2D Seismic Structural Interpretation of Yamama Formation in Al-Fao Area, Basrah, Iraq

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Abstract
A structural study was conducted in Al-Fao area, southeastern Iraq using two-dimensional seismic data. The seismic lines were divided into three surveys (F, Kl, and Sa). Al-Fao is an exploratory area that does not contain any wells; the well information was based on Siba field, located north of the study area. The primary reservoir target in the lower Cretaceous was Yamama Formation. Two reflectors, top and base Yamama Formation are defined using synthetic seismogram in the time domain for Sb well. A top Yamama Formation was defined as Z-crossing, and a base Yamama Formation as S-crossing. The results showed that the strata tended to slope from the south and southwest to the north and northeast, and the area was affected by multiple structural orogenies. Siba field is an elongated fold whose axis extends northeast-southwest; it consists of a structural nose and northeastern dome. The Two-Way Travel Time map showed higher values in the southeast and east, indicating sloping reflectors in those directions. The depth maps of Yamama Formation showed the deepest part in the southeast and east, suggesting a plunging structure in those directions. The study also revealed the presence of numerous closures as structural noses, which could serve as potential structural traps.

Keywords: 2D Seismic; Yamama Formation; Cretaceous; Siba Field; Al-Fao

1. Introduction
The reflection method has been the most successful seismic method for identifying subsurface geologic conditions suitable for the accumulation of oil and gas (Al-Sinawi, 1981). Seismic data provides information about the elastic contrasts at the interface between adjacent layers in the subsurface. The continuity of reflections indicates geologic structure; various reflections indicate stratigraphy, fluids, and reservoir material (Grana, 2013). It is essential to understand the subsurface geology to identify the locations of oil and gas accumulations, and this includes mapping the subsurface structure to detect structures that could trap oil and gas or faults that might block oil flow in a production field (Bacon et al., 2003). The interpretation of seismic data is the final step of a seismic exploration investigation; hence, the accuracy of earlier work affects the accuracy of the interpretation stage (Telford et al., 1990). The interpretation sequence is a series of processes that carry out an interpretation in a form similar to that typically used to process seismic data. The four significant steps of the typical sequence are reflecting identification, computations of the isochron map, velocity map, and depth map (Al-Sadi, 2017). Previous geological studies dealt with Yamama Formation in terms of the type of

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stratigraphic sequences, the vertical and horizontal sedimentation of the components of the sedimentary basin, and the factors that controlled the formation of this basin. Yamama Formation in Siba Field is composed mainly of limestone with some areas of dolomite. Overall, the formation is considered clean because there is a low volume of shale present in Siba wells (Ali et al., 2021). In the southern Fields of Iraq, Yamama Formation has several main limestone facies, including mudstone, mudstone-wackestone, wackestone-packstone, packstone-grainstone, and grainstone (Al-Iessa and Zhang, 2023). According to Al-Shahwan's (2002) research on the lower Cretaceous reservoirs in southern Iraq, Yamama Formation is a good source rock in the mature oil zone. Yamama basin is a stable flank on the carbonate platform characterized as a ramp setting. The ramp setting impacts the stacking patterns of Yamama Formation (Idan et al., 2020). The current study aims to interpret 2D seismic data and well data (P-sonic and Density logs) from Siba field to gain insight into the subsurface structure of Yamama Formation in Al-Fao area for the possibility of structural traps for drilling wells.

2. Location of the Study Area

The study area is located in the southeastern part of Iraq, in Basrah Governorate, along the Iraqi-Iranian border, approximately 20 km from Basra city. Table 1 shows the coordinates of the study area according to the Universal Transverse Mercator system (U.T.M., WGS-84, zone-38). Shatt Al-Arab penetrates the area from the northwest towards the southeast, and it is surrounded from the west by Khor-Abdullah and from the south by the Arabian Gulf. Al-Fao is an exploratory area that does not contain any wells, so the well information was based on Siba field, located in the north of the study area. The study area was about 1900 km² (Fig. 1). It is characterized by straightforward surface terrain whose height does not exceed 3-4 meters above sea level. The study area is located within a compatible sedimentary basin without interruption in deposition, and there is an increase in the thickness of the rock layers. Deposited formations in the Cambrian-Permian and Lower Cretaceous periods are the thickest in the area, in addition to the presence of the (Infracambrian) rocks in the basin above the basement rocks (Aqrawi et al., 2010) (Fig. 2).

