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## Interpretation of 3D Seismic Reflection Data to Reveal Stratigraphic Setting of the Reservoir of Mishrif Formation in Dujaila Oil Field, Southeast of Iraq

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### Abstract

This research is an attempt to solve the ambiguity associated with the stratigraphic setting of the main reservoir (late Cretaceous) of Mishrif Formation in Dujaila oil field. This was achieved by studying a 3D seismic reflection post-stack data for an area of 602.62 Km<sup>2</sup> in Maysan Governorate, southeast of Iraq. Seismic analysis of the true amplitude reflections, time maps, and 3D depositional models showed a sufficient seismic evidence that the Mishrif Formation produces oil from a stratigraphic trap of isolated reef carbonate buildups that were grown on the shelf edge of the carbonate platform, located in the area around the productive well Dujaila-1. The low-frequency attribute illustrated that it is restricted in the area around the productive well Dujaila-1, which confirmed the existence of reef porous carbonate buildups and hydrocarbon accumulation in this region. The pay zone of the reef mound trap extends for about 7 km from the well Dujaila-1 toward the southwest side and 4 km toward the well Dujaila-2, without reaching it, which is explaining why it was dry. Therefore, this area to the south of the productive well Dujaila-1 represents a good area for low-risk drilling. Consequently, the hydrocarbon system observed in the Dujaila oil field provides a new opportunity to explore and produce oil in Mishrif Formation in other areas on the flank of the productive structures and in flat areas situated on the belt of the carbonate platform edge.

**Keywords:** 3D-Seismic reflection, seismic reef buildups, 3D- seismic deposition model, Frequency attribute, Mishrif Formation.

تفسير بيانات الانعكاس الزلزالي ثلاثي الأبعاد لكشف الوضع الطبقي لخزان تكوين مشرف في حقل نفط الدجيلية ، جنوب شرق العراق

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### الخلاصة

الهدف من هذا البحث هو محاولة حل الغموض المرتبط بالوضع الطبقي لتكوين مشرف ( العصر الطباشيري المتأخر) الخزان الرئيسي في حقل نفط الدجيلية ، من خلال دراسة البيانات الزلزالية ما بعد التكند ثلاثية الأبعاد لمساحة 602.62 كم<sup>2</sup> في محافظة ميسان، جنوب شرق العراق. يظهر التحليل الزلزالي لأقسام

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انعكاس السعة الحقيقية ، والخرائط الزمنية ، ونماذج الترسيب ثلاثي الأبعاد أن تكوين مشرف ينتج النفط من مصيدة طبقية تتكون من تراكم كربونات الشعاب المرجانية تقع في المنطقة حول البئر المنتجة دجيلة-1، والتي نمت على حافة الرف لمنصة الكربونات. أظهرت خاصية التردد الأني أن التردد المنخفض محصور في المنطقة المحيطة ببئر الدجيلة-1، وهذا يؤكد وجود كربونات مسامية لتراكم الشعاب المرجانية مع تراكم الهيدروكربونات في هذه المنطقة . تمتد منطقة دفع مصيدة تل الشعاب المرجانية على بعد حوالي 7 كم من بئر الدجيلة-1 باتجاه الجانب الجنوبي الغربي و4 كم باتجاه بئر الدجيلة-2 ، ولم تصل إليها وهذا ما يفسر سبب جفافها. لذلك ، تمثل هذه المنطقة الواقعة جنوب البئر المنتجة الدجيلة-1 منطقة جيدة للحفر منخفض المخاطر. وبالتالي ، فإن نظام الهيدروكربونات المستكشف في حقل نفط الدجيلة يوفر فرصة جديدة لاستكشاف وإنتاج النفط في تكوين مشرف في المناطق الواقعة على جانب التراكيب المنتجة وفي المناطق المسطحة التي تقع على حزام حافة منصة الكربونات.

## Introduction

This study is an interpretation of 3D-seismic reflection post-stack time migrated data integrated with the wells data in Dujaila oil field, which is an untapped field to yet. The 3D seismic survey was carried out in 2010 covering an area of about 602.62 km<sup>2</sup> at Dujaila field in Maysan province, southeast of Iraq. The Iraqi Oil Exploration Company (OEC) implemented the seismic data acquisition and processing. Their teams utilized a specific design to ensure ease of execution with a high-quality resolution of the recorded seismic data [1]. The total number of inlines (receiver lines) was 94 with 300 m interval distance, and the total number of crosslines (shot-lines) was 73 with an interval distance of 300 m and a bin size of 25 m x 25 m.

Based on the results of previous 2D-seismic reflection works, the two exploratory wells were drilled in the study area, where they penetrated the Mishrif Formation. The first well is Dujaila-1 (Du-1) that was drilled in 1960 to reach a depth of 4124 m. It produced oil from the upper part of Mishrif Formation. While the second well is Dujaila-2 (Du-2), located 7 km away to the northwest of the well Dujaila-1. It was drilled in 1981 at a depth of 4589 m, over the crest of folded (anticline) structural trap, as was reported previously [2]. It is a dry well, despite being structurally about 26 m higher than the well Dujaila-1 [3].

Several previous geophysical and geological studies have been conducted on the Mishrif Formation, the main reservoir in the Dujaila oil field, by the Iraqi Oil Exploration Company and other researchers [4,5,6]. These contributed to understanding the geological and structural setting of the study area and identification of reservoir characteristics.

Our task in this study is to reveal the clear image of the reservoir architecture of Mishrif Formation and the type of the hydrocarbon trap, its size, extension and safe drilling location, besides explaining why the well Dujaila-2 is dry.

## Location of the study area

The study area (Dujaila oil field) is located in the southeastern part of Iraq in the Maysan Governorate about 50 Km to NW of Amara city and about 250 Km to the south of the capital Baghdad, as seen in Figure-1. The study area is generally a flat terrain, covered by Holocene deposits within the Quaternary Period, and characterized by flood plain deposits and swamp deposits [7]. Its surrounding area contains many buried structures, which mostly produce oil from Mishrif Formation, such as Abu Ghirab, Ahdab, Amara, Buzurgan, Abo Aamod, Jabel Fauqi, Gharraf, Hawaiza, and others [8], as illustrated in Figure-1.

