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Stratigraphic and Structural Study of Khlesia Region Using 2D Seismic Data - North Western Iraq

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Abstract

This study deals with interpretation of stratigraphic and structural of Khlesia area north-west Iraq in Nineveh province, near the Iraq- Syria border, by using 2D seismic data. Synthetic trace are prepared by using available data of the well (Kh-1) using Geoframe program to define and picking the reflectors on seismic section. These reflectors are: (Within Fatha and Kurra Chine reflectors) representing Middle Miocene and Late Triassic ages respectively. A listric growth normal fault is affecting the stratigraphic succession, and normal fault as a result of collision of Arabian plate with Eurasian plate. In addition, minor normal faults (Dendritic and Tension) are developed on the listric normal growth fault and influenced the studied reflectors, the fault system extends (NE-SW) direction. The structural interpretation result shows two grabens (Khlesia and Tayarat) and number of structures domes. Seismic interpretation of the study area confirms the existence of some stratigraphic features which are probable to be hydrocarbon traps. Application of seismic attributes (instantaneous phase, instantaneous frequency and reflection strength section) showed low values in frequency and reflection strength, these values reflect or indicate to presence of hydrocarbon areas.

Keywords: 2D seismic reflection data, Structural interpretations, Attributes, Seismic stratigraphy.

دراسة طباقيه وتركيبية باستخدام المعلومات الزلزالية ثنائية الابعاد لمنطقة خليصيه – شمال غرب العراق

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

الخلاصة

يمثل هذا البحث تفسيرات لدراسة زلزالية انعكاسيه طباقيه وتركيبية لمنطقة الخلصيه شمال غرب العراق، التي تقع في محافظة نينوى، بالقرب من الحدود العراقية السورية باستخدام البيانات الزلزالية ثنائية الأبعاد. تم إعداد الأثر المصنع باستخدام البيانات المتاحة من البئر (خليصيه -1) باستخدام برنامج Geoframe، لغرض تعريف والتقاط العواكس على المقاطع الزلزالية، هذه العواكس هي: (عاكس ضمن الفتحة وعاكس الكوراجين) المترسبة خلال الميوسين الأوسط و أواخر العصر الترياسي على التوالي. يؤثر الفالق الاعتيادي المنحني الانمائي على التتابعات الطباقيه, والفالق الاعتيادي الناتج من اصطدام الصفيحة العربية بالصفيحة الايرانية. بالإضافة إلى ذلك نشوء فوالق اعتياديه ثانويه (التفرعيه والشديه) على الفالق الاعتيادي المنحني الانمائي والتي تؤثر على العواكس المدروسة, نظام الفوالق يمتد باتجاه (شمال شرق-جنوب غرب). بينت نتائج التفسير التركيبي وجود منخفضين هما منخفض الخليصيه ومنخفض الطيارات, وعدد من القباب التركيبية.

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التفسير الزلزالي لمنطقة الدراسة اثبت وجود بعض الظواهر الطباقيه التي ممكن ان تكون مصائد للهيدروكربون.
استخدام تقنيات الملامح الزلزالية المتضمن (الطور الاني ، التردد الاني وشدة الانعكاس) أظهرت تناقص قيم
التردد وشدة الانعكاس ، هذه تعكس الصخور التي تشير إلى وجود مواد الهيدروكربون.

Introduction

Seismic reflection method is the most extensively used geophysical technique, it gives direct and more detailed picture of the geological subsurface structures. Depths to interfaces are mapped very accurately. Certain difficulties arise when reflection is used for beds of complex faulting, folding and steep dip [1]. This information could be used to determine and interpretation the internal stratigraphic geometry through of environmental deposition paleogeography and analysis of sedimentary basin [2]. Structural and stratigraphic seismic interpretations are indirect detection techniques, because the final target of geophysicists in Exploration is not just the localization and mapping of structural features or determination size and shape of structures, the main task is to answer if it contains hydrocarbon or not and whether a probable promising location of hydrocarbon in the area [3]. The aim of this research is draw structural features (folds and faults) in study area and detect stratigraphic features that probably present in study area.

Location of the study area

Khlesia area is located in north west of Iraq within administrative border of Nineveh province, south west of Mosul city at a roughly distance (140km), and (70km) approximately north of AL-Qhim and Anah cities. It's bounded by the Iraq- Syria border from the west as shown in Figure-1. Tectonically Khlesia area is located within the Stable Shelf in Rutba- Jezira zone exactly in Jezira Subzone.

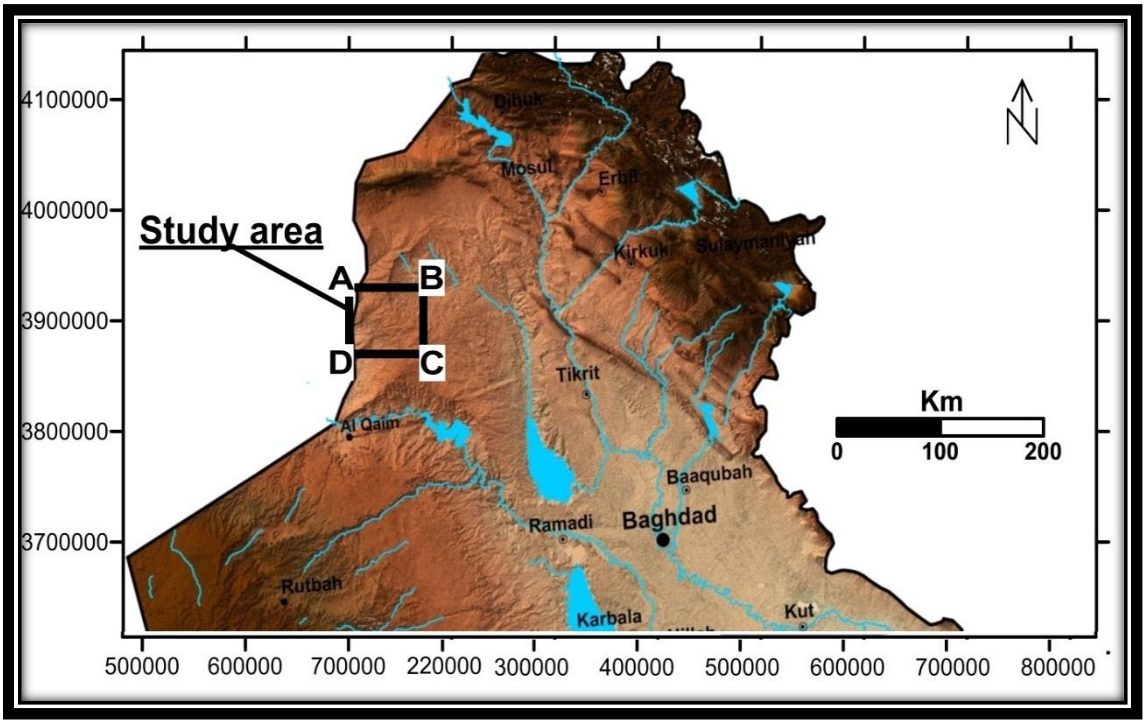

Figure 1- Location maps of the study area [4].

