### Two-way time maps

#### Top of Zubair TWT Map

Two-way time (TWT) map of the top Zubair (Figure- 4) shows that the higher value of TWT is towards the NE direction and decreases in the W and NW directions of the area. The map indicates many enclosures, named A (represents anticline), B (syncline), and C (nose). The TWT value to the center of the anticline (A) is about 720 ms while it reaches to 940 ms at the center of the syncline (B). In the central part of the area, the nose is trending to the SE, as given in (C), and the well EK-2 is near this area.



**Figure 4-** Two-way time (TWT) map of the Top of Zubair in the study area.

#### TWT Map of the Base of Zubair

The TWT map of the Base Zubair presents a higher value of TWT in the NE, which indicates that the slope of the reflector is towards the NE. The value of TWT in the W and NW directions is about 880 ms, while it reaches to 1200 ms in the NE, as shown in Figure-5. The anticline (A), the syncline (B), and the nose structure (C) are still existent at the base of the Zubair. Another anticline (D) to the south of anticline (A) appears at the west of the base Zubair reflector.

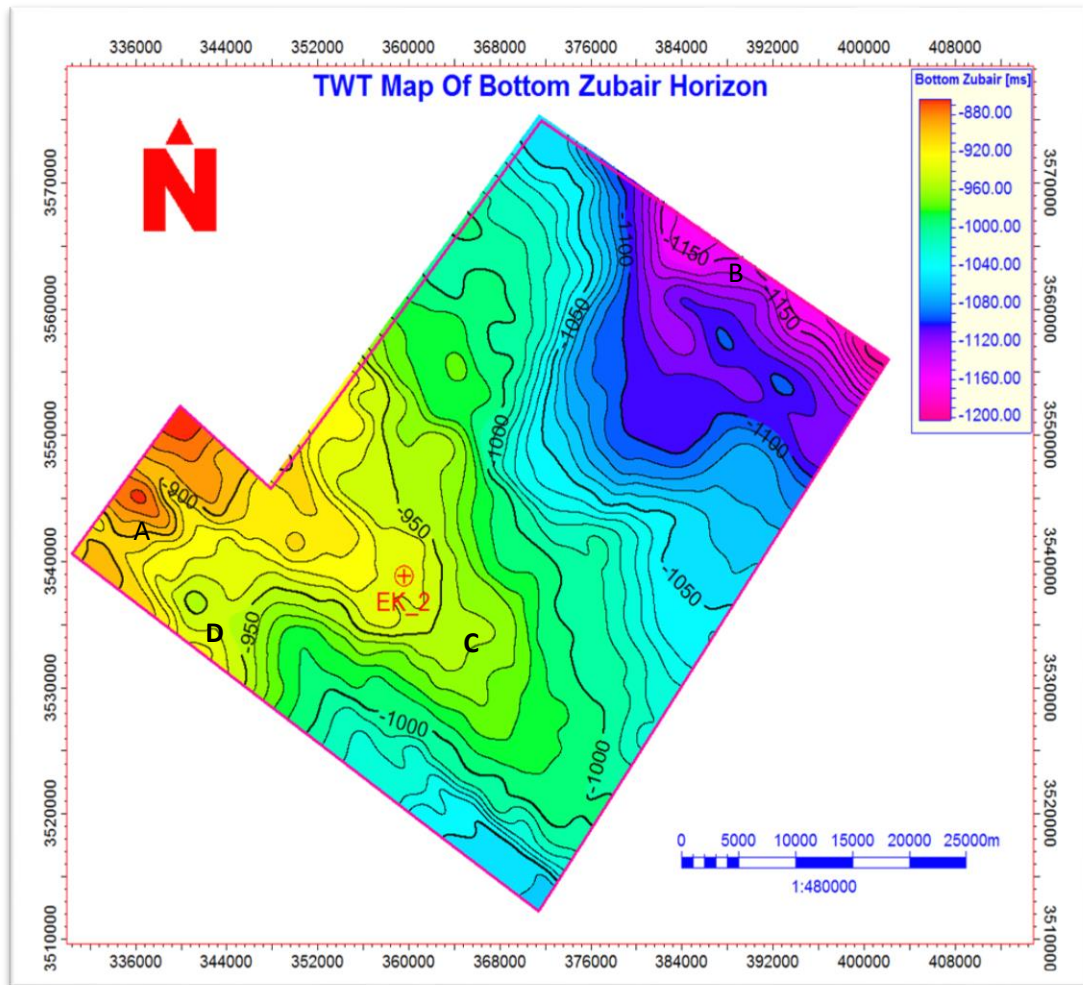


Figure 5- Two-way time (TWT) map of base of Zubair Formation in the study area.

