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OIL RESERVOIR DETECTION USING VOLUME ATTRIBUTES IN CHIA SURKH AREA, KURDISTAN REGION, IRAQ

Faris H. Yousif[a, b, *], Bakhtiar Q. Aziz[a], Ezaddin N. Baban[a]

[a]Dept. of Geology, College of Science, University of Sulaimani, Kurdistan Region, Iraq- faris.yousif@uoz.edu.krd, (bakhtiar.aziz, ezadin.mohamed)@univsul.edu.iq
[b]Dept. of Environmental Science, Faculty of Science, University of Zakho, Kurdistan Region, Iraq- faris.yousif@uoz.edu.krd

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ABSTRACT:

This study includes picking seven reflectors from intense sampling of 3D Seismic survey composed of 40 inlines and 30 crosslines, the distance between the seismic lines is equal to 250m. The study deals with extracting and analysing volume seismic attributes of 3D seismic data of Chia Surkh area. The area is located east of Kalar City, Sulaimani Government, Kurdistan Region, Iraq. The main aim is to determine locations of hydrocarbon accumulation by picking seven horizons as well as studying and analysing both subsurface structure and direct hydrocarbon indicators. The seismic volume attributes are calculated from the original seismic data that consist of (400) inlines and (300) crosslines, and the distance between two adjacent lines is equal to (25m). The seismic attributes used in the current study are, variance edge, curvature, root mean square, envelope and sweetness. Revealed existence of a major anticline, a major fault. As well as two small faults were detected and running parallel to the major fault, while the envelope and sweetness attributes emphasized appearance of several bright spots within Lower Fars, Dhiban, Jeribe and Euphrates Formations, which give quite evidence for accumulation of hydrocarbon. The study concluded that the complete system requires for existence of petroleum is available such as the major anticlinal structure, carbonate rocks as an excellent reservoir rocks and gypsum or (anhydrite) as an optimal cap rock. The existence of hydrocarbon is confirmed by bright spots.

KEYWORDS: 3D Seismic attributes, Oil reservoir characterization, Hydrocarbon indicators, Chia Surkh, Kurdistan Region.

1. INTRODUCTION

Seismic attributes are quantities derived from seismic data to allow the user to make unconventional interpretation in the investigation of the reservoir characterization (Avseth et al., 2010; Chopra & Marfurt, 2007; Chen & Sidney, 1997), They improve results of interpretation and subsurface geologic features reflected by the seismic data (Taner, 2001), being used extensively in the oil industry to detect hydrocarbon traps (Pramanik et al., 2003), They can be measured by time, amplitude, frequency and attenuation or combinations of all (Sarhan, 2017). Many studies concluded that attributes are good tools to highlight seismic characteristic of interest (Adero, 2017; Chen & Sidney, 1997).The attributes derived from the amplitude are used to improve the structural image of the subsurface and give more detail about the physical properties such as acoustic impedance and velocity, via application of variance edge, curvature, envelope and root mean square. On the other hand, the phase attributes are referring to stratigraphy, revealing continuity in addition to the configurations of the reflector. While frequency derived attributes are adequate in providing an assessment of the reservoir, usefully in stratigraphic events, fault detecting and as direct hydrocarbon indicators (DHI) (Brown, 2011; Chopra & Marfurt, 2005). Envelope and sweetness reflect bright spot phenomena, which gives evidence for the presence of hydrocarbon. In calculating ~~of~~ seismic attributes the entire seismic volume can be used as input (Liu & Marfurt, 2006; Partyka, 2001).