Preparation of base map

The seismic data after processing are loaded to the interactive workstation to interpretation in SEG-Y format and before beginning; must be operated special subprograms to determine the required data to the loading. This process is called (project creation) to achieve the interpretation process on an interactive workstation, and after that create the base map of study area. This operation includes entering all of the strike line numbers, all of the dip line numbers, the spacing between bin size along strike line direction and dip line direction as in Figure -2

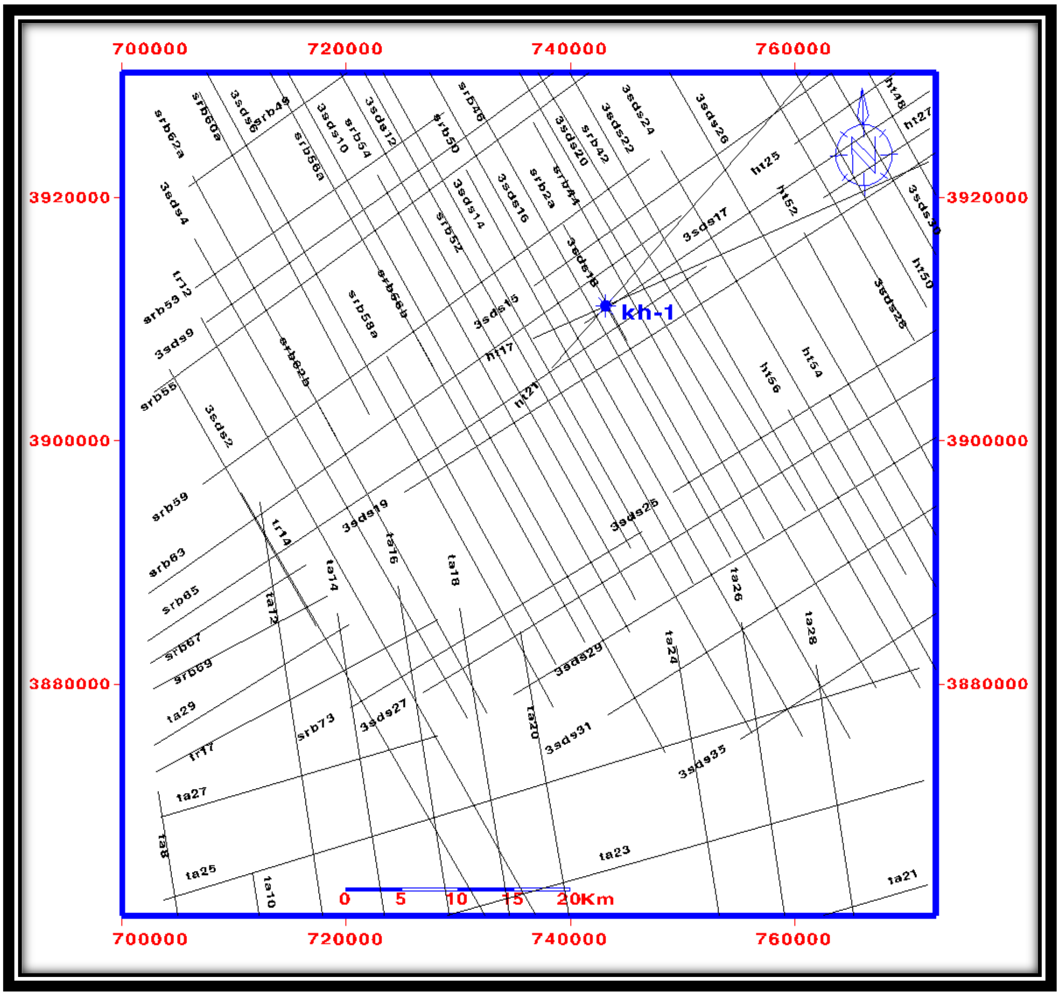

Figure 2- Base map of the study area.

Generation of synthetic seismogram

Synthetic seismograms were created for Khlesia well-1 through velocities survey in the well and sonic log using GeoFrame software package.

The essential steps for the synthetic seismogram generation referred by [5] which they are:

1-computing the acoustic impedance (Z) = $\rho \times v$ Where:

v: is seismic velocity

ρ: is density measured from density log.

2-computing the reflection coefficients of the vertical incident wave on reflector separating two series time intervals such (i) and (i+1) that have values of acoustic impedance (ρi vi) and (ρi+1, vi+1) respectively. According to [5] we can compute the reflection coefficients as the following:

$$Rc_i = \frac{(Zi+1)-(Zi)}{(Zi+1)+(Zi)}$$

Where:

$(Zi, Zi+1)$ the acoustic impedance at two successive layers (i), (i+1).

-After computing the acoustic impedance and reflection coefficient respectively a perfect wavelet was extracted to obtain the synthetic seismogram by convolution operation between the reflection coefficients and experimentally chosen wavelet. The geological velocity (average velocity) of geological strata obtains by compared sonic log data with the well velocity survey which represents the direct method. The synthetic seismogram traces of the Khlesia-1 well were generated by programs within the IESX (synthetic programs) Figure-3. These have efficiency to extract the relation between the time and depth functions in the well site, and this relation is so significant in determining the reflection on a time axis of seismic section and synthetic trace against the require bed in the well. Check-shot survey can be used to convert log data which acquired in depth into time, so the data can be correlated to surface seismic data by correcting the sonic log and creating a seismogram to affirm or modify seismic interpretations, the time-depth curve from check shot can be used to transform the time map section to depth sections.

