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Structural subsurface model of Samawa-Diwan area (south of Iraq)

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Abstract

Seismic instantaneous phase attribute was applied for conventional seismic interpretation (structural interpretation) on 3D seismic cube of 1914.72km^2 of Samawa-Diwan area, located in the south part of Iraq within Muthna governorate. Instantaneous phase section is very important to detect structural and stratigraphic features. Six reflectors represent Upper Jurassic and Cretaceous formations were defined from synthetic seismogram of wells in study area, then picked over seismic cube. Fault boundaries maps for each horizon were drawn depending on horizon contacts then fault planes were constructed. Finally, a 3D structural model was constructed in time domain, then converted to depth domain by using 3D average velocity model. Structurally, 3D models showed that study area affected by two types of normal faults formed a graben appear at west side a long study area, and separated by transverse fault to the north and south parts at Hartha Fn. and deep layers, while Tertiary formations have not affected by any type of faults systems. Also, structural map showed existence of four structural domes which they are Samawa and Diwan folded domes, Samawa south faulted dome and fourth one is new folded dome locates in the northwest of study area. All these features extend in northwest-southeast trend.

Keywords: Instantaneous phase attribute, fault contacts, fault boundaries, fault planes, 3D structural model and 3D average velocity model.

الموديل التركيبي التحت سطحي بالأبعاد الثلاثة لمنطقة سماوة–ديوان (جنوب العراق)

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قسم علوم الأرض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تم أستخدام خاصية ملامح الطور الآني في التفاسير الزلزالية التقليدي (التفاسير التركيبية) على مكعب البيانات الزلزالية ثلاثي الأبعاد بمساحة 1914.72 كم^2 لمنطقة سماوة–ديوان الواقعة في الجزء الجنوبي من العراق ضمن محافظة المثنى. تعتبر سمة الطور الآني مهمة للغاية للكشف عن الخصائص التركيبية والطباقية. درست ستة تكوينات تمثل عصري الجوراسي الأعلى والطباشيري، تم تعريف العواكس على البيانات الزلزالية من الآثار الزلزالية للآبار المحفورة في منطقة الدراسة، بعد ذلك التقطت هذه العواكس على مساحة مكعب البيانات الزلزالية. رسمت حدود الصدوع اعتمادا على نقاط الأتصال العواكس بالصدوع المؤشرة على المقاطع الزلزالية بعد ذلك رسمت مستويات التصدع بالأبعاد الثلاثة. أخيرًا، أنشأ الموديل الثلاثي الأبعاد في المجال الزمني وتحويله إلى المجال العمقي باستخدام موديل السرع المعدلية الثلاثي الأبعاد. من الناحية التركيبية، أظهرت الموديلات التركيبية ثلاثية الأبعاد أن منطقة الدراسة تأثرت بصدعين من النوع الأعتيادي شكلت منطقة تخسف تمتد على طول الجانب الغربي من منطقة الدراسة، وقسمت المنطقة بواسطة صدع من النوع المستعرض إلى جزئين شمالي وجنوبي عند عاكس الهارتة والطبقات التي تقع للأسفل منه، في حين أن

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العواكس التي تمثل تكوينات العصر الثلاثي لم تتأثر بأي نظام من الصدوع. بالأضافة الى ذلك، أظهرت الخرائط التركيبية وجود أربعة قباب تركيبية هي قبتي السماوة وديوان المحدبتين وقبة السماوة الجنوبي المتصدعة وقبة جديدة محدبة تقع في شمال غرب منطقة الدراسة. أن الظواهر التركيبية أعلاه تمتد باتجاه شمال غرب−جنوب شرق من منطقة الدراسة

1. Introduction

The seismic trace represents the variable function between the amplitude and time in the time domain [1]. The Hilbert transform is a kind of filtering which does not affect the amplitude of the spectral component, but it causes changes in the phases of these components by 90° to obtain the imaginary part of the complex function that we get from knowledge of the real part which represents the conventional seismic section [2].

The seismic instantaneous phase attribute is considered as various aspects of the seismic data [3]; it's obtained by complex trace analysis (Figure-1).

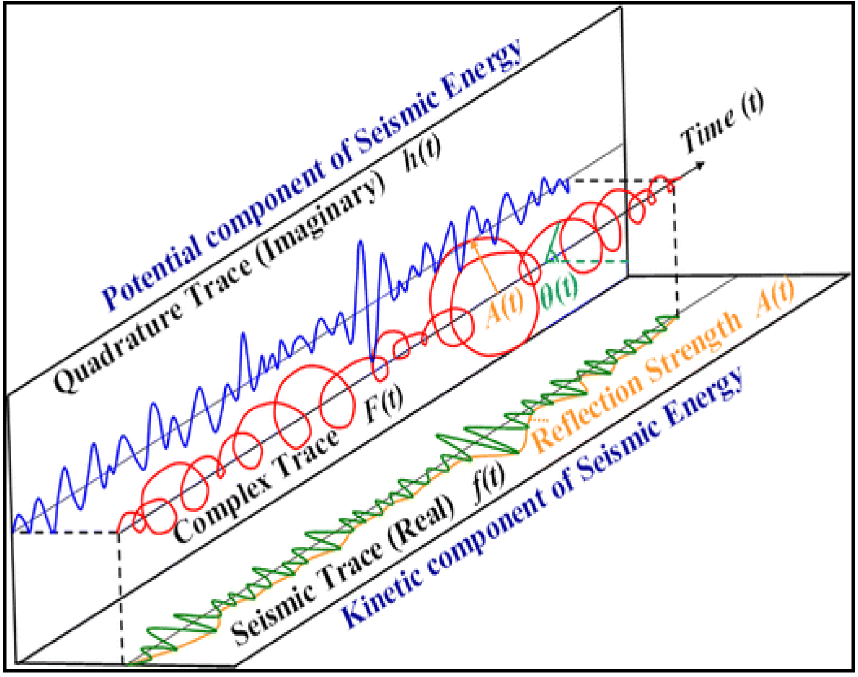


Figure 1-The complex seismic trace and seismic attributes [2].

The imaginary trace is calculated from real trace by using Hilbert transform [4].

The analytic trace is given by: $F(t) = g(t) + h(t)$ ……..(1)

The instantaneous phase is: $\phi(t) = h(t) / g(t)$ ……..(2)

Where: $g(t) = A(t) \cos \phi(t), h(t) \sin \phi(t)$ ……..(3)

The seismic section represents the end product of seismic work (field work and data processing), so the accuracy of the interpretation depends on the accuracy of previous works. The geophysicist uses interpretation workstation to map the structural and stratigraphic seismic features correlating them with geological settings in the subsurface [5]. A structural trap is a type of geological features such anticlines and faults that forms as a result of changes in the dip of the subsurface layers due to Basement up-left, compositional processes, gravitational, salt and igneous intrusive. Changes in blocks causes the migration of hydrocarbons and can lead to the formation of a petroleum reservoir. Structural traps are the most important type of traps; they represent the majority of the world's discovered petroleum resources [6].

The current research is structural analysis study of the seismic reflection data for the Samawa-Diwan 3D seismic survey which carried out by the Iraqi seismic 3D crew in 2015.

2. Location of the study area

The study area is located to the south part of Iraq within Muthna governorate, approximately 40Km to the southwest of Samawa city [7]. It lies within the Universal Transverse Mercator (U.T.M/ WGS.1984/zone-38) coordinates system which given in table-1. Surface topography shows the area is flat and there is no structural feature appear on the surface, and elevation rises towards southeast about 10m above sea level in the northeast and about 120m above sea level in the southeast. The area bounded by Euphrates river from the northeast as shown in the Figure-2.