The study area was the first block targeted by governments for oil exploration in Iraq since 1902. Many wells were drilled starting of the wild cat well CS-1 to evaluate the presence of oil, and the results were encouraging to continue prospecting for hydrocarbons (Adams et al., 2013). Topographically, Chia Surkh anticline is a northwest-southeast trending topographic feature located along the major Kirkuk structural trend. The structure is a double-plunged and asymmetrical anticline which was limited by the reverse fault from the south flank. The dips of the beds are ranging (40°-90°) on the SW limb and (15°-20°) on the NE limb of the structure. A part from some mountainous areas that delineate the Iranian border, the study area is generally of low relief with good accessibility. The area is mostly located within the foothill folded zone (FFZ) next boundary of high folded zone (HFZ), and this area is studied for the first time using 3D seismic data in 2022 (Yousif et al., 2022). This study aims at evaluating the capability of detecting oil reservoir and existence of hydrocarbon using seismic attributes derived from 3D seismic data and CS-11 well logs. The study site lies in Chia Surkh (Table 1) east of Kalar city, approximately 70km south-southeast of Sulaimani Governorate covering an area equal to 75km^2 (Fig.1).

Table 1. Geographic Coordinates of the Study Area

NO.	Latitude	Longitude
1	34° 42′ 07.0645″N	45° 36′ 16.9517″E
2	34° 39′ 10.4738″N	45° 32′ 53.4541″E
3	34° 42′ 51.8791″N	45° 28′ 04.6001″E
4	34° 45′ 47.5386″N	45° 31′ 28.0746″E

* Corresponding author

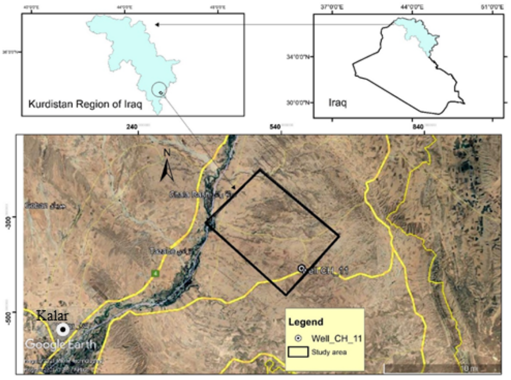

Figure 1. Location of the study area (Chia Surkh)

2. GEOLOGY AND TECTONIC BACKGROUND OF THE AREA

The geological column of the well CS-11 shows the existence of several geological formations, starting from the younger to older one. They are: Upper Fars, Lower Fars, Jeribe, Dhiban and Euphrates. Upper Fars Formation has thickness equal to 980m, it is mainly composed of claystone and sandstone alternations. Sandstones are poorly cemented by carbonate and usually uncompact. The claystones are reddish brown colored, fine to medium grained with cross bedding, ripple marks and laminations (Adams et al., 2013). The M. Miocene Lower Fars Formation is widely spread in Iraq (Al-Juboury et al., 2001), it is mainly lagoonal evaporitic (Al-Juboury & McCann, 2008). Lower Fars lithofacies are divided into four units, from well CS-11, as described by (Bellen et al., 1959; Dunnington, 1958).Unit one has thickness of 255m exposed widely and consists of marl, limestone, anhydrite with frequent, claystone, red claystone and less frequent anhydrite. Unit two shows thickness equal to 256m, and it is composed of anhydrite with interbedded siltstone and mudstone. The third unit has thickness equal to 173m and it is composed of rock salt and anhydrite with some siltstones, mudstones and with less frequentlimestone intercalations. Finally, unit four has thickness of about 116m, which is composed of anhydrite, mudstone and thin limestone beds usually overlie the so-called Basal Fars Conglomerate (Al-Juboury & McCann, 2008). Jeribe Formation has thickness of 57m, recrystallized, dolomitised, reefal and generally massive limestone, argillaceous limestones and anhydrites were also recorded. Jeribe Formation was one of the main reservoir targets in Chia Surkh-11. Dhiban Formation has thickness equal to 48m consisting of bedded (cyclic) anhydrites, halites and thin interbedded mudstones and limestones or dolomites (Bellen et al., 1959) precipitated from sea in a gulf or sea arm. Interfingering takes place between the Dhiban anhydrite Formation and the Euphrates limestone. The Euphrates Formation has thickness of about 65m, as its bottom is not reached, consists of limestone with textures from oolitic graduating to chalky, locally containing corals and shells, most recrystallized and siliceous. Beds of green marls, argillaceous limestones, breccia, conglomerates and conglomeratic limestones also occur (Bellen et al., 1959). Tectonically, the area is mainly within the foot hill folded zone (Al-Qayim et al., 2016), (Fig. 2) neighboring high folded zone, located on the northeastern part of the Arabian plate. It is considered as a part of the Zagros fold-belt, which results from the collision between the Arabian plate and the Iranian plate (Ameen, 1992; Fouad, 2010). The study area is a part of the central faulting zone. The system of northwest faults characterizes this zone to southeast trend during lower Miocene and by overthrust of NW–SE (Zagros) trending in middle Miocene sediments (Jassim & Goff, 2006).