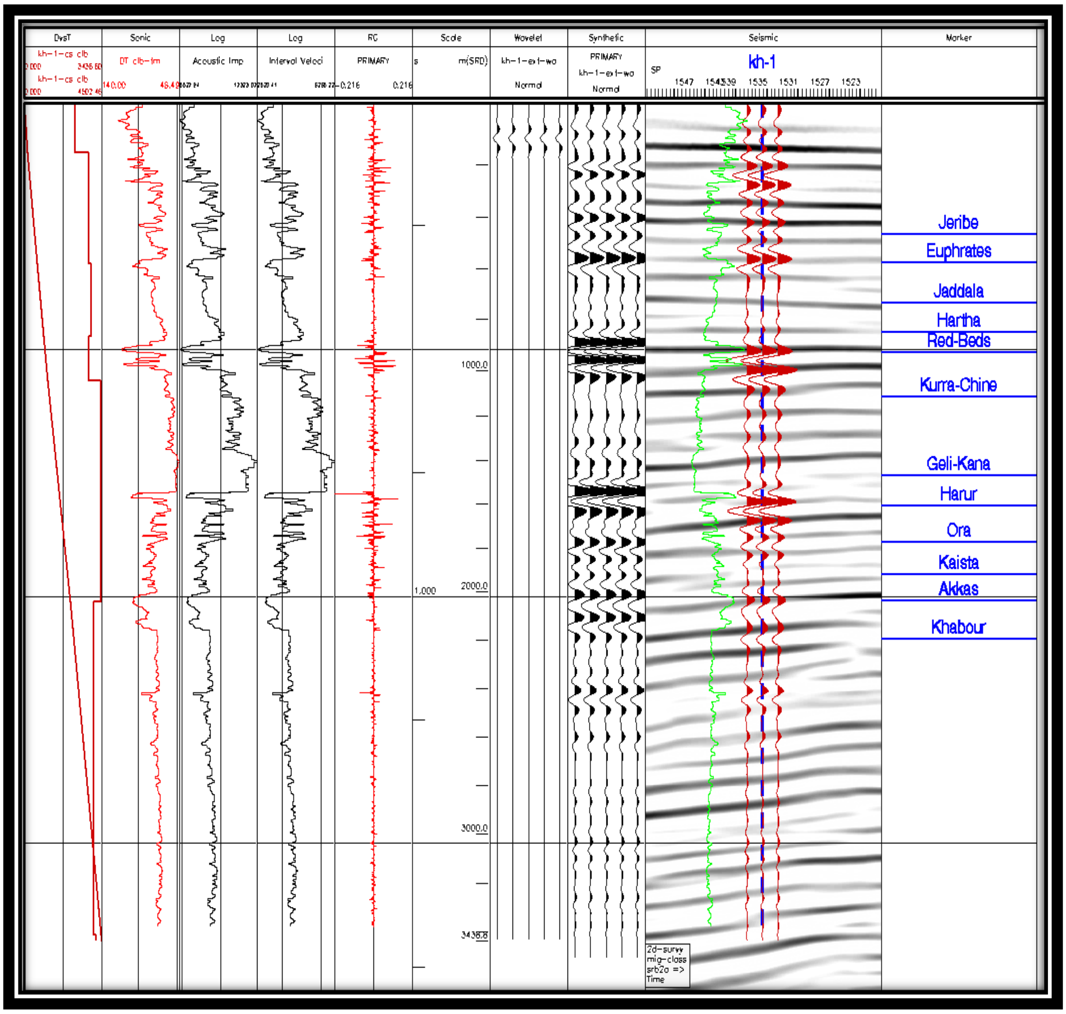

Figure 3- Illustrates the synthetic seismogram of Kh-1 well.

Seismic Data Interpretation

The third and last stage in the seismic exploration project is called seismic interpretation. In the two preceding stages (data acquisition and processing), first generated the reflected waves then processed to make the seismic sections are proper for the final stage of exploration which is the data interpretation. This comprises transition of these seismic data into the identical geological information [6].

Structural interpretation includes the following:

- Reflectors picking on all seismic lines that cover the study area.
- Determination of the important structural features in the region (structural domes and active faults).
- Capture the faults, paths, types and extents vertically and horizontally.
- Structural mapping in the time and depth domains.
- Draw the 3D model of the maps above.

The faults picking operation in all the area were along inline, cross lines and arbitrary lines. After picking of studied reflectors the seismic section shows effect of major normal fault in study area which called Listric growth normal fault lt and its branches (Dendritic faults); it is interpreted as main major grabens with variable width on seismic sections and large displacements of all studied reflectors except the within Fatha reflector. The seismic section displys that the study area to be influenced by two grabens (Khlesia and Tayarat) with variable width by approximately (4-7km) on seismic sections, generally, the grabens axes have northeast- southwest trends. Khlesia graben (north graben) effected on study area from surface to all reflectors beneath it, Tayarat graben (south graben) effected on Hartha reflector and reflectors beneath it Figure -4.

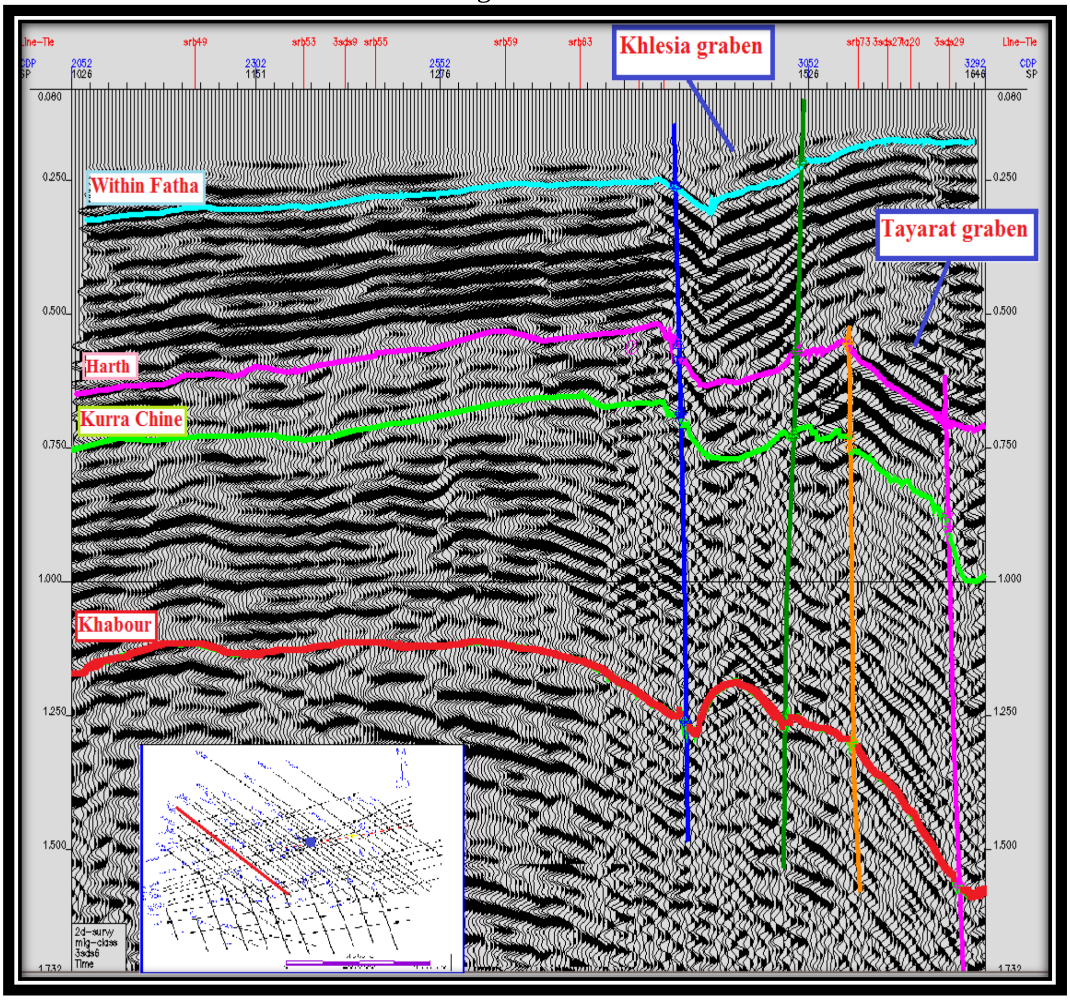

Figure 4- Seismic section shows faults that effect on study area that formed two grabens.

Structural pictures of picked horizons

Depending on analysis of the seismic data and synthetic seismogram, two reflectors were recognized and picked Within Fatha reflector and Kurra Chine reflector. After the definition of studied reflectors using synthetic seismograms in time domain for Khlesia-1well, tops of these reflectors were picked in the area to produce the time maps which are later transformed to structural maps in depth domain by using velocity data of these reflectors, by using CPS3 program available on Geoframe workstation. Datum to all maps is (200)m above sea level used as reference.

Time maps

The time maps may illustrate the subsurface picture of the geologic features. Within Fatha and Kurra Chine Formations two way time maps.

1- TWT map of Within Fatha reflector Figure -5 are dominated by a NE-SW trending high value to the west and south west, and decrease to the north east direction of the area. The study area at this level affected by two normal faults with approximately displacement (40)m formed graben has variable width (4-7km) extend NE-SW and separated to the north and south parts. The north part observed as structure nose extend NE-SW, and the south part dominated by two small domes locates at east part. The contour values show the left side deeper than right side of study area.

2- TWT map of Kurra Chine Figure -6 is dominated by a NE-SW trending high value to the west and south west, and decrease to the north east direction of the area. The study area at this level is affected by two set of normal faults with approximately displacement (40)m formed two grabens (north and south) have variable width (4-7km) extend NE-SW and separated to the north, middle and south parts. The north part appear as structure nose extend NE-SW with Khlesia structure at Kh-1 well. The middle part is restricted by these grabens from north and south, structurally deformed due to faults, in the north graben there are three small structure domes. The south part dominated by two small domes locates at east and west parts. The contour values show the south part deeper than middle and north parts.