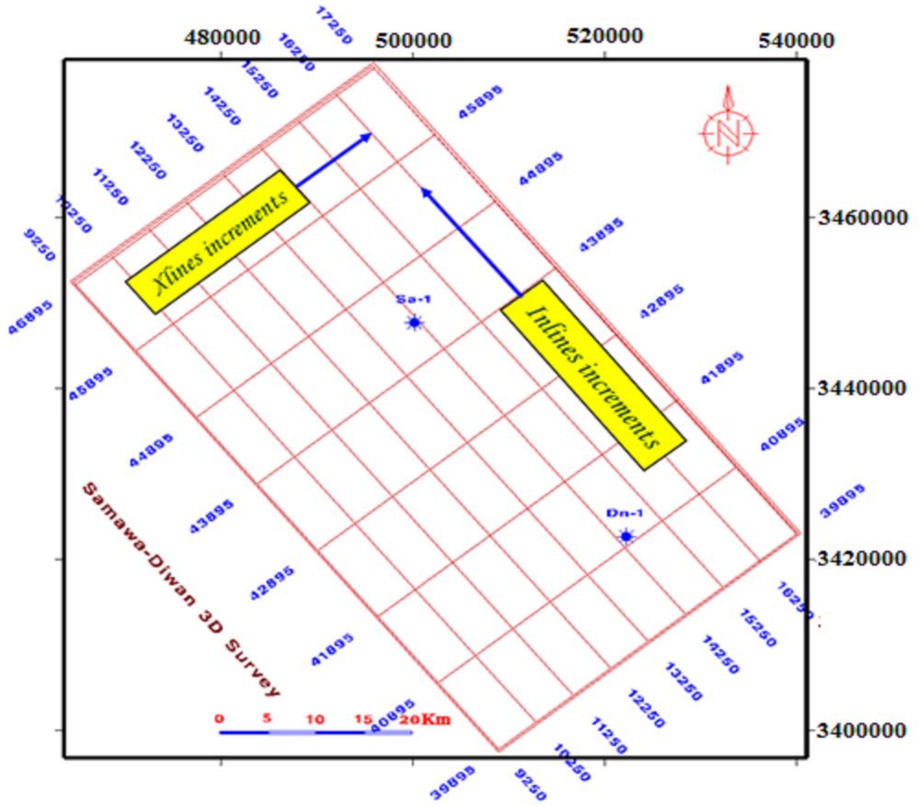


Figure 2-Location map of the study area [7]

Table 1-The coordinates of the three-dimensional survey of Samawa-Diwan area

point	Northern	Eastern
A	*479000*	*3447000*
B	*500000*	*3464000*
C	*534000*	*3423000*
D	*511000*	*3406000*

Before execution 3D survey project, the pre-planning report was prepared and included specific design that ensures easy of execution with good quality of recorded data. The main parameters and characteristics such as recording requirements, spread patterns, source points, CDP-bin volume, offsets and coverage degree. The orthogonal pattern and swaths spread direction were selected for achieving the survey because it is very appropriate for the flat land, the survey consist of 148 swaths and each swath includes four receiver lines [8]. In general, the survey requirements can be summarized in table-2.

Table 2-A pre-planning parameters of Samawa-Diwan 3D survey [8]

Specifications	**parameters**
Spread shape	Rectangular
Bin size	25 × 50 m
Receiver line interval	400m
Source line interval	300 m
Receiver interval	50 m
Source interval	100 m
Live receivers per line	120
Live patch length	5950m
Fold	70
Maximum offset	4051m
Maximum minimum offset	445m
Bearing	51°

3. Loading data and Basemap preparation

First, project created on Geoframe workstation and the following data were downloaded to achieve structural interpretation:

- Post stack time migrated cube of Samawa-Diwan survey with SEG-Y format.
- Data of Samawa-1 and Diwan-1 wells (marker, velocity survey and sonic logs) with ASCII format.
- In addition, seismic cube variable was displayed as amplitude (VA) and instantaneous phase attributes to pick horizons and faults on seismic sections.

Consequently, the basemap of the study area is drawn. This process includes entering the first and last inline number, the first and last cross line number, the separated distance between bin size along inline direction and cross line direction (Figure-3).

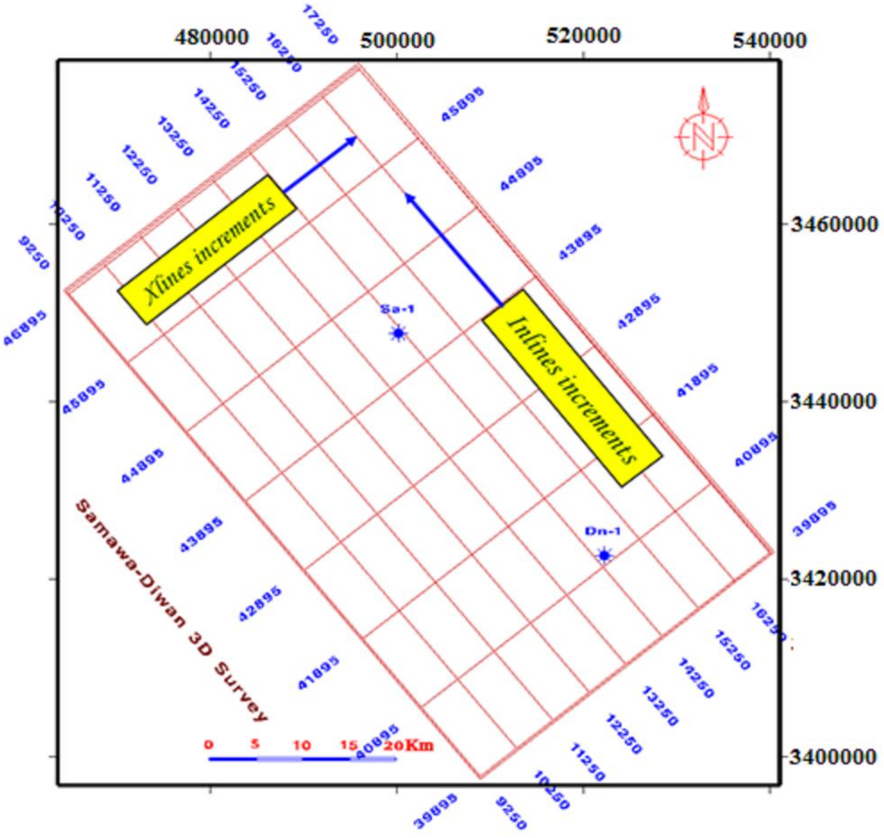


Figure 3-Basemap of study area.

4. Generate Synthetic seismograms

Synthetic seismograms were generated for two wells (Samawa-1 and Diwan-1). The well database consists of stratigraphic markers, sonic and check-shot logs. The fundamental elements in transformation from geological domain to seismic signal were used to tie a stratigraphic sequence of seismic data to define reflectors [9]. Figure-4 An arbitrary seismic section shows seismic correlation between synthetic traces of Sa-1 and Dn-1 wells.