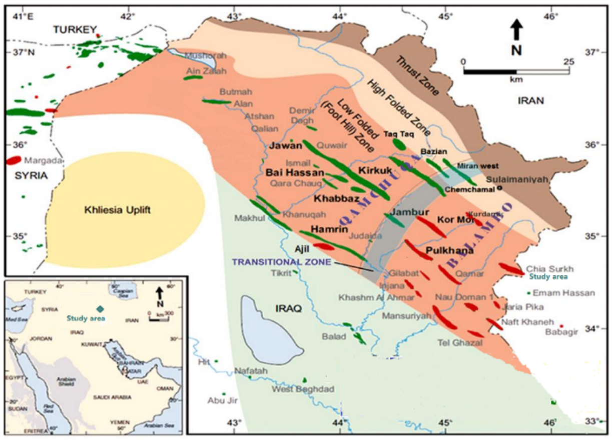

Figure 2. Tectonic map of Kurdistan Region (after Al-Qayim et al., 2016)

3. SEISMIC DATA AND METHODOLOGY

A 3D cube of Seismic data covering area equal to 75km^{2}used to image subsurface structures and detect direct hydrocarbon indicators (DHIs), utilizing seismic interpretation and volume seismic attributes. A cube of seismic data is used to image subsurface horizons in the study area. Two sets of seismic lines are used, the first set is 40 inlines sections trending (NE-SW), and the length of each line is equal to 7.5km, while the second set is 30 crosslines trending (NW-SE) and the length of each line is equal to 10km, the distance between the two adjacent lines is equal to 250m. The data of the well CS-11 is also obtained and used in the study, (Fig. 3). Synthetic seismograph is used for linking well data to seismic data. Several horizons were picked, they are representing of Lower Fars, Jeribe, Dhiban, Euphrates formations and faults (F1, F2, F3) are detected. Volume seismic attributes are derived from Seismic data cube, using 400 inlines verses 300 crosslines utilizing Petrel Schlumberger 2017 software, which uses sophisticated algorithms. Attributes derived are curvature, variance and root mean square to detect anticlines and Faults. Bright Spot phenomena is used to spot oil and gas situated in traps based on differences in amplitude (Ahmed & Meehan, 2016; He et al., 2017), and considered a revolution method in hydrocarbon prospecting showing fantastic outcomes in the oil and gas discoveries (Avseth et al., 2010; Wang, 1984), however, this feature is not clear evidence for the presence of oil and gas, so there is need for further analysis (He et al., 2017). So, envelope and sweetness seismic attributes are applied in this study to detect direct hydrocarbon indicators (DHIs), which refer to the existence of oil and gas accumulation.