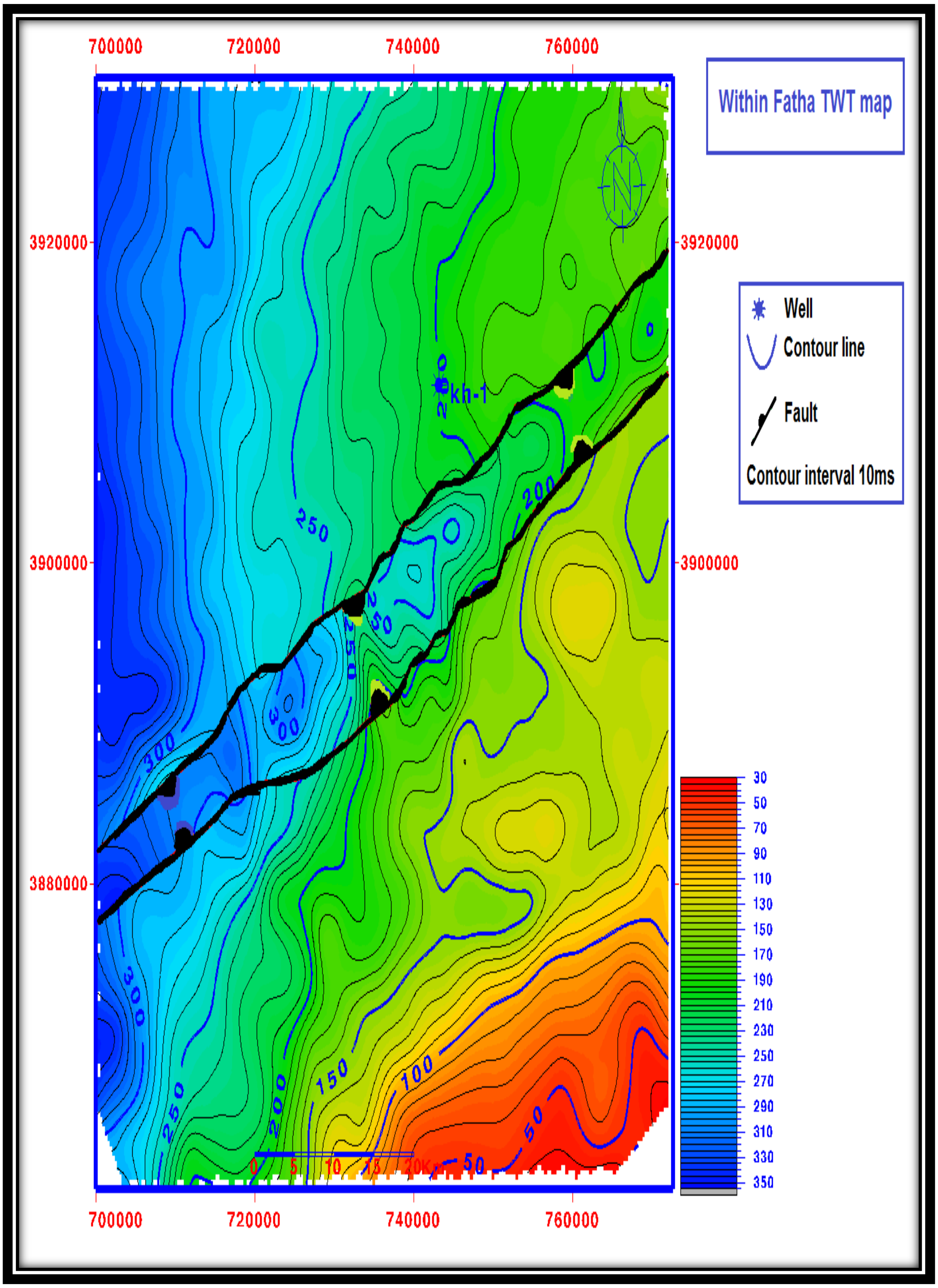

Figure 5- Within Fatha two way time map.

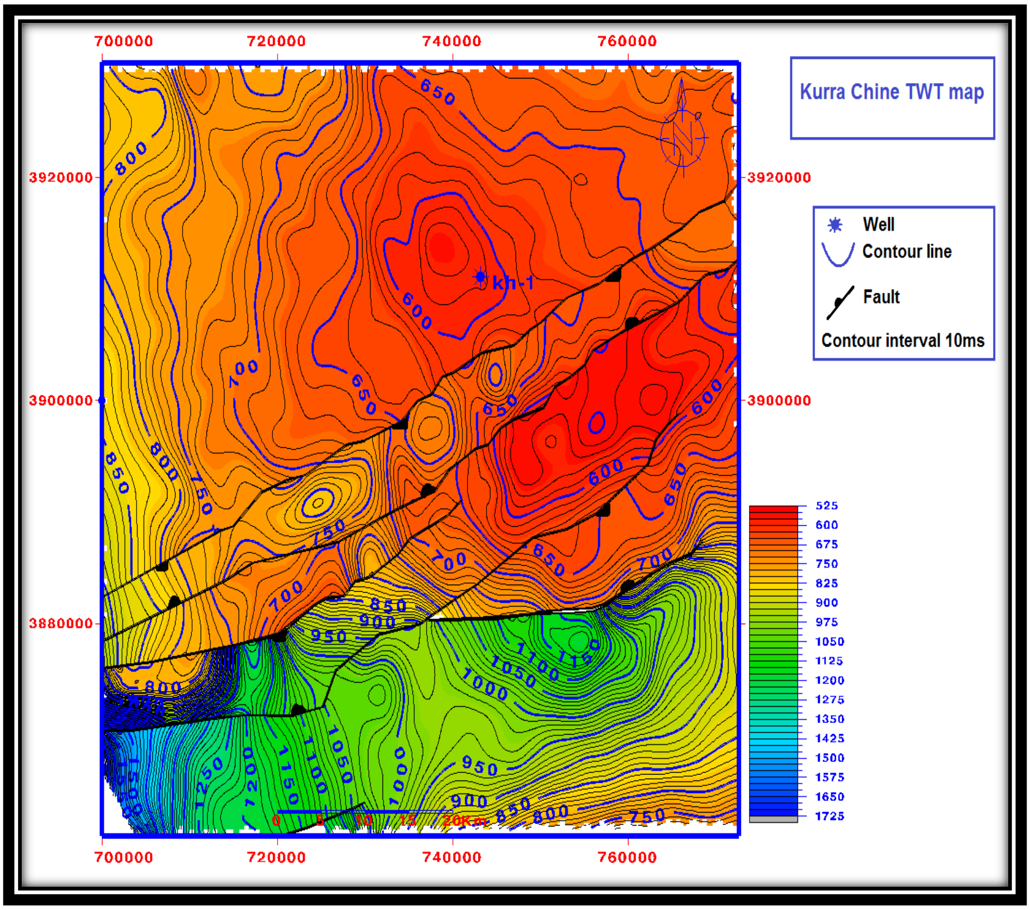

Figure 6- Kurra Chine two way time map.

Velocity maps

The average velocity is the appropriate velocity applied to convert the two way time maps to depth maps. It considered the more accurate velocity type used in seismic methods and directly calculated from well velocity survey (check-shot) [7]. The well of Khlesia area (Kh-1) used data of check shot to achieve the velocity maps.