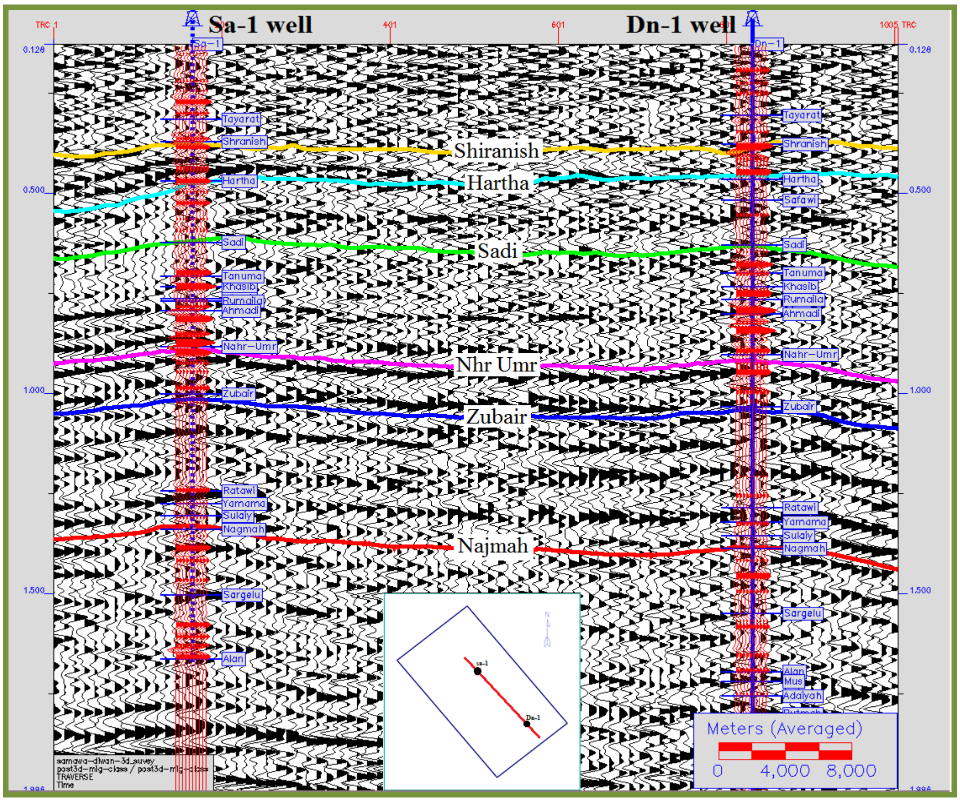
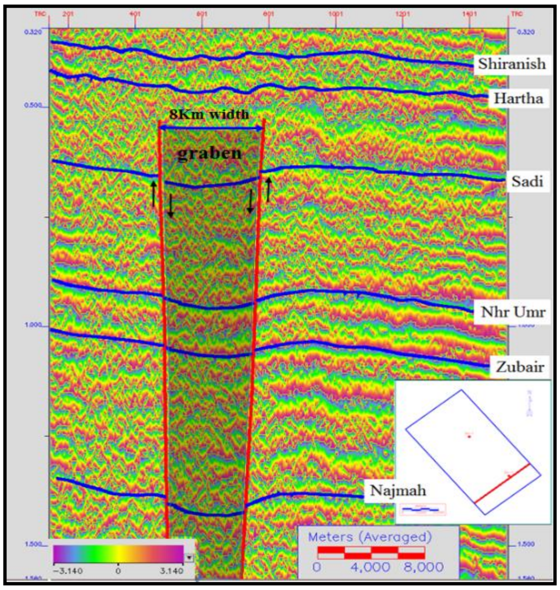


Figure 4-An arbitrary seismic section shows reflectors definition and seismic correlation between synthetic traces of Sa-1 and Dn-1 wells.

5. Faults recognition and horizons picking

The intervals of 5 in-lines and cross-lines were chosen to achieve structural interpretation. Interpretation operation on seismic sections shows the area deformed by fault systems at Cretaceous and deep horizons. The following structural features were detected on seismic sections:

- Two types of fault systems, the first one observed and picked on seismic inline sections and represents two normal faults, they're formed a graben which has 6-8km width. This graben was effected on Hartha and deep reflectors Figures-(5, 6). The second one represents a transverse fault observed on crossline sections Figure-7.
- Four structural domes, the first one represents Samawa folded dome in the north part of study area and penetrates by Sa-1 well (Figure-5). The second one represents Diwan folded dome in the south part of study area and penetrates by Dn-1 well Figure-6. The third one represents Samawa south faulted dome in the middle of study area Figure-8. The fourth one is folded dome in the northwest of study area Figure-7.



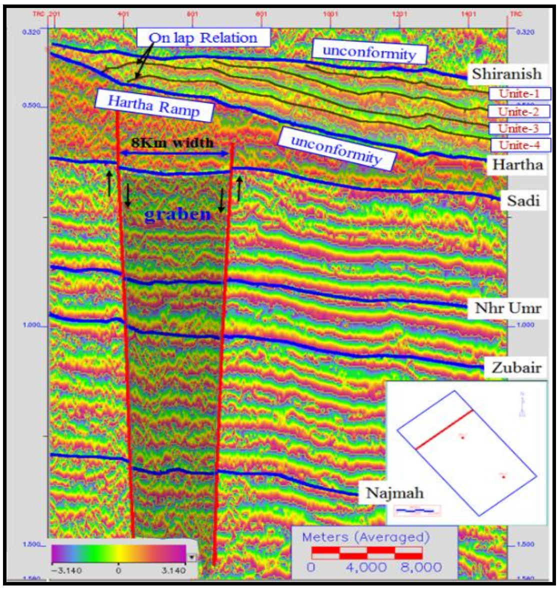
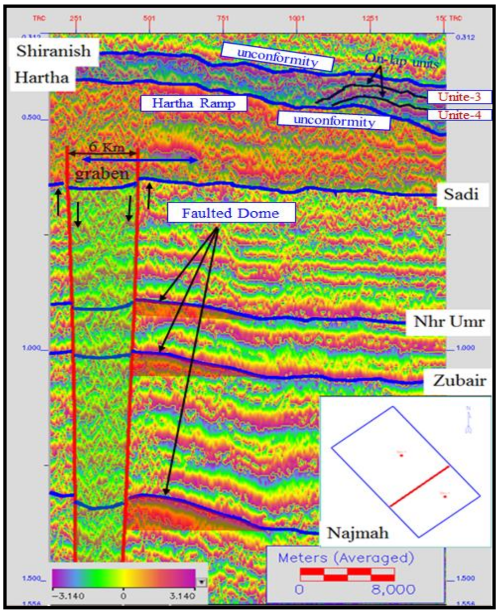


Figure 5-An instantaneous phase section no. 40875 shows graben in south part of area.

Figure 6-An instantaneous phase section no. 45375 shows graben in north part of area.



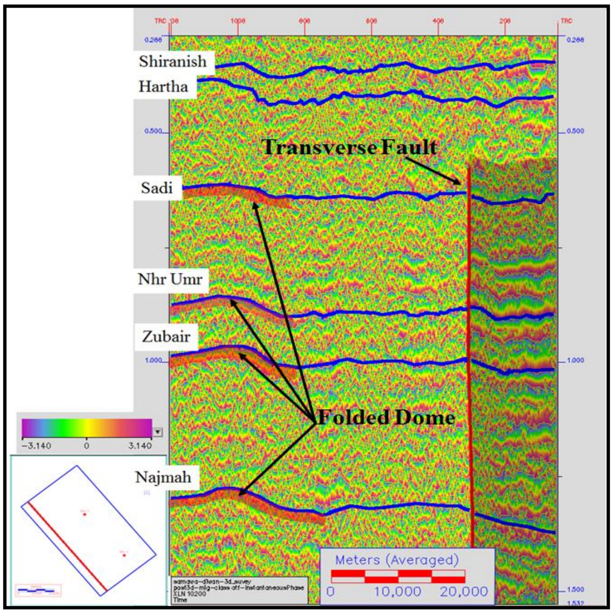


Figure 7-An instantaneous phase section no. 10200 shows folded dome in the northwest part of area.

Figure 8-An instantaneous phase section no. 42300 shows Samawa south faulted dome.

6. Time way time maps

Six structural time maps were drawn. First, fault boundaries for each horizon were drawn depending on horizon contacts, then contour maps were drawn for each horizon as shown in Figures-9, 10,11, 12, 13, 14.