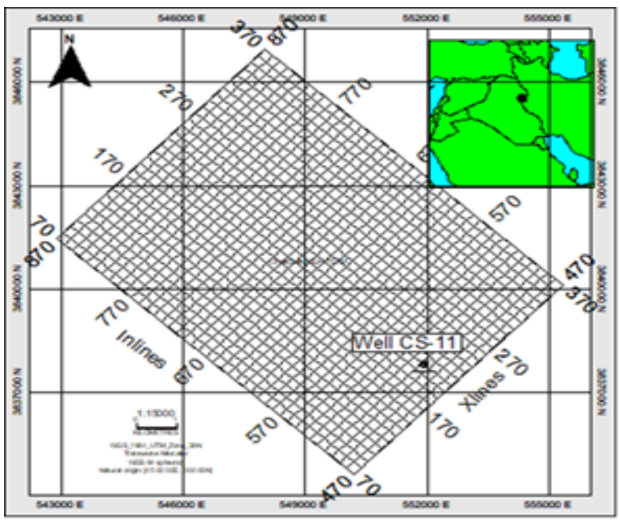

Figure 3. Shows base map of the study area

4. RESULTS AND DISCUSSIONS

4.1 3D Seismic Data Interpretation

Depending on the geological column and check shot of Well CS-11, several horizons representing Lower Fars, Jeribe, Dhiban and Euphrates formations were picked, correlated, and linked to seismic data using Petrel Schlumberger 2017 software. The tops of the four reflectors are identified and picked through the whole seismic lines, in structural point of view, the subsurface of the area characterized by existence of a large anticline extending through the whole seismic section and it is subjected to a major reverse fault (F1) near its crest as well as two others smaller faults (F2, F3) on its south western limb, as shown in Fig (4). The limbs are asymmetrical with inclination of (30°) for NE limb and (45°) for the SW limb, so it coincides with Zagros belt series. Fault (F1) trending NW-SE intersecting the anticline close to the crest on the SW limb, it is a reverse fault that has throw equal to 180m the fault plane is dipping (45°) NE, penetrating Lower Fars Formation unit one, two, and three to the the depth of 1665m. Fault (F2) trending NW-SE and intersecting SW limb also, it is a reverse fault that has throw equal to 90m, and its plane is dipping 45° NE, penetrating all units of Lower Fars Formation from 1800 m to the depth 2600m. Fault (F3) passes through the SW limb it is a reverse fault also has throw of 40m, trending NW-SE and its plane dipping (45°) SW, penetrating Lower Fars Formation unit one from 1300m to the depth of 1800m. These three faults are parallel and longitudinal faults and adequate with Zagros belt series. From well CS-11 and seismic inline section (520), depths and thickness of the formations; Lower Fars unit 1, unit 2, unit 3, unit 4, Jeribe, Dhiban and Euphrates are found and listed in (Table 2).

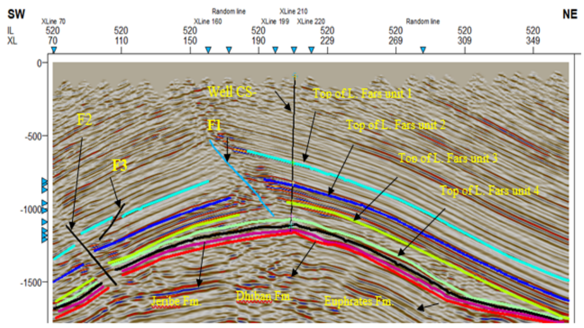

Figure 4. Interpretation of the Seismic inline 520

Table 2. Depths and thicknesses of the geological formations in the well CS-11

Formation Name	Top depth (m)	Bottom depth (m)	Thickness (m)
Lower Fars unit one	980	1235	255
Lower Fars unit two	1235	1490	255
Lower Fars unit three	1490	1664	174
Lower Fars unit four	1664	1780	116
Jeribe	1780	1837	57
Dhiban	1837	1885	48
Euphrates	1885	-------	-------

4.2 Seismic Attributes

4.2.1 Structural Attributes

Geometric seismic attributes are derived calculations of 3D seismic reflection data. They are used to extract geological features such as faults, stratigraphy, channels, and rock properties from seismic data. For structural interpretation, faults, folds, and fractures are important for identifying possible hydrocarbon leads and developing plays. This shows the importance of geometric attributes for the ease of fault, fold, and fracture identification. The main geometric attributes used for structural interpretation include: dip magnitude and azimuth, coherence, and curvature (Chopra & Marfurt, 2007). In this study three of these attributes, curvature, variance and root mean square, applied and showed an anticline and Faults.