**Velocity maps**

**Top of Zubair velocity maps**

Figure-6 shows that the velocity value increases toward the NW direction and decreases toward the NE and S directions, while the contour interval is 10m/s.

**Base of Zubair velocity map**

Figure-7 shows that the velocity value increases toward the NW direction and decreases toward the S and NE directions, while the contour interval is 10m/s.

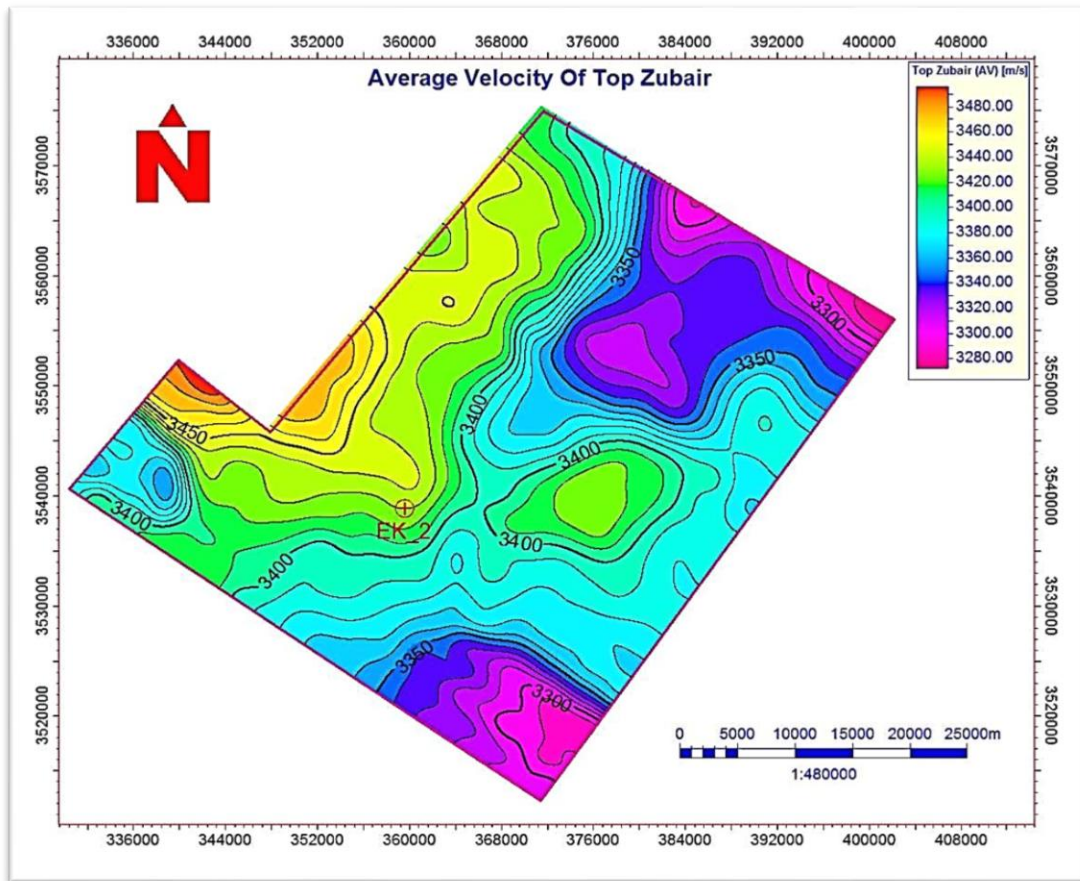


Figure 6- Velocity map of top of Zubair in the study area.