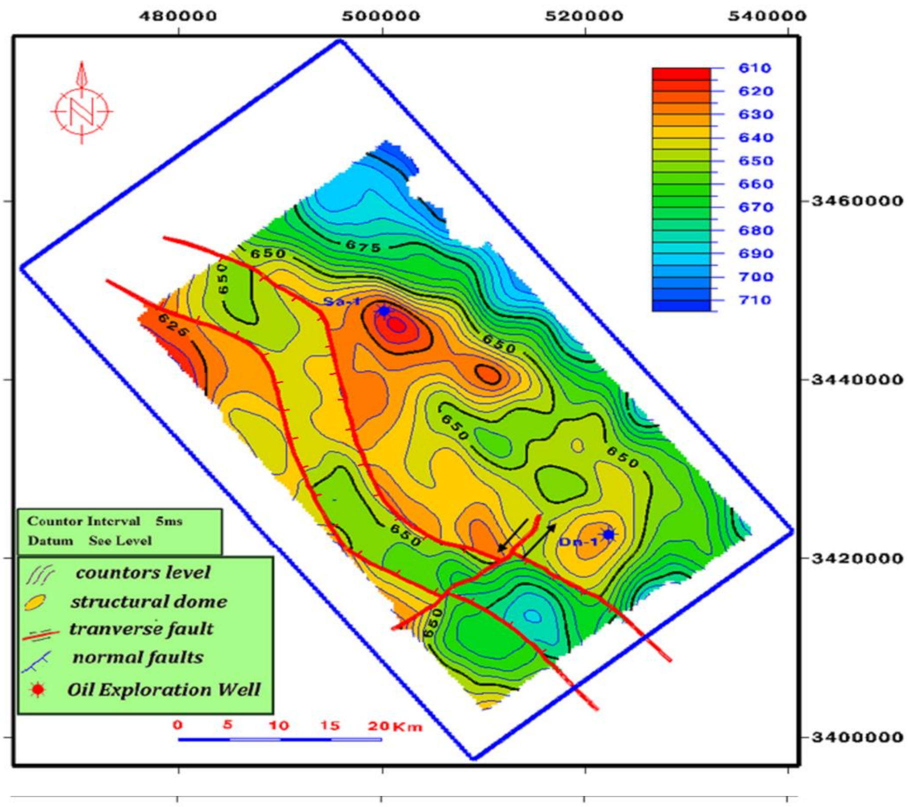


Figure 9-Time map of top Shiranish horizon.

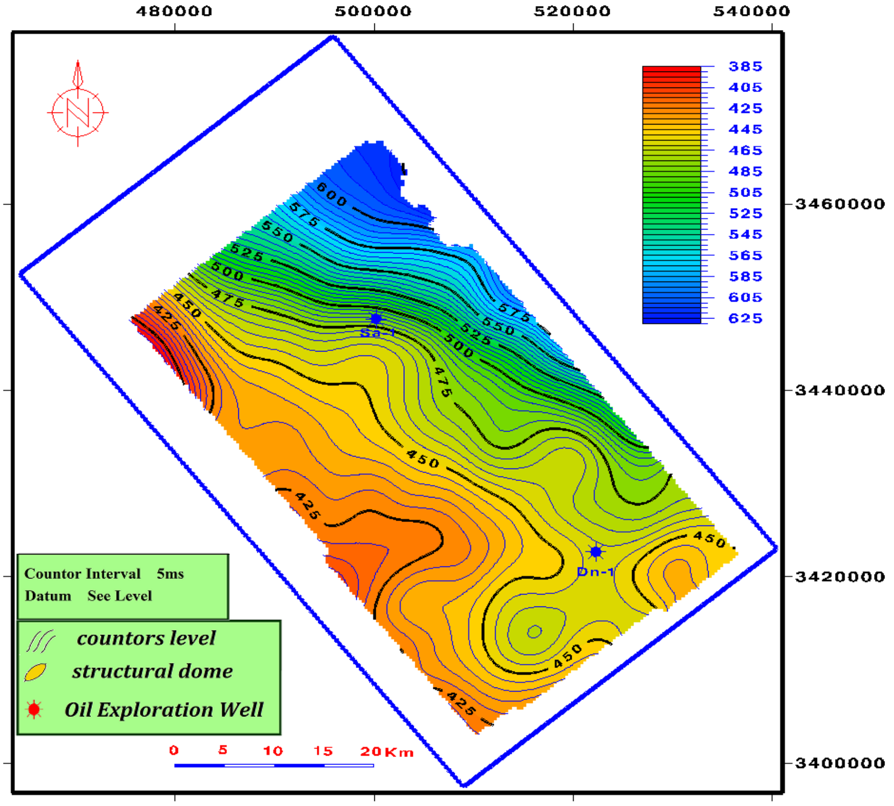


Figure 10-Time map of top Hartha horizon

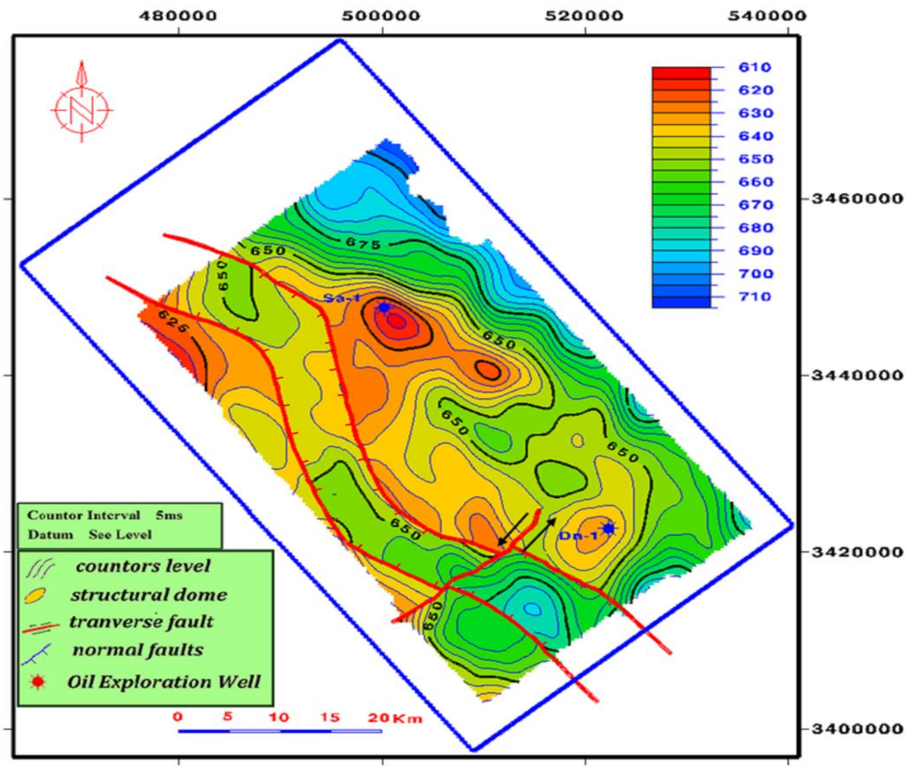


Figure 11-Time map of top Sadi horizon.

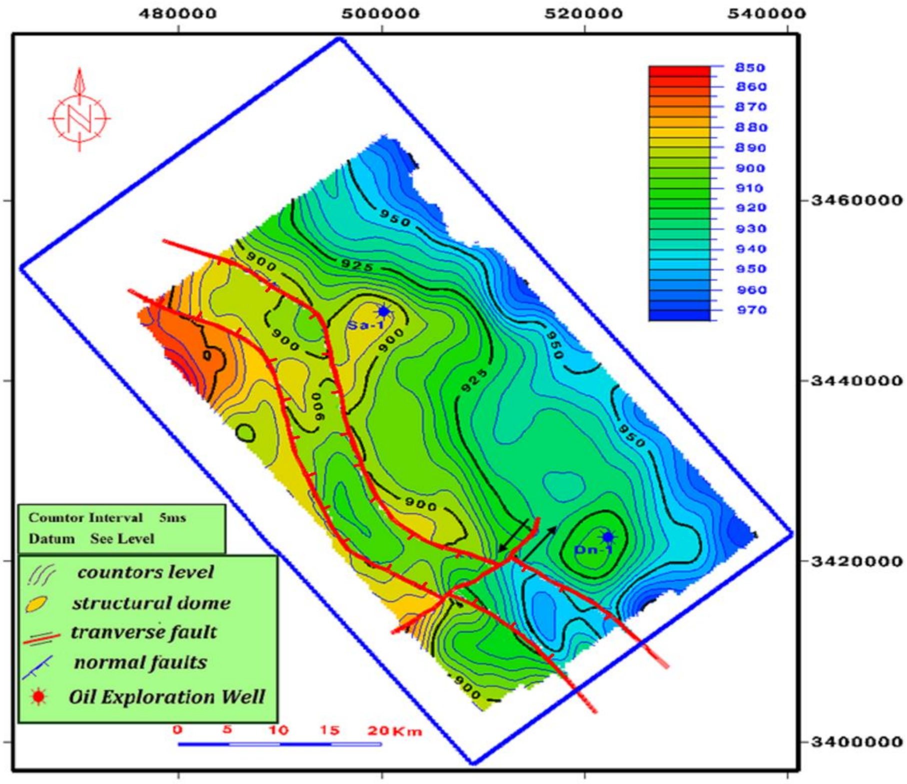


Figure 12-Time map of top Nhr Umr horizon.