4.2.1.1 Curvature Attribute

Curvature time slice section (1170 ms), (Fig. 5), shows the existence of three reverse faults in the study area F1, F2 and F3.They are a set of reverse faults parallel to each other's, their fault planes trending NW to SE as the general trend of the longitudinal faults in the area which emphasized on the hypothesis of the formation of these faults as a result of the same stress came from NE in past geological time , fault F1 is the major fault passing through the study area its length about 10km, the seismic fault zone width is about one km and is extremely deformed, located in the middle between crossline (Xl170) and cross (Xl 210) upward to the inline (IL750) then turning left towards the corner of the area where inline (IL 870) and cross (XL 70) intersects. F2 is minor fault located in the south corner close to the inline (IL470) and cross line (XL70), which extends for 3km and continues to the inline (IL520). F3 is another minor fault located between inlines (IL520), (IL570) and cross lines (XL80), (XL100). These three faults locations are QC checked with structural interpretation part of this study and they matched.

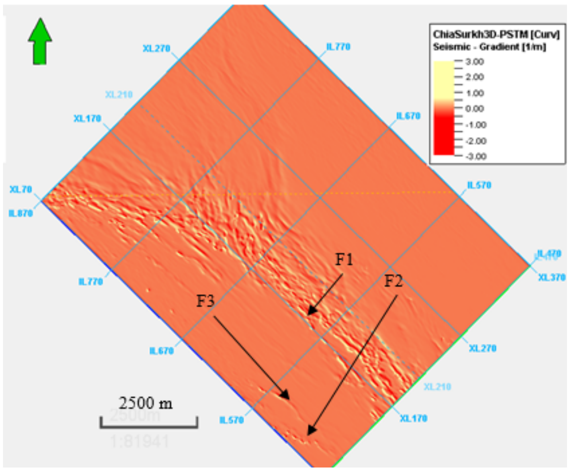

Figure 5. Curvature time slice section 1170

Curvature attribute (IL480), (Fig. 6) has NE-SW direction shows existence of major asymmetrical anticline has inclination equal to (40°) on NE limb and (50°) on SW limb. It has width equal to (7.5Km). Also, three revers faults are detected and symbolled by F1, F2, and F3; the major one F1 its plane is dipping (50°) NE, and has throw equal to 70ms. F2 is a minor fault parallel to the major fault, and has same dip direction and dipping about 70°, while the third fault F3 is parallel to both faults dipping angle same as F2 but opposite to both faults in dip direction. The features locations are QC checked with seismic structural interpretation and matched.

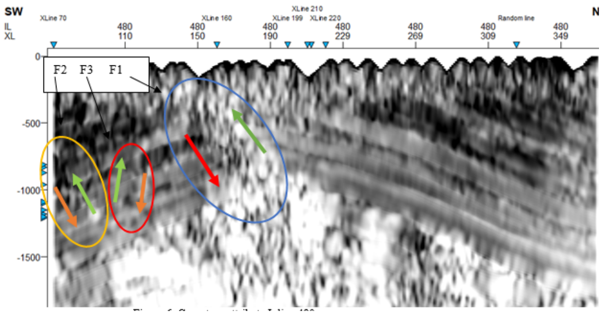

Figure 6. Curvature attribute Inline 480

4.2.1.2 Variance Attribute

Variance attribute time slice section (1180ms), (Fig.7), also shows the existence of the three faults F1, F2, F3 which occurred in the previous seismic attribute. F1 is the main and biggest fault extending through the area that has the length of 10km, and it is located in the center of the area between cross lines (Xl 170), (Xl 210) upward to the inline (IL750) then turning left towards the corner of the area where inline (IL870) and cross line (XL70) intersects. F2 is minor fault located in the south corner close to the inline (IL470) and cross line (XL70), which extends to about 3km and continues to the inline (IL520). F3 is another minor fault located between inline (IL520) and cross lines (IL570) and cross lines (XL80), (XL100). These three faults locations are QC checked with structural interpretation part of this study and they are matched.