Depth maps

The depth map is extracted from time map of a given reflector with average velocity map at the same reflector, as follows:

Depth at any point = (velocity × one way time) at this point.

The depth map is an important step in seismic reflection method, permits the production of depth and thickness of depict subsurface layers based on reflection data.

1- Within Fatha depth map Figure -7 shows structural feature having general trend NE- SW direction. We noticed a decrease at the south east and gradually increase toward the west and north west. The study area affected by two normal faults with approximately displacement (40)m formed graben has variable width (4-7km) extend NE-SW and separated to the north and south parts. The north part appears as structure nose extend NE-SW and the south part dominated by two small domes located at east part. The contour values show the north part deeper than south part.

2- Kurra Chine depth map Figure-8 displays a structural feature within a general trend in the NE-SW direction. We noticed a decrease in the northeast and increase gradually toward the west and southwest of the area. The study area at this level affected by two set of normal faults with approximately displacement (40)m formed two grabens (north and south grabens) have variable width (4-7km) extend NE-SW along of study area and separated to the north, middle and south parts. The north part appears as structure nose extend NE-SW with Khlesia structure at Kh-1 well and Bydaa dome at NW. The middle part is restricted by these grabens from north and south, structurally deformed due to faults, in the north graben there are three small structure domes. The south part dominated by two small domes located at east and west parts as well as showed a new structure feature undiscovered in previous studies. The contour values show the south part deeper than middle and north parts.

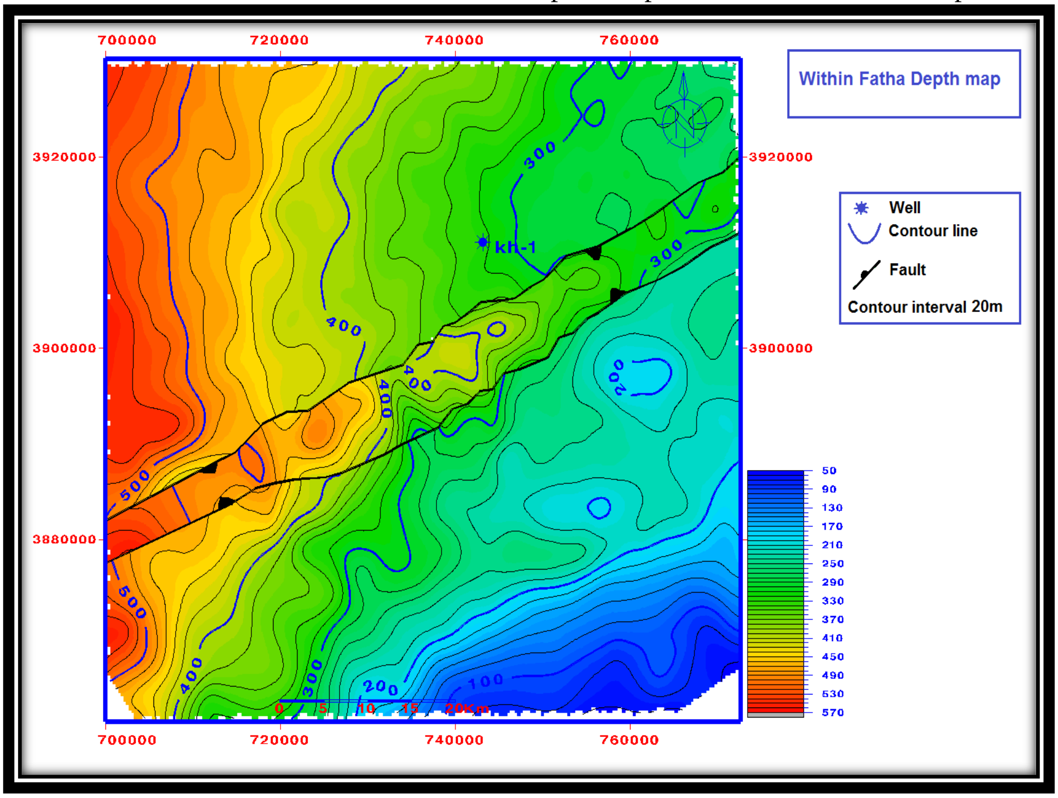

Figure 7- Within Fatha depth map.

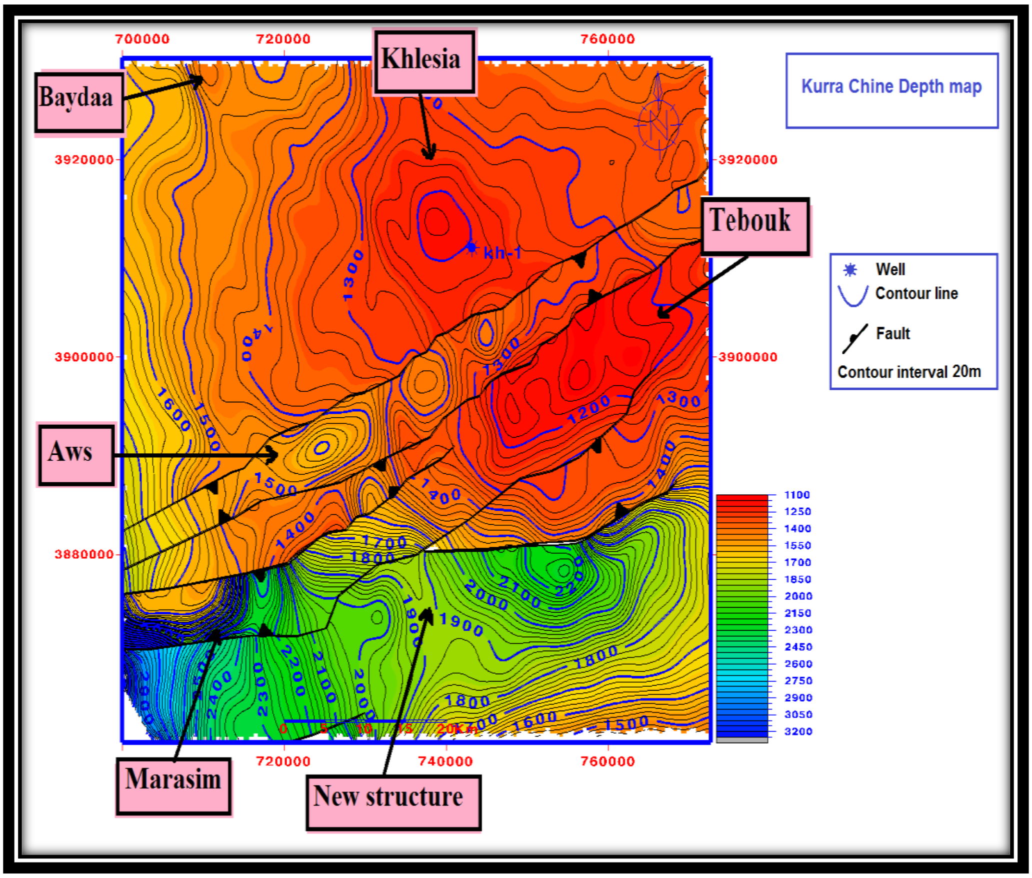

Figure 8- Kurra Chine depth map.

Seismic Attribute Sections

Cosine Instantaneous phase

The phase is a lag in the motion between either one body in two different time periods or two bodies at a time period and show bedding very well and its helpful in lateral continuity determination. Figure -9 shows the ends of the continuity of reflective surfaces at unconformity feature in seismic section.