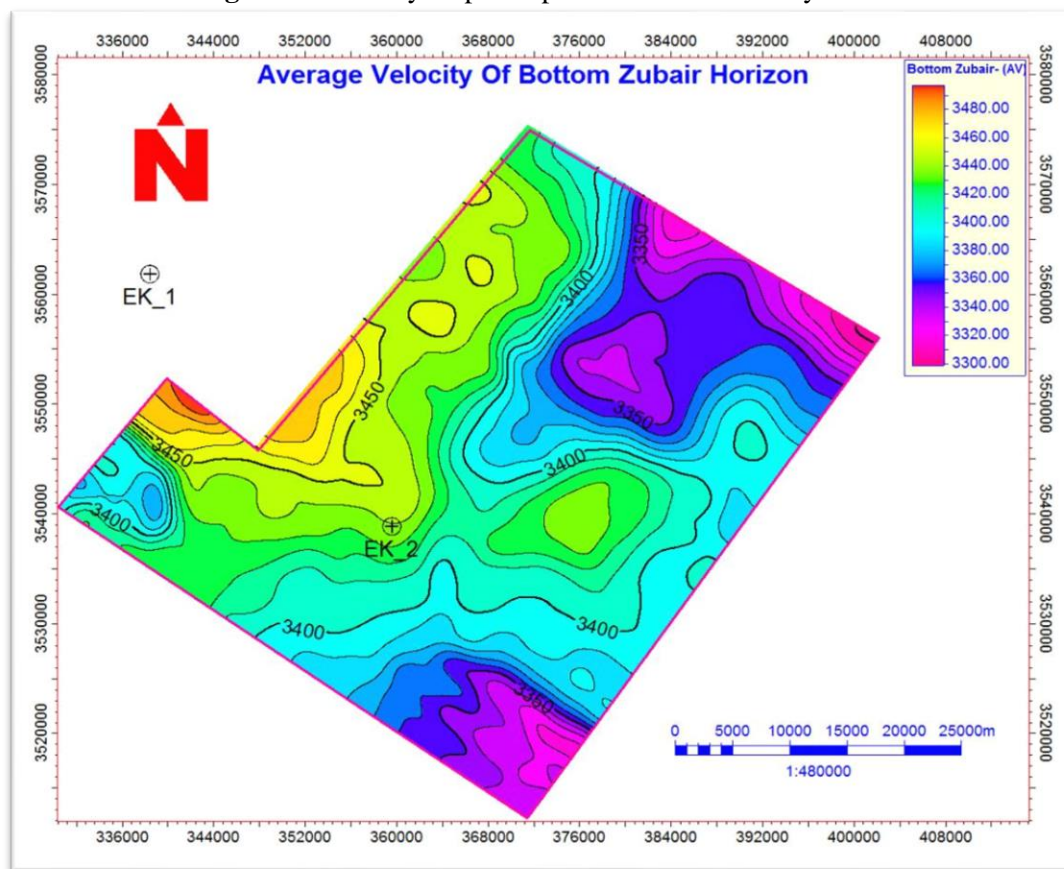


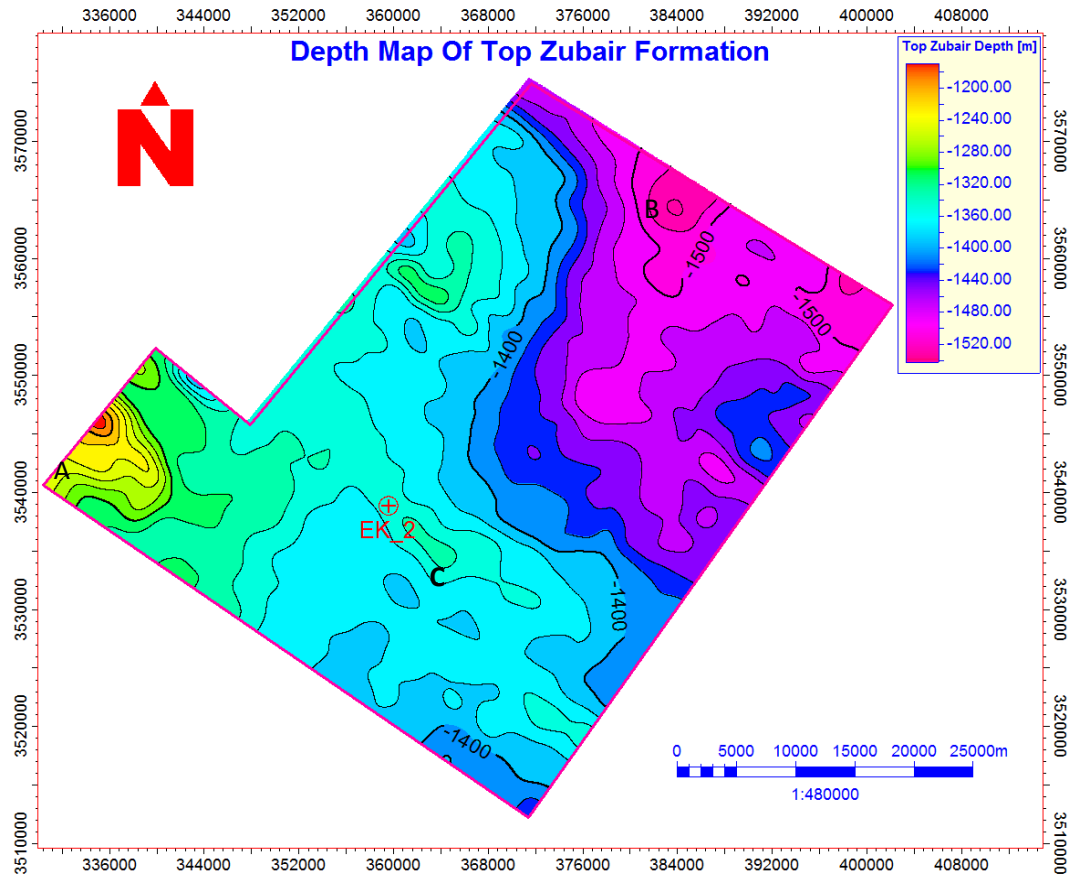
Figure 7- Velocity map of base of Zubair in the study area.



**Depth maps**

**Depth map of top Zubair**

The higher area appears in the west and is about 1880 m in depth, which represents the anticline (A). There is a syncline structure (B) in the NE of the study area and a nose structure (C) in the middle of the area, trending NW-SE (Figure-8).



**Figure 8-** Depth map of top of Zubair in the study area. (C.I=20m).

**Depth map of base Zubair**

The depth reached to 1975 m in the E direction and decreased to 1500 m in the W direction of the study area. Figure- 9 shows the anticline structure (A) in the W of the area and the synclinal structure (B) in the NE area, those are the same structure features which appear in the top Zubair reflector. There is a nose structure (C) trending SE in the study area and a closure structure (D) in the SW of the study area.