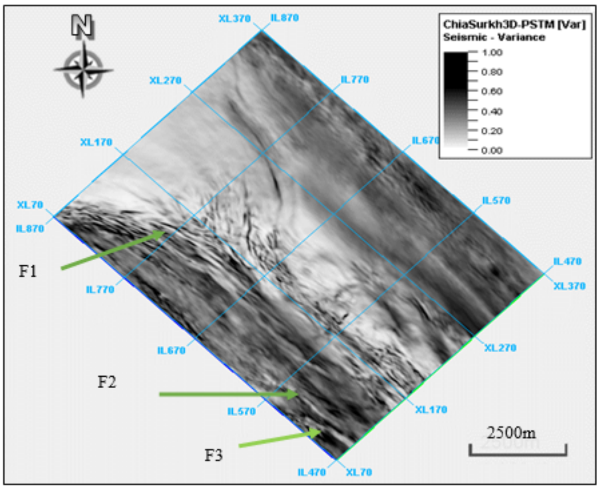

Figure 7. Variance attribute time slice 1180 ms

Variance attribute inline (IL480), (Fig. 8), has NE-SW direction shows the major anticline, major fault and the two smaller Faults. The anticline is asymmetrical, with NE limb dipping (40°) while the SW limb dips (50°) due to the effect of stress coming from the NE direction in past geological time. The fold has width equal to 7.5km. Three reverse faults are seen and named F1, F2, and F3, where the major one F1 its plane is dipping (50°) NE, and has throw equal to 70ms. F2 is minor fault parallel to the major fault and has same dip direction while the dip is equal to (70°). The third fault F3 is parallel to both faults while the dip angle same as F2 but opposite to both faults F1 and F2 in dip direction. The geologic features locations are QC checked with seismic structural interpretation and are matched.

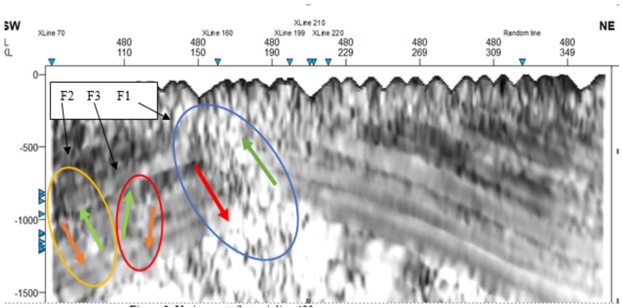

Figure 8. Variance attributes inline 480

4.2.1.3 Root mean Square Attribute

Root mean square attribute time slice section (1150ms), (Fig. 9), shows the three faults F1, F2 and F3 which appeared in the previous attributes and confirms them. F1 is the main and biggest fault passing through the area its length is about (10Km), located in the middle between cross lines (Xl170), (Xl210) upward to the inline (IL750), then turning left towards the corner of the area where inline (IL870) and cross line (XL70) intersects. F2 is small fault located in the south corner close to the inline (IL470) and cross line (XL70), which extends for 3k and continues to the inline (IL520). F3 is another small fault located between inlines (IL520), (IL570) and cross lines (XL80), (XL100). These three faults locations are QC checked with structural interpretation part of this study and are matched.