Instantaneous Frequency

Instantaneous frequency is the time derivative of the phase [8]. The application of attribute help to determine the sites of instantaneous frequency changes and their relation to changes in petrophysical qualities, the hydrocarbon accumulation area is linked with low frequency zone [9].

The instantaneous frequency Figure -10 displays the lateral changes of frequency at the studies reflectors. Frequency signals noticed within this section ranged from low to intermediate, the area of low frequency may reflect presences hydrocarbon.

Reflection strength section

Reflection strength associated with the lithological changes between adjacent rock layers, unconformity surfaces and hydrocarbon content in the rocks referred by [10]. Figure -11 illustrates reflection strength section in study area, from studying reflection magnitude showed the presence of high reflection strength in the negative side in unconformity stratigraphic feature, and this feature is surrounded by rocks completely different depending on color scale in the section of reflection strength that may refer to hydrocarbon accumulations in this area because there is a matching between high reflection strength and the presence of hydrocarbons.

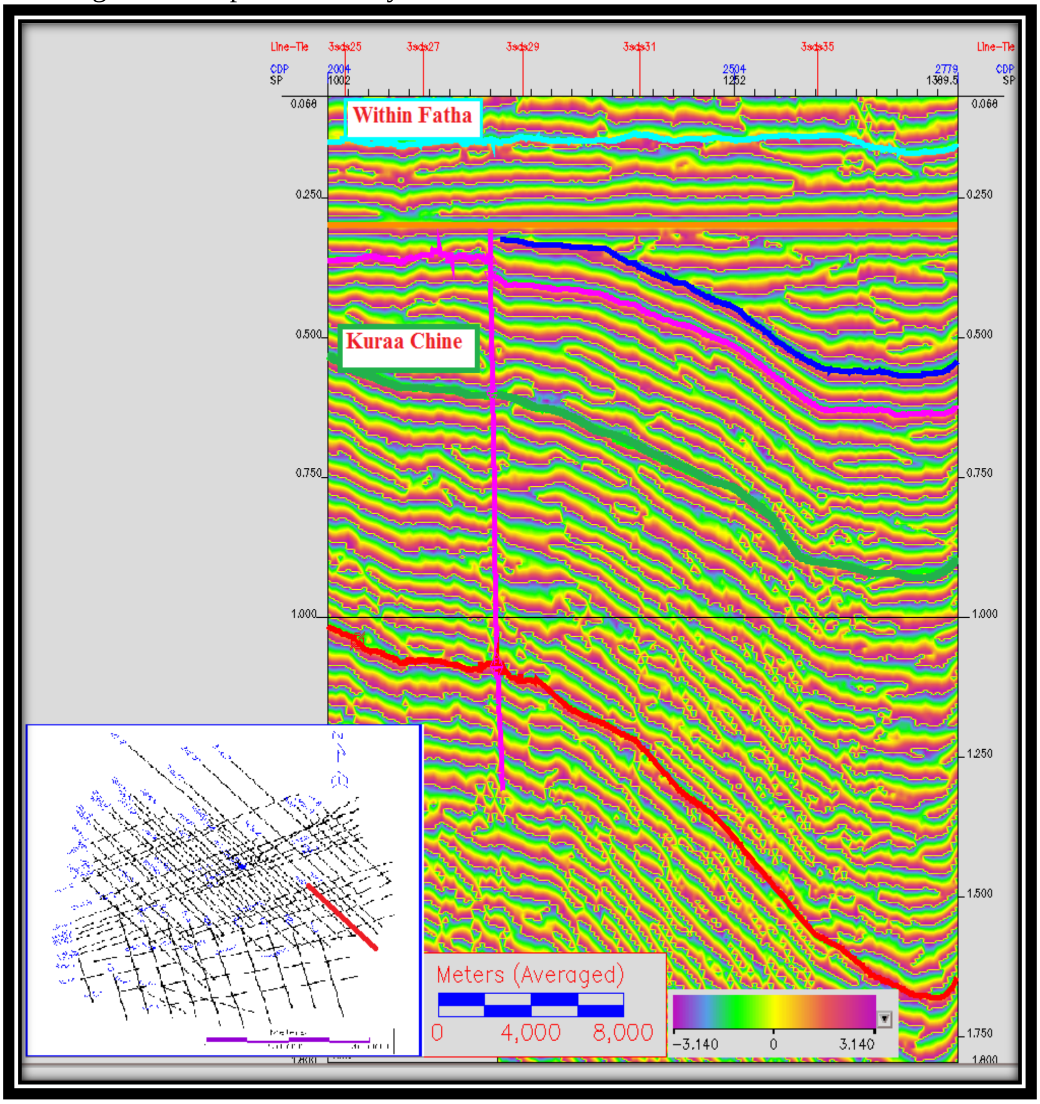

Figure 9- Shows cosine instantaneous phase section of studied reflectors.

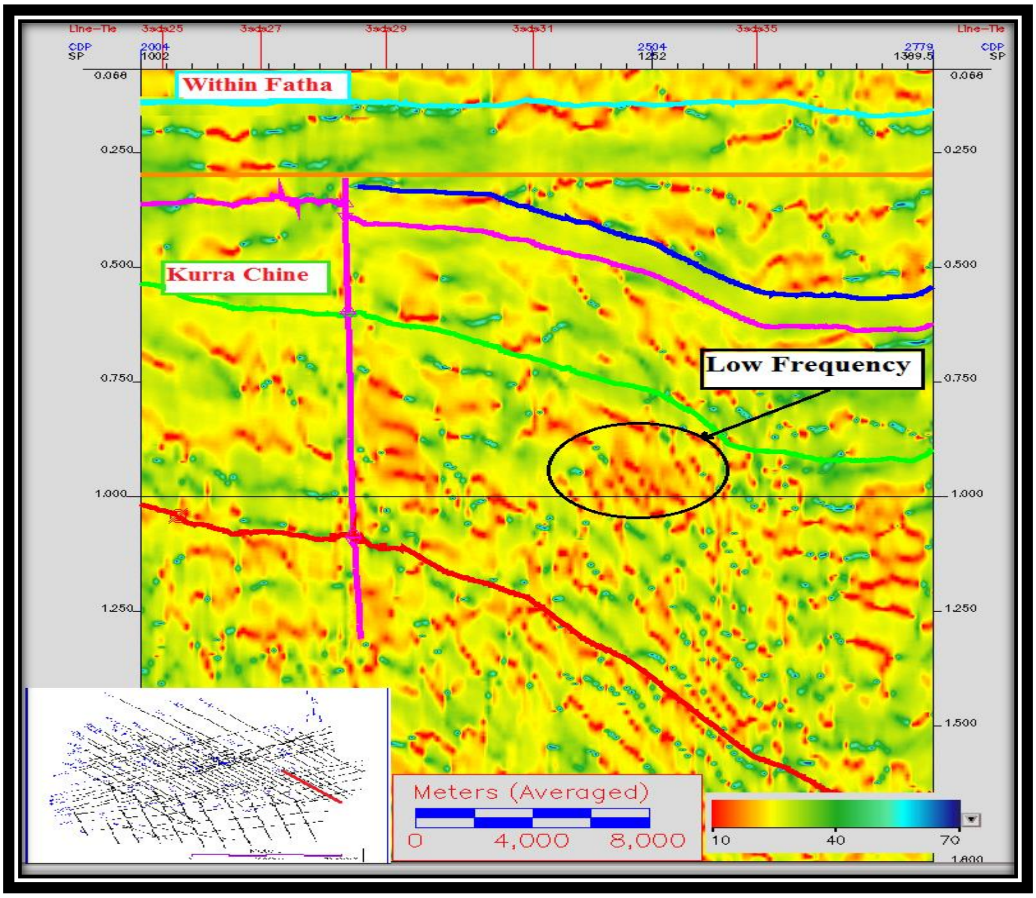

Figure 10- Shows instantaneous frequency section of studied reflectors.