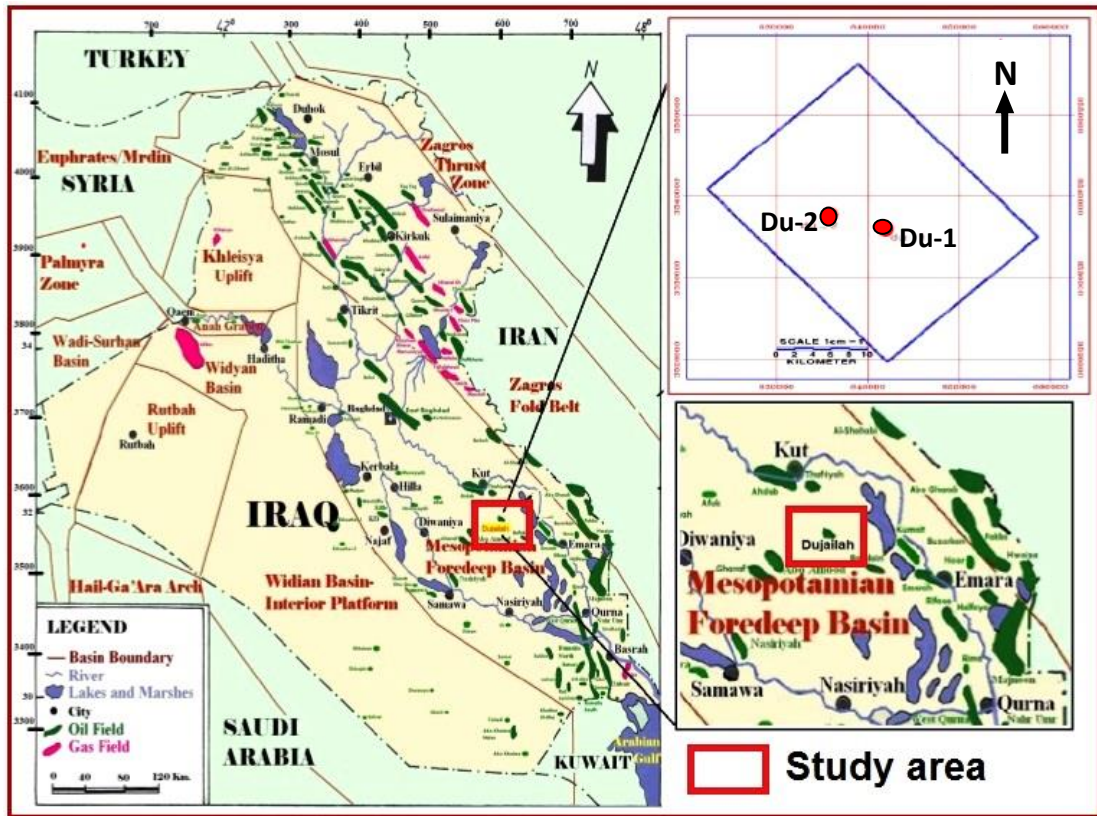


Figure 1- The location map of the study area on the tectonic map of Iraq, after Al-Ameri *et al.* [8].

**Structure and Tectonic Setting of the Study Area**

Structurally, the study area lies in the unstable zone of the Mesopotamian foredeep basin of the Arabian plate [9]. It is surrounded by many oil fields producing the hydrocarbons from large anticline structures extended in NW-SE trend, which is generally consistent with the trend of the Zagros folded axis [8], as shown in Figure-1. The relative influence of tectonic events and relative changes in sea level made the architecture heterogeneity of the depositional sequences and are affecting the facies of Mishrif Formation positively. This is resulting in the growth of the bio zone of Rudist on carbonate platform, as well as on the post-depositional processes of cementation, dolomitization and dissolution [9,10].