Table 1. The study area's boundaries' coordinates

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<thead>
<tr>
<th>Point</th>
<th>X (Eastern)</th>
<th>Y (Northern)</th>
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<tr>
<td>N</td>
<td>785449</td>
<td>3326121</td>
</tr>
</tbody>
</table>
Fig. 1. Location map for the study area

Fig. 2. Map of Iraq shows the locations of geological cross-sections (1-15), with the study area shows in cross-section 1 (modified after Aqrawi et al., 2010)

3. Geology of the Study Area

Yamama Formation (one of the Thamama Group) is related to the Late Berriasian–Valanginian Sequence (Douban and Medhadi, 1999; Abdulla and Kinghorn, 1996). It was initially identified as outcrops in Saudi Arabia (Khorshid and Salman, 2014). "Yamama-Sulaiby" Formation was referred to as a 257 m interval in borehole Ratawi-1 by Bellen et al. in 1959. The upper 203 m, which is currently referred to as Yamama Formation, is composed of 191 m of micritic limestone and oolitic limestone,
which is topped by 12 m of specular and brown detrital limestone with thin shale beds (Jassim and Goff, 2006) (Fig. 3). One of the primary Lower Cretaceous carbonate-promising reservoirs is Yamama Formation, which is located in southern Iraq's Mesopotamian Basin. In the southeast of Iraq, it can be up to 360 m thick (Jassim and Goff, 2006).

Deposits Yamama platform were represented intrashelf basins of the Arabian Plate with New-Tethys Sea beginning in the first sequences of the Early Cretaceous (Mohsin et al., 2022). Yamama Formation consists of three deposition sequences lasting 2 to 3 million years. These sequences are made up of parasequences that show highly developed cyclicity over a range of a few to ten meters (Alhakeem et al., 2019). According to Jassim and Goff (2006), the study area is located in Basra Block (Fig. 4), which is affected by Pre-Cambrian transversal faults. The shape and pattern of current structures are heavily influenced by the late stage of the Alpine Orogeny, indicating that traps began to form in the Early Cretaceous period due to compressional forces caused by Arabian plate subduction (Jafar, 2010), here Oilfields are located along narrow, elongated anticlines (Jassim and Goff, 2006).

4. Materials and Methods

The research began with acquiring well data, 2D seismic data from F, Kl, and Sa surveys, and various logs, including P-Sonic and Density. The 2D seismic lines and Sb well are shown in the base map of the study area (Fig. 5). Seismic data is presented in SEG-Y format, whereas well logs data is presented in LAS and ASCII formats. In the subsequent stage, the collected data was combined, analyzed, and interpreted to better understand the geological features of the research area. The principal methodology consists of well log analysis, which involves correlating the well with seismic data by creating a synthetic seismogram and matching the synthetic seismogram with the seismic sections.
(seismic well tie), which means converting the measuring of data wells (density log and sonic log) from depth units to time units. The first step to create a synthetic seismogram is sonic calibration; this is done by entering the checkshot time and the sonic log for Sb well to ensure consistency and accuracy; this involves aligning the well data with the seismic data in terms of depth or time and correcting for any depth or time shifts.

![Fig. 4. Tectonic map of Iraq shows the location of the study area within the transversal blocks and faults system of Iraq (modified after Jassim and Goff, 2006)](image)

The second step is constructing the synthetic, which is done by computing the acoustic impedance (AI) log using the density and sonic velocities data, calculating the reflection coefficient (Rc) at each interface between contrasting velocities using the resulting AI curve, and creating a reflection series in
time. This series is convolved with a wavelet to create the synthetic, representing the expected seismic response at each well location. The wavelet must filter broadband reflectivity to tie the well to the seismic data, and the earth’s transmission response must be considered while estimating the wavelet (White and Simm, 2003). The matching method estimates the wavelet through a coherency matching technique. The results of this procedure gave several outputs that effectively defined whether the tie was good or not. Fig. 6, shows the final results of synthetic seismogram generation.

![Fig 6. Synthetic seismogram for Sb well](image)

Fig. 6. Synthetic seismogram for Sb well

![Fig 7. Horizon picking for top and base Yamama Formation in composite seismic line in the study area](image)

Fig. 7. Horizon picking for top and base Yamama Formation in composite seismic line in the study area

With this information, a conventional seismic interpretation was performed and integrated well and seismic data to identify the best-defining interest reflectors. The top Yamama reflector was defined as Z-crossing, and a base Yamama reflector as S-crossing depending on synthetic seismogram for Sb well, as illustrated in (Fig. 7). Finally, two-way time, average velocity, and depth maps were created to identify the subsurface structure of Yamama Formation. The workflow was visualized in Petrel software, as shown in (Fig. 8).
5. Results and Discussions

5.1. Two-Way Travel Time (TWT) Maps

The picked reflection values are regularly placed onto the seismic lines to create the TWT map, which expresses the structural behavior of the reflector. All seismic data is initially recorded in the time domain, which is the time recorded for the transmission of the wave, its reflection from a reflector in the subsurface, and then its return to the receiver (TWT). Two TWT maps are created for the top and base of Yamama Formation with a contour interval of 10 ms (Fig. 9). Sea level is used as a datum plane for all maps. In general, the TWT maps showed the same structural image.