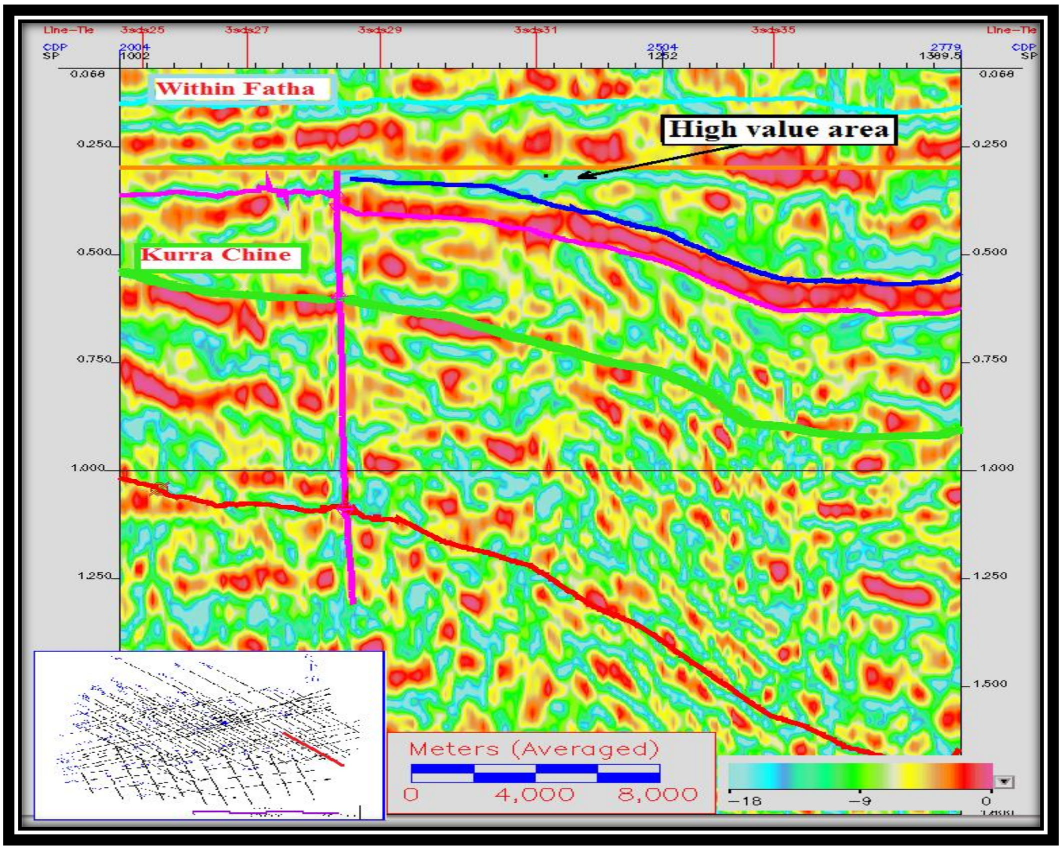

Figure 11- Reflection strength section of the study area.

Seismic Stratigraphic Interpretation

Seismic stratigraphy is approch can add significant geological information and useful to enhance the understanding of the depositional environments, which may support of the comprehension the source, accumulation, and trapping mechanisms of the hydrocarbon deposits [11].

Seismic stratigraphic traps

Stratigraphic traps are formed when there are changes in lithology, nature of the strata or depositional pattern. They prevent continued migration of hydrocarbons within reservoir beds. The stratigraphic trap is the most difficult to find on a seismic section. So far, we have explored how sedimentary basin is formed and how oil and gas are formed and trapped in the subsurface. The exploration geophysicists need to be able to look into the various layers of the earth to determine where oil and gas is trapped. In other to do this the geophysicists apply seismic reflection technology to locate oil and gas traps in the subsurface [12]. two seismic stratigraphic traps capture in study area

The stratigraphic interpretations included the capture of two seismic stratigraphic traps in study area that represents high potential hydrocarbon traps:

1- "Angular unconformity trap": is easily distinguished in seismic section by the angular relation and thinning phenomena. The angular unconformity refers to certain amount of tectonic deformation before the sediments that deposited recently. The angular unconformity is considered a good hydrocarbon trap if the conditions are appropriate from source and seal rocks. Termination of angular unconformity by thinning or pinch out of reservoir against a impermeable cap rocks creates a suitable geometry to traps hydrocarbon when the adjacent rocks are a source rocks such as shale. Figure -12 shows angular unconformity trap with area approximately (2.12)km^2.