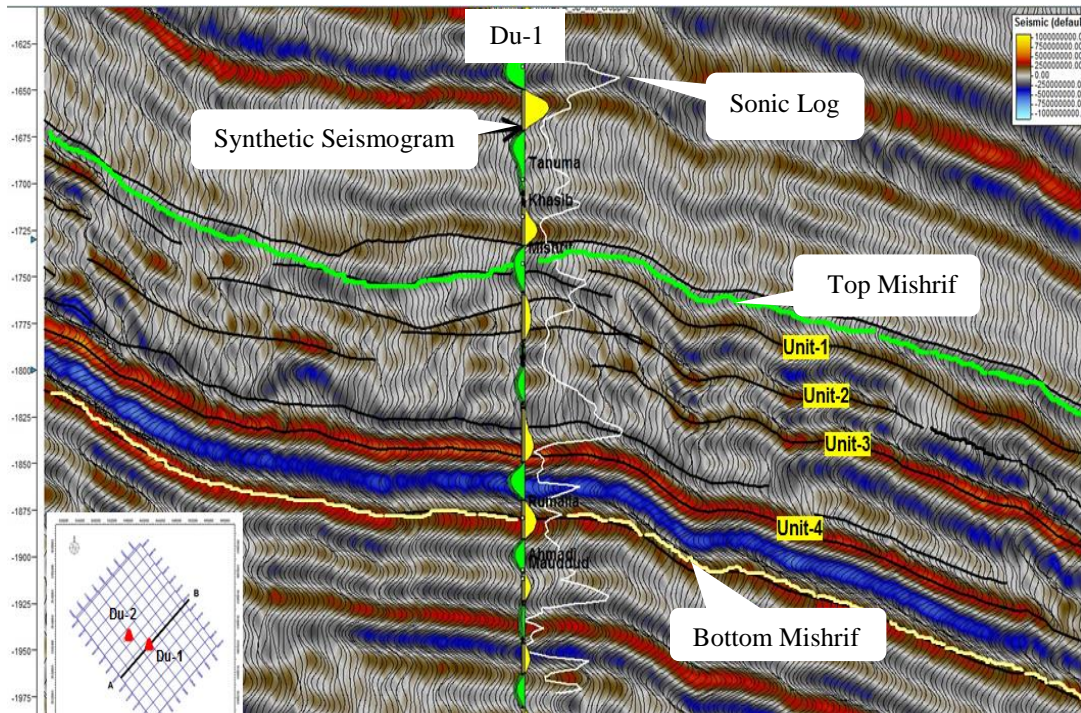
**Mishrif Formation**

The late Cretaceous (Cenomanian-Early Turonian) Mishrif carbonate Formation represents a heterogeneous carbonate succession containing different carbonate facies deposited in the various marine environments [7,9]. The reefal facies is dominant on Mishrif facies and consist of vast congregations Rudist shells forming extensive biostromes. These congregations exist in a more localized pattern (do not continue in all wells) and form the patch reef interbedded with related bioclastic, having a primary porosity which makes it one of the best locations for hydrocarbon accumulation [10]. Mishrif Formation is composed of two major sedimentary cycles abruptly terminated by the unconformity. The lower contact of the formation is conformable with the underlying Rumaila Formation, whereas the upper contact is uncomfortable with Khasib Formation [7, 9]. The thickness of Mishrif in the study area is about 300 m, but in general, it decreases in the west side to 250 m and increases to 400 m in the east, at Buzurgan oil field which lies on the Iraq-Iran border [10].

**Identification and picking of the main reflectors of Mishrif Formation**

The Top Mishrif was picked in the trough of the amplitude of the wavelet (blue color in Figure-2) because the reflectivity value is negative. This is due to the fact that the interval velocity of the Top Mishrif (unconformity surface) is lower than that of the overlying Khasib Formation. While the bottom contact of Mishrif Formation was picked in the peak of the amplitude of the wavelet (red color

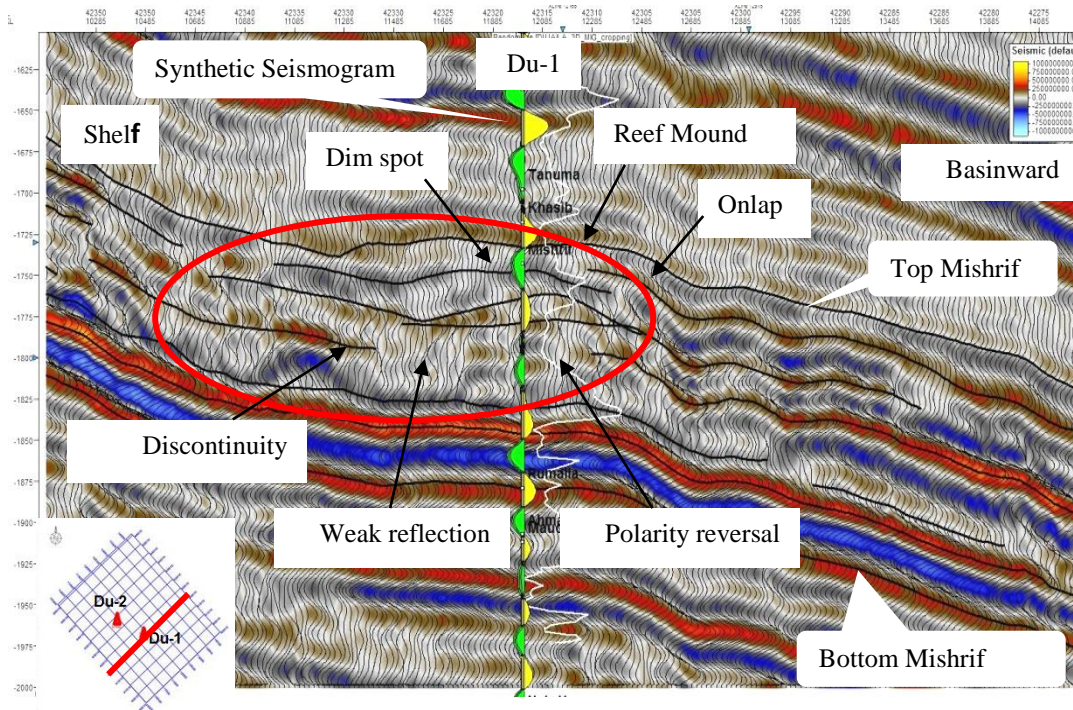
in Figure-2) because the reflectivity is positive, because the interval velocity of the bottom part is less than that of the underlying Rumaila Formation (dense tight limestone) [9]. In addition, four reflection horizons were identified which represent the main strata in Mishrif Formation. They were named from top of the formation to the bottom as unit-1, 2, 3, and 4 respectively, as shown in Figure-2. They are consistent with the geologic subdividing of Mishrif Formation units that are MA1, MA2, MB, MC, respectively [1, 5, 11, 12]. The seismic reflectors of units 1, 2, 3 manifested many abrupt discontinuities, so that each unit consists of many members. Meanwhile, unit 4 clearly showed continuity throughout the study area.