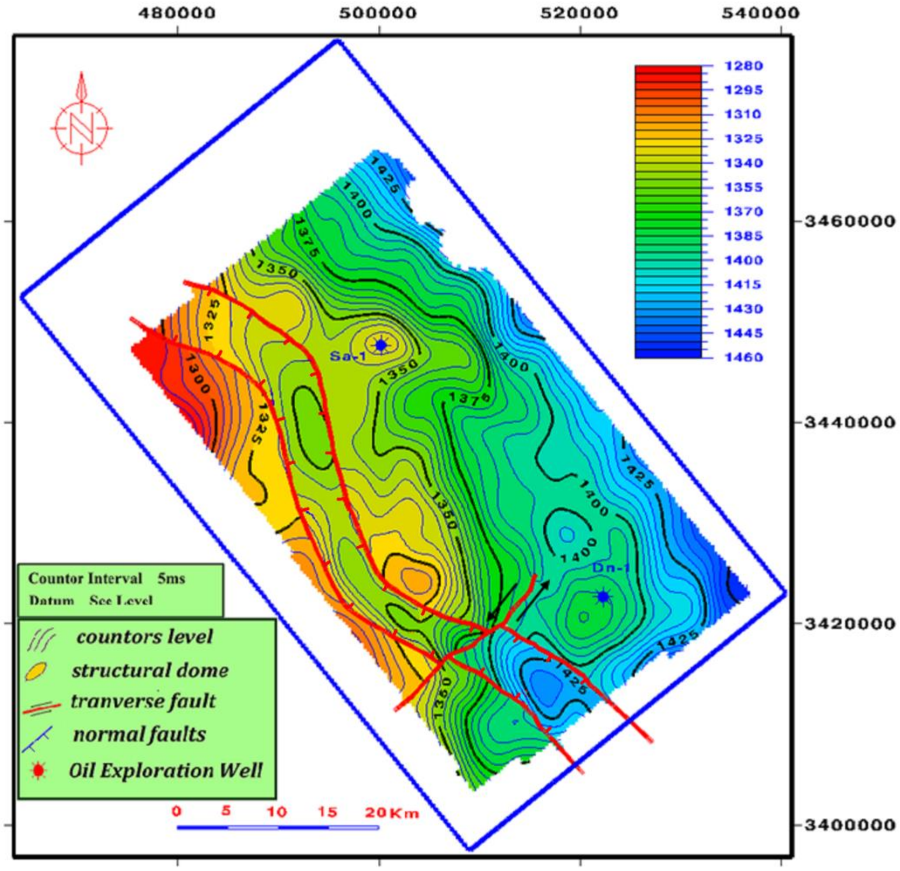


Figure 14-Time map of top Najmah horizon.

A 3D window available on petrel software was used to construct 3D structural model in time domain. First, based on faults boundaries and their faults sticks, the planes of affected faults in study area were drawn (Figure-15). Fault plane is a surface formed between the two rock blocks that slip one with the other during an basement dislocation. Geologists use the term fault zone when referring to the zone of deformation associated with the fault plane. The edge of the fault plane can often be seen on the seismic section as fault sticks. Also, fault trace (fault boundary) is commonly plotted on geologic maps to represent a fault boundary [10].

A 3D structural model in time domain was constructed by a signing the contour maps with their fault planes as shown in Figure-16. This model capture essential structural features within the selected of upper Jurassic and Cretaceous horizons, in order to create 3D structural model in depth domain

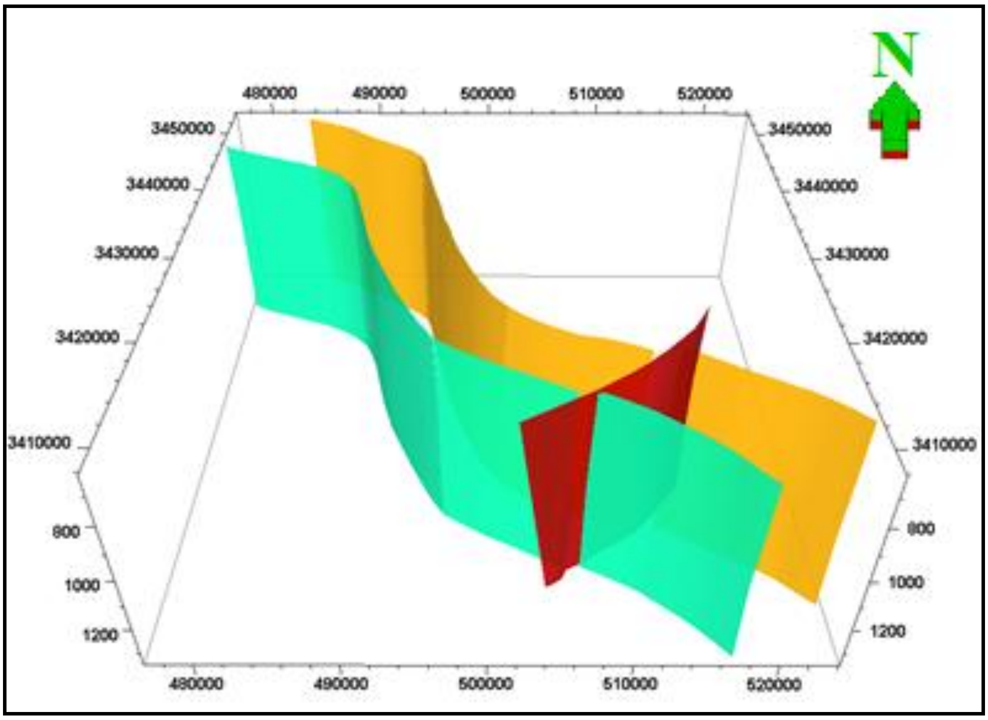


Figure 15-A 3D view of faults planes model in time domain.

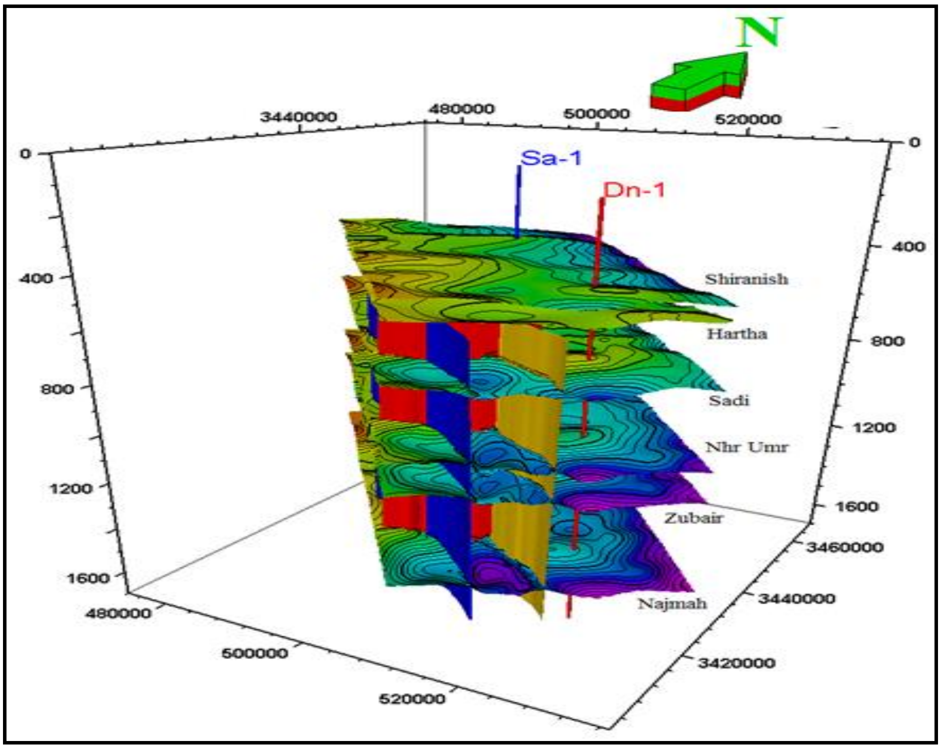


Figure 16-A 3D view of structural model in time domain.