The general trend of the study area is towards the northeast. The time of the TWT map of top Yamama Formation ranges from (1870 to 2319) ms with unequal closures, representing a structural nose and northeast dome of the Siba field. Siba field is an elongated fold whose axis extends in a northeast-southwest direction. The time of the TWT map of base Yamama Formation ranges from (2144 to 2524) ms and shows closure (A) south of siba dome. The closure (A) dimensions are (length: 5 km, width: 2 km, and TWT: 5 ms). Fig. 10 shows the closures previously mentioned as they appear in seismic sections in the time domain.

![Fig. 9. Time structure maps (TWT) with contour interval (10 ms) (a) top Yamama (b) base Yamama](image-url)
Fig.10. (a)TWT map of Yamama Formation, along with the seismic lines, (b) the location of Dome in Siba field at the composite seismic line sa12 and sa13, (c) the location of structural nose at Kl 18b seismic line, and (d) the location of closure A at the composite seismic line f4 and Kl-14

5.2. Velocity Maps

From the velocity model, average velocity maps were extracted for the top and base Yamama Formation(Fig. 11). The contour interval was set at 5 m/s. Both maps revealed a gradual increase in velocity values from the northeast to the southwest. The average velocity for the top Yamama Formation ranges from (3658 to 3778) m/s, while the average velocity for the base Yamama Formation ranges from (3662 to 3811) m/s.

Fig. 11. Average velocity map with contour interval 5m/s (a) top Yamama (b) base Yamama
5.3. Depth Maps

Based on the information provided, the depth map plays a crucial role in identifying the subsurface structures in terms of depth. The use of TWT map and smoothed average velocity map resulted in the creation of two depth maps that showed the top and base of Yamama Formation with a contour interval of 20 m. The maps were presented as true vertical depth (TVD) (Fig. 12). The structural image of the depth maps was similar to the TWT maps due to the uniformity of the utilized velocities that were equivalent to the depths. However, the depth maps showcased increased structural closures, which helped to reveal the distinctions between the two maps. Closure (B) appeared as an extension of the structural nose in the Siba Field, and it was located in Al-Fao area, as per the depth map of the base Yamama Formation. The depth of top Yamama Formation ranges from (3438 to 4300) m, and the depth of base Yamama Formation ranges from (3622 to 4621) m. Table 2 provided an overview of the dimensions of the closures that were visible in the depth maps.

Fig. 12. Depth maps with contour interval 20 m (a) top Yamama (b) base Yamama

<table>
<thead>
<tr>
<th>Formation</th>
<th>Closure ID</th>
<th>Length (Km)</th>
<th>Width (Km)</th>
<th>Closure (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Yamama</td>
<td>Structural nose</td>
<td>3</td>
<td>2.5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Structural nose</td>
<td>6</td>
<td>3.5</td>
<td>35</td>
</tr>
<tr>
<td>Base Yamama</td>
<td>Closure A</td>
<td>3</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Closure B</td>
<td>2.5</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

6. Conclusions

In this study, the aim was to interpret the seismic lines from the two-dimensional surveys previously conducted in Al-Fao area to get an image of the subsurface structure of Yamama Formation, southeastern Iraq. The general tendency of the strata was from the south and southwest to the north and northeast. The study area was affected by multiple structural orogenies, including the Nabita orogeny, whose effects can be seen in Al-Fao area and which is equivalent to the direction of the structures of the fields in southern Iraq, which is north-south, followed by the Najd, Herycnian, and Alpine orogenies, which gave the study area its current structural shape.

The TWT map showed a higher value in the southeast and east of the study area, which means that the reflectors are sloping in the mentioned directions. Additionally, the depth maps of Yamama Formation showed that the most deep part is in the southeast and east, which indicates that the structure is plunging in the mentioned directions. Also the presence of numerous closures as structural noses in the study area were observed, which indicates the possibility that they are structural traps.
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References