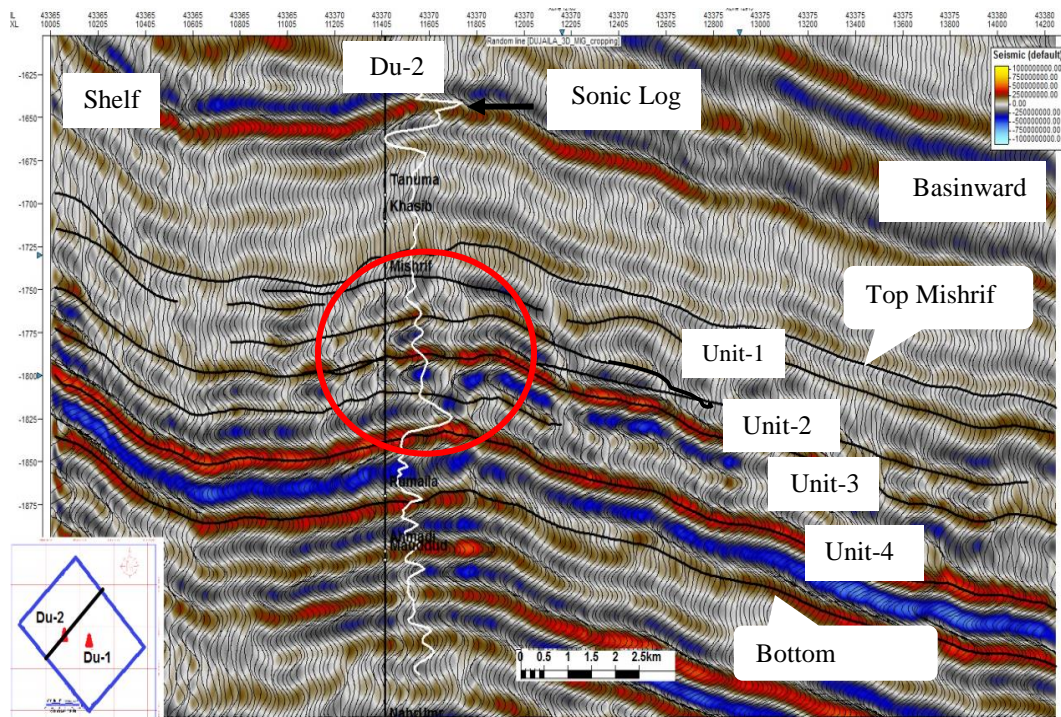
**Figure 2-** The picked seismic reflection horizons that are correlated with the synthetic seismogram of well Dujaila-1.

**Interpretation of the seismic amplitude reflection data in the time domain**

The precise seismic analysis greatly enhances the chances of successfully locating hydrocarbon traps in sedimentary basins [13]. Hydrocarbon accumulations and porous carbonate reef buildups can be detected directly on the amplitude seismic section, by localized zones of anomalously reflection events, such as velocity decreases, frequency decreases and amplitude phase reversal with high signal diming [14, 15]. Figure-3 represents a seismic section passing through well Dujaila-1. It shows several abnormal amplitudes of the reflected events and many distinct criteria identifying the Rudist reef buildup, especially in the vicinity of the well Dujaila-1 (as seen in the red circle area), such as a dim spot, pinchout, onlap, discontinuity, polarity reversals, and mound shape. Therefore, these seismic characteristics represent clear clues to the presence of reef buildups with hydrocarbons accumulation in the area around well Dujaila-1 [16, 17]. In contrast, the section passing through the well Dujaila-2, as in Figure- 4, displays a different seismic picture, especially in the vicinity of well Dujaila-2, which is marked by a red circle. It shows approximately the disappearance of the seismic characteristics of the reef buildup, which confirms that the two wells have different lithofacies.



**Figure 3-** Different seismic evidence for reef identification on inline section passing through well Dujaila-1 (approximate edges of the reef are shown in red circle).



**Figure 4-** reduction in the abnormal amplitude as clearly shown inside red circle around the well Dujaila-2.

Figure-5 illustrates a seismic section passing through the two wells. The locations of the polarity reversal of the reflected amplitudes (marked with red arrow) may represent the approximate edge of the reef mound (Trap) in the area between the two wells. Accordingly, the black arrows outline the approximate edges of the reef buildups [16].

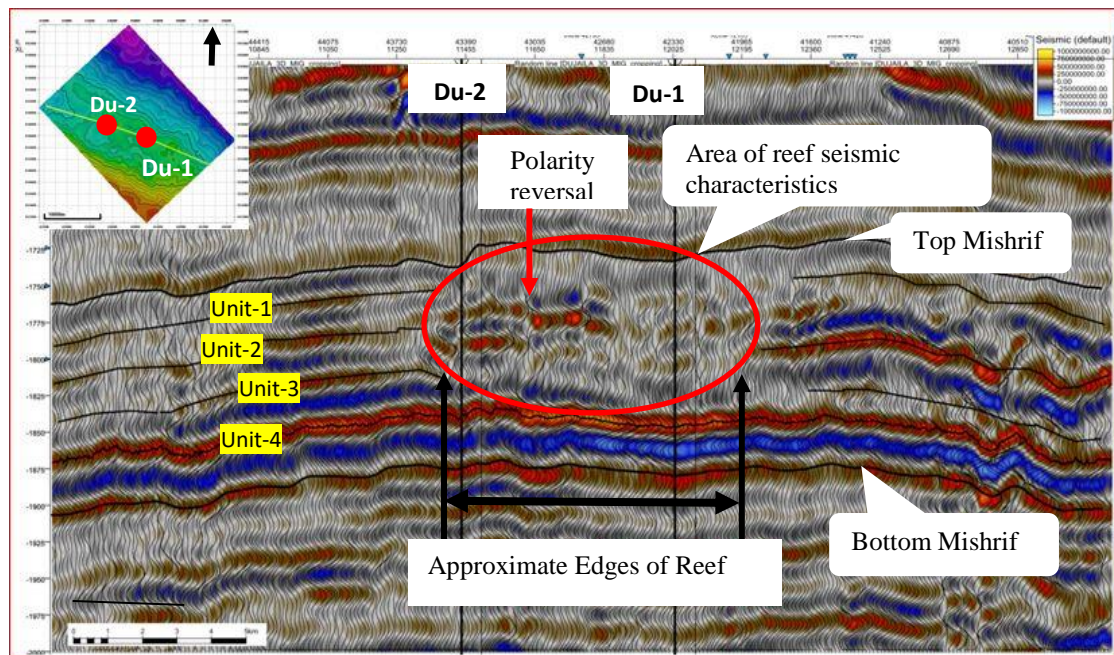


Figure 5-A seismic section passing through wells Dujaila-1 and 2.