7. Velocity model construction

The following velocity equation ($V = V0 + K*Z$) was chosen in this research to calculate average velocity values [11], where:

V: Average velocity.
$V0$: Instantaneous velocity.
K: Constant Ratio of Time/ Depth.
Z: Depth.

This equation means, at each XY location, the velocity changes in the vertical direction by a factor of k. Typical values used in modelling work range from around (100 to 5000) m/s for *V0* and −0.2 to 1.8 s^{-1} for *K* [12].

The average velocity values of interest horizons were calculated by using time of these horizons which were picked on seismic data and their markers in Sa-1 and Dn-1 well check-shot logs. Then, a 3D velocity model has been constructed in Petrel software which explains the distribution of velocities in both vertical and horizontal direction that is equivalent to wells check-shot velocities, Figure-17.

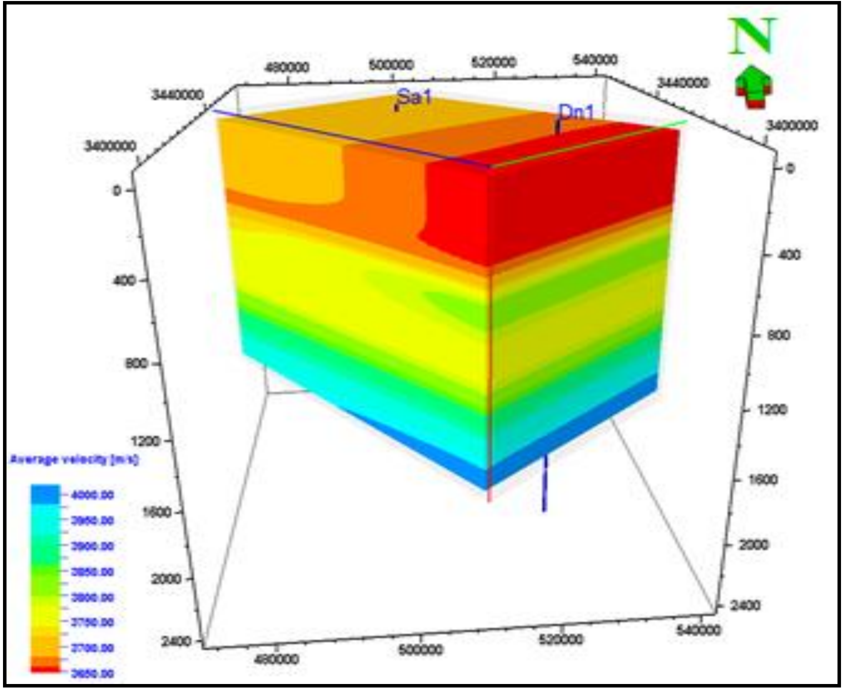


Figure 17-A 3D view of average velocity model throughout study area.

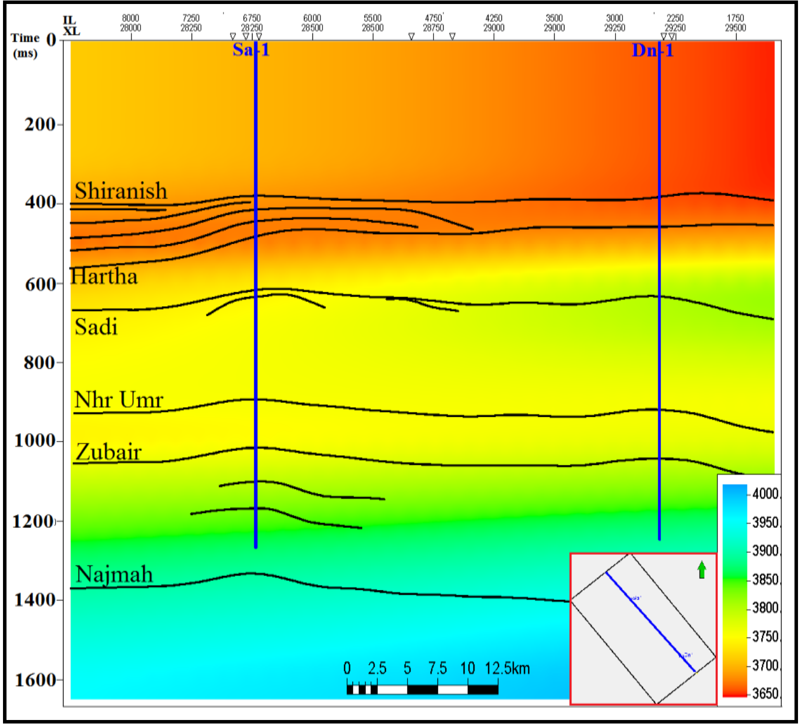


Figure 18-An arbitrary seismic section Pass through Dn-1 and Sa-1 wells shows vertical distribution of velocity along study area.

Vertically, one observes high velocity values at shallow reflectors with low positive gradient with the depth throughout the area. This due to high consolidation of rocks.

Horizontally, the average velocity maps show the fallowing: At Shiranish, velocity values increase toward northwest and decreased toward east and southeast of study area. At Hartha, velocity values increase toward northeast and decreased toward south and southwest of study area. While at Sadi, Nhr Umr, Zubair and Najmah, velocity maps show the same horizontal distribution of average velocity, where the values increase toward southeast and decreased toward northwest of study area, Figure-18

8. Depth maps

Generally, these maps are crucial in hydrocarbon exploration because they permit the volumetric evaluation of gas and oil in place [13]. In addition, depth estimation can be done in wide range of existing methods [14], but which can be separated into two broad categories:

1-Direct time-depth conversion.

2-velocity modeling for time-depth conversion.

In this research, velocity modeling was used to convert time maps in into depth domain Figures-(19, 20, 21, 22, 23, 24). In addition, velocity modeling was used to convert fault planes from time domain to depth domain Figure-25. Finely, depth maps are used to construct the structural framework of the area which is important to framework of area, Figure-26.

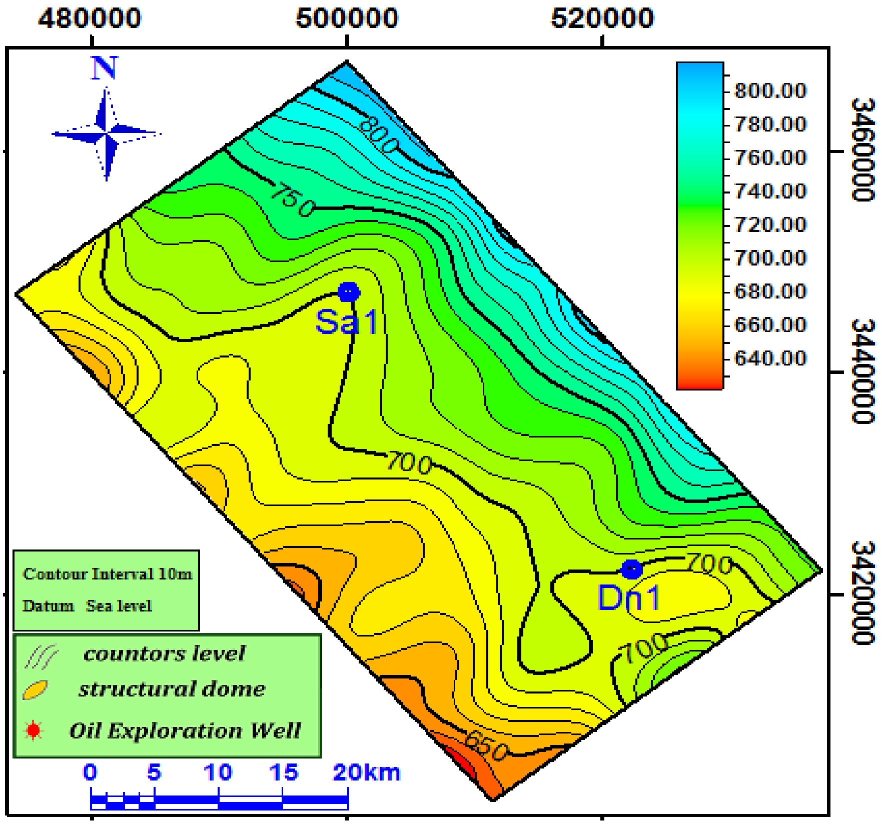


Figure 19-Depth map of top Shiranish Fn.