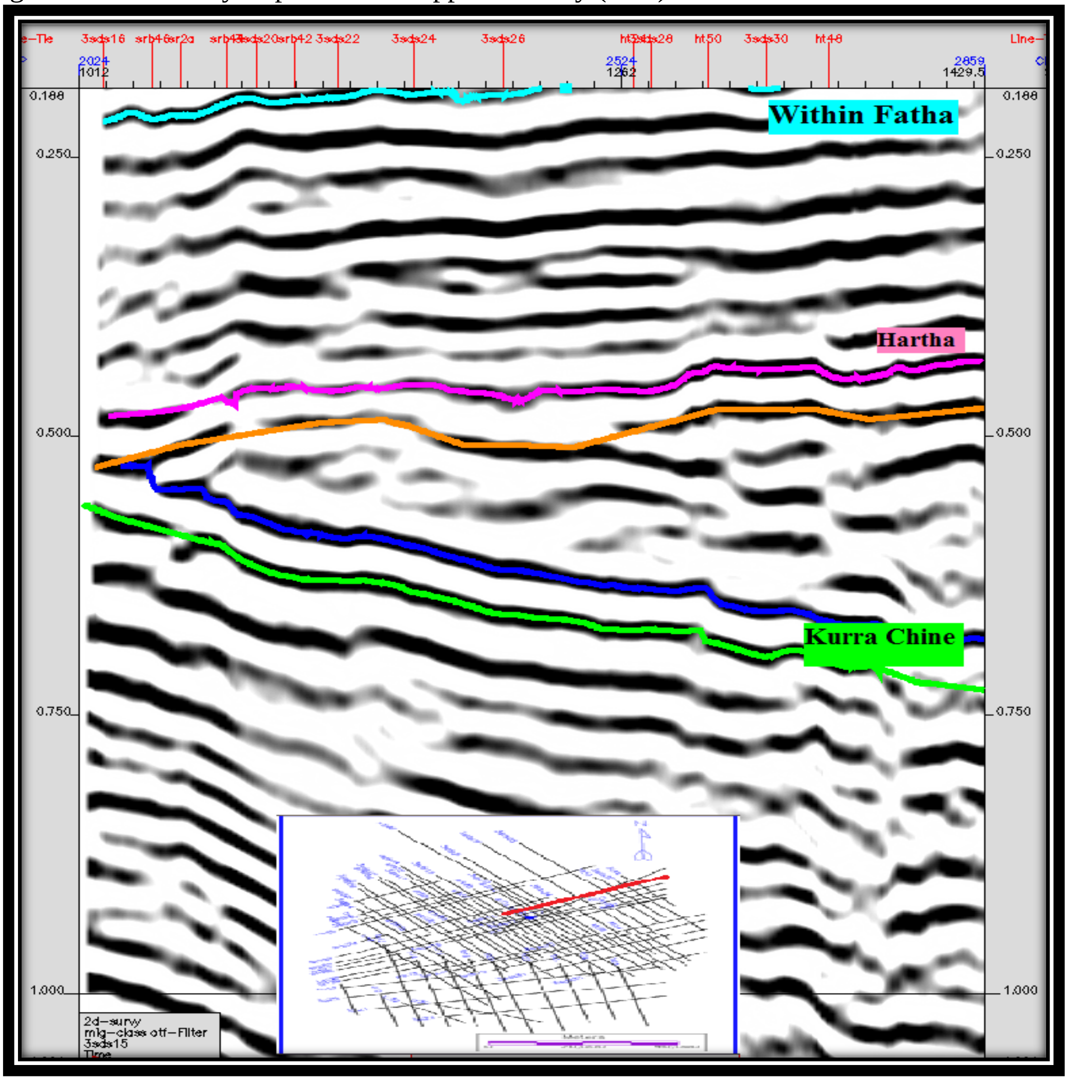

Figure 12- Seismic section displays the angular unconformity stratigraphic trap.

2- Growth stratigraphic trap: it compounds trap that is a depression that forms as a result of movement on a normal fault and fault forms one of the boundaries of the depression. Pre-rift deposit are hanging wall block of a normal fault (in this case, the block to the right of the fault) moves down whereas the foot wall block moves up. Layers of sediment can accumulate within this depression. The sediments (mostly clastic sediments) are commonly eroded from the uplifted shoulder area and completely fill the depression these sediment called syn-rift deposit. After filled the depression the post-rift deposit will deposit above syn-rift deposit and consider seal rocks if its nonporous rocks this geometry consider good hydrocarbon trap. Figure -13 shows angular unconformity trap with area approximately (2.45)km^2.

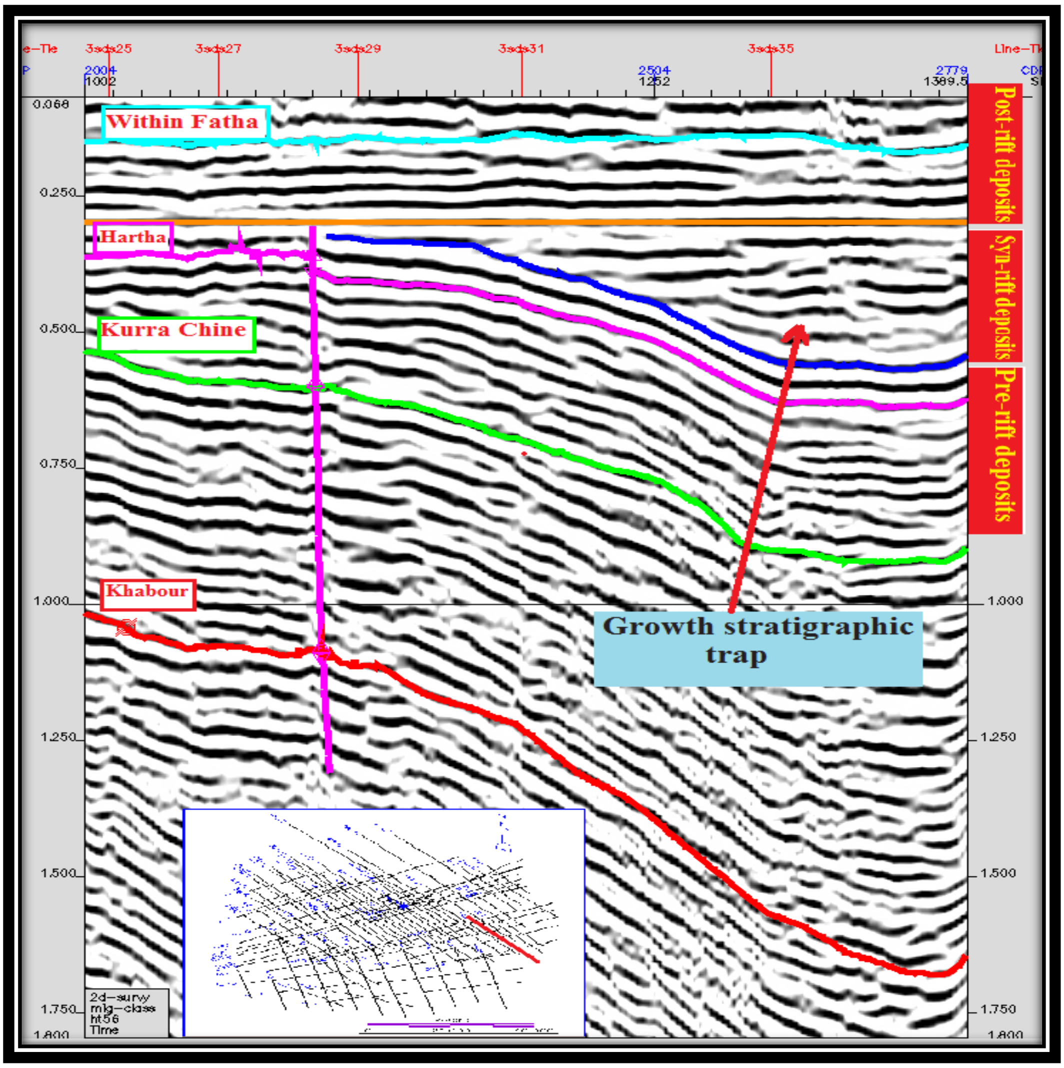

Figure 13- Seismic section displays the growth stratigraphic trap.

Conclusions and Recommendations

Two reflectors, Within Fatha, and Kurra Chine Formations are defined by using synthetic seismograms in time domain for Kh-1 well. A Listric growth normal fault and its branches of northeast-southwest trending was picked, and extends from Hartha Formation to Kurra Chine Formation and limit Khabour Formation. Listric growth normal fault represents a normal fault formed as a results of compression stress and vertical loading of sediments deposit in the depression, and its formed Tayara graben. After stage of listric growth normal fault the sediments deposited, and due to collision between Arabian with Eurasian plates that occurred in the Oligocene age formed continental Khlesia graben appear on all reflectors by tension faults. The faults system in the study area is a major factor in trapping and distribution of hydrocarbon. The time maps of the studied reflectors showed the existence of structure nose on Within Fatha reflector have NE-SW trend, and several phenomena as domes on Kurra Chine reflector. The average velocity is used to convert the TWT maps to depth maps. The depth map shown a new structure feature does not discover in previous studies on Kurra Chine reflector as well as the previous discovered structures of Khlesia area. Depth maps appear the lower depth values are noticed at the southeast and increase gradually toward the west and northwest for Within Fatha reflector, and the lower depth values are noticed at the northeast and increase gradually toward the west and southwest for Kurra Chine reflector. Seismic attributes techniques were applied in Khlesia area 2D seismic volume, which include, instantaneous phase, instantaneous frequency, and reflection strength, these attributes showed indicates of hydrocarbon accumulation. Khlesia area represents combined traps (Growth stratigraphic trap) and stratigraphic traps (Angular unconformity stratigraphic trap) are created by faulting, tension and tectonic movements, these traps consider high potential hydrocarbon reservoirs.

We recommend drilling an exploratory well in the Tayarat graben to reach Khabour Formation which has a good gas reservoir in surrounding area depending on Ah-2 well; also this area needs to achieve wide depositional environmental study in order to recognize depositional facies, reservoir specifications and location of hydrocarbon source.

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