**Time maps of Mishrif Formation**

The structural interpretation of 3D seismic reflection data is directly dependent on the time map of reflection horizons, which results from identifying and picking the seismic reflectors in the two-way vertical time unit that is calibrated with the well data [17]. Contour time maps for Top and Bottom surfaces of Mishrif Formation were drawn with contour interval 5 ms to show the geometry of the captured reflection horizons, as seen in Figures-(6 and 7), respectively.

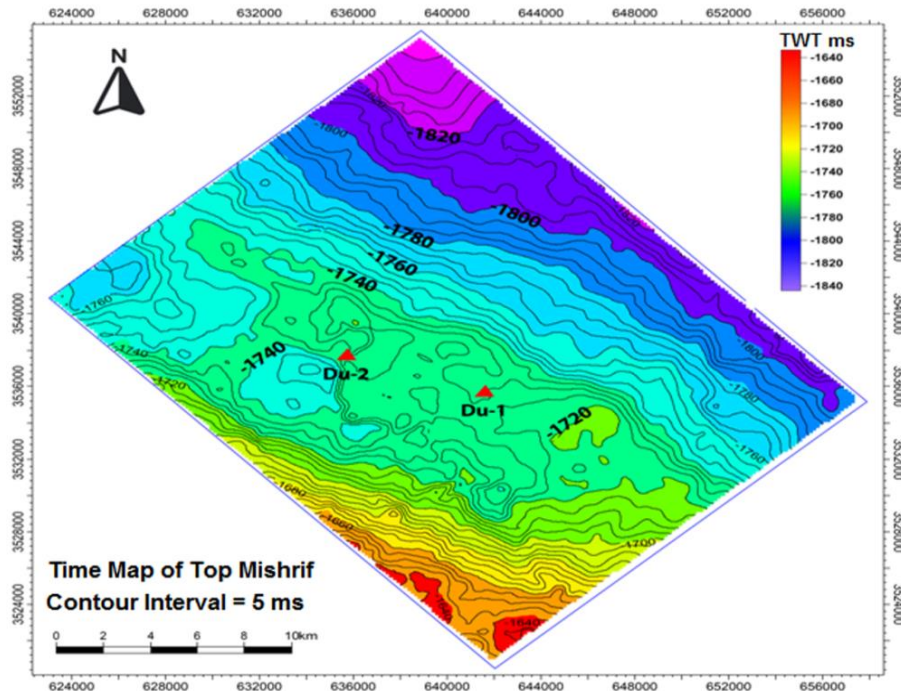


Figure 6- The TWT map of Top Mishrif, contour interval 5 ms.

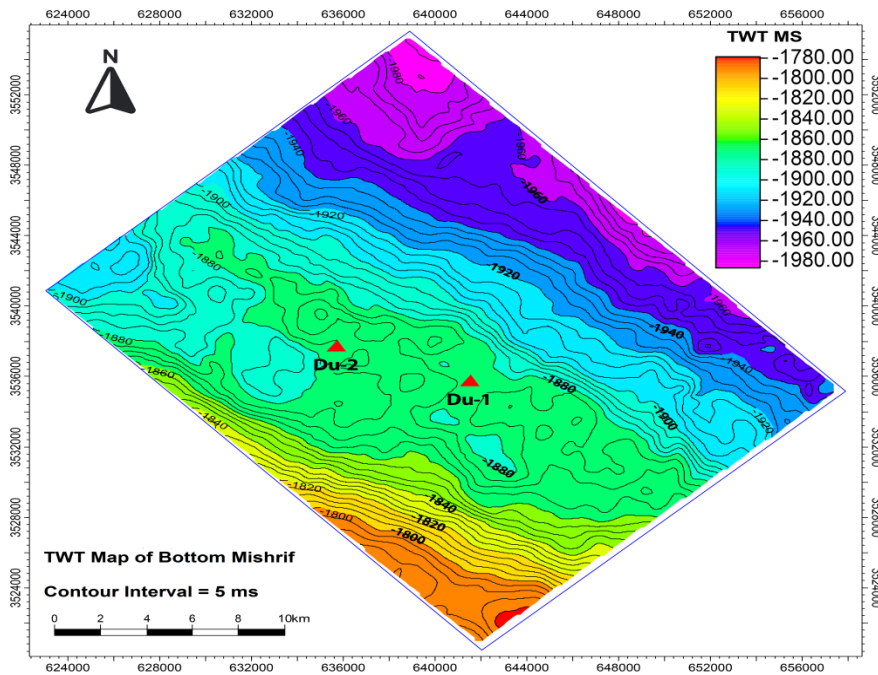


Figure 7- The TWT map of Bottom Mishrif, contour interval 5 ms.

While Figure-8 exhibits the topographic reliefs of the Top Mishrif through the profile A-B on the time map, with a contour interval of 10 ms.