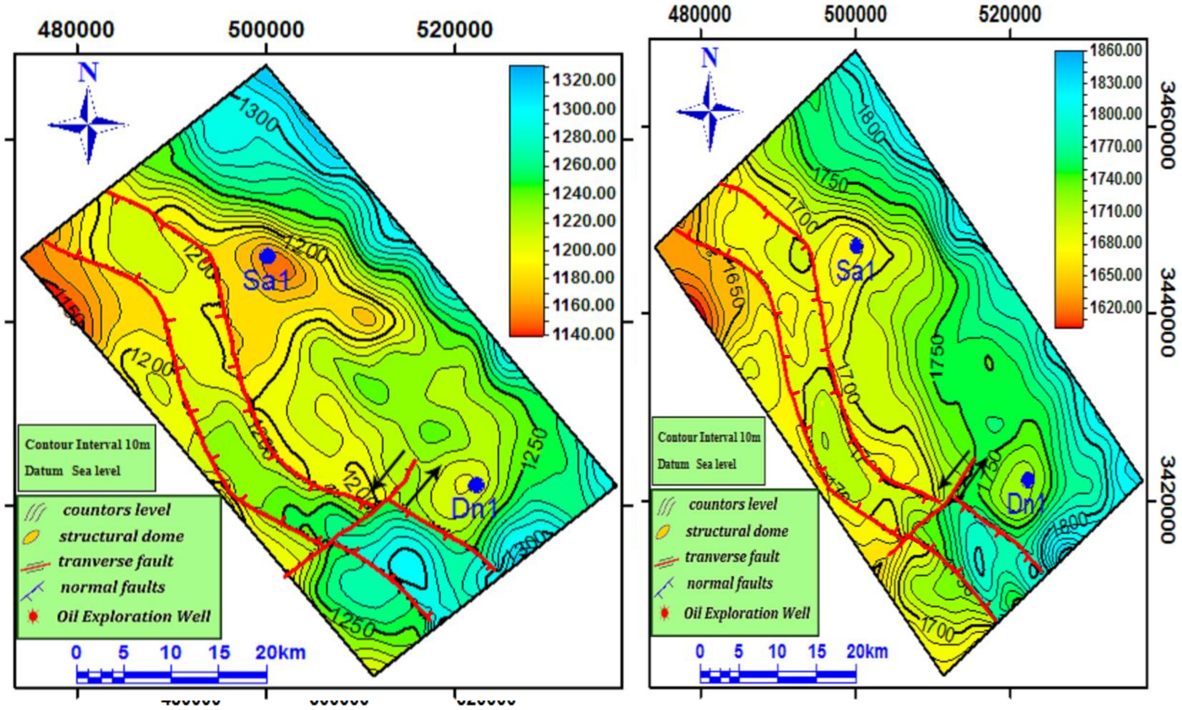


Figure 20-Depth map of top Hartha Fn.

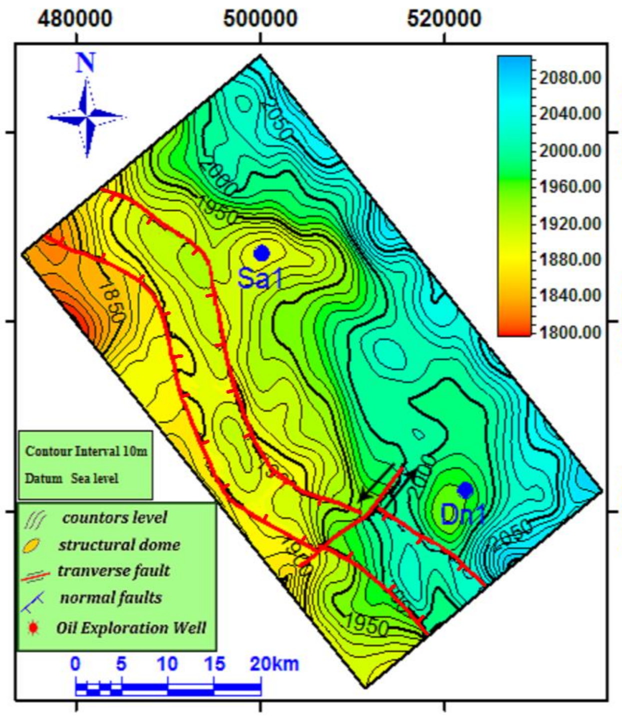


Figure 22-Depth map of top Nhr Umr Fn

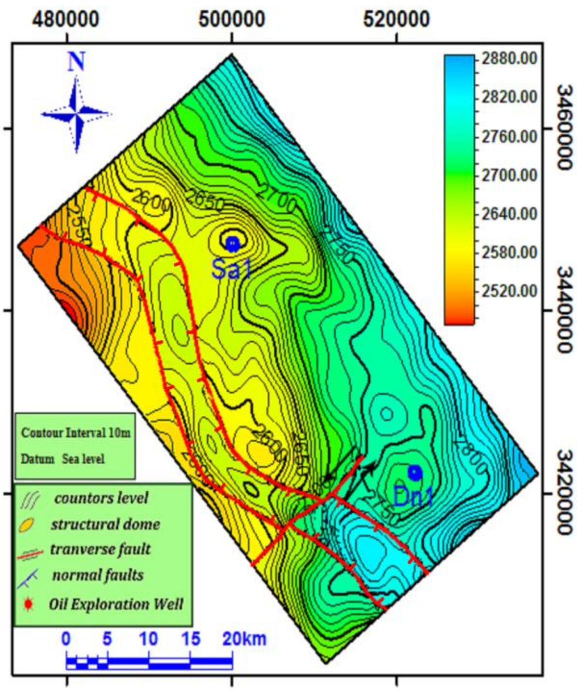


Figure 21-Depth map of top Sadi Fn.