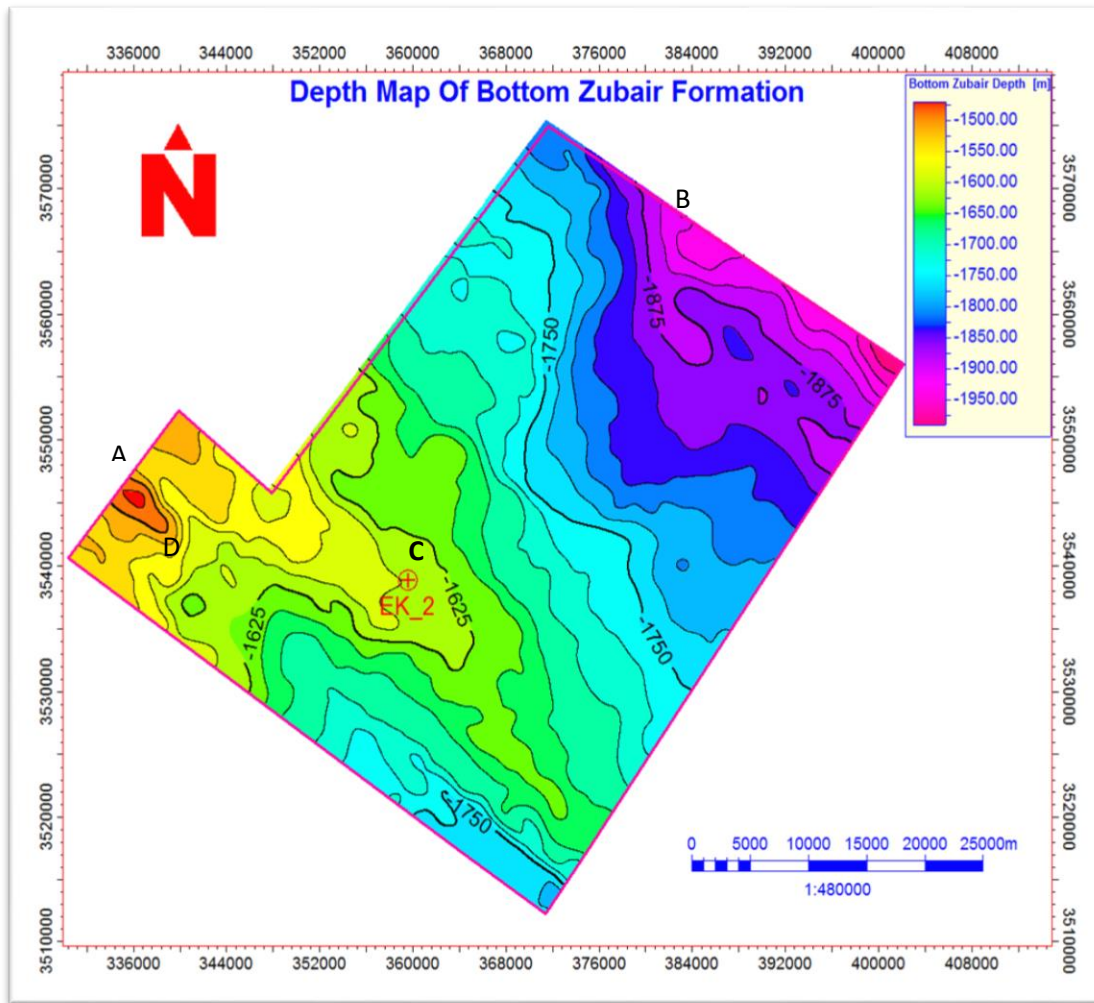
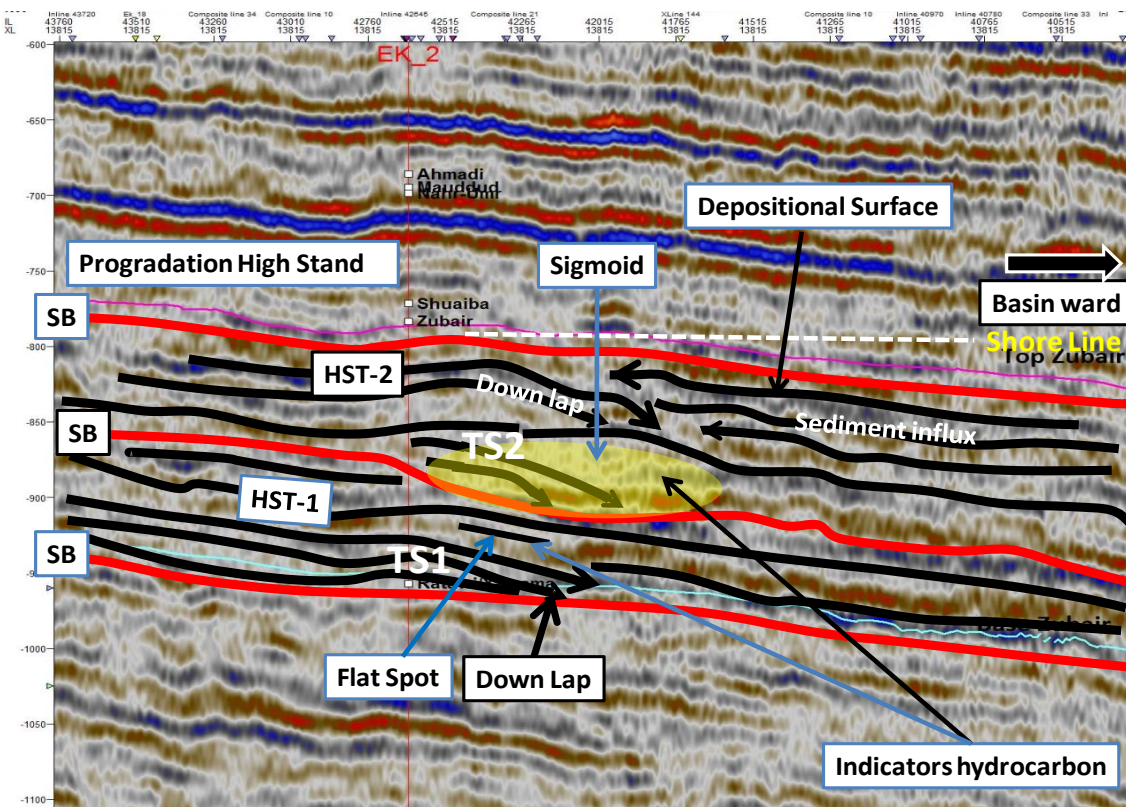