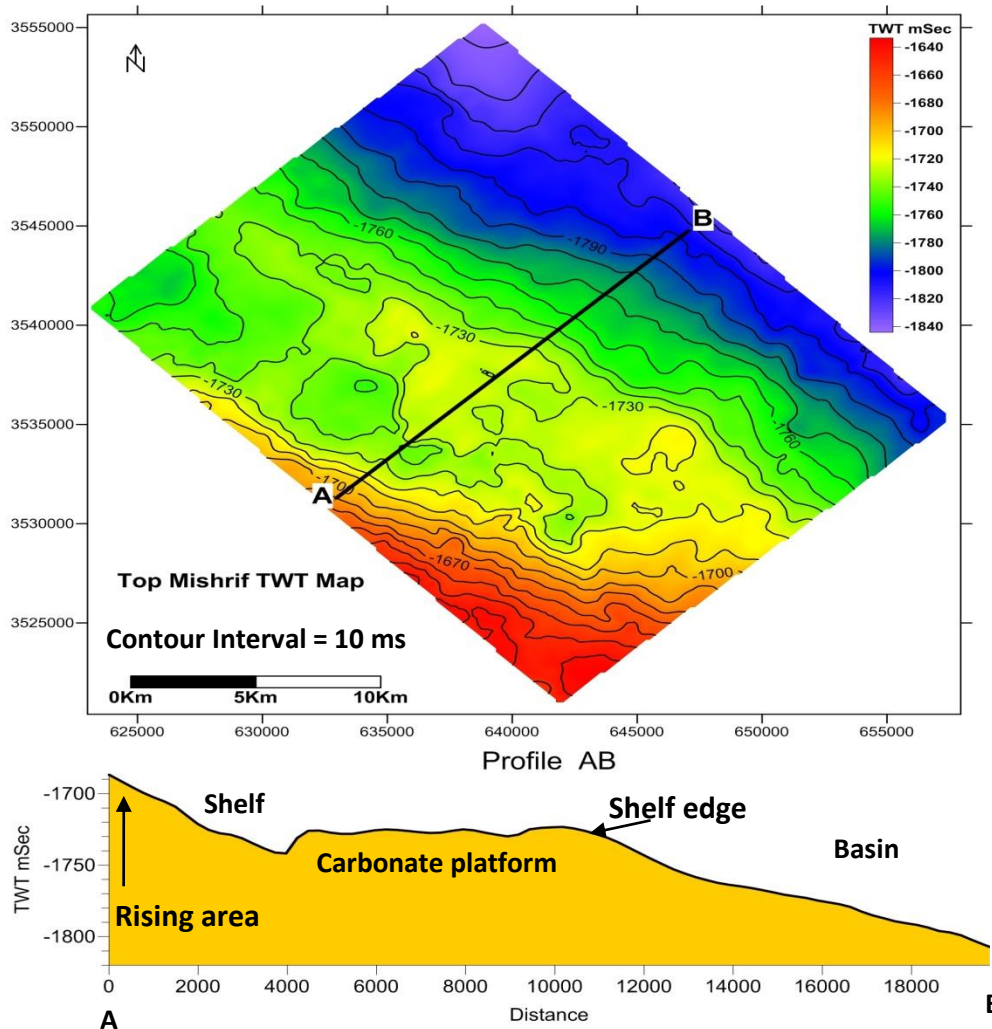


Figure 8- The TWT map with a contour interval of 10 ms of Top Mishrif with a supposed geologic interpretation of profile A-B.

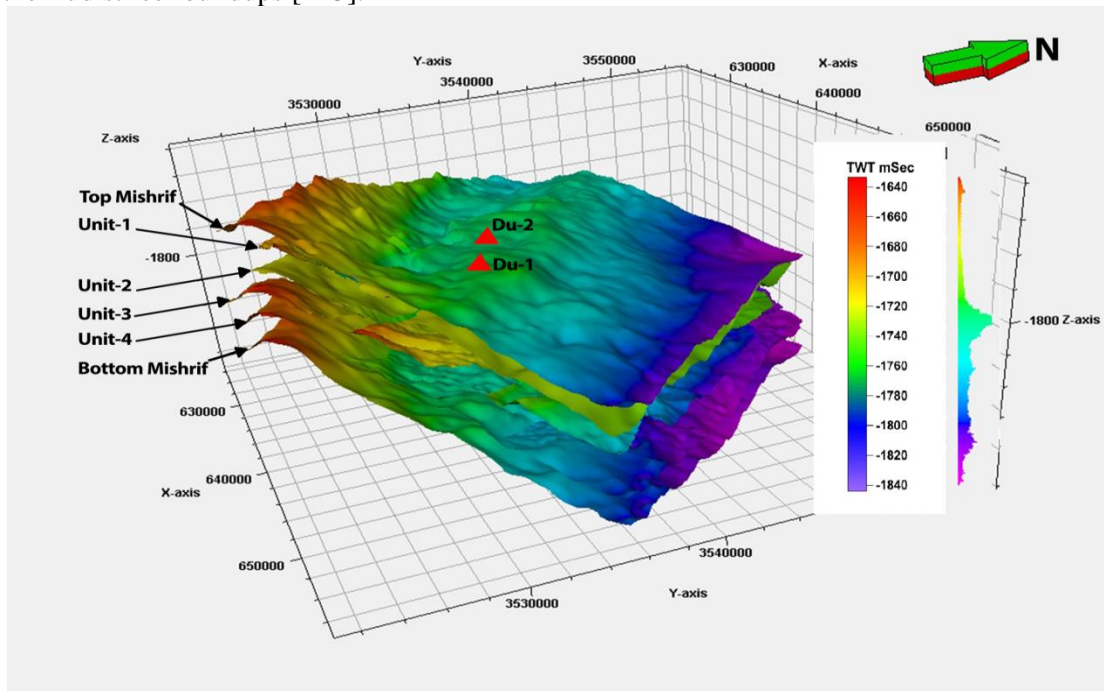
In general, the TWT structural maps of Mishrif exhibited several seismic structural features, which can be interpreted depending on integration with geological information and wells data, as follows:

- In general, the Mishrif layers are inclined toward the east and northeast.
- The west and southwest side of the map is rising in what could represent a part of a folded structure that extends out of the study area.
- The middle part is a longitudinal wide flat area extended in the NW-SE trend. It could represent a carbonate platform for Mishrif deposits.
- The east and northeast side is steeply lowering and may represent a part of the deep basin.
- The central part of the map shows a simple closure (according to the shape of contour lines) in the region where the two wells (Du-1 and Du-2) are located. This is visibly related to the presence of reef buildup mounds on the rim of the carbonate platform, which is compatible with the location of the reef buildups that were seen in the seismic amplitude reflection sections (Figures- 3, 4, 5).
- The time map of Bottom Mishrif generally showed the same topographic picture of Top Mishrif surface, but the longitudinal flat area in the middle part became narrow and had slightly reliefs that may reflect the absence of reef buildups.