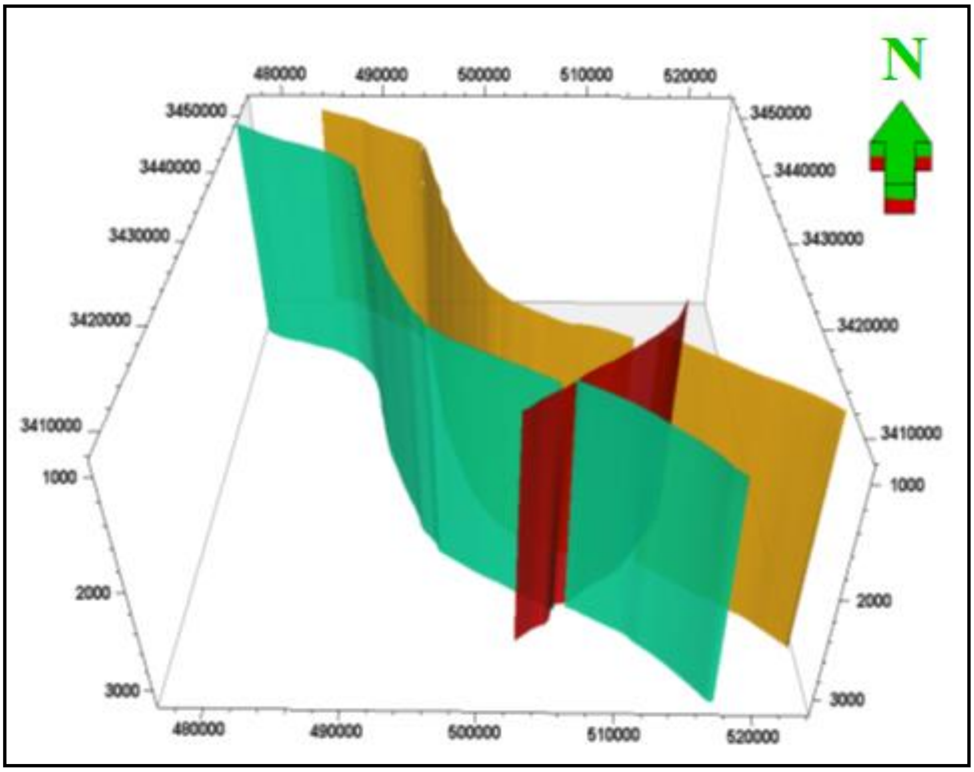


Figure 23-A 3D view of faults planes model in depth domain.

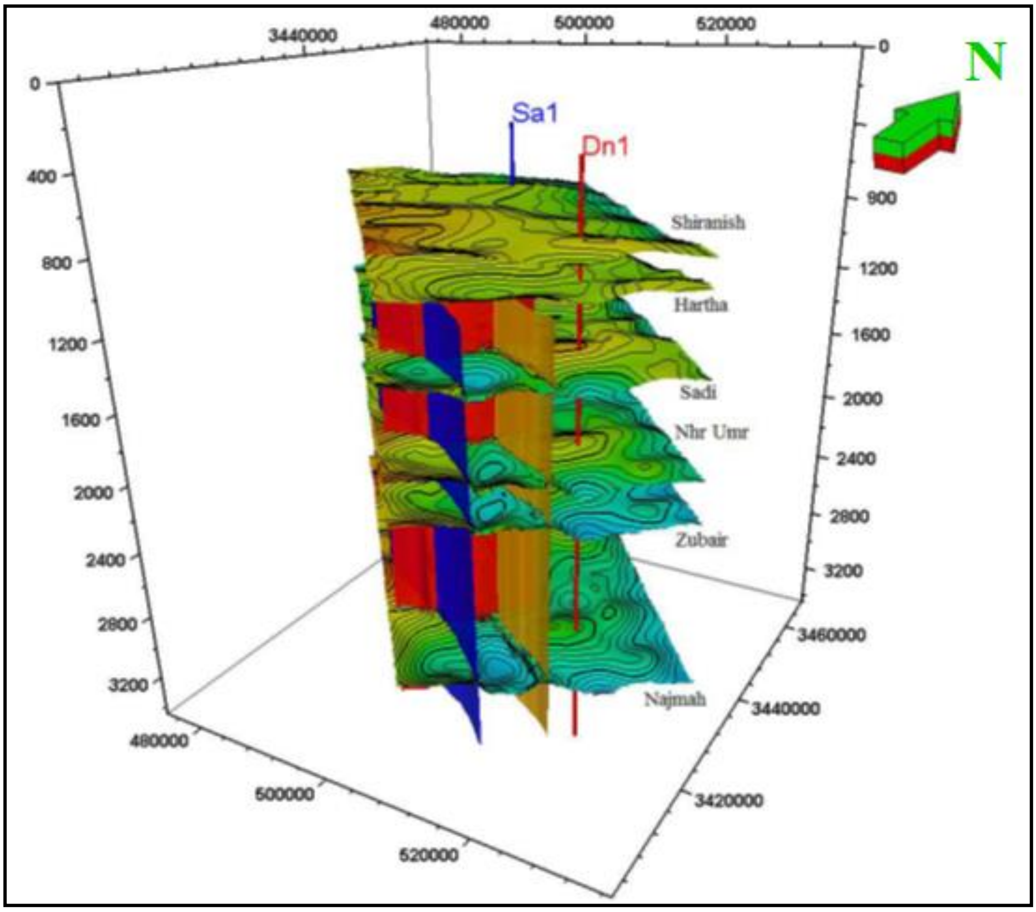


Figure 24-A 3D view of structural model in depth domain.

9. Structural picture description

One of the most important principles in the interpretation of reflection method is that the depth maps reflect same structural picture of time maps, but the difference between these maps is the depth maps give more details for closures dimensions, number of contour interval, faults displacements [15]. Consequetelly, the structural picture of selected Formations can describe as the following:

The study area at top of Shiranish Fn. (Figure-19). are dominated by a SW-NE trending without any deformation (faults effect), the map shows a small dome locates south of Dn-1 well and large structural nose locates at Sa-1well. A similar trend and shape of contour is observed at top Hartha Fn. (Figure-20) and contour values rise further towards the north-east.

At top Sadi, Nahr-Umr, Zubair and Najmah Formations (Figures-21, 22, 23, 24), the depth maps show same subsurface image because they were affected by two types of fault systems, they are describe as following:

A major graben was affected on study area, it dominated NW-SE along left side of study area and separated to the east and west parts. Also, a transverse fault dominated E-W trend and separated the area to the north and south parts. Thus, the study area is divided to the following regions:

- The north and south graben areas with width between (6-8km), they represent faulted Synclines dominated NW-SE along study area.
- The east shoulder of the major graben is divided into two parts (southeast and northwest). Diwan dome locates in the southeast part where Dn-1 well was drilled, it represents semicircle dome with axis dominate to the NE-SW. Samawa dome locates in the northwest part where Sa-1 well was drilled, it represents elongated dome with axis dominate to the NW-SE. Samawa south structure locates in the middle part with axis dominate to the NW-SE trend, it represents elongated dome surrounded by two faults from east and south parts.
- The west shoulder also divided into two parts (southeast and northwest), a structural dome locates the northeast part with axis dominate to the NW-SE, it extends outside of study area.
- depth maps illustrate that the domes dimensions, number of enclosures and faults displacements have been increased with the depth.

10.Conclusions

According to seismic structural interpretation, the following conclusions are achieved:

1. The instantaneous phase attribute sections showed the study area was affected by two types of fault systems, two normal faults formed a graben appear at west side of these sections, and transverse fault at Hartha Fn. and deep reflectors. While Tertiary reflectors were not affected by any type of fault systems.
2. The structural maps with their 3D models show a new subsurface image of area as following:

- A major graben extend northwest-southeast was effected along area at Hartha Fn. and deep layers. A transverse fault extend northeast-southwest was effected and parted the area into north and south parts.
- Structural domes were formed at Sadi Fn. and deep layers. They are Samawa folded dome, Samawa south faulted dome and Diwan folded dome, these dome at east shoulder of graben. In addition, a folded dome appears at west shoulder of graben in the northwest of study area.

3. Tectonically, 3D structural model has been confirmed the following:

- The study area during upper Jurassic and lower Cretaceous period was seated within a contact boundary between stable and unstable shelves (Mesopotamian basin and Salman subzone).
- The separation of Arabian plate from the African continent and collision it with the Eurasian plate at the end of Cretaceous was caused the rotational motion of Arabian plate toward the north and north-east. Seismic data have been showed that the study area influenced by these events, where is noted the stratigraphic succession by normal fault system which formed a graben. This graben has been cut by transverse fault which extend northeast-southwest trend as a result of rotational motion. In addition, shape and axes of fold domes which dominated to northwest-southeast consistence with general trend of Zagros Mountains belts.

4. Seismic sections show that there is no indication to any tectonic effect on Tertiary succession. It's characterized by low with regular thicknesses and no structural features. Tectonically, it's reflect the area quit at that time.

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