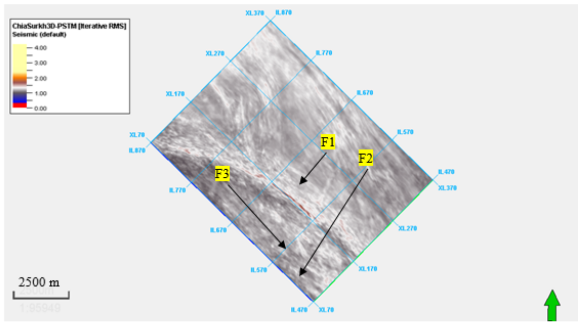

Figure 9. Root mean square attribute time slice 1150

Root mean square attribute for inline (IL490), (Fig.10), with NE-SW direction shows the major anticline, major fault and two small faults. The anticline has asymmetrical two limbs dipping about (40°) on NE limb and (50°) on SW limb, so the anticline is leaning to the SW direction formed due to stress coming from NE in the past geologic time. The anticline width is equal to 7.5km. Three reverse faults are seen F1, F2, and F3, where Fault 1 is the major one trending NW-SE, dipping (50°) NE, its throw about (70ms). F2 is small fault parallel to the major fault and same dip direction but more amount about (70°), while the third fault F3 is parallel to both faults while its dip angle is same as F2 but opposite to both faults F1 and F2 in dip direction. The geologic features locations are QC checked with seismic structural interpretation and are matched.

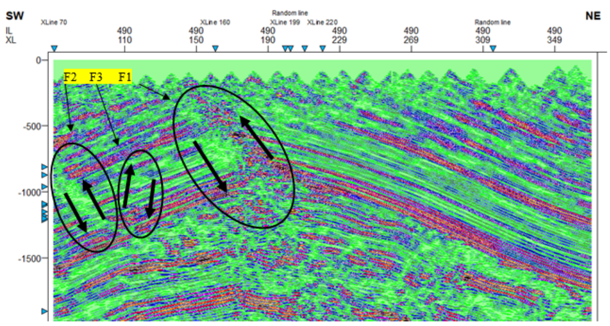

Figure 10. Root mean square attribute Inline 490

4.2.2 Hydrocarbon indicators (HCI) attributes

Some seismic attributes might show bright spots as indicators, in the current study two types of these attributes have been applied, envelope attribute and sweet attribute, (Figs. 11, 12, 13, 14) show areal extent of the bright spots (Sweet spots). Seismic attributes are computed from the seismic cube data, showed number of bright spots, which may be caused by increased oil and gas saturation along the top of the reservoir. The observed outstandingly strong reflection (bright spots) is indicative of reservoir rocks, which may be due to the presence of hydrocarbons in the identified carbonates in different formations Lower Fars, Jeribe, Dhiban and Euphrates.

4.2.2.1 Envelope attribute:

Envelope attribute inline (IL520), (Fig. 11), shows one bright spot at yellow color in Lower Fars unit one on the crest of the anticline. In unit two one yellow bright spot with three yellow reddish flat spots are shown that are close to the top of the anticline, indicating possibility of good hydrocarbon prospect existence in this unit.

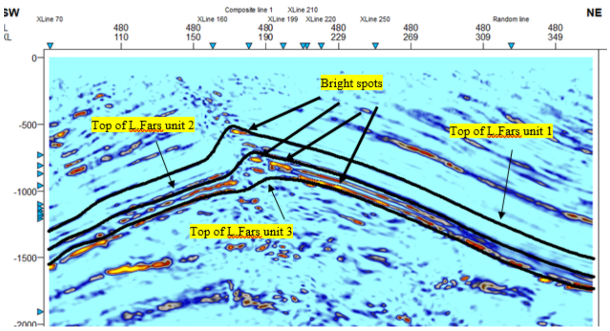

Figure 11. Envelope attribute inline 480.