**Construction of 3D-depositional layers model for Mishrif Formation**

One of the important benefits of the 3D reflection survey is permitting the construction of three-dimensional models for the depositional layers, which could exhibit the architectural geometry of the depositional layers of reservoir. It also permits the visualization of the lateral and vertical distribution of the different lithofacies throughout the study area [18].

A 3D depositional layer model for Mishrif Formation in Dujaila oil field was constructed using Petrel software-2015, as seen in Figure-9. It shows that Mishrif Formation is a monocline structure with a general dip toward the east and northeast. The wells (Dujaila-1 and 2) were located at a relatively uplifting area that represents a shelf edge of the carbonate platform, which is a preferable place to the growth of reef buildups. This proposal is confirmed by the fact that the well Dujaila- 1 produces oil from the Rudist reef buildups [1- 5].

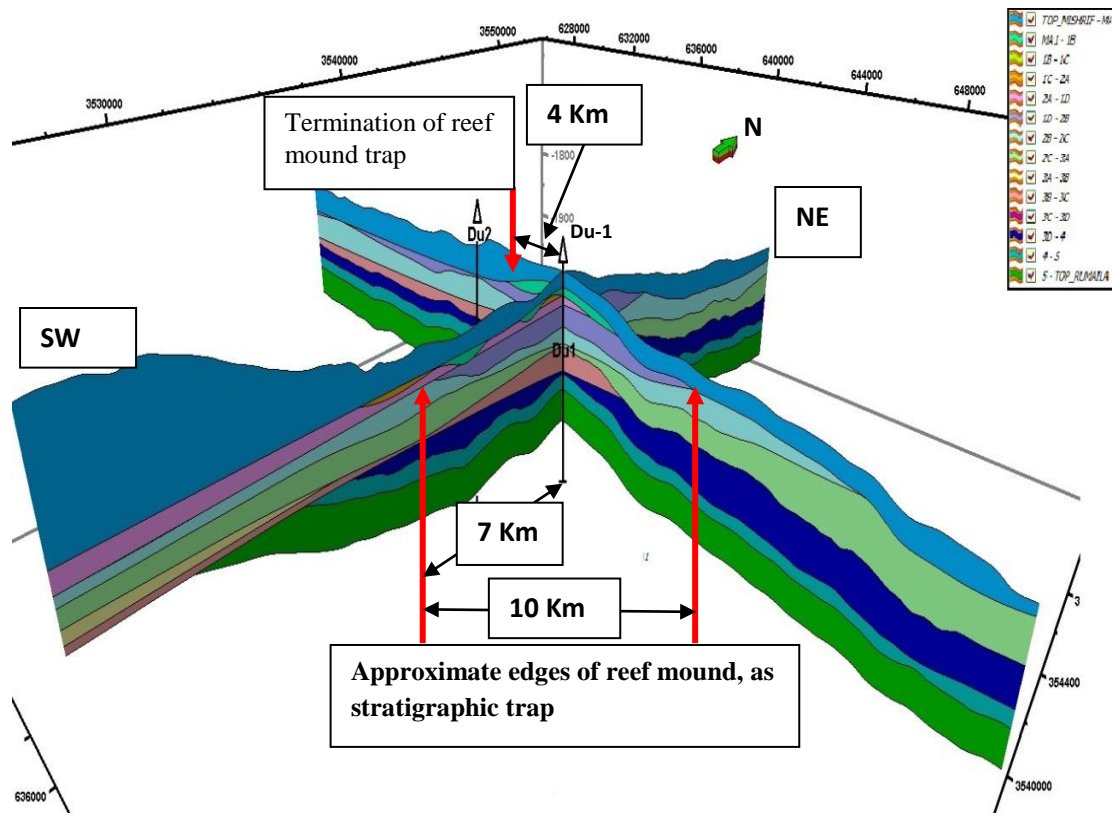


**Figure 9-** A 3D deposition layers model of the structural framework of the reflection horizons of Mishrif Formation.

Figure-10 represents two perpendicular sections on the constructed 3D depositional model to demonstrate the geometry of the layers sequence of Mishrif Formation. It shows that the layers of the upper part of Mishrif Formation around well Dujaila-1 have a dome shape with many abrupt discontinuities that are due to the growth of Rudist mounds. Consequently, it acts as a stratigraphic



trap due to the dome shape for the reef mound and the lateral changes in the lithofacies [19, 20]. It also shows that the stratigraphic trap extended about 7 km to the southwest of the well Dujaila-1, and 4 km toward well Dujaila-2, which the trap did not reach. This may explain why the latter well was dry despite being structurally higher than well Dujaila-1.



**Figure 10** - Two perpendicular sections on 3D depositional model of Mishrif Formation in Dujaila oil field.

**Instantaneous Frequency Attributes of Mishrif**

The low-frequency attribute is considered as the main property to distinguish the existence of the porous carbonate reef buildups on seismic reflection sections [21], whereby the seismic reflected responses from the reef buildups are associated with weak reflections (dim spots) and low frequency [22, 23]. Therefore, the seismic instantaneous frequency attribute was used in this study to improve the seismic interpretation image with the purpose of exhibiting strong amplitude abnormalities and confirming the occurrence of the low frequencies within reef buildups and hydrocarbon accumulation. A 3D frequency model of Top Mishrif showed that low-frequency reflections are restricted in the area around the productive well Dujaila-1, as shown in Figure-11. This is considered as a clear evidence of the existence of a reef porous carbonate buildups with hydrocarbon accumulation in this region, which is located upon the shelf edge belt of the carbonate platform, as noted in the black circle in Figure-11. At the same time, it also shows that the well Dujaila-2 is located on the edge of the low-frequency area, out of the reservoir zone. While the 3D-frequency attribute model of the bottom of Mishrif Formation shows a different picture so that high frequency is predominant in the study area, as shown in Figure-12. The figure illustrates that the bottom Mishrif is consisting of homogeneous dense carbonate rocks, and confirms the vertical variations in the carbonate lithofacies of the Formation.