Figure 9- Depth map of base of Zubair in the study area (C.I= 25m).

**Stratigraphic Interpretation**

Seismic stratigraphy aims to enhance the understanding of the depositional environments by attempting to interpret seismic data supported by the geological information. This includes understanding the types of traps, accumulation of hydrocarbons, system of migrations, etc. All these information and details of the subsurface are the aim of the seismic section interpretation [19].

The type of reflection configuration within the Zubair reflectors is progradational, with fundamental type of sigmoid configuration. Figure-10 illustrates the sigmoid formed through the progradation high stand (HST), which is deposited during some parts of a relative sea level rise cycle.



**Figure 10-** Seismic section shows the flat spot, downlap, and sigmoid (inline 43760).

The structural and stratigraphic pictures of the studied horizon (Zubair Formation) could be described as follows; the strata units are mainly horizontal with some stratigraphy and structure phenomena. There are some enclosures represented by an anticline in the NW of the horizon and a syncline in the NE, while the nose structure appears in the middle of the horizon and trends N-S (Figures-(4, 5, 8, 9))

Stratigraphically, some indications suggest a depositional channel which represents the trend of sediment influx from the basin toward the continental shelf, whereas others pattern from the HST to the margin of the shelf insulating of sigmoid within the transgression stand tract deposited on the surface boundaries (SB) within the Zubair Formation.

Two high-stand tracts were recognized in the left side of the horizon as well as two transgression stand tracts in the middle which represents the delta front environment of the Zubair Formation. It is ended by the sea level rise and deposition of Shuaiba Formation which represents a marine environment [3]. The nose structure in the seismic structure map appears in this part of the study area.

This part of the horizon could be described as having hydrocarbon indicators. Other phenomena could be shown in this part, such as flatspot, down lap, and top lap, which give indicators of potential hydrocarbon accumulations (Figure-10). The final picture of the horizon in this area could be described as a structure-stratigraphic reservoir.

**Conclusions** the study concludes the following

1. Two reflectors of top and base Zubair Formation were defined by using synthetic seismogram in the time domain for well EK-2. Zubair wavelet appeared as peak /trough due to the difference in reflection coefficient.

2. The TWT, average velocity, and depth maps were used to interpret the structure and stratigraphy pictures of Zubair horizon. The TWT maps demonstrated a higher value of TWT in the NE, which indicates that the reflector is sloping towards the NE of the area. Also, the TWT maps show closure structures (anticline and syncline) in NW and NE and a nose structure in the middle of the area. The structural features seem to be parallel to the boundary between Iranian and Arabian plates, which is caused by their collision.

3. Velocity values increase toward the NW direction of Zubair Formation, according to the velocity maps. These maps of the studied Zubair reflectors have velocities that ranged between 3280-3500 m/s.
4. The depth maps of the studied horizon showed the structural configuration of Al-Akhadeir area. Depth maps illustrated that the depth increases gradually from W and NW toward the NE and E.
5. The seismic section shows that the Zubair Formation represents clastic facies with a delta front environment that is represented by two transgressed stand system tracts (TST). The presence of fluvial channels refers to the end of this stage. This case is repeated again in the upper part of Zubair Formation which is represented by HST and ended by the rise of the sea level. The Shuaiba Formation began to be deposited in this stage as carbonate rocks, which represents marine environment. Facies of Zubair Formation have progradational configuration (sigmoid) subjected to truncation erosion of the stream onlap surface of the carbonate platform.
6. The middle part of the Zubair Formation, which is labeled as sigmoid in the seismic section, may represent good hydrocarbon indicators.

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