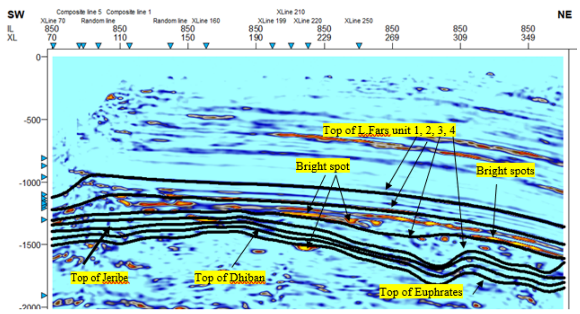

Figure 12. Envelope seismic attribute inline 850

4.2.2.2 Sweetness Seismic attribute

Sweetness seismic attribute as presented in Figs. (13) and (14) shows and emphasizes the bright spots appered in the envelope attribute. Sweetness attributes inline (IL490), (Fig.13), shows bright spots in Lower Fars unit one, unit two, unit three, unit four, Jeribe, Dhiban and Euphrates Formations, where some are close to the crest of the anticline, while others are on the limbs of the anticline.

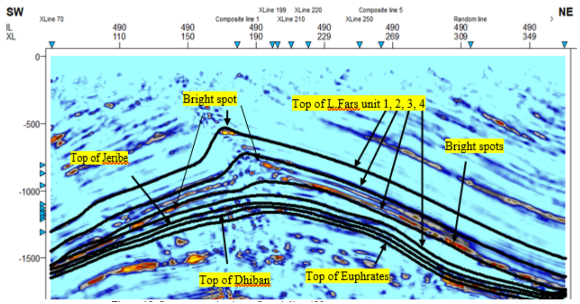

Figure 13. Sweetness seismic attribute inline 490

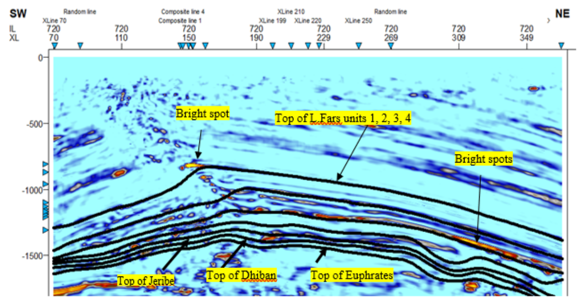

Figure 14. Sweetness seismic attribute inline 720

From application of seismic attributes, it can be inferred that the study area is suitable place to be an oil reservoir, structurally within the major anticline the geologic formations of Euphrates, Dhiban and Jeribe forming an excellent reservoir for petroleum accumulation, while the Lower Fars Formation acts as a cap rocks; detecting bright spots on the top of Lower Fars, unit one, unit two, unit three, unit four, Jeribe, Dhiban and Euphrates confirmed existence of hydrocarbons, in Iraq Lower Fars works as a reservoir and seal rocks at the same time (Al-Juboury & McCann, 2008). Not all bright spots refer to the existence of hydrocarbon, it may appear due to the big difference in lithologies, also differentiating between water caused bright spots and hydrocarbon spots needs further analyses (He et al., 2017). Bright spots close to the crest of the anticline are targets for hydrocarbons more than those located in the flanks.

5. CONCLUSIONS

1- Seven reflectors were picked, their depths are tied with the well CS-11. They are: Lower Fars unit one (980m), Lower Fars unit two (1235m), Lower Fars unit three (1490m), Lower Fars unit four (1664m), Jeribe (1780m), Dhiban (1837m) and Euphrates (1885m).
2- In structural point of view, several important geologic features were detected, such as a major anticline trending NW-SE same as the tectonic trend of the Zagros series, its dimension is equal to (10*7.5 Km), and a major fault has a throw equal to 150m, length about 10km and continues out of the study area boundary and two minor faults with throws of (40 to 70m) and length (1.25-3Km) respectively. The three faults are parallel to each other.
3- Seismic attributes Curvature, Variance and root mean square approved the existence of the major anticline and the three faults. They are totally coinciding with their locations that were found in the seismic interpretation, Seismic attributes Envelope and Sweetness attributes showed bright spots in all Formations; Lower Fars, Jeribe, Dhiban and Euphrates referring to hydrocarbon existence.

4- The detected geologic features; major anticline, carbonate rocks, gypsum and anhydrite as cap rocks and bright spots phenomena as DHIs approved existence of an oil trap reservoir in multiple overlying formations.

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