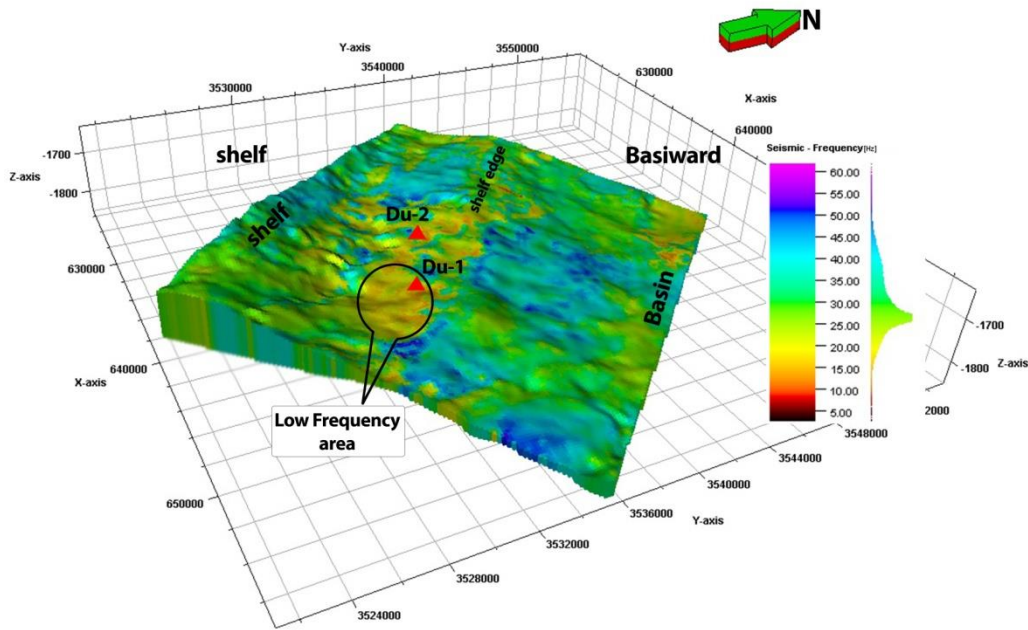


Figure 11- A 3D frequency model of Top Mishrif surface.

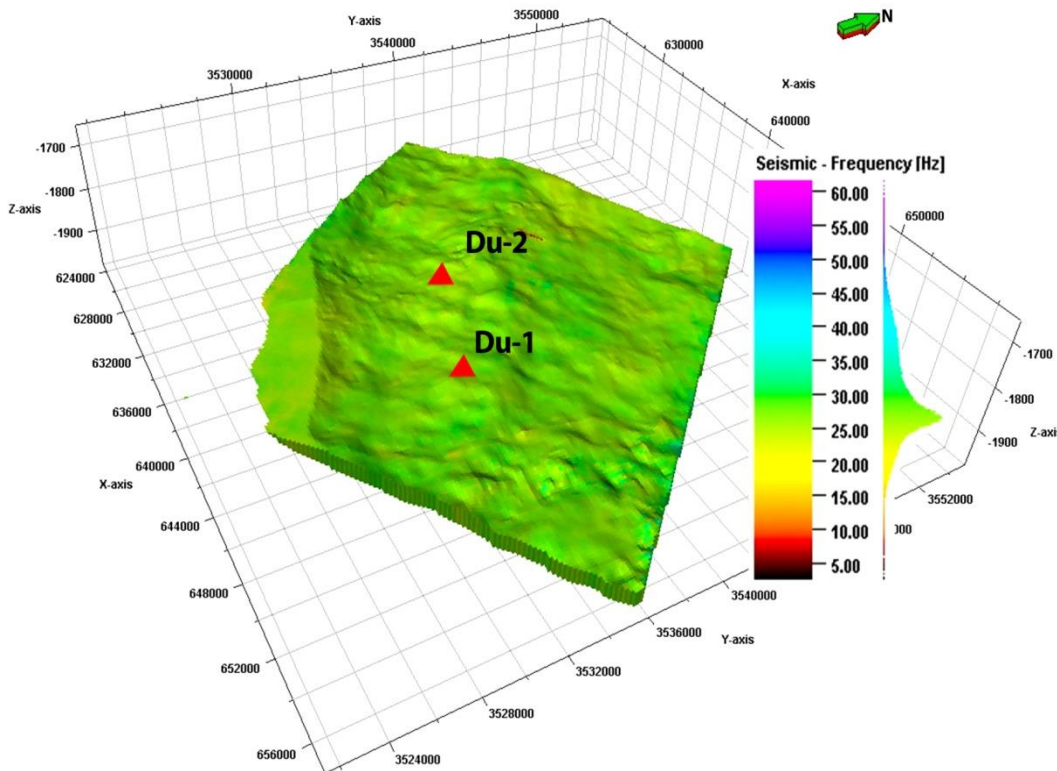


Figure 12 -Shows a 3D-frequency model of Bottom Mishrif surface.

**Conclusions**

Mishrif Formation in the study area is a monocline structure inclined toward the east and northeast that form from four main carbonate layers. The pay zone consists of reef buildup in the upper part of Formation at the region around productive well Dujaila-1, which is located on the shelf margin of the

carbonate platform and acts as a stratigraphic trap of hydrocarbon accumulation. This stratigraphic trap extends about 7 km to the southwest and 3 km to the northeast of the well Dujaila-1, and 4 km towards Well Dujaila-2, which the hydrocarbons trap does not reach. This may explain why it was dry despite being structurally higher than the productive well Dujaila-1. Furthermore, the low frequency of reflection events is constricted in the region around the well Dujaila-1, which confirmed the presence of the porous Rudistone and a hydrocarbon accumulation there. The observed hydrocarbons system in the Dujaila oil field provides a new chance for the exploration and production of oil in Mishrif Formation (and other productive carbonate Formations) in areas that are located on the flanks of the known producing structures and in the flat areas are situated on the edge of a carbonate